Integrating grazing into cropping systems – *For soil health and productivity*

Alan J. Franzluebbers

Raleigh, North Carolina

USDA United States Department of Agriculture

Agricultural Research Service

Outline

- ✓ **Characteristics of integrated crop-livestock systems**

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- ✓ **Grazing impacts on soil**

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- ✓ Characteristics of integrated crop-livestock systems (ICLS)
- ✓ Grazing impacts on soil
- ✓ **Some results from a multi-year ICLS experiment with cover crop grazing**

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- ✓ Some results from a multi-year ICLS experiment with cover crop grazing
- ✓ Soil organic matter under perennial grasses
- ✓ **Soil biological activity and nitrogen availability**

Contemporary agriculture



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Ecological issues

Production

- Economic opportunity, but also vulnerability with specialized production
- High cost of fuel and nutrients
- Pests often greater in monocultures / simple rotations
- Yield can stagnate in monoculture

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Environment

- ✓ **Improved nutrient cycling is needed at field and regional levels; in crop and animal systems**
- ✓ **Need for conservation of resources is as strong as ever**
  - ➢ **Soil, water, carbon, nitrogen, biodiversity**

Integrated crop-livestock systems

Variety of approaches

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- Animal manure application to cropland
- Grazing of cover crops

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- **Sod-based rotations**
- **Dual-purpose grain crops (grazing and grain)**

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- **Grazing crop residues**
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- **Regional recycling potential**

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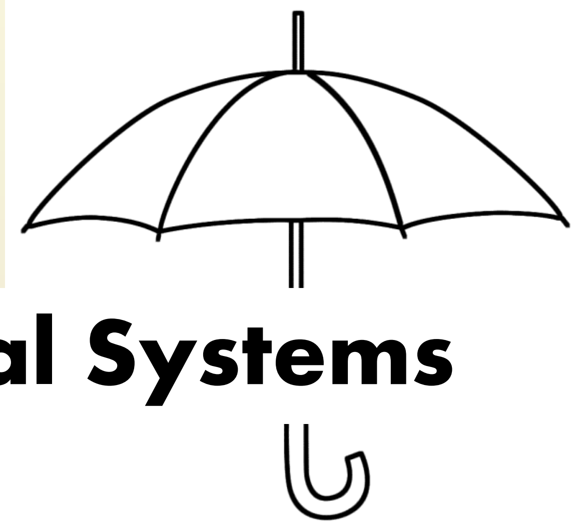

Conservation Agricultural Systems

…resource efficiency…

Integrated crop-livestock systems

— *Issues of concern in cropping*

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— Issues of concern in cropping

National level
Federal regulations
Government support
Commodity price
Supply / demand

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Labor availability
Processing
Storage

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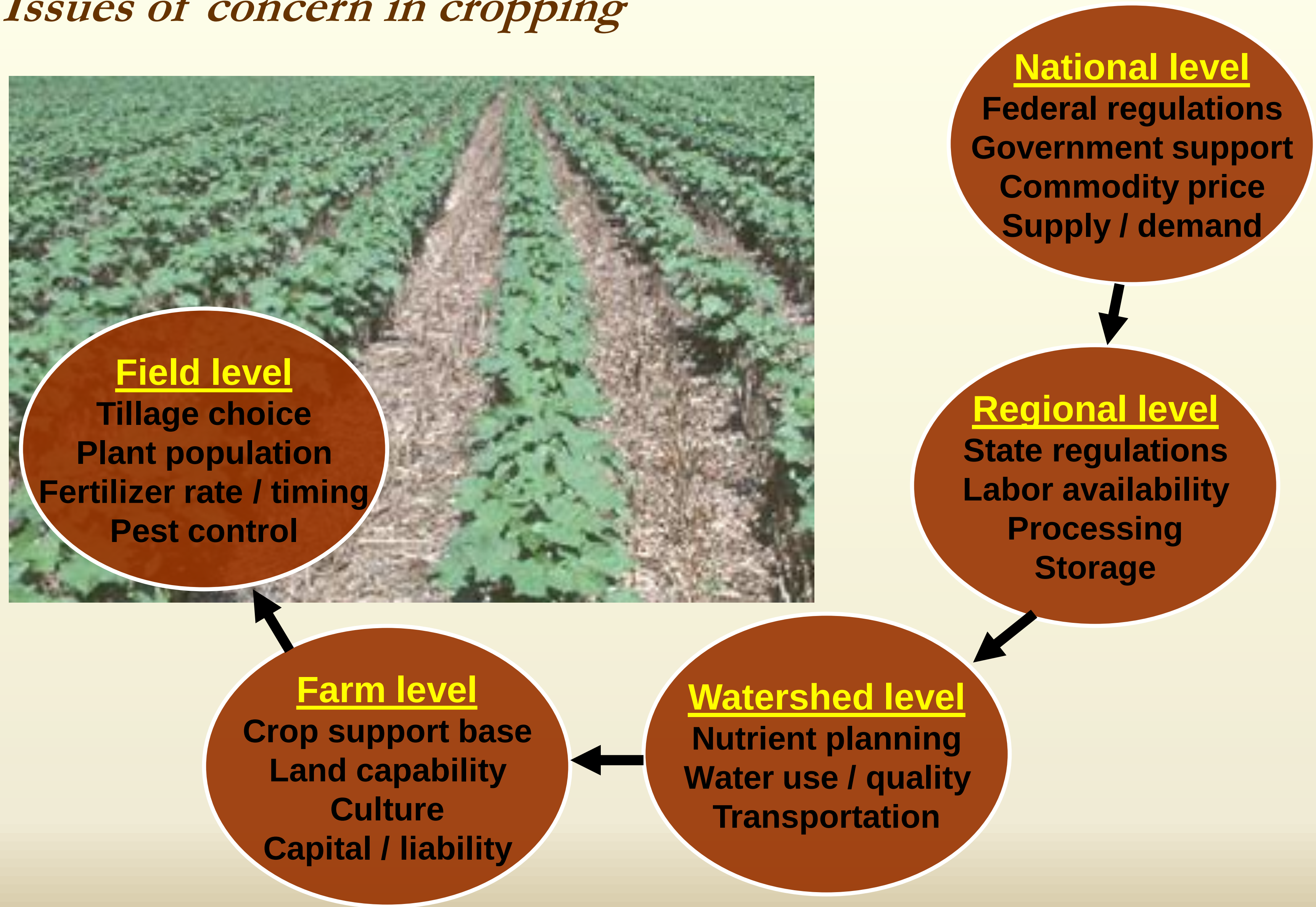
Farm level
Crop support base
Land capability
Culture
Capital / liability

Integrated crop-livestock systems

— Issues of concern in cropping



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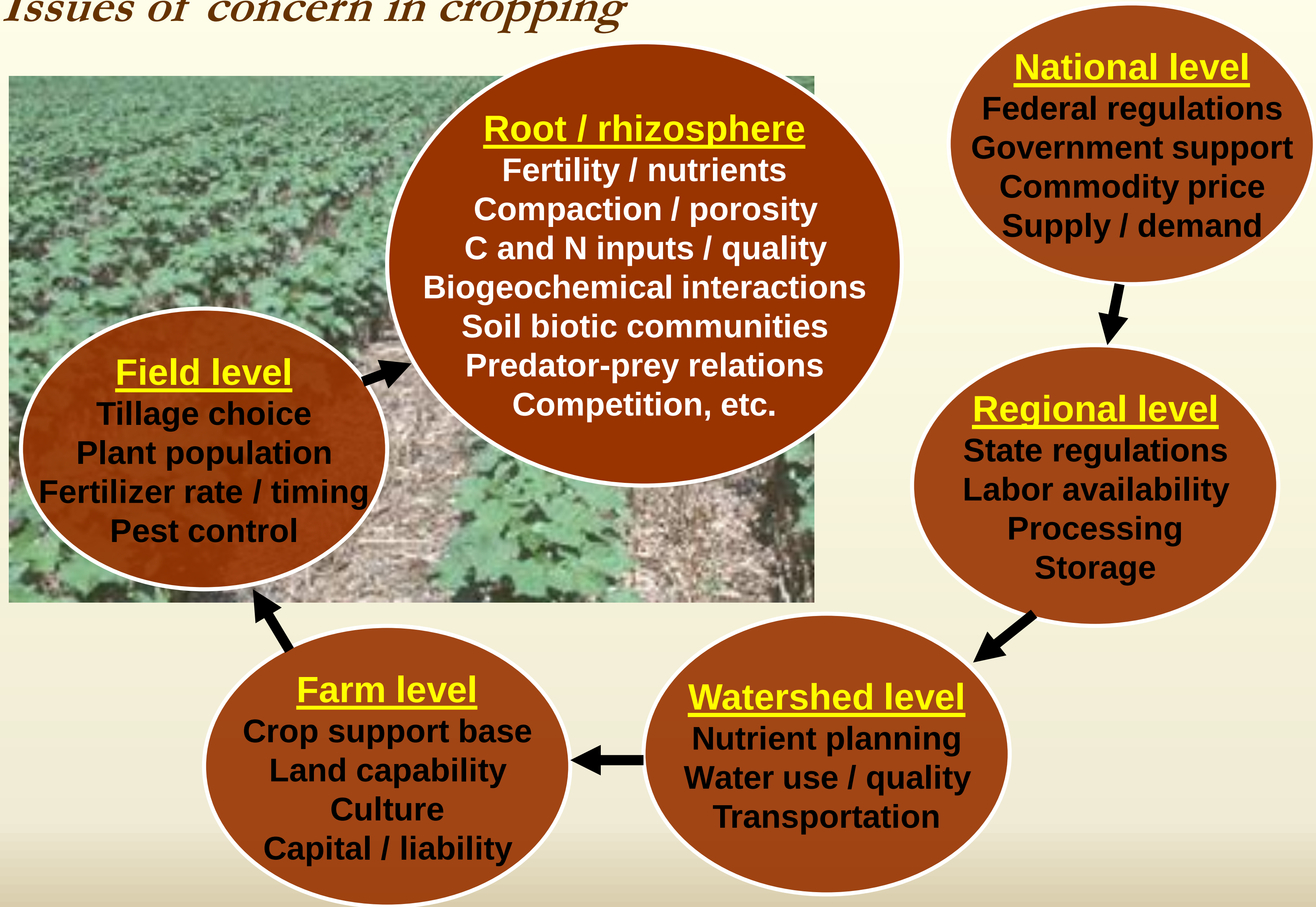

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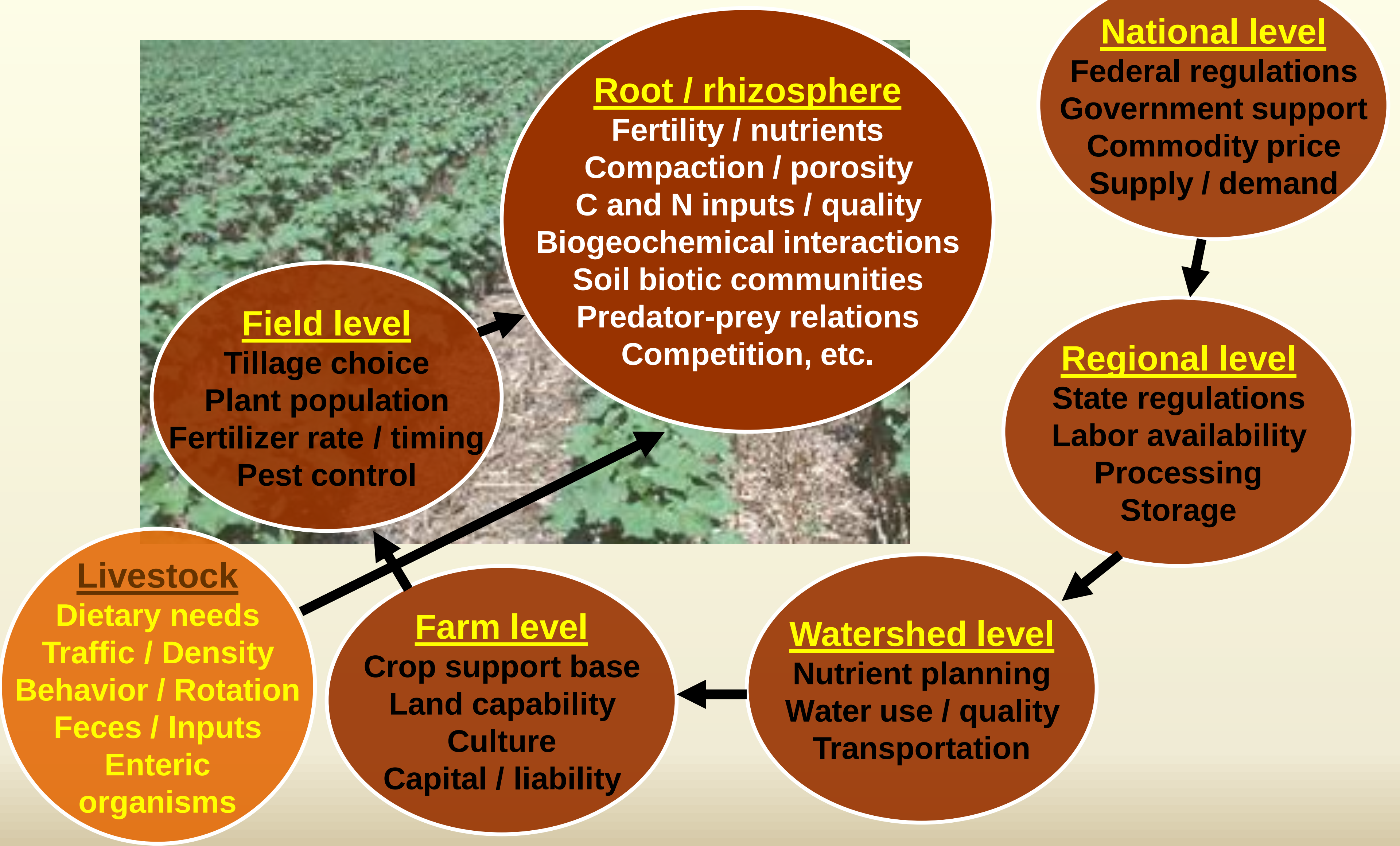

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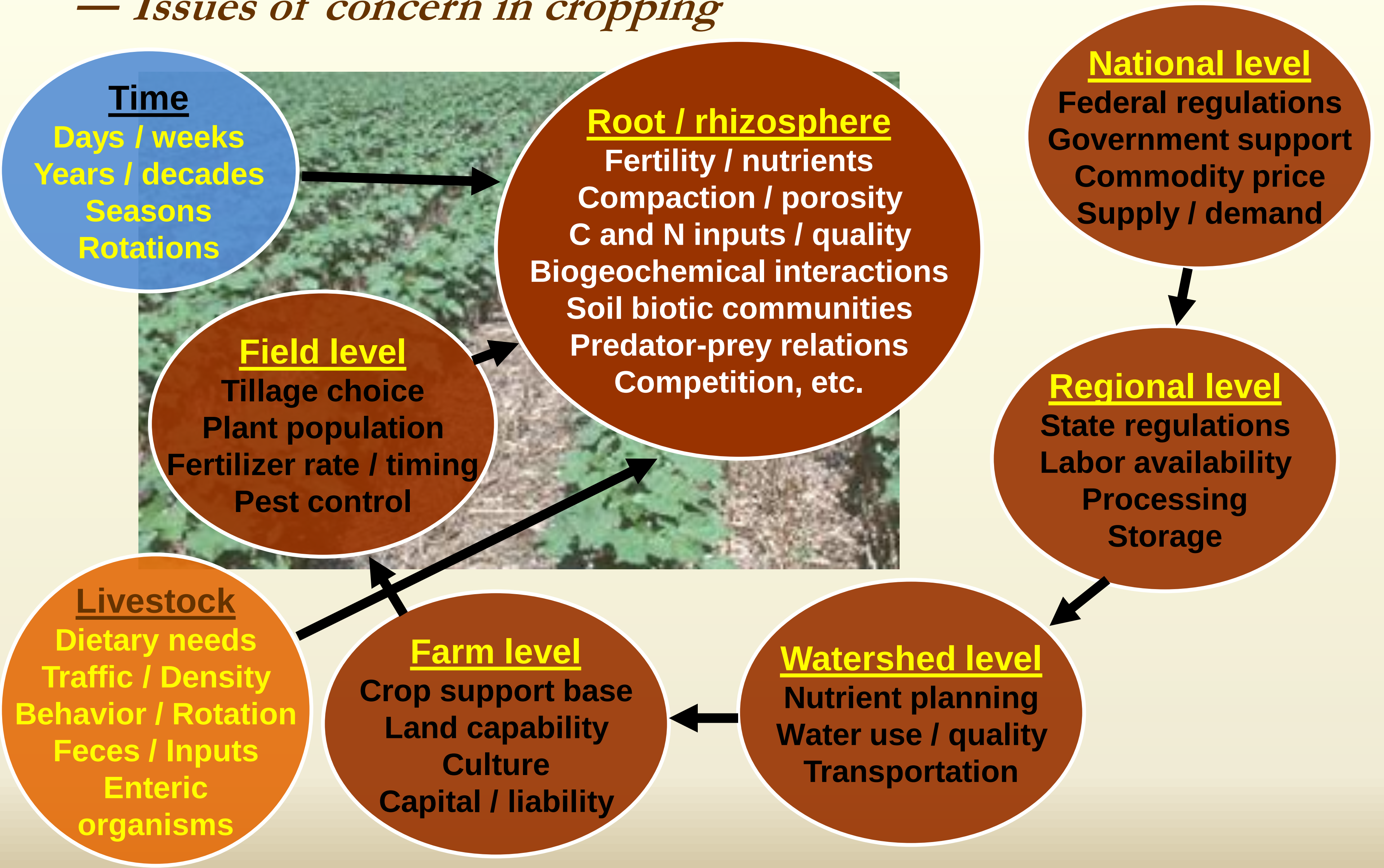

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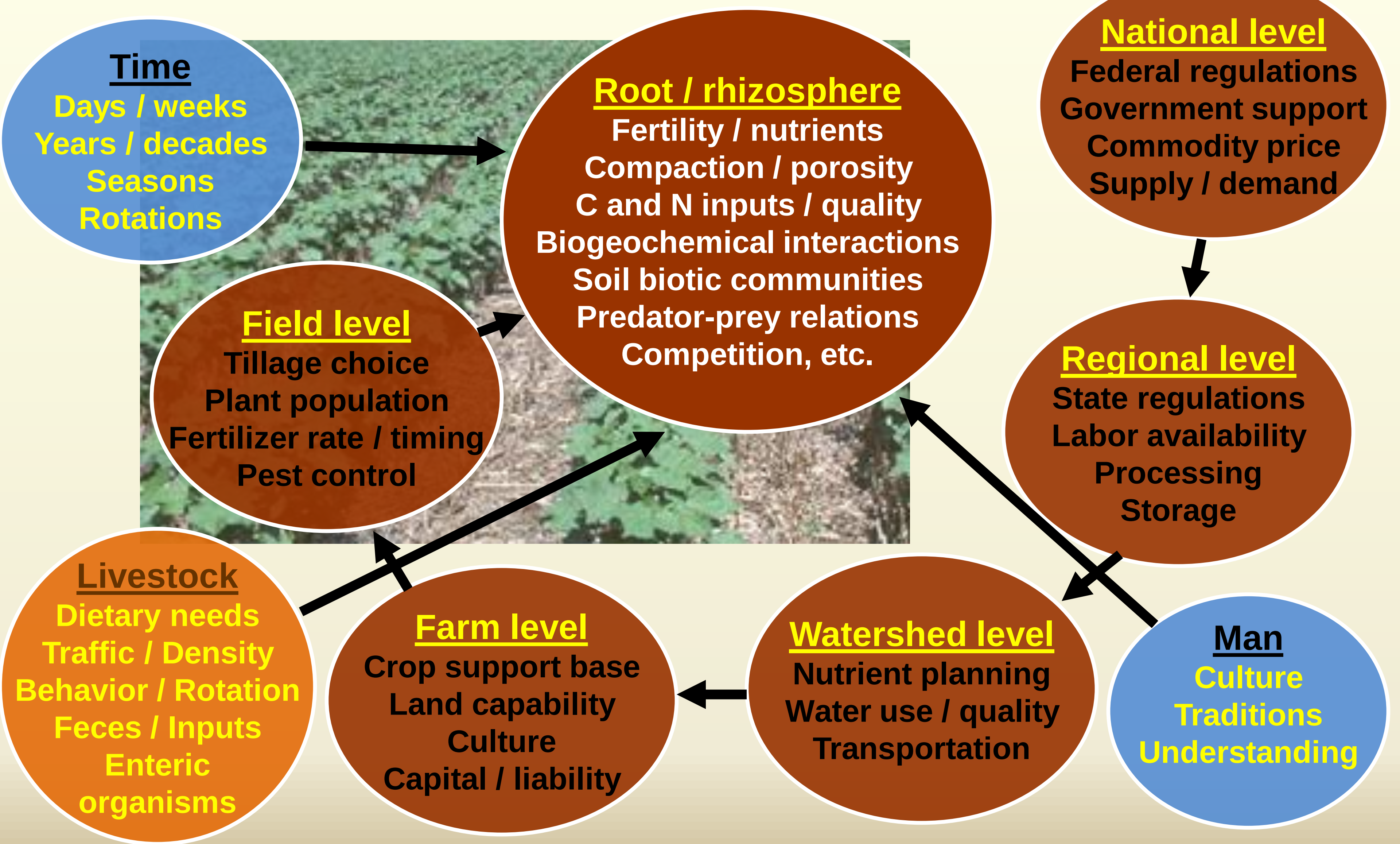
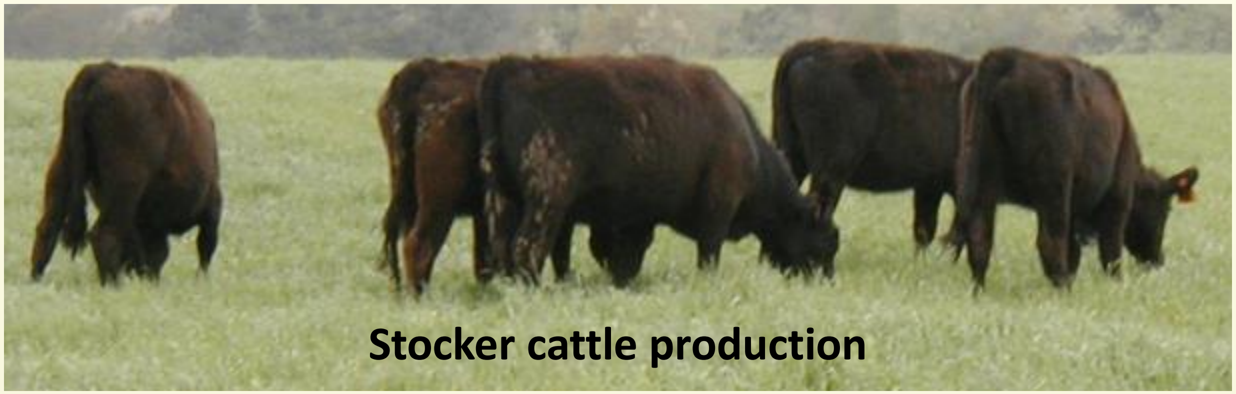
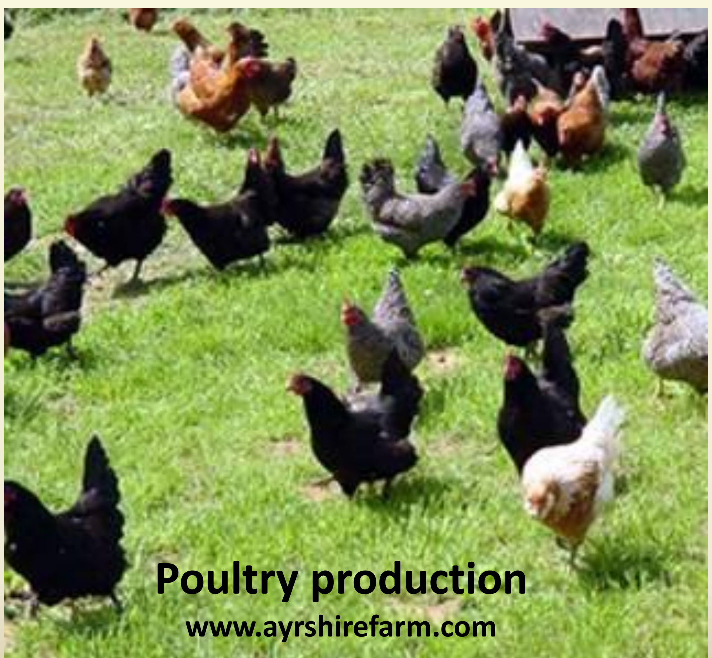
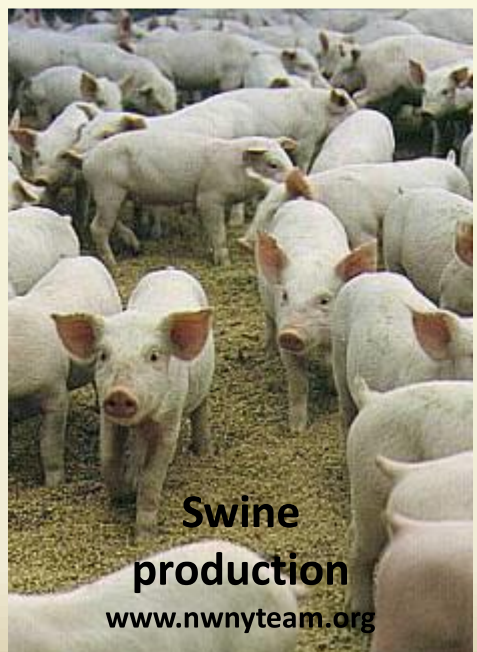


Integrated crop-livestock systems

— *Livestock component*

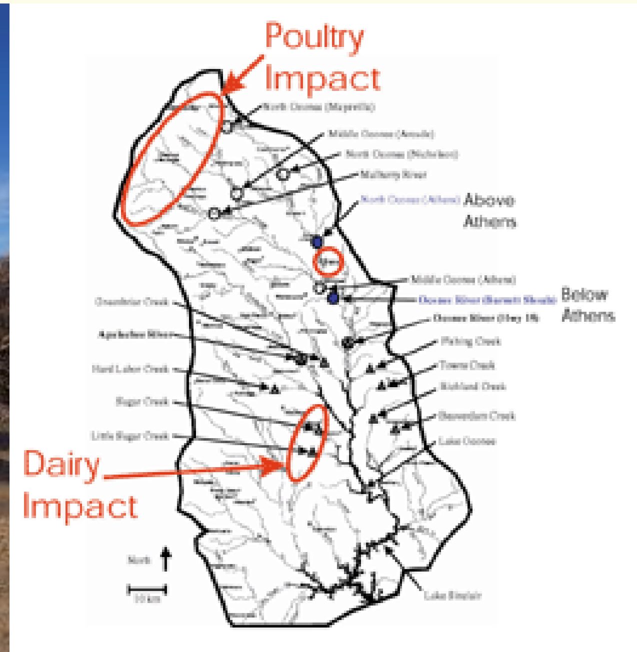






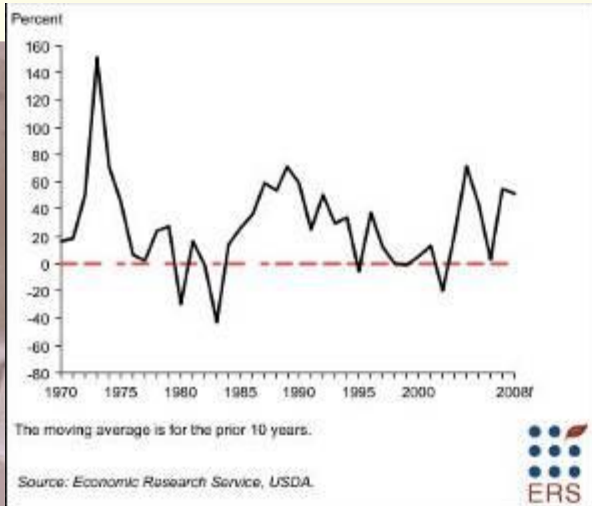
Integrated crop-livestock systems

— *Environmental component*



Integrated crop-livestock systems

— *Socio-economic component*



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The simplicity of soil...

The simplicity of soil…

Hypothetical soil response to grazing

Management (as a form of perturbation) can enrich or degrade the environment

From Odum et al. (1979) Bioscience 29:349-352

Hypothetical soil response to grazing

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Perturbations may be

- **energy** (harvest by machine or grazing, tillage inputs, chemical control, etc.)
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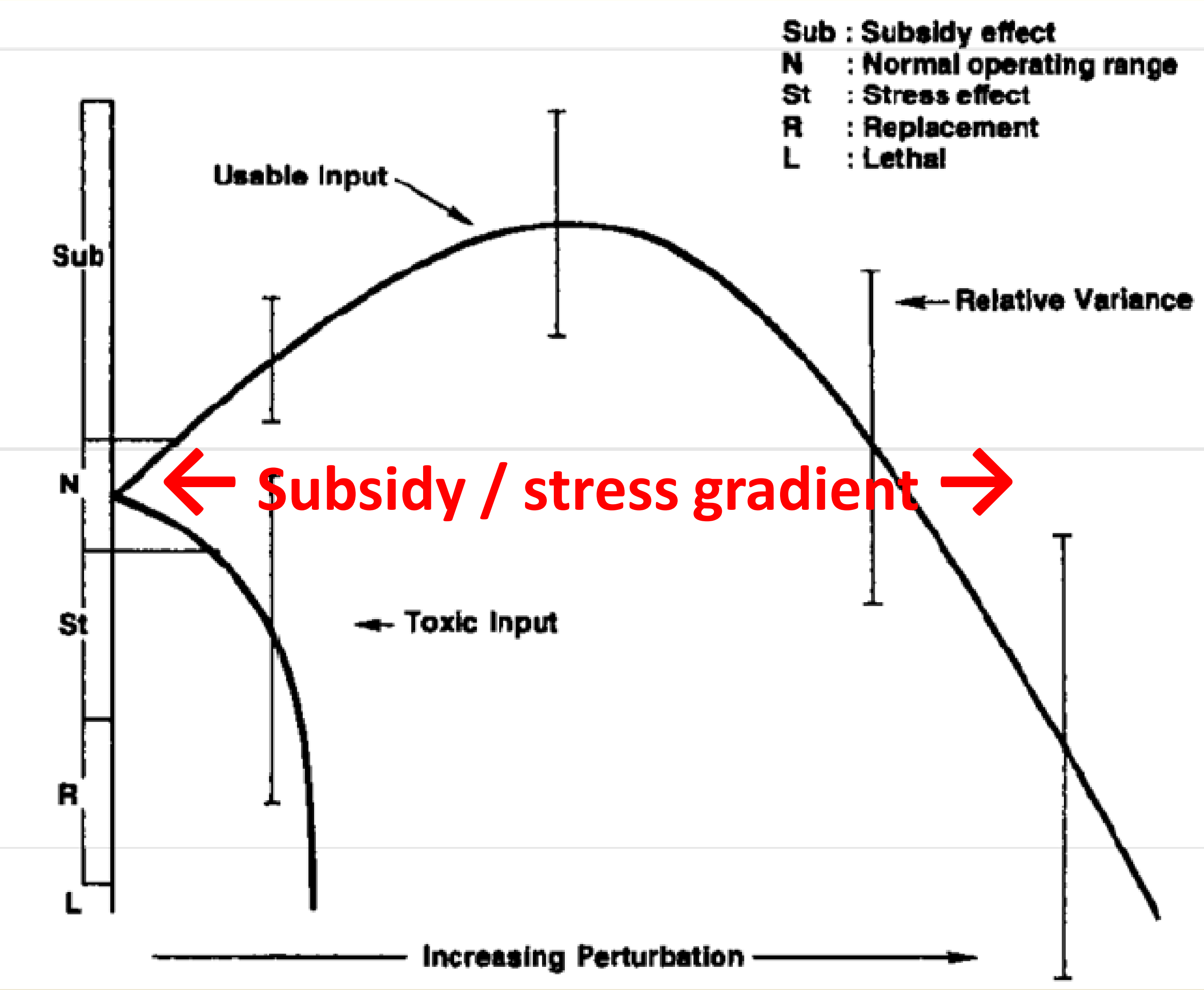

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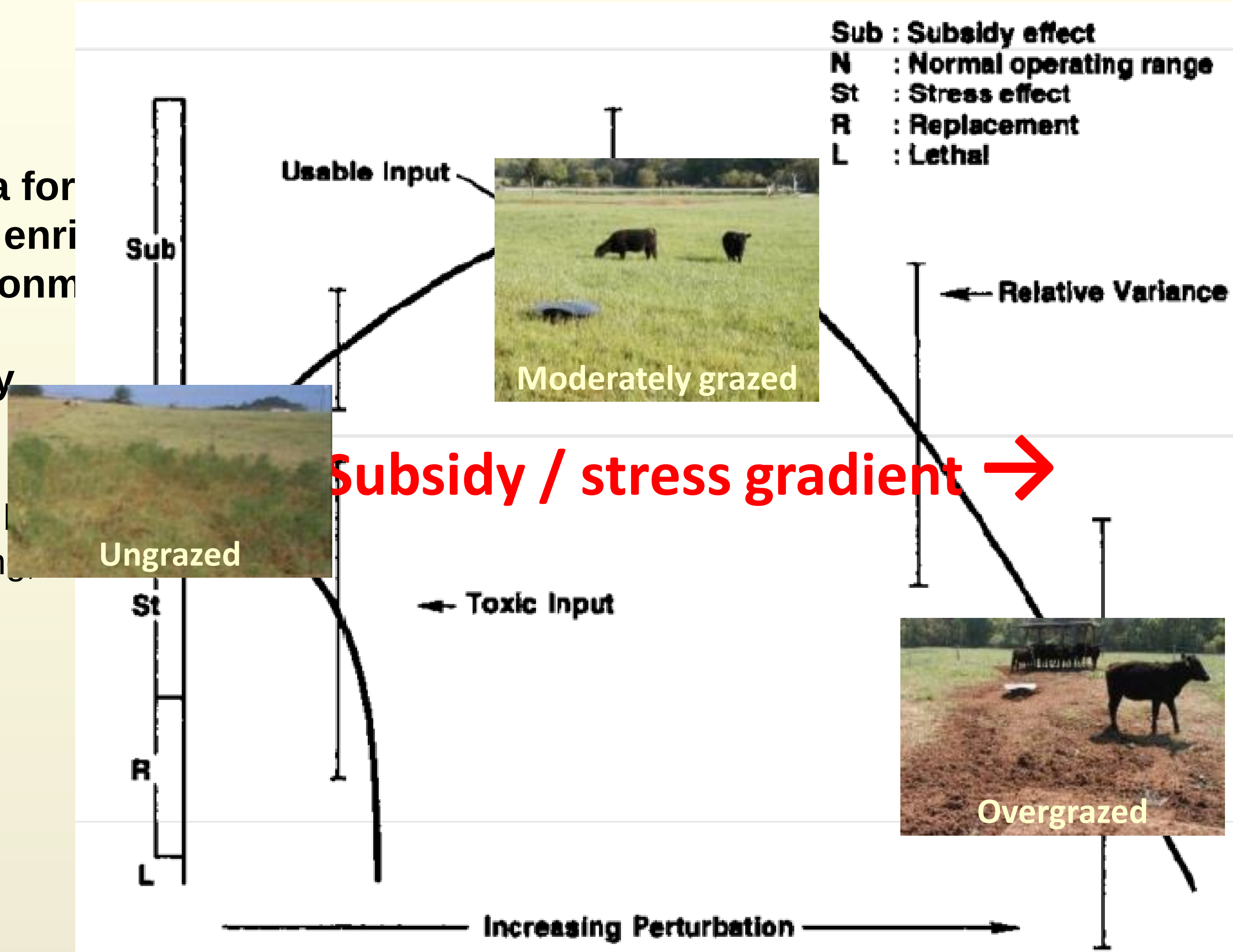

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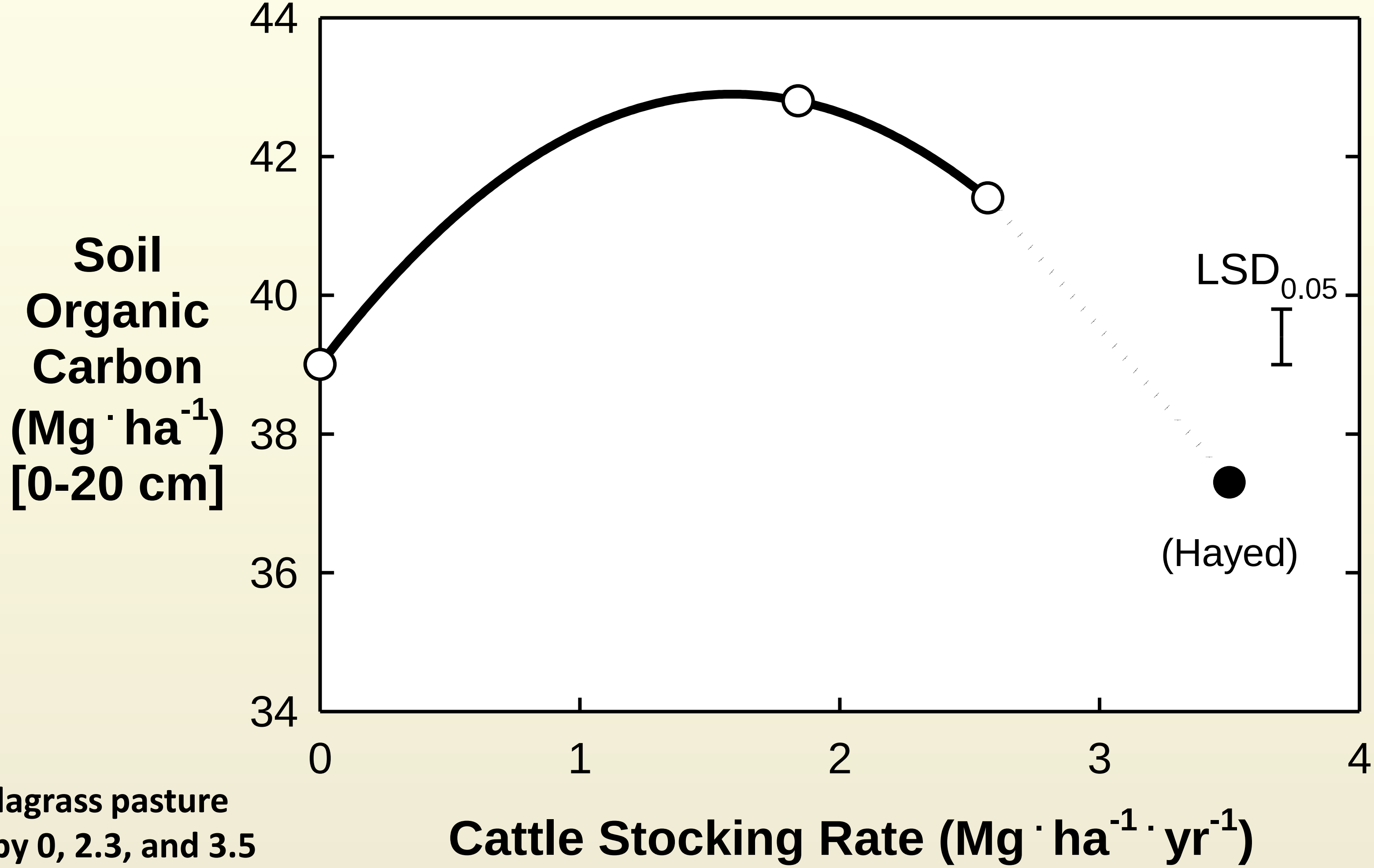
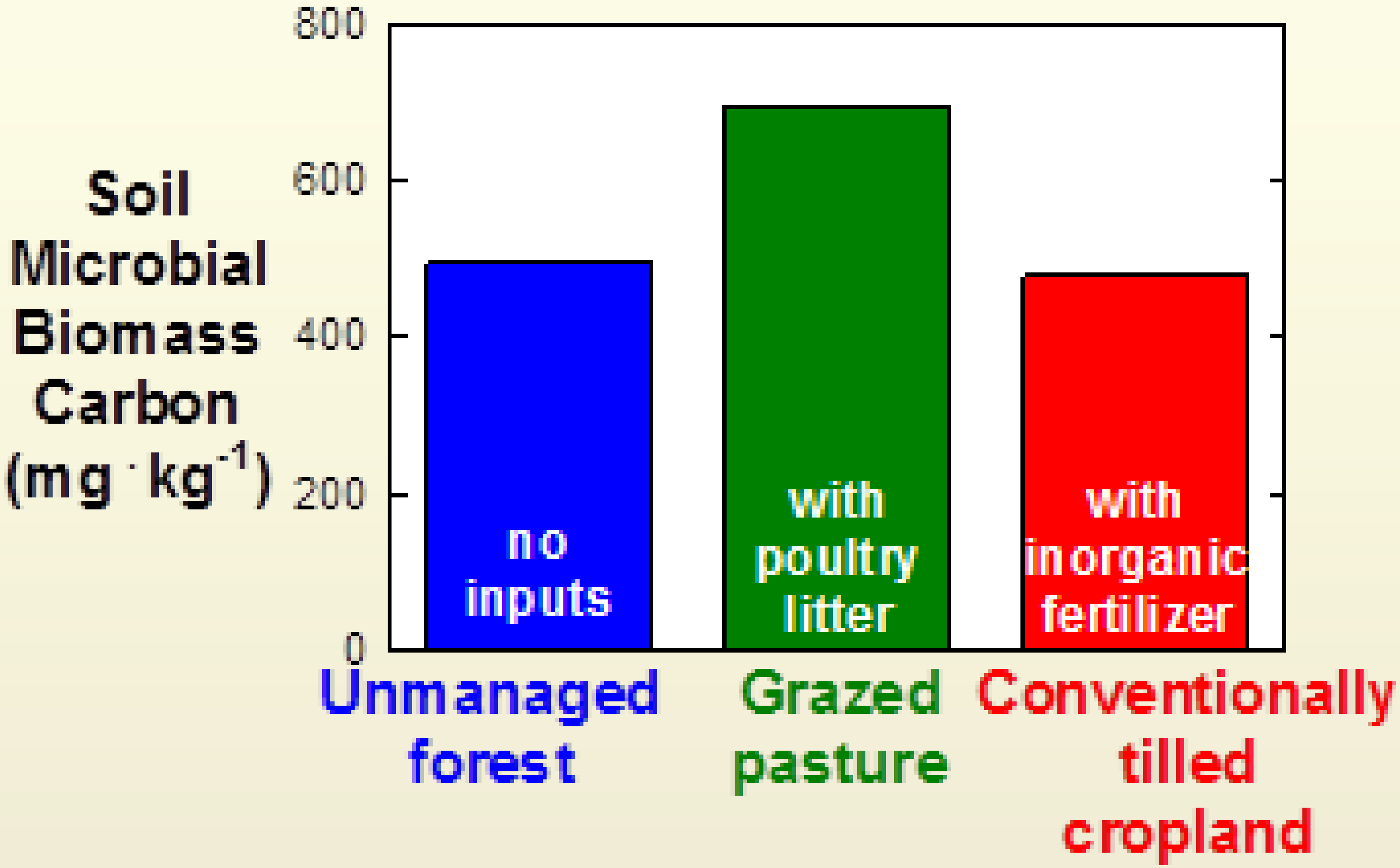
Measured soil carbon response to grazing disturbance



Bermudagrass pasture grazed by 0, 2.3, and 3.5 steers/acre from May-Sep for 5 yrs

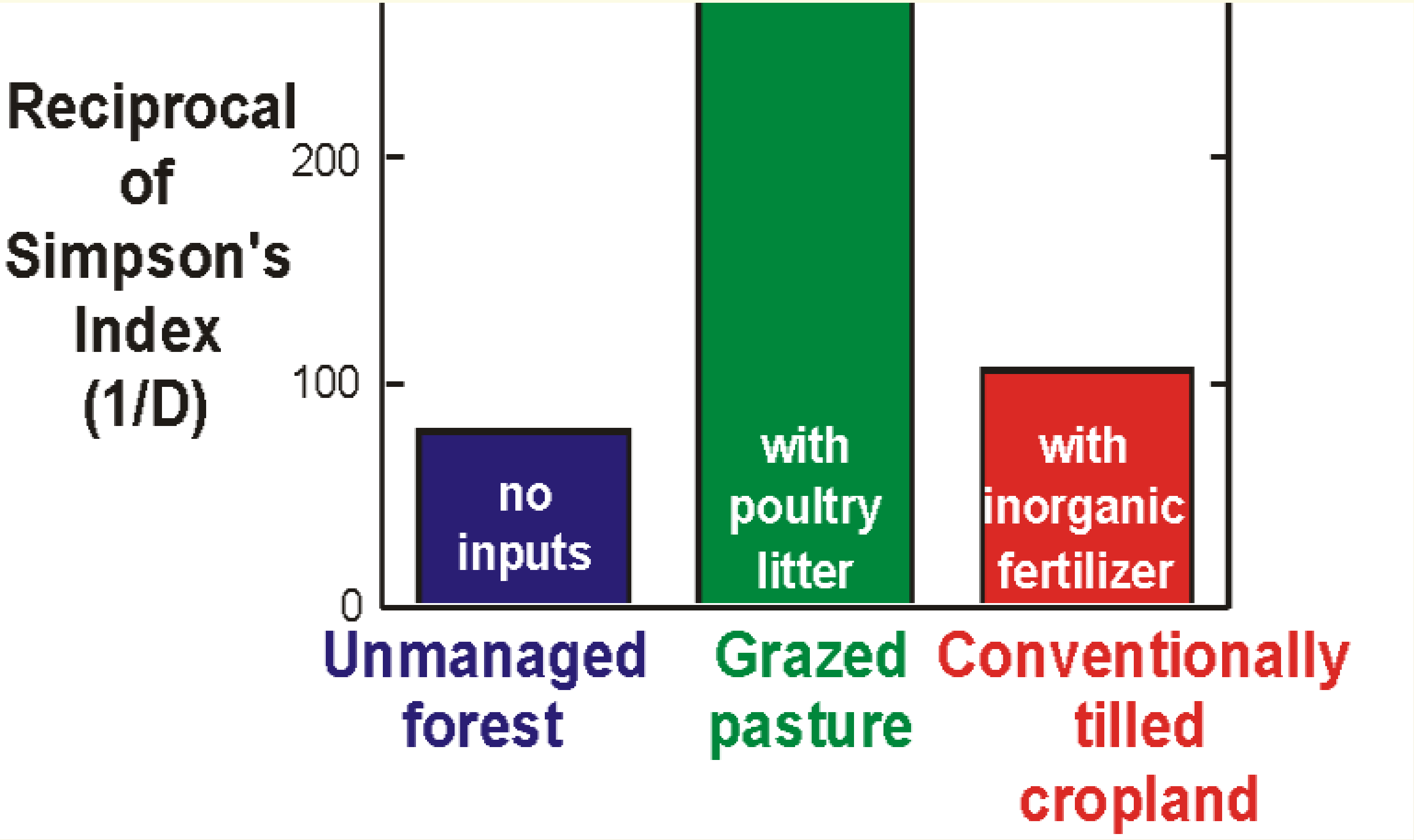
Data from Franzluebbers et al. (2001) Soil Sci. Soc. Am. J. 65:834-841

Soil microbial biomass response to management intensity



Data from Jangid et al. (2008) Soil Biol. Biochem. 40:2843-2853

Soil biodiversity response to management intensity



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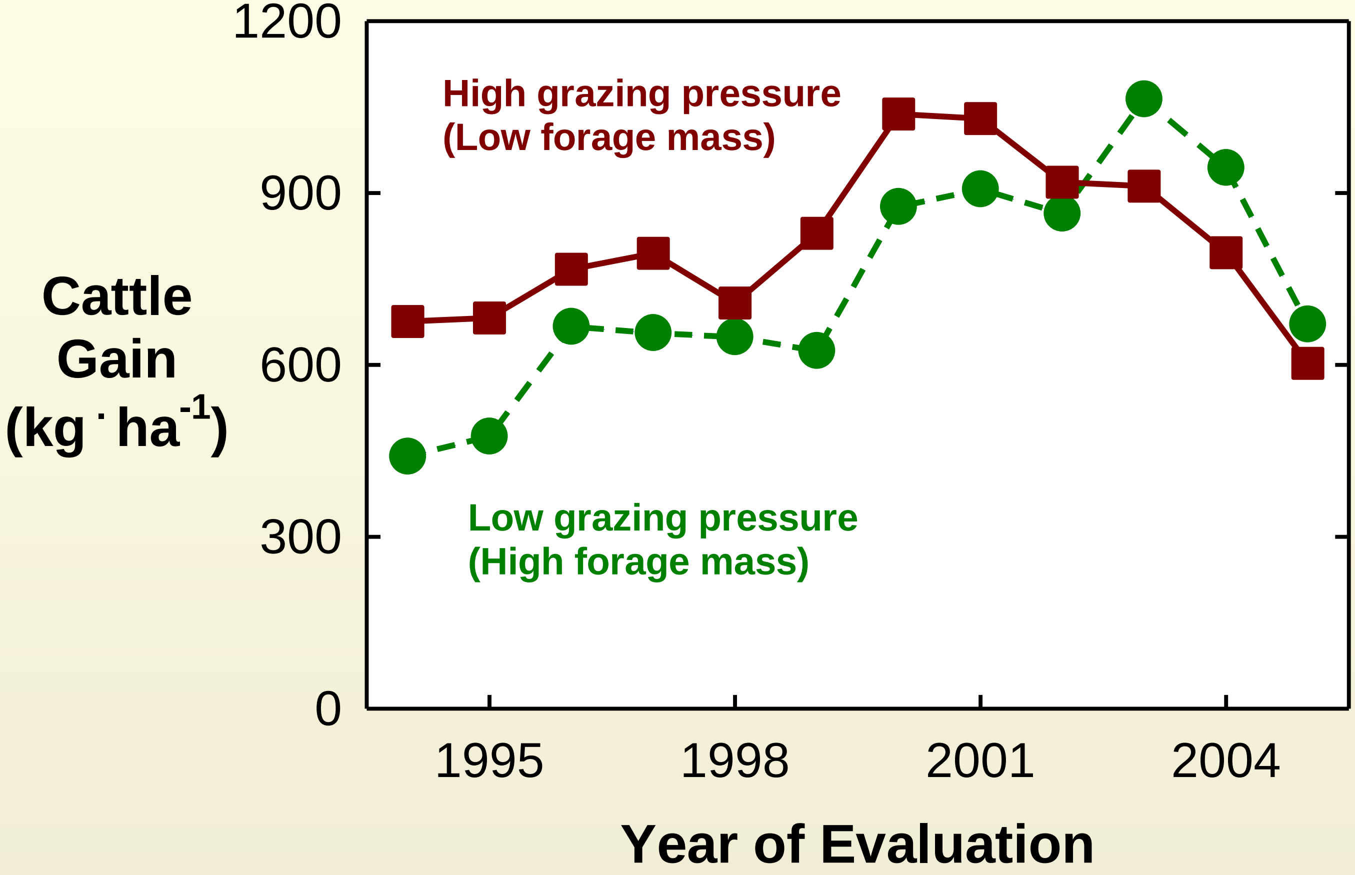
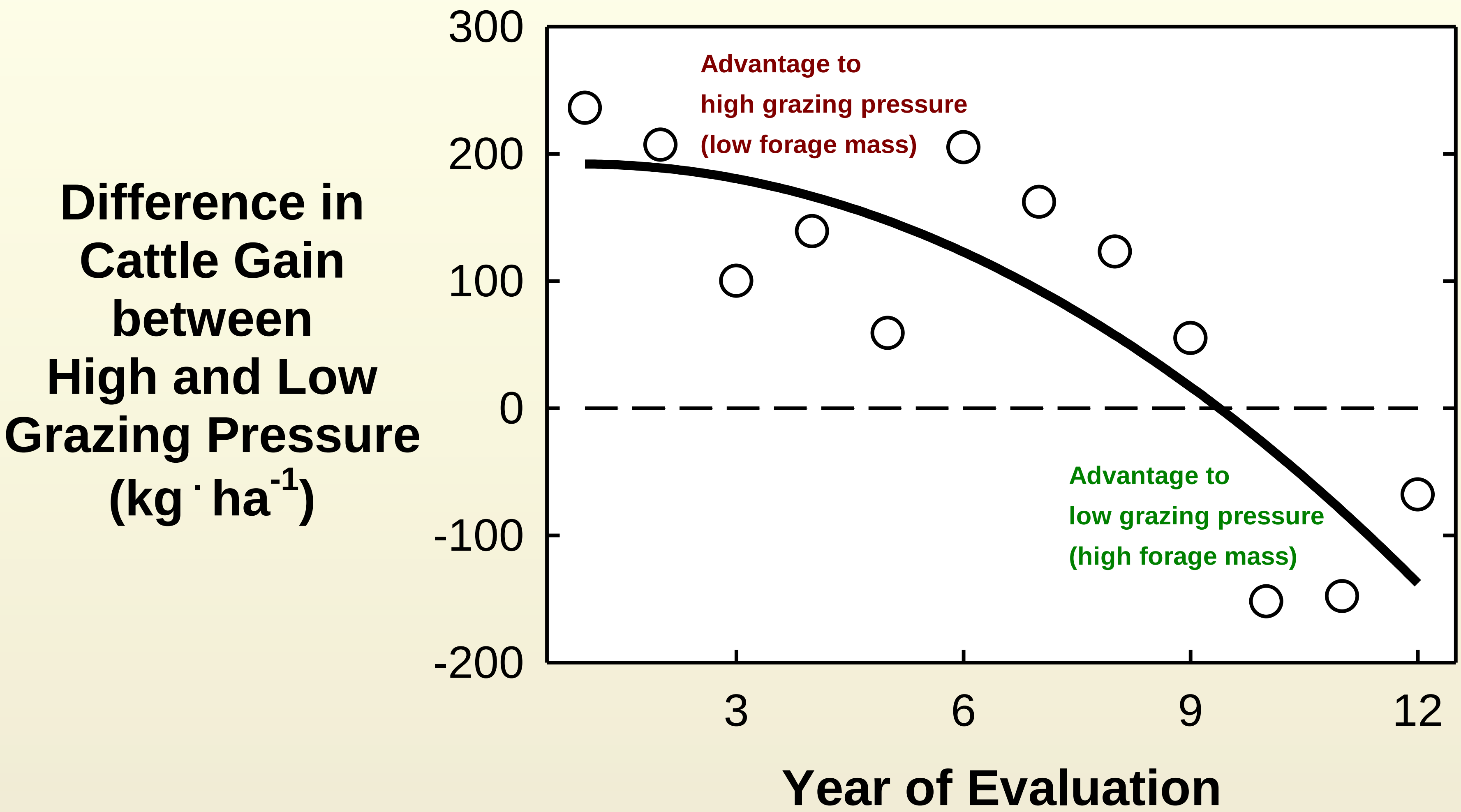
Grazing pressure and its impact on productivity



Bermudagrass pasture in Georgia Piedmont grazed by yearling steers

Data from Stuedemann and Franzluebbers (2007) J. Animal Sci. 85:1340-1350 and Franzluebbers et al. (2013) Renewable Agric. Food Syst. 28:160-172

Long-term perspective is needed…



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Multiple-year study investigating grazing of cover crops in north Georgia

Early Response of Soil Organic Fractions to Tillage and Integrated Crop–Livestock Production

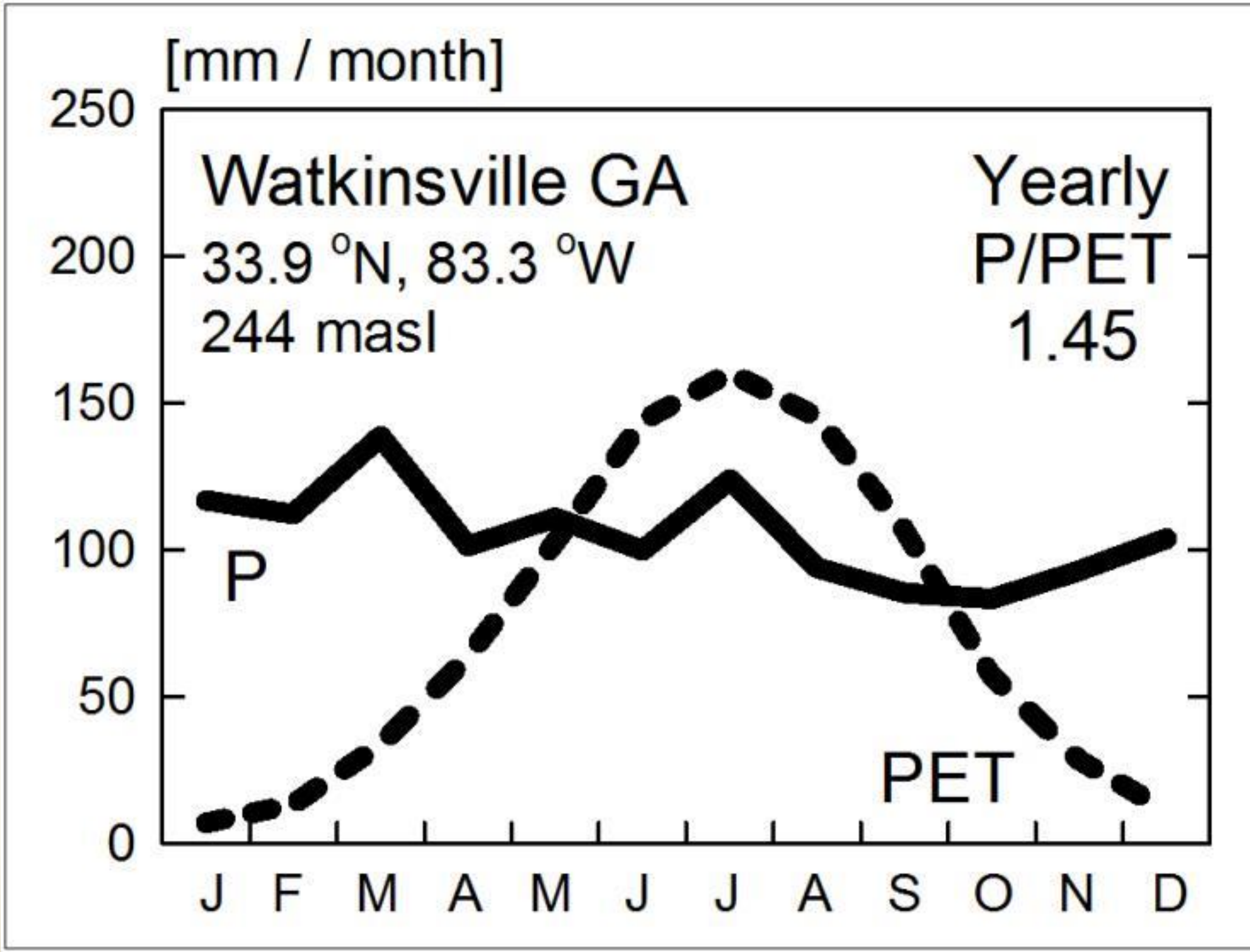
Alan J. Franzluebbers*
John A. Stuedemann
USDA-ARS, Natural Resource Conserv. Ce
1420 Experiment Station Rd.
Watkinsville, GA 30677

Crop and cattle responses to tillage systems for integrated crop–livestock production in the Southern Piedmont, USA

A.J. Franzluebbers*, and J.A. Stuedemann

Background

— Environmental conditions



Data from National Climatic Data Center

Methods

— Tillage treatments

Methods

— Cover crop utilization treatments

Crop production

— *Summary of major effects*

- ✓ **Summer grain crops (sorghum, corn, soybean) were sometimes inhibited by spring grazing of winter cover crop, but wheat was unaffected by summer grazing of cover crop**

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- ✓ **Summer grain crops (sorghum, corn, soybean) were sometimes inhibited by spring grazing of winter cover crop, but wheat was unaffected by summer grazing of cover crop**
- ✓ **Both rye and pearl millet cover crops were enhanced with no-tillage (NT) compared with conventional-tillage (CT) management**
- ✓ **Long-term NT resulted in greater yields than short-term NT**

Animal production

— *Animal gain on cover crops*

Year	Days of grazing	Spring Grazing		Summer Grazing	
		CT	NT	CT	NT
		-------------------- kg ha^{-1} --------------------			

Animal production

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Year	Days of grazing	Spring Grazing		Summer Grazing	
		CT	NT	CT	NT
		-------------------- **kg ha^{-1}**		--------------------	
2002	0 – 56				
2003	42 – 58				
2004	49 – 50				
2005	26 – 42				
2006	35 – 0				
2007	36 – 0				
2008	33 – 0				
Mean	**37 – 52**				

Animal production

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Year	Days of grazing	Spring Grazing		Summer Grazing	
		CT	NT	CT	NT
		-------------------- kg ha^{-1} --------------------			
2002	0 – 56	-	-		
2003	42 – 58	219	292		
2004	49 – 50	386	518		
2005	26 – 42	76	163		
2006	35 – 0	113	109		
2007	36 – 0	79	240		
2008	33 – 0	335	223		
Mean	**37 – 52**	**201**	**258**		

Animal production

— *Animal gain on cover crops*

Year	Days of grazing	Spring Grazing		Summer Grazing	
		CT	NT	CT	NT
		-------------------- kg ha^{-1} --------------------			
2002	0 – 56	-	-	248	323
2003	42 – 58	219	292	297	335
2004	49 – 50	386	518	158	181
2005	26 – 42	76	163	250	324
2006	35 – 0	113	109	-	-
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Mean	**37 – 52**	**201**	**258**	**238**	**291**

Animal production

— Added value provided by grazing of cover crops

- ✓ **With cattle gain of 243 ± 112 kg ha^{-1} on cover crops, this could equate to an additional \$320-640 ha^{-1} in gross sales, depending on cattle price (historically, \$0.60-1.20 lb^{-1})**

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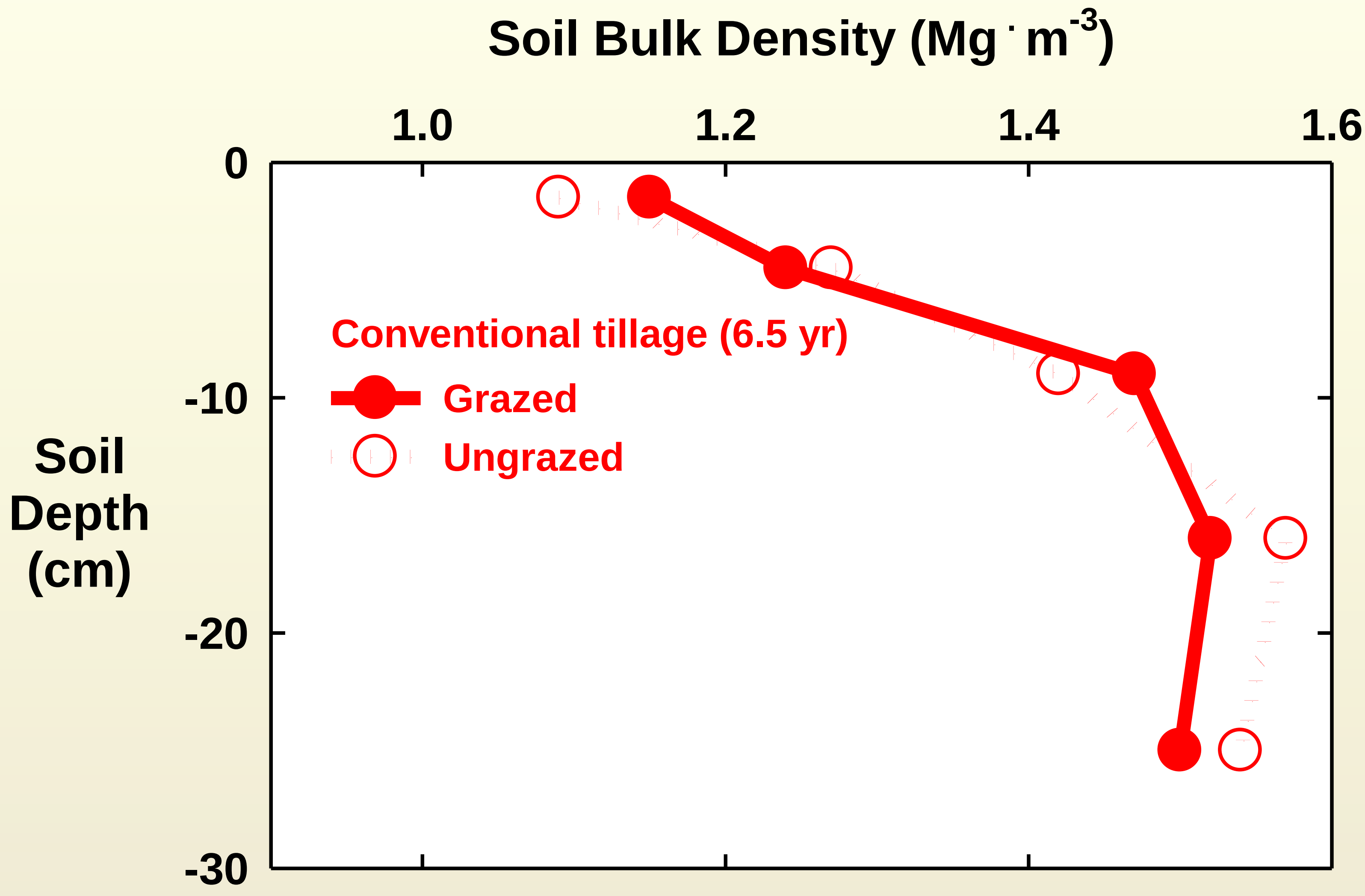
- ✓ **No-tillage management of cover crops compared with conventional tillage resulted in 28% greater cattle gain in spring (57 kg ha^{-1}) and 22% greater cattle gain in summer (53 kg ha^{-1})**

Soil response to treading



Franzluebbers and Stuedemann (2008) Soil Till. Res. 100:141-153

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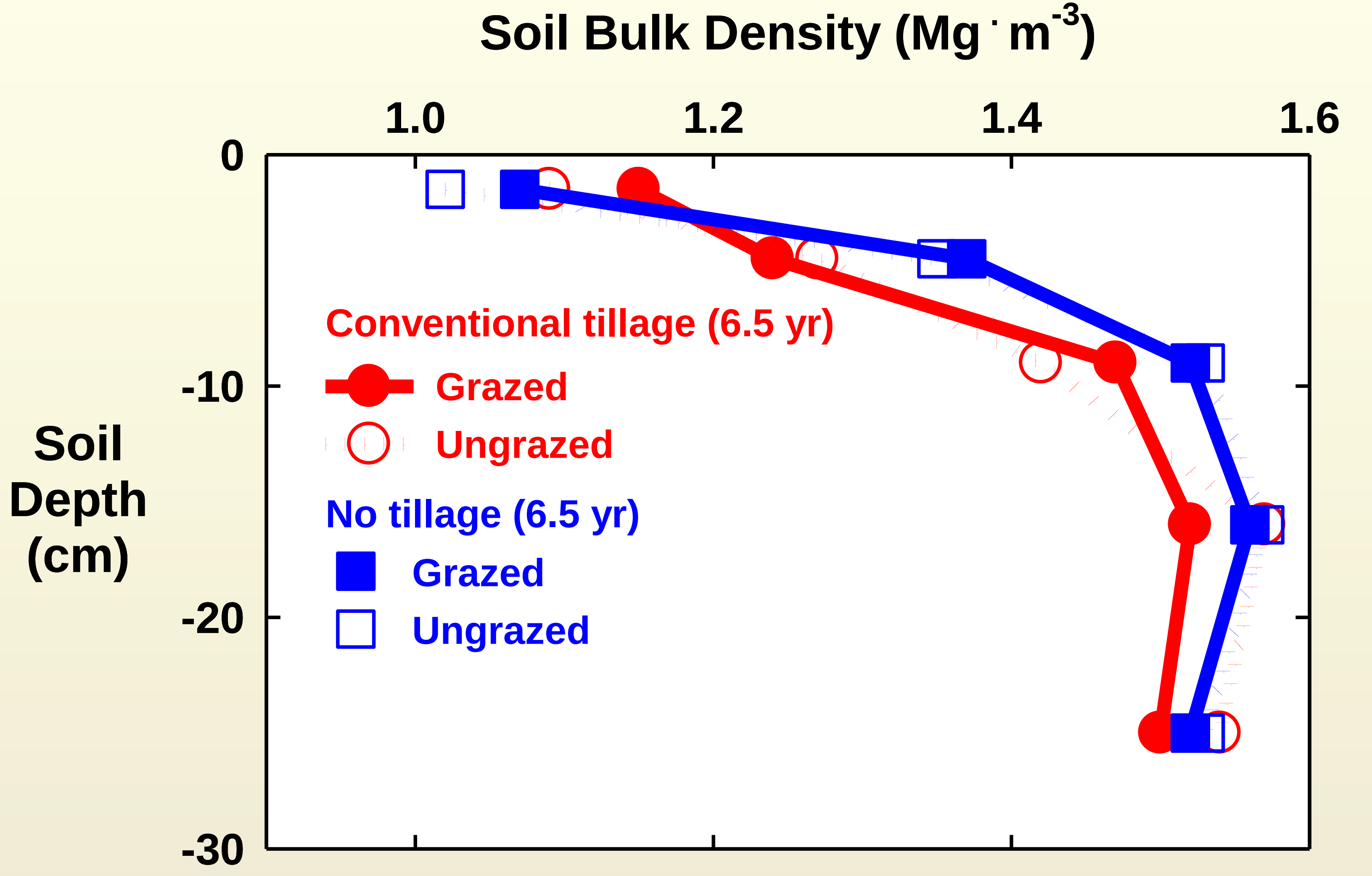

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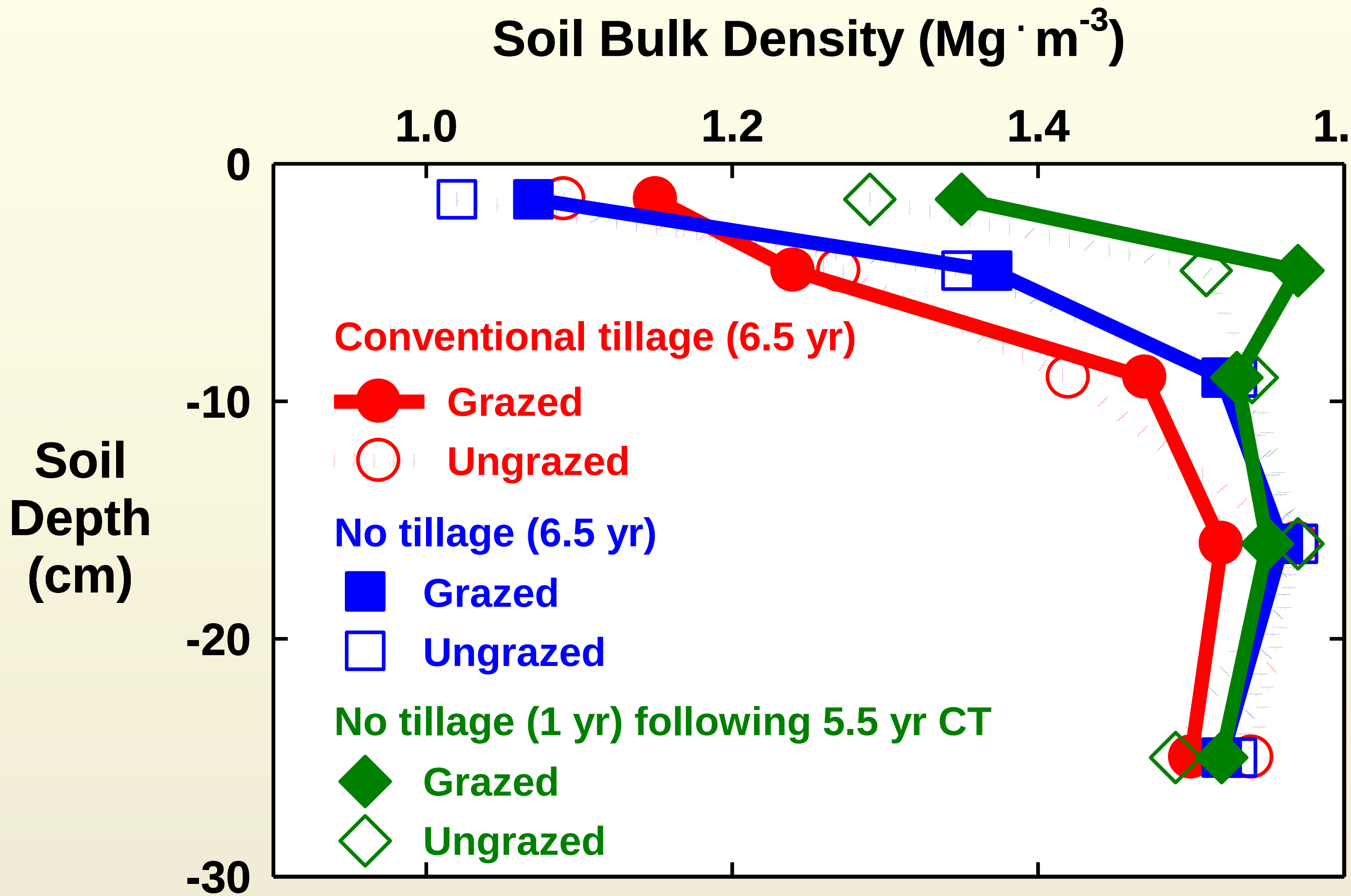

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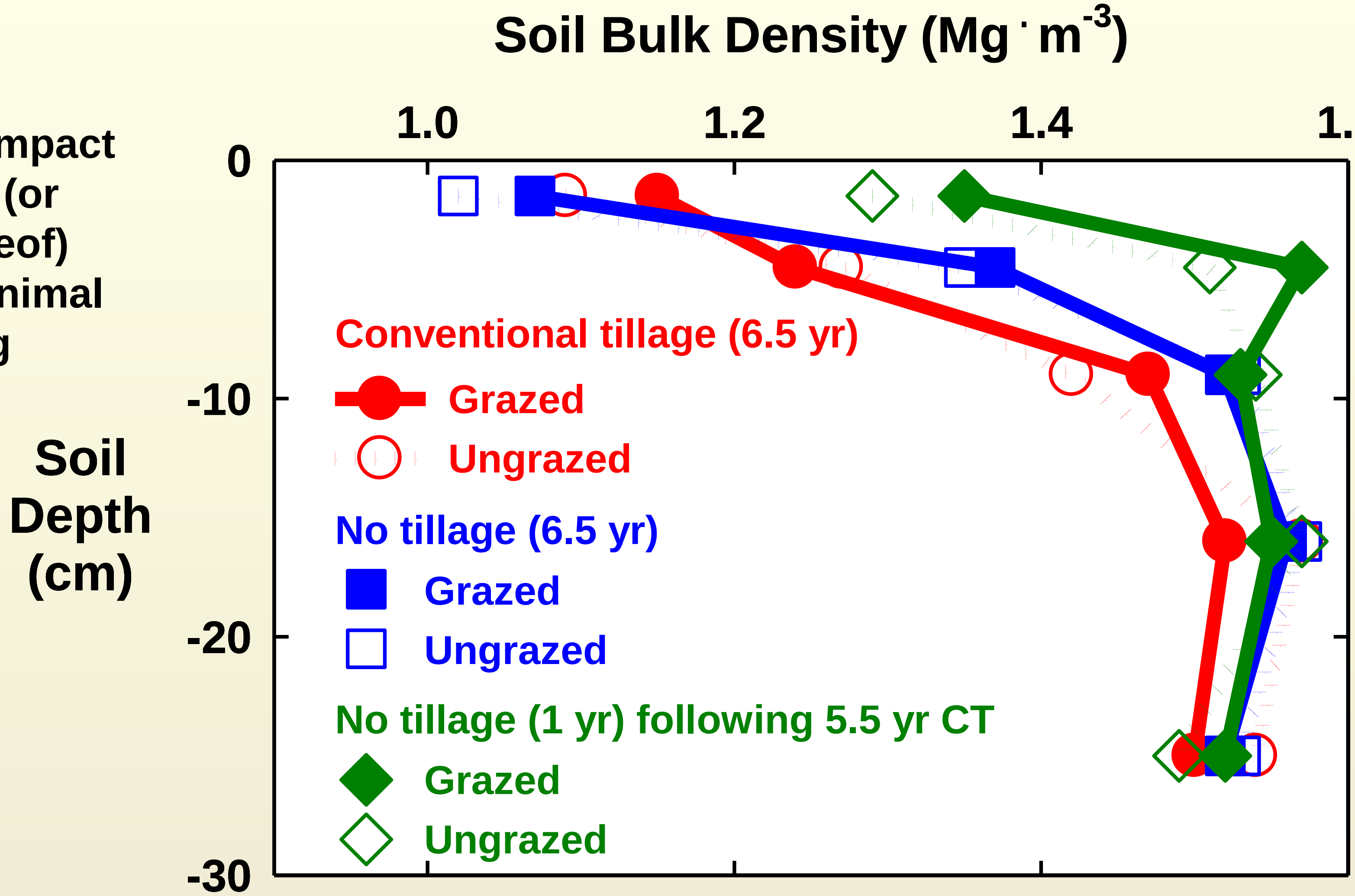
Soil response to treading

Greater impact of tillage (or lack thereof) than of animal trampling



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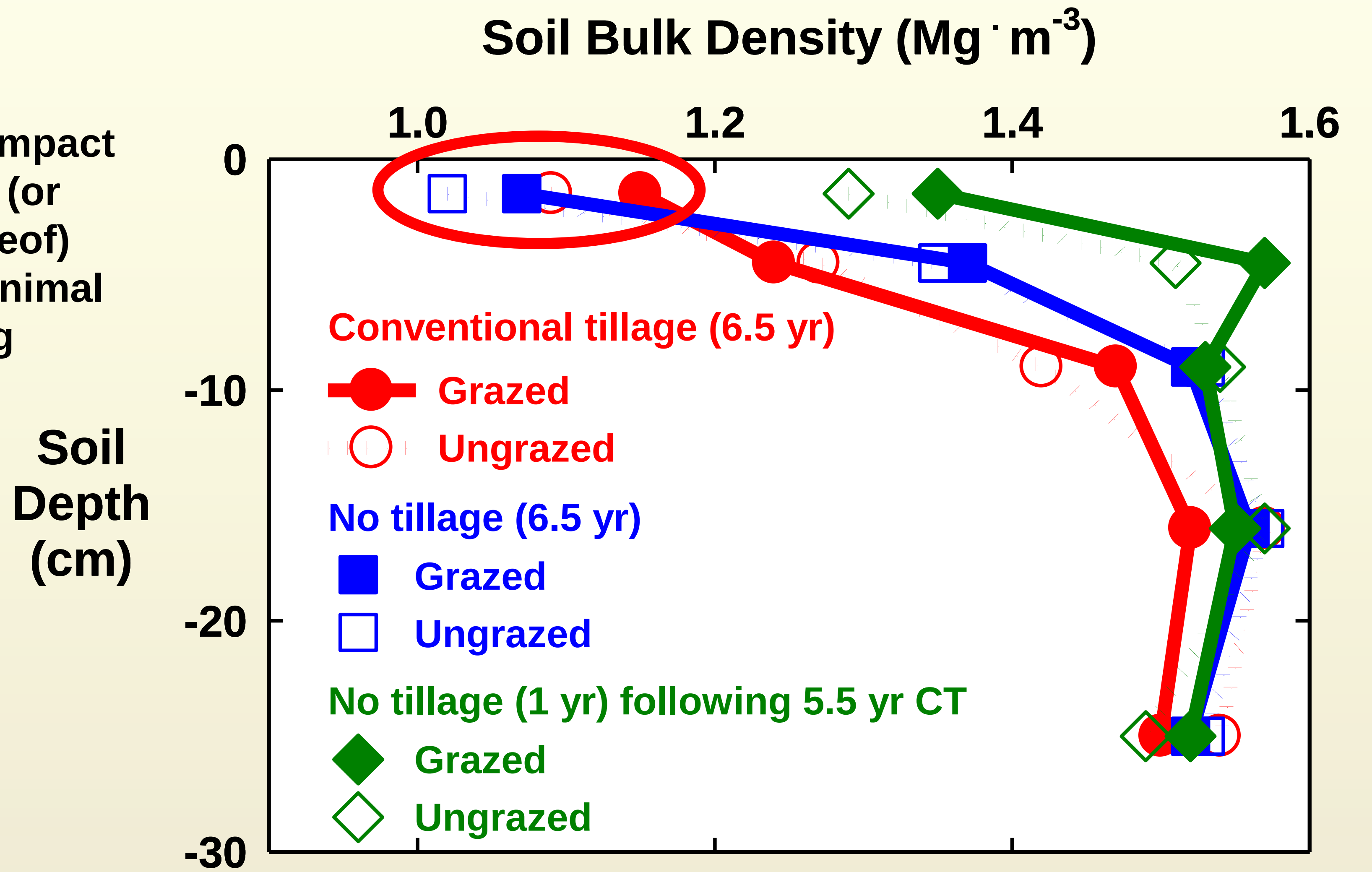

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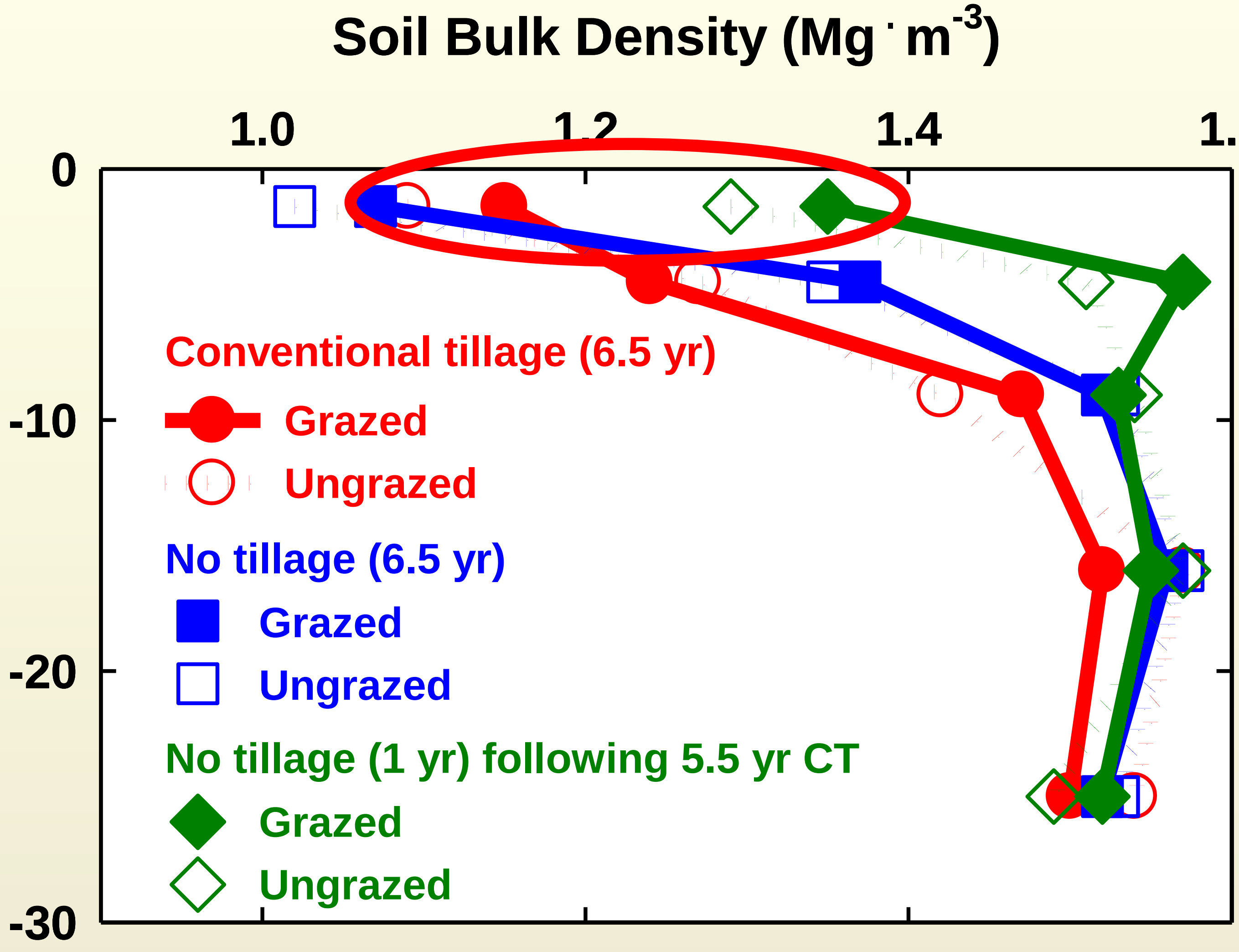

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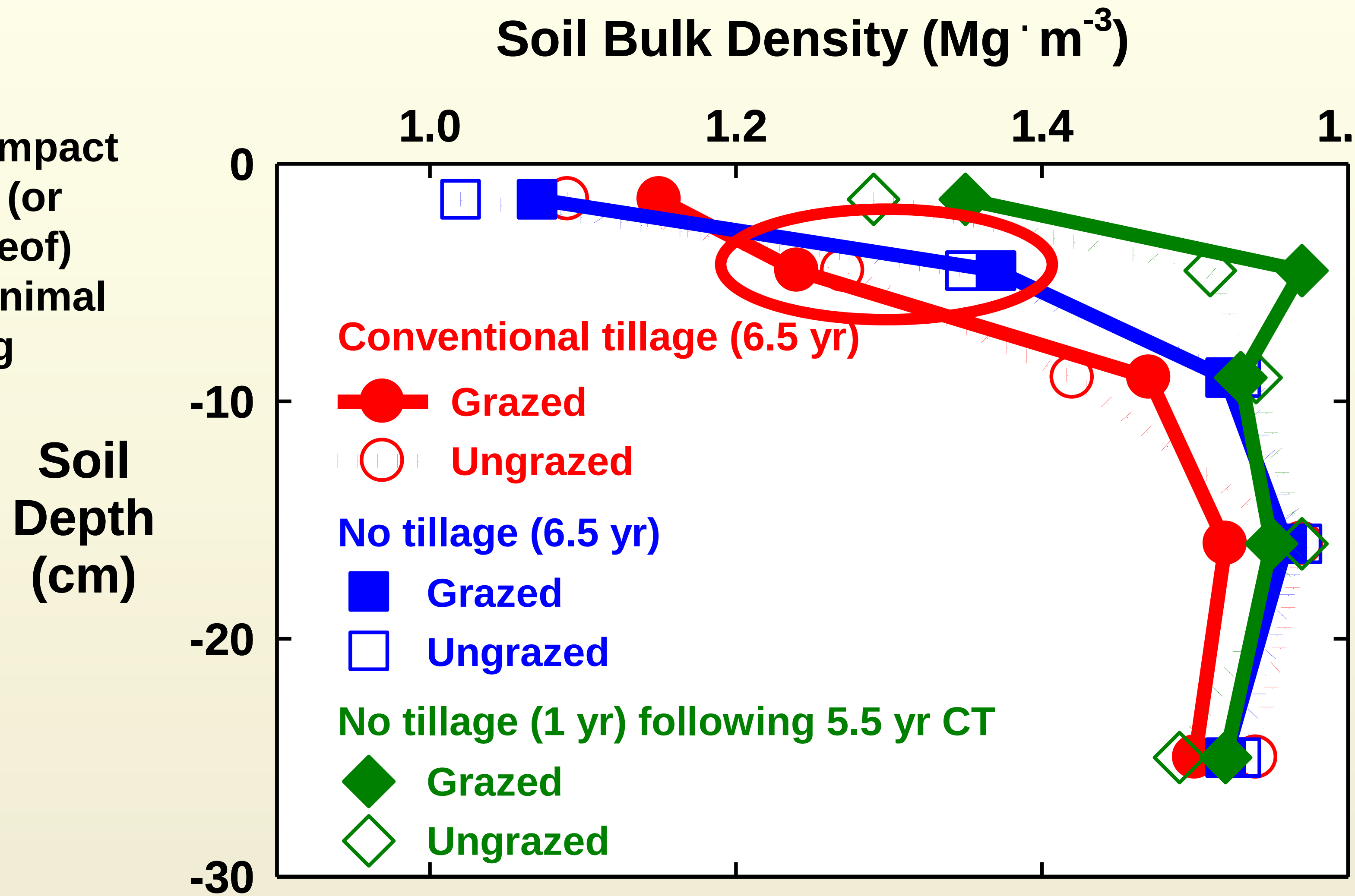

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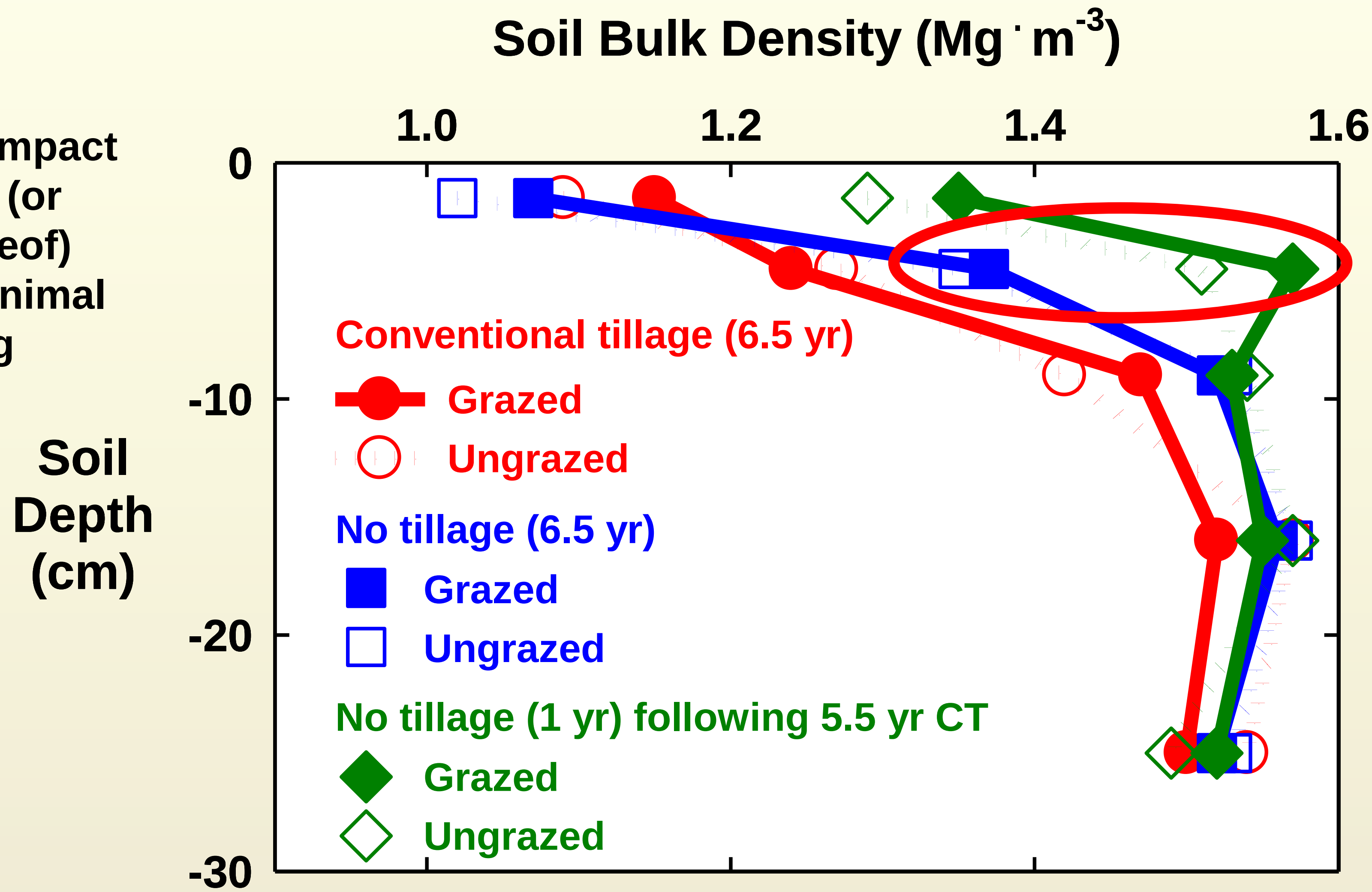

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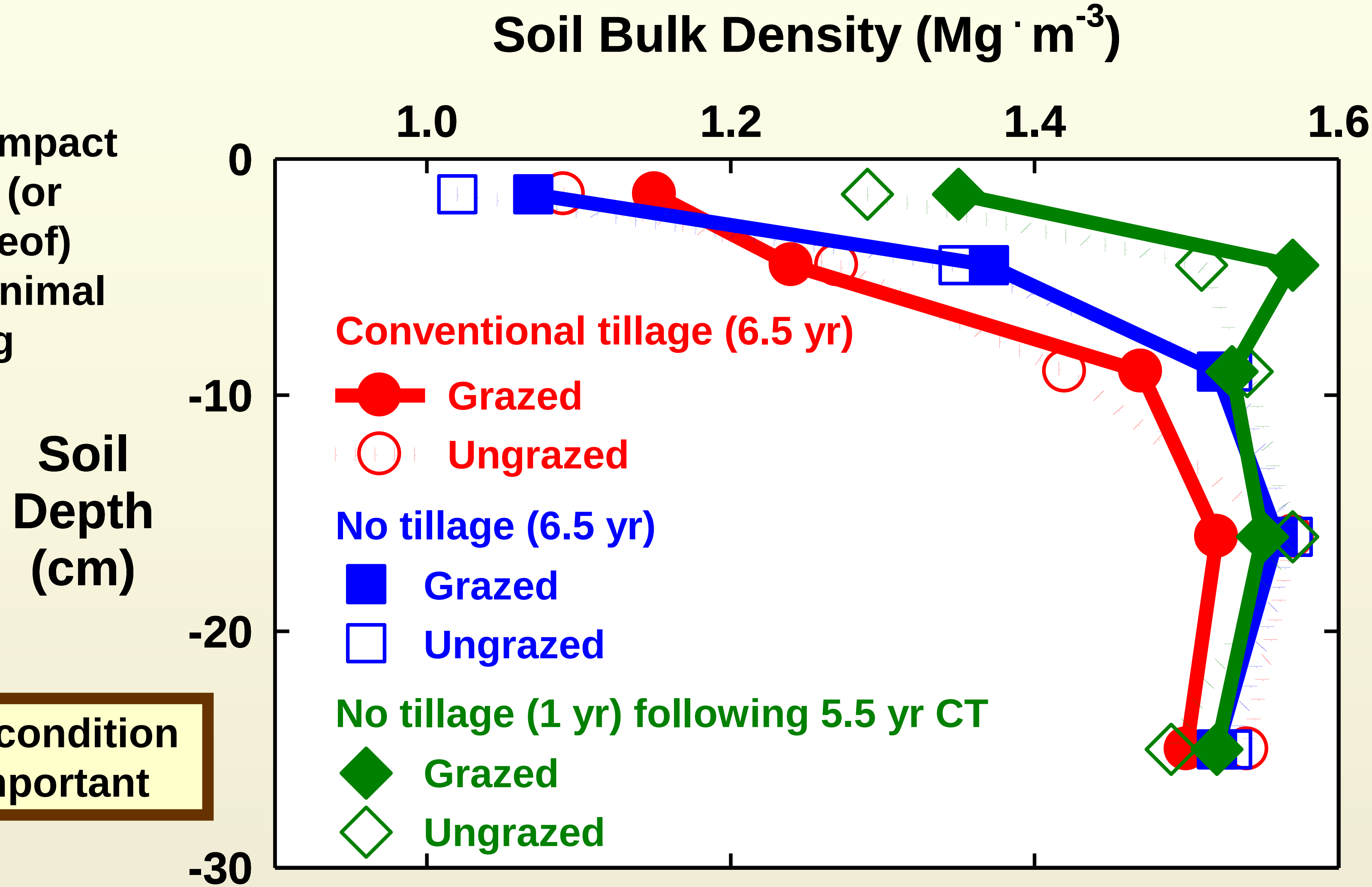

Starting condition for NT important

Franzluebbers and Stuedemann (2008) Soil Till. Res. 100:141-153

Soil penetration resistance

Soil penetration resistance

Tillage	Cover crop	Water content	Soil depth (cm)		
			0-10	10-20	20-30
		$m^3\ m^{-3}$	--------------- Joules ---------------		
		0.12	*123*	*267*	*329*

Wet soil conditions (6 events in Years 2, 3, and 4)

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NT	Ungrazed	0.22	90	131	137

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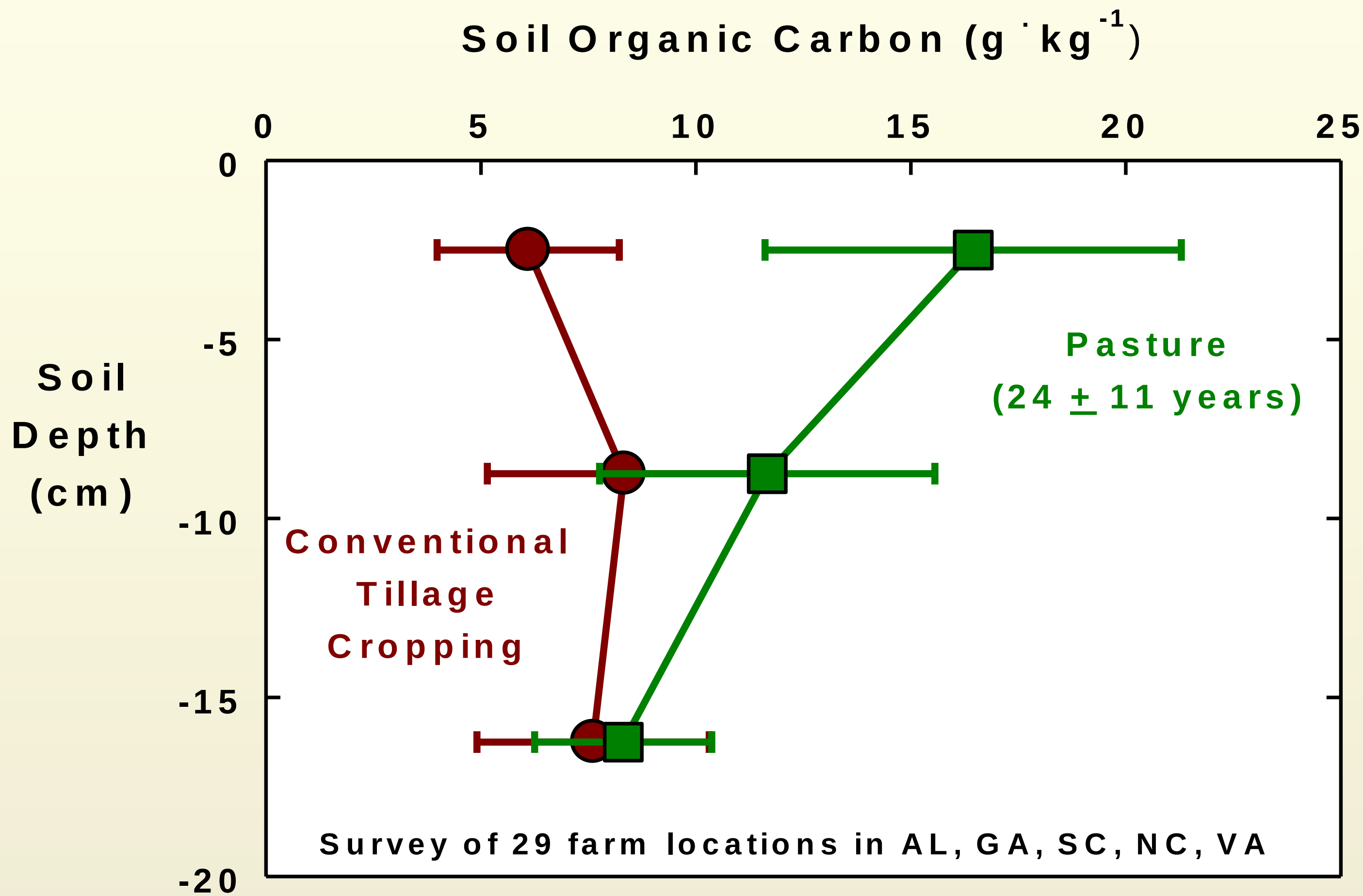
Accumulation of soil organic matter with perennial grasses

Soil organic carbon under cropping and pastures



Sequestration of SOC ($Mg\ ha^{-1}\ yr^{-1}$)

0.53 **

0.17 **

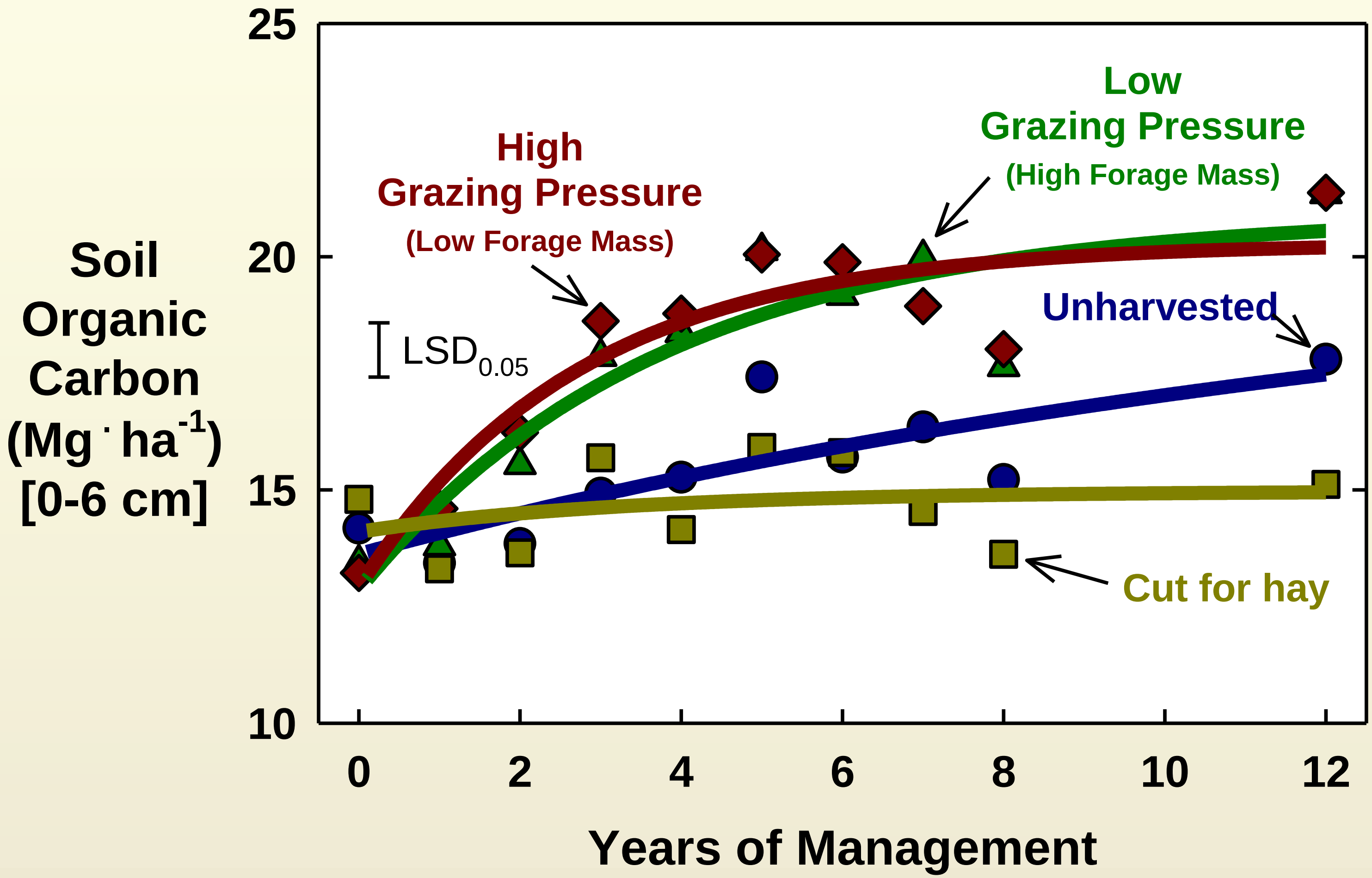
0.05 ns

0-20 cm

0.74 **

Data from Causarano et al. (2008) Soil Sci. Soc. Am. J. 72:221-230

Soil organic matter accumulation under pasture management

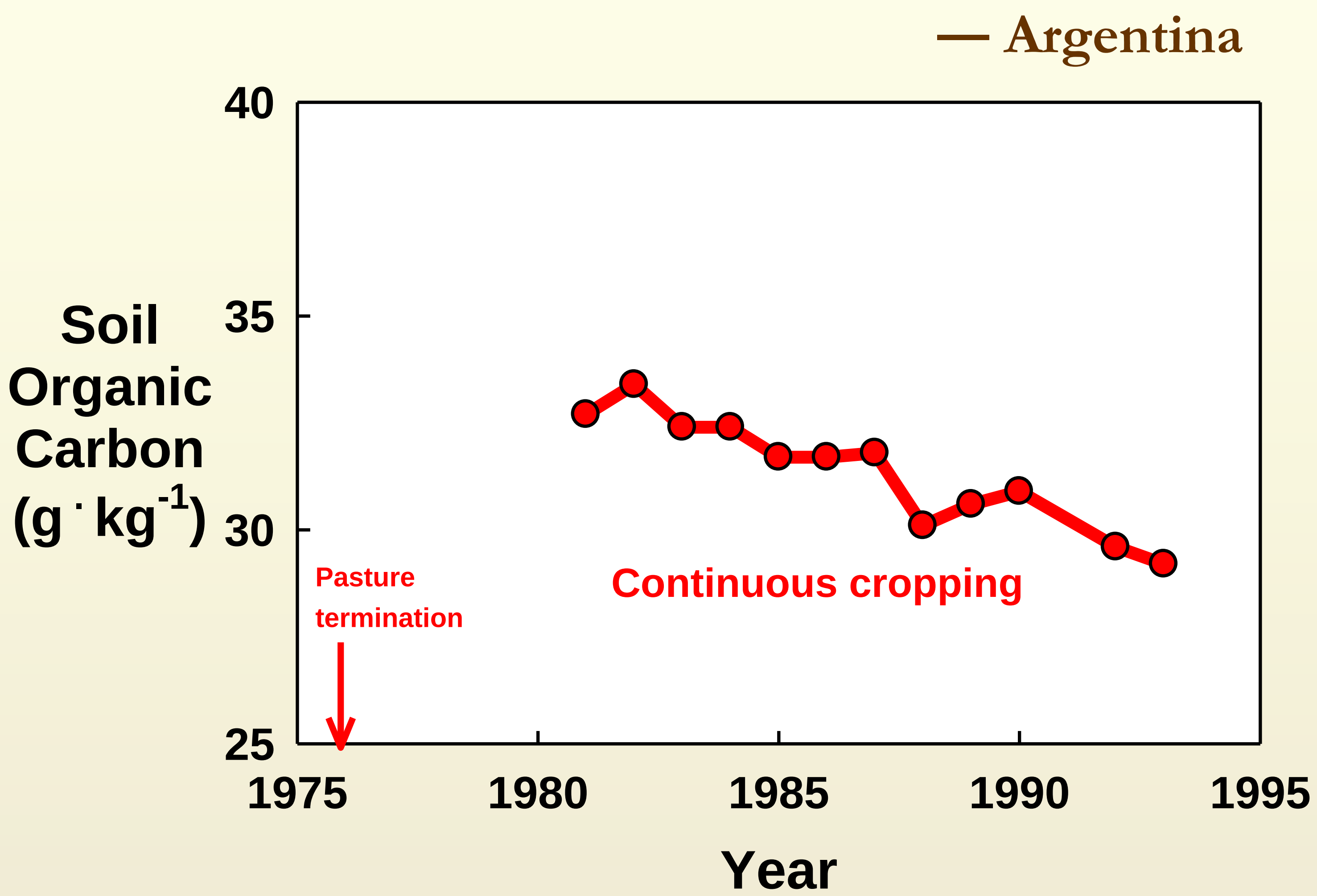


Yearly Accumulation Rate

C Mg ha^{-1} yr^{-1}	N kg ha^{-1} yr^{-1}
0.62	71
0.59	76
0.32	31
0.07	8

Franzluebbers and Stuedemann (2010) Soil Sci. Soc. Am. J. 74: 2131-2141

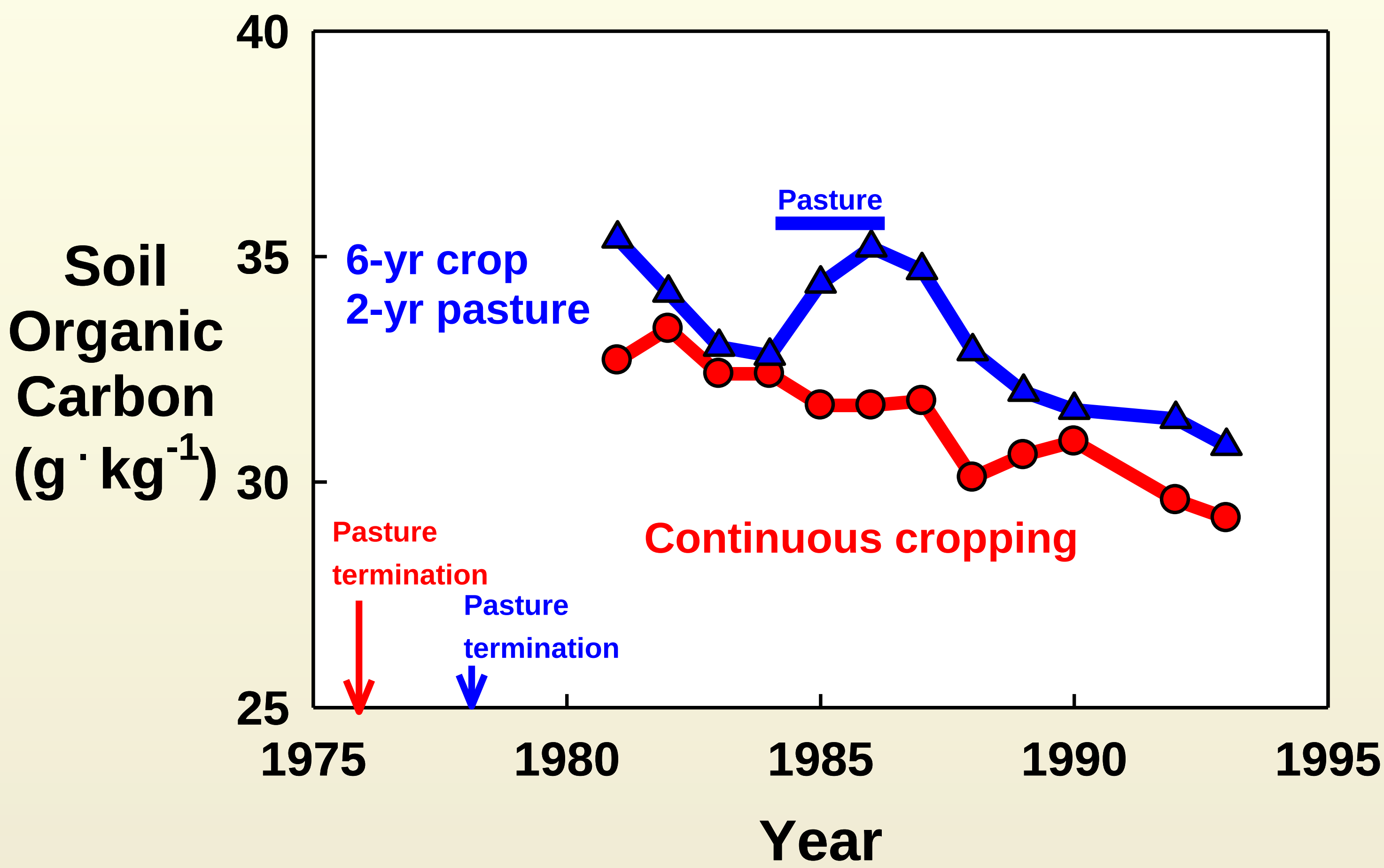
Dynamics of soil organic matter in rotations



Data from Studdert et al. (1997) Soil Sci. Soc. Am. J. 61:1466-1472

Dynamics of soil organic matter in rotations

— Argentina



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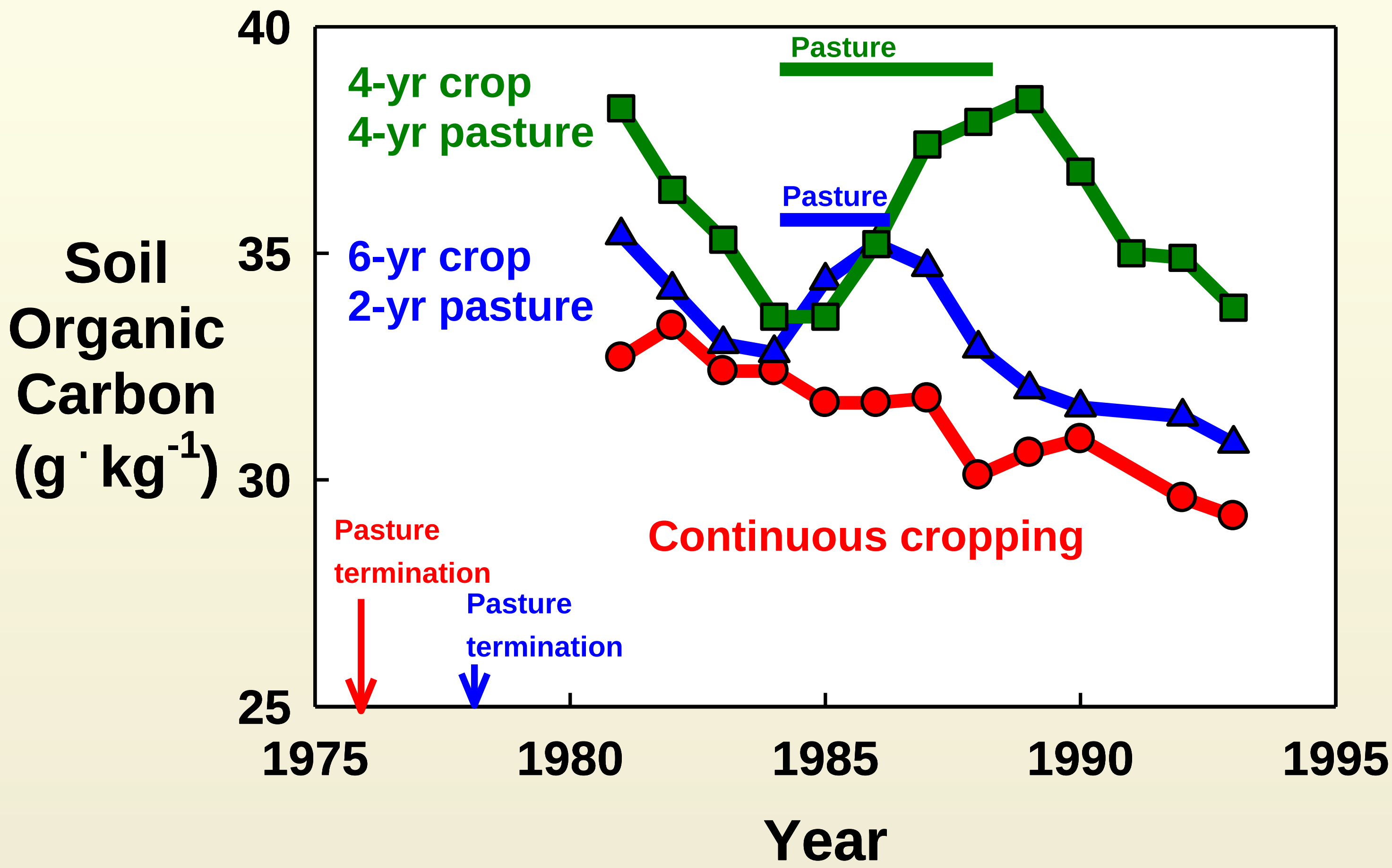
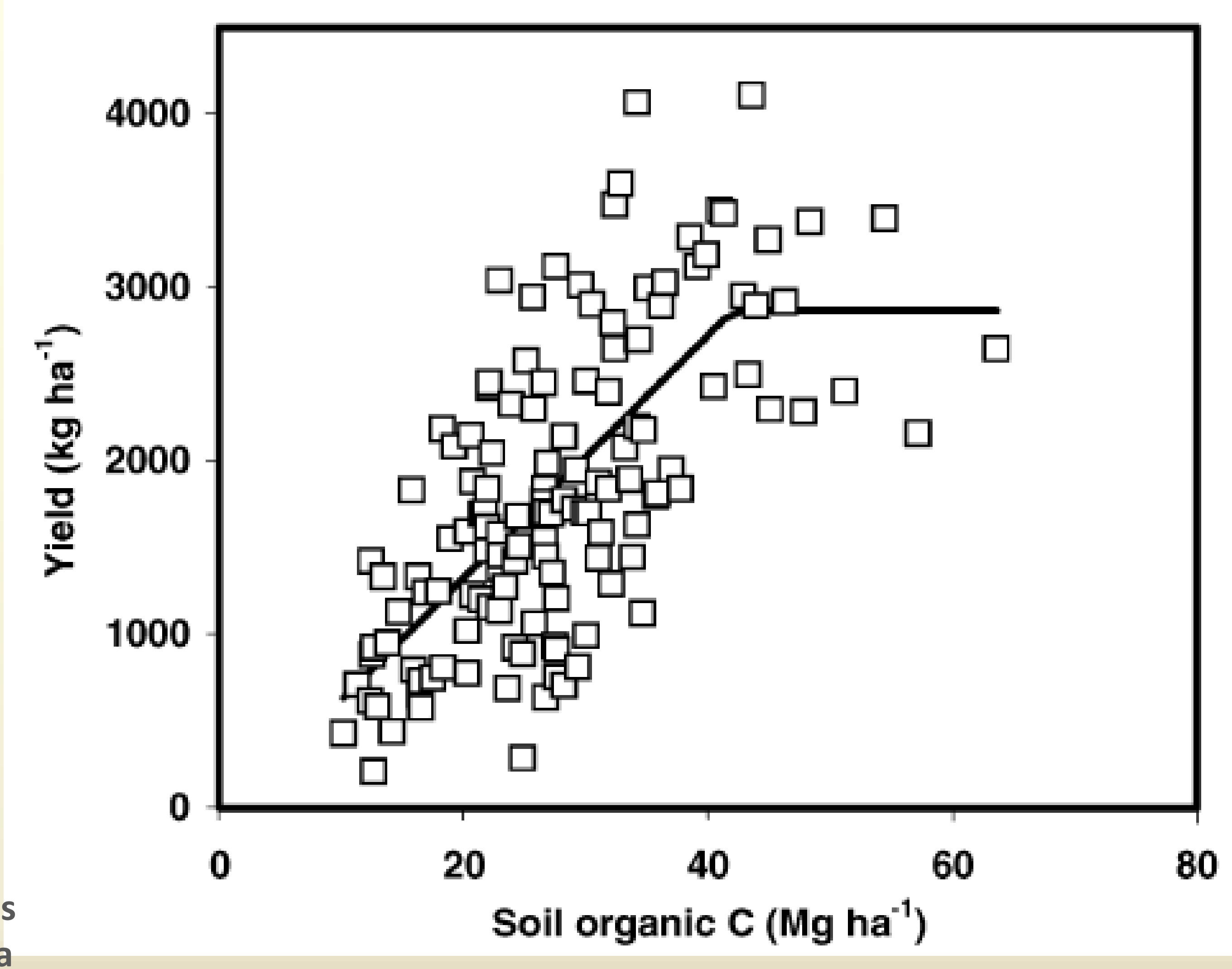
Dynamics of soil organic matter in rotations

— Argentina



Data from Studdert et al. (1997) Soil Sci. Soc. Am. J. 61:1466-1472

Soil organic matter as a baseline ecosystem indicator of productivity

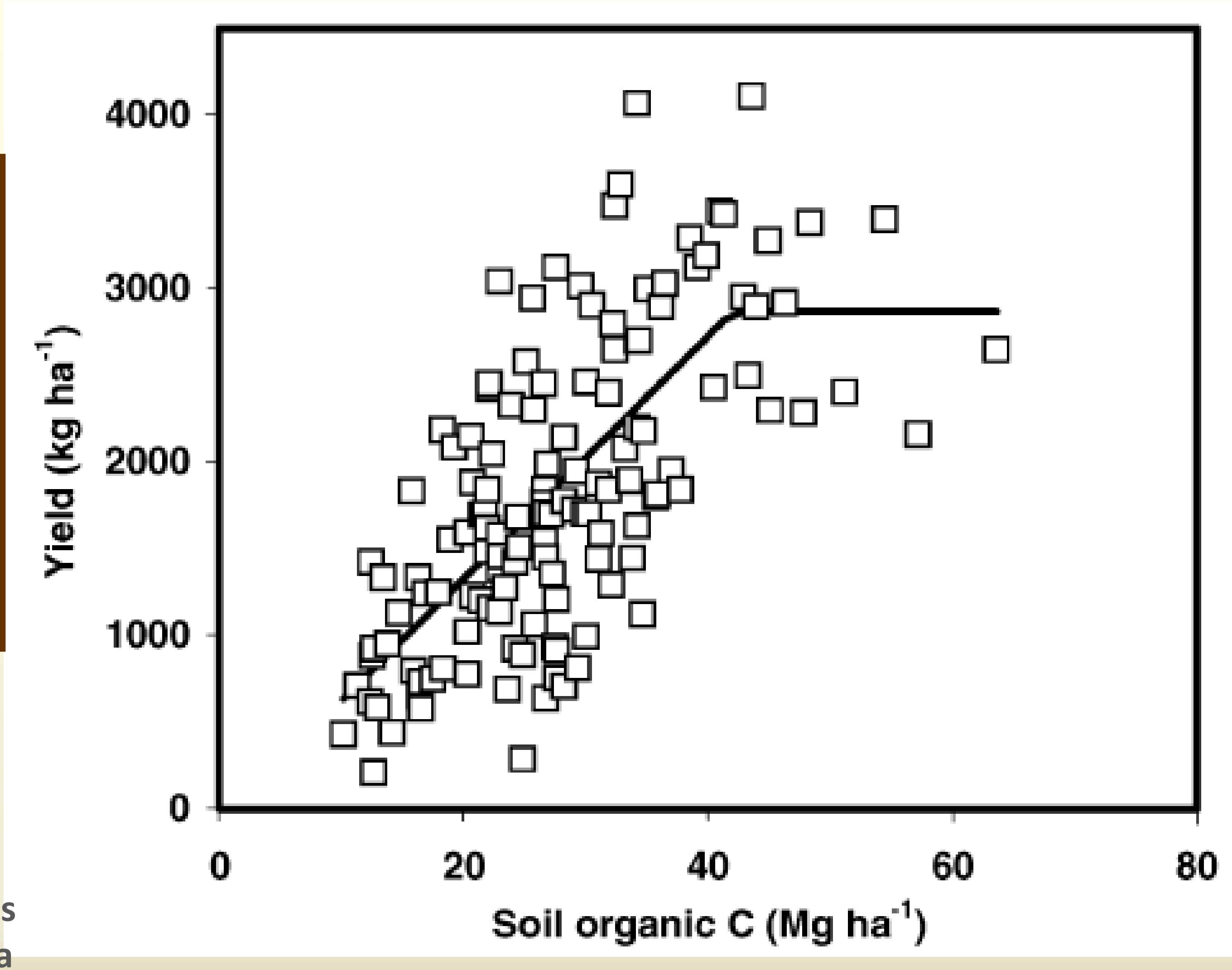


Argentine Pampas
134 farmer fields
Udolls, Ustolls, Psamments
3 years of wheat yield data
0-20 cm depth

From Diaz-Zorita (1999) Agron. J. 91:276-279

Soil organic matter as a baseline ecosystem indicator of productivity

Achieving or maintaining maximum soil organic matter storage is beneficial to crop productivity



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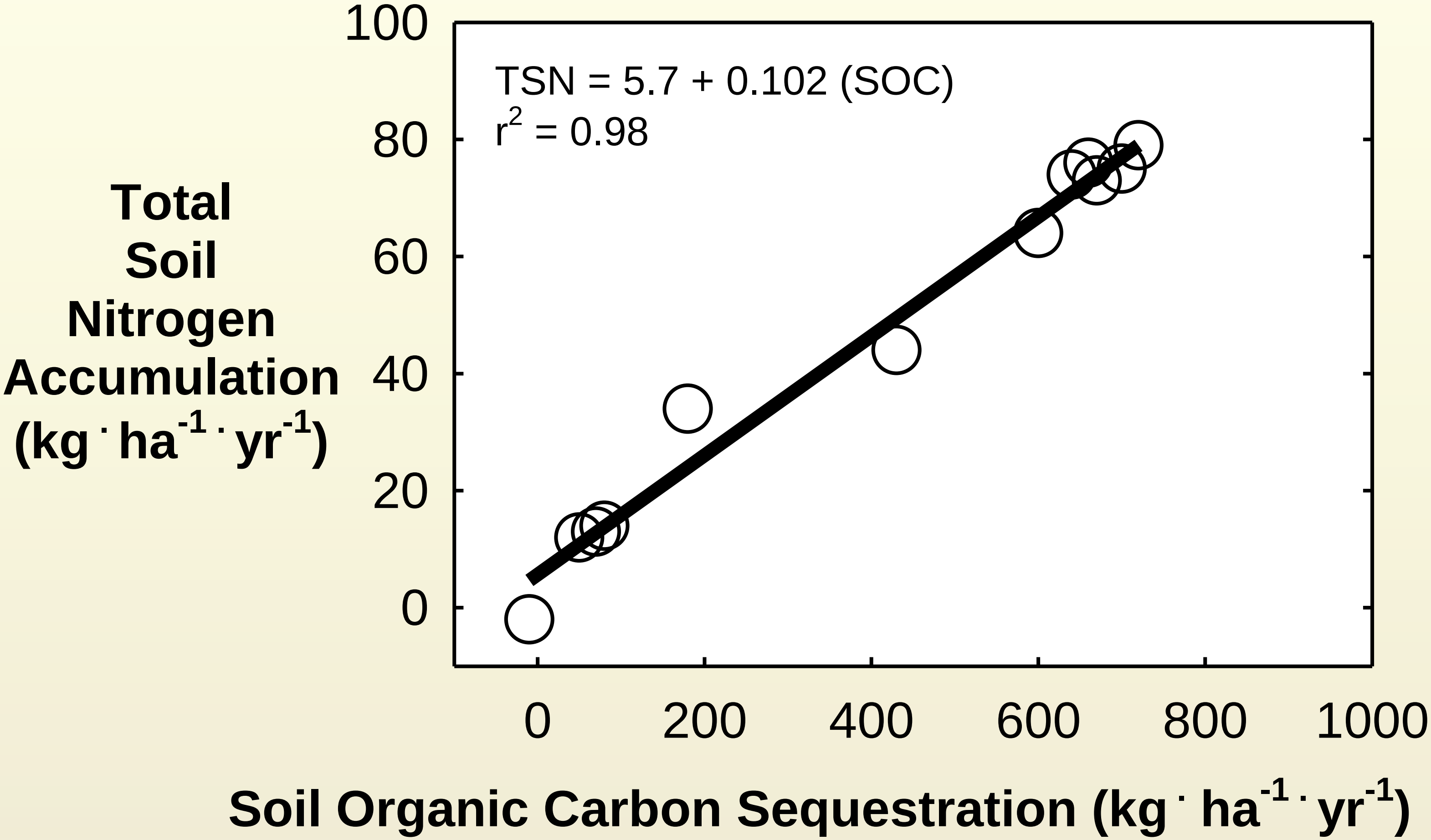
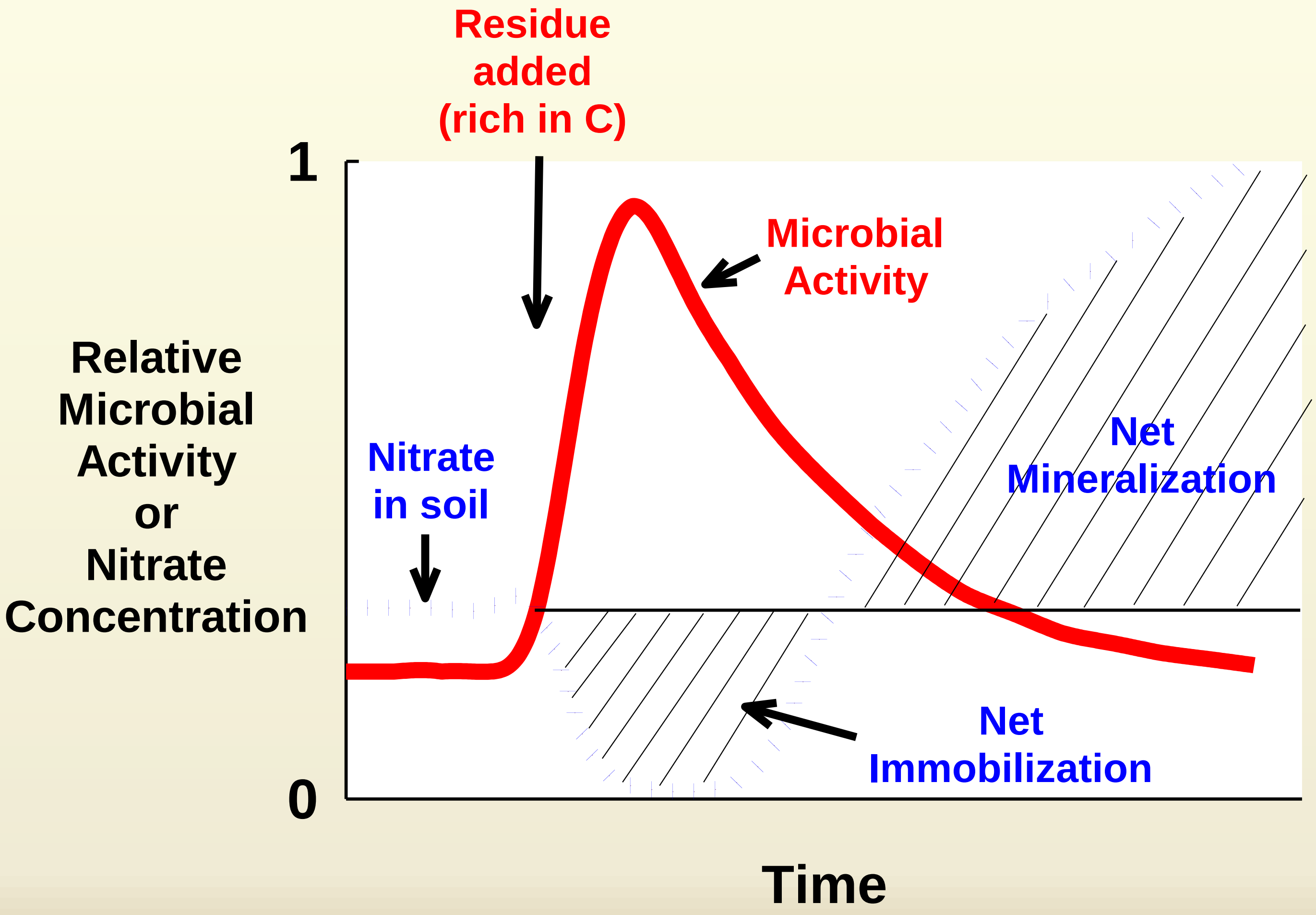
Relationship between soil C and N accumulation



Franzluebbers and Stuedemann (2010) Soil Sci. Soc. Am. J. 74:2131-2141

Linkage of nitrogen with carbon

Mineralization and immobilization of N linked with C availability



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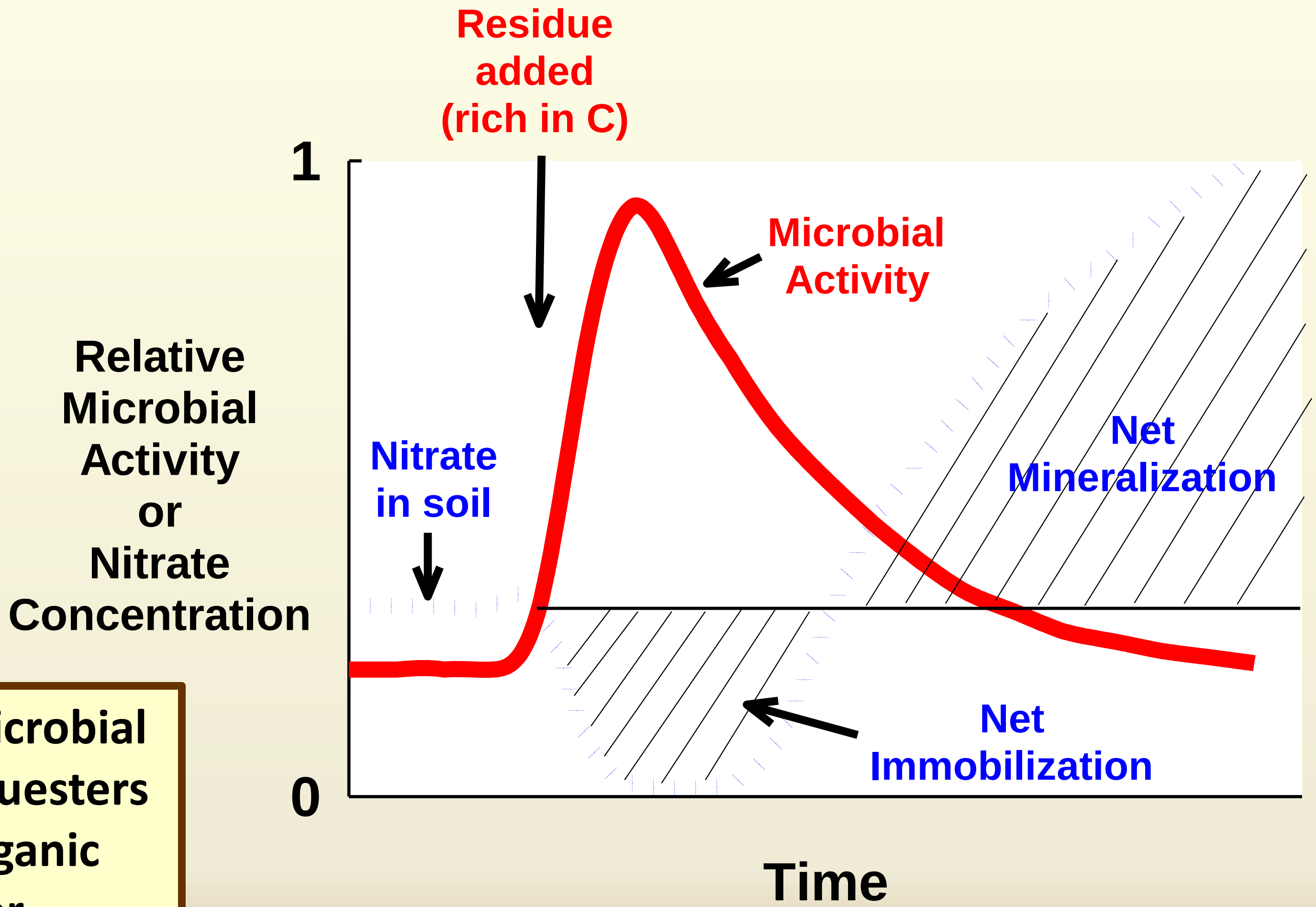
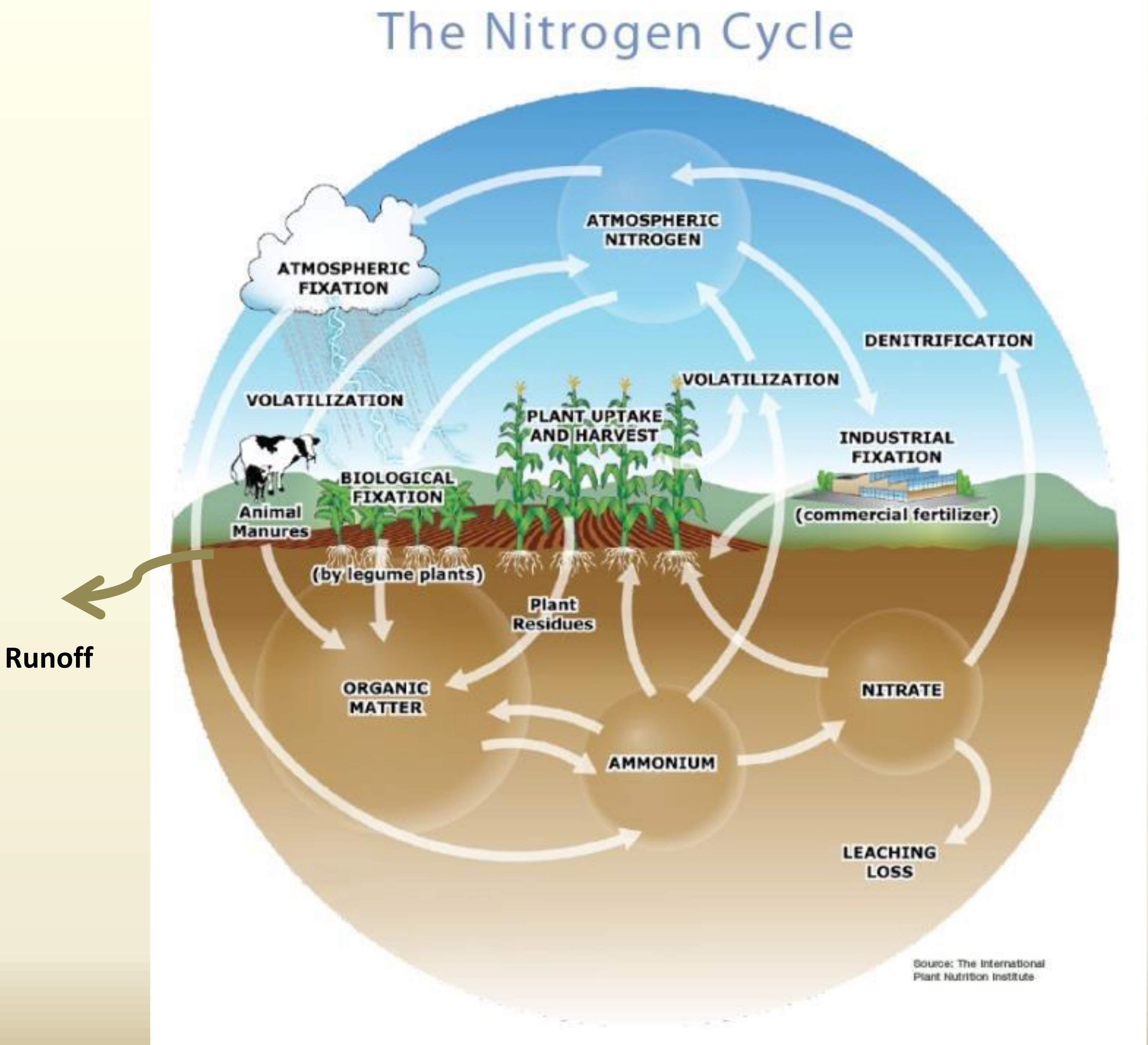


High soil microbial activity sequesters N into organic matter


The Nitrogen Cycle
ATMOSPHERIC NITROGEN
ATMOSPHERIC FIXATION
DENITRIFICATION
VOLATILIZATION
VOLATILIZATION
PLANT UPTAKE AND HARVEST
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Animal Manures
Plant Residues
ORGANIC MATTER
NITRATE
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LEACHING LOSS
Runoff
Source: The International Plant Nutrition Institute

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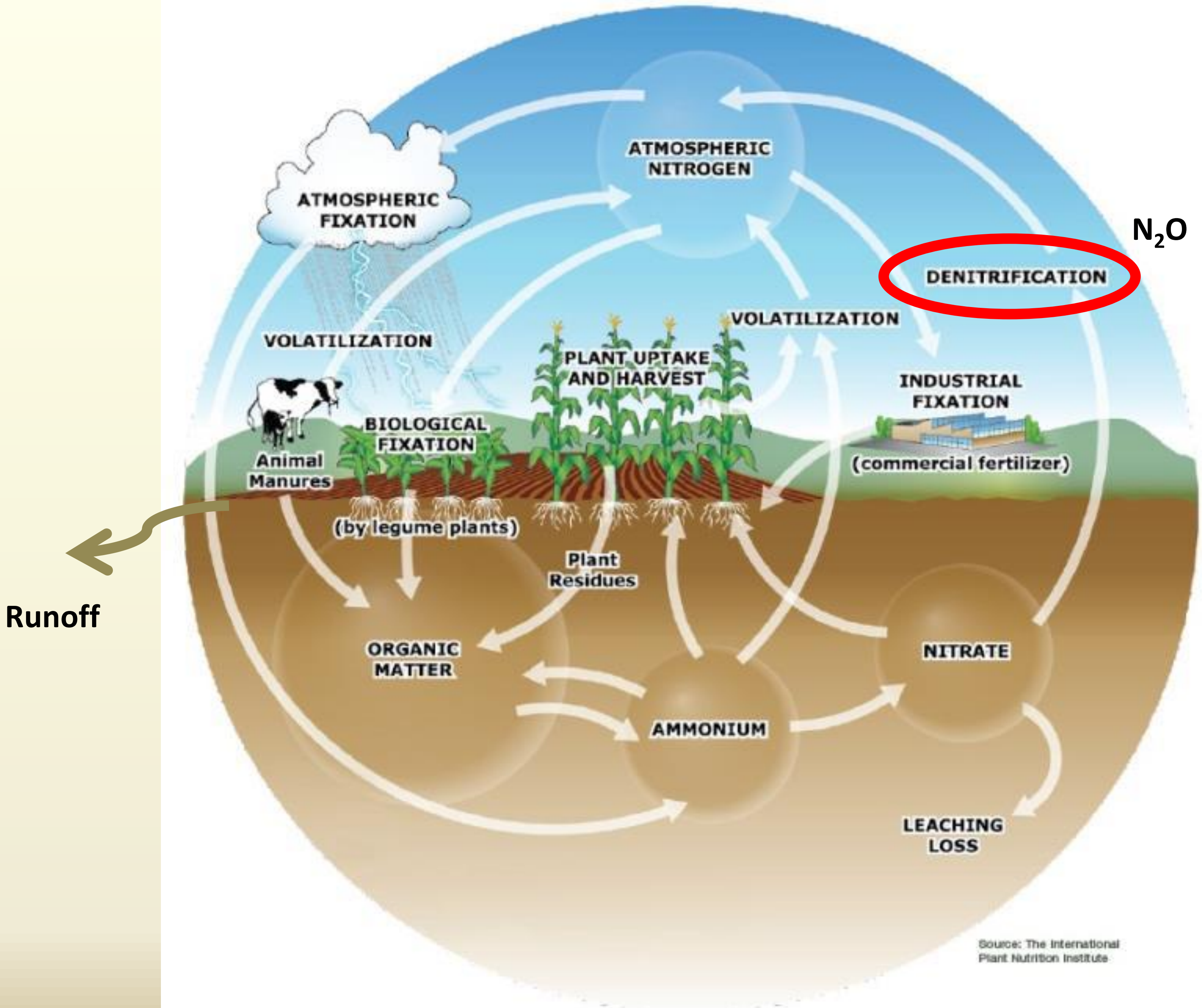

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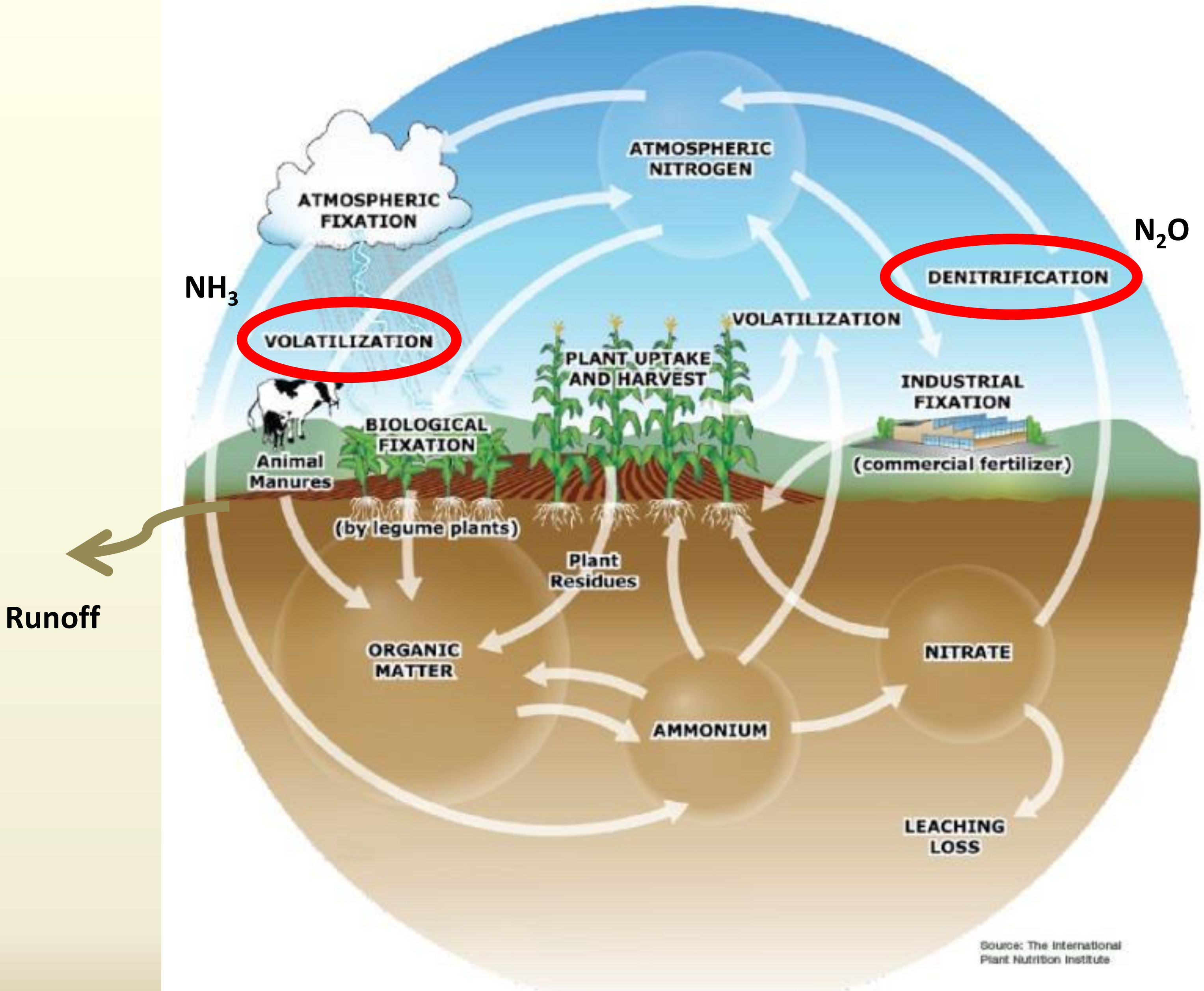

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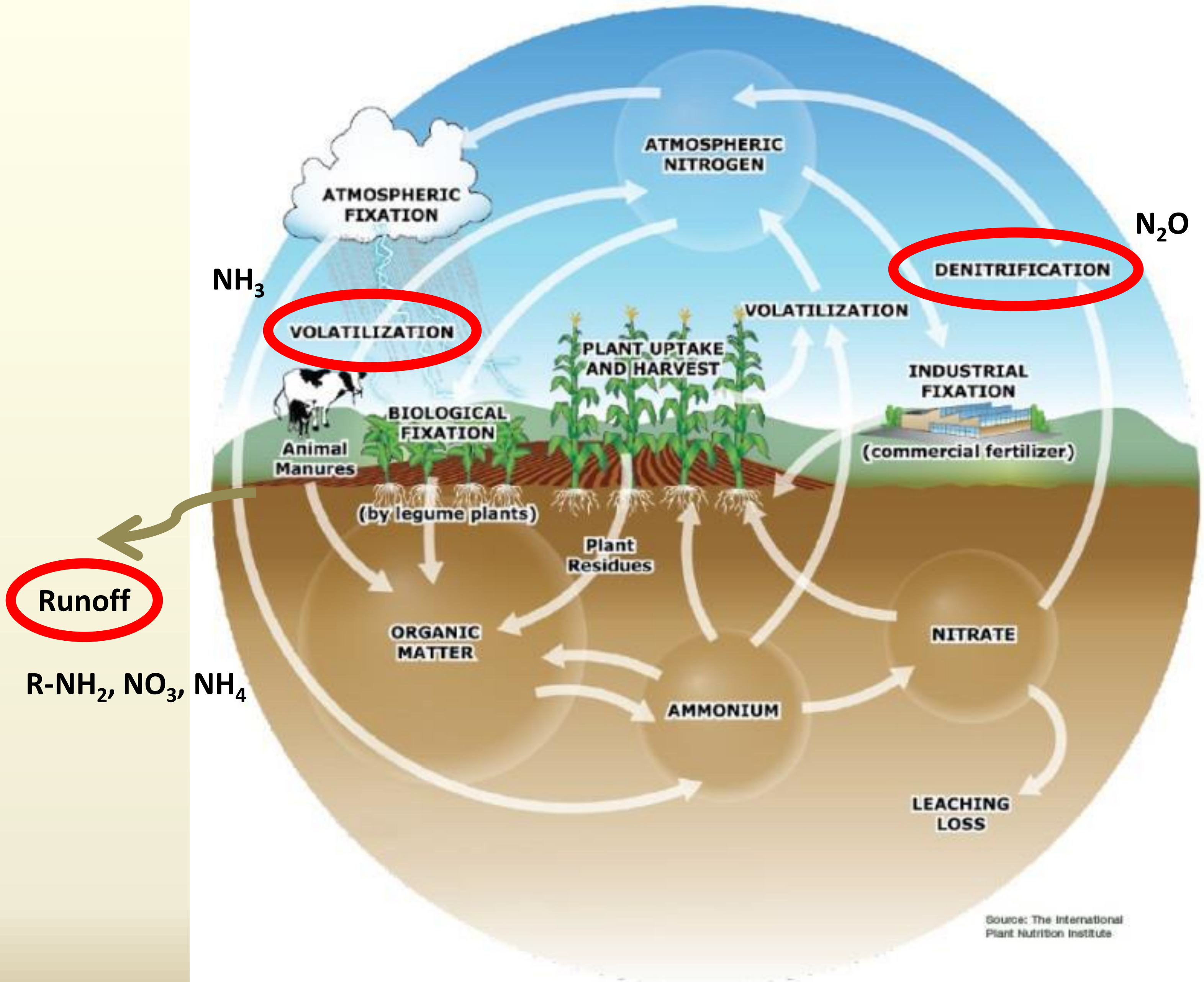

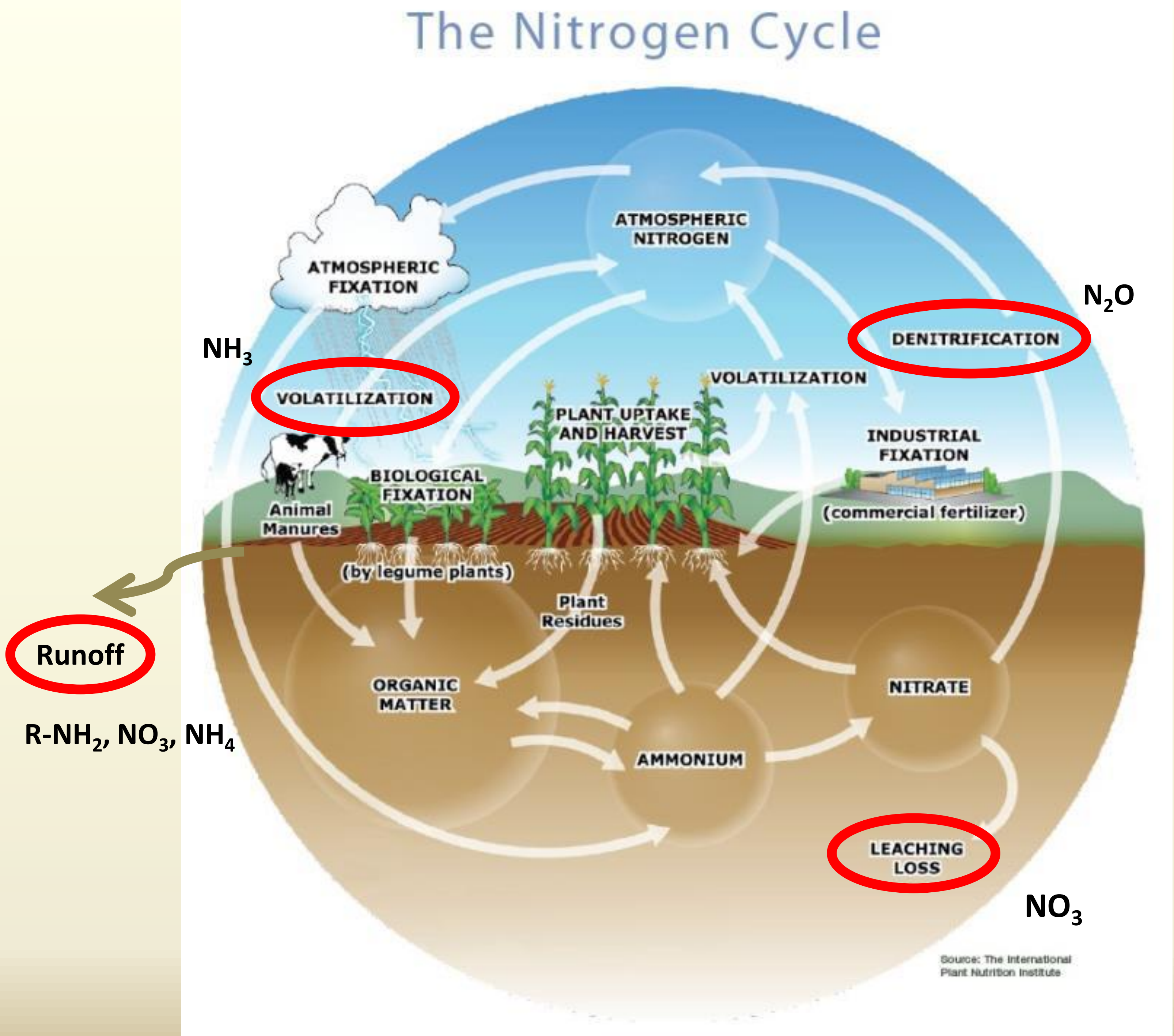

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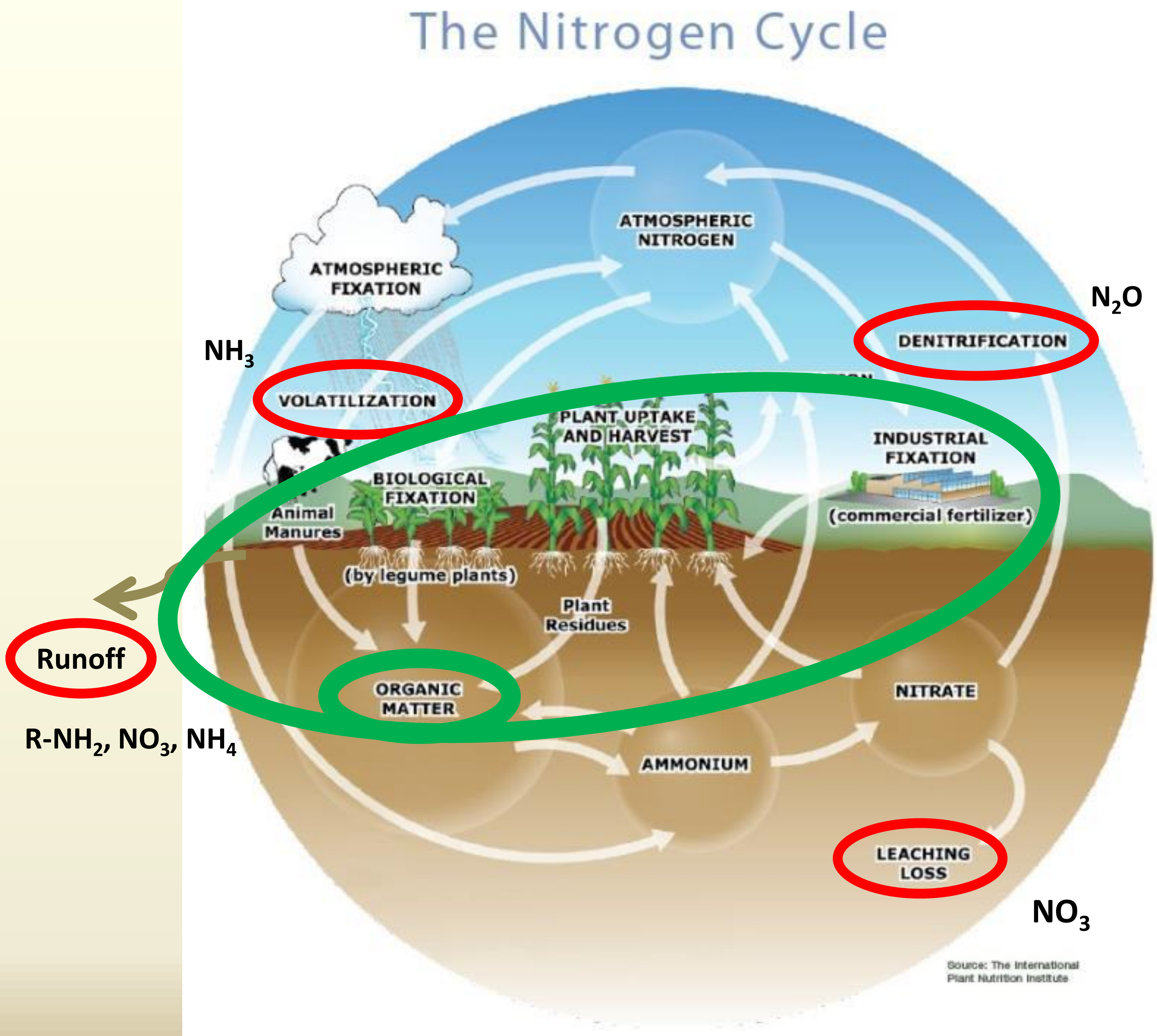
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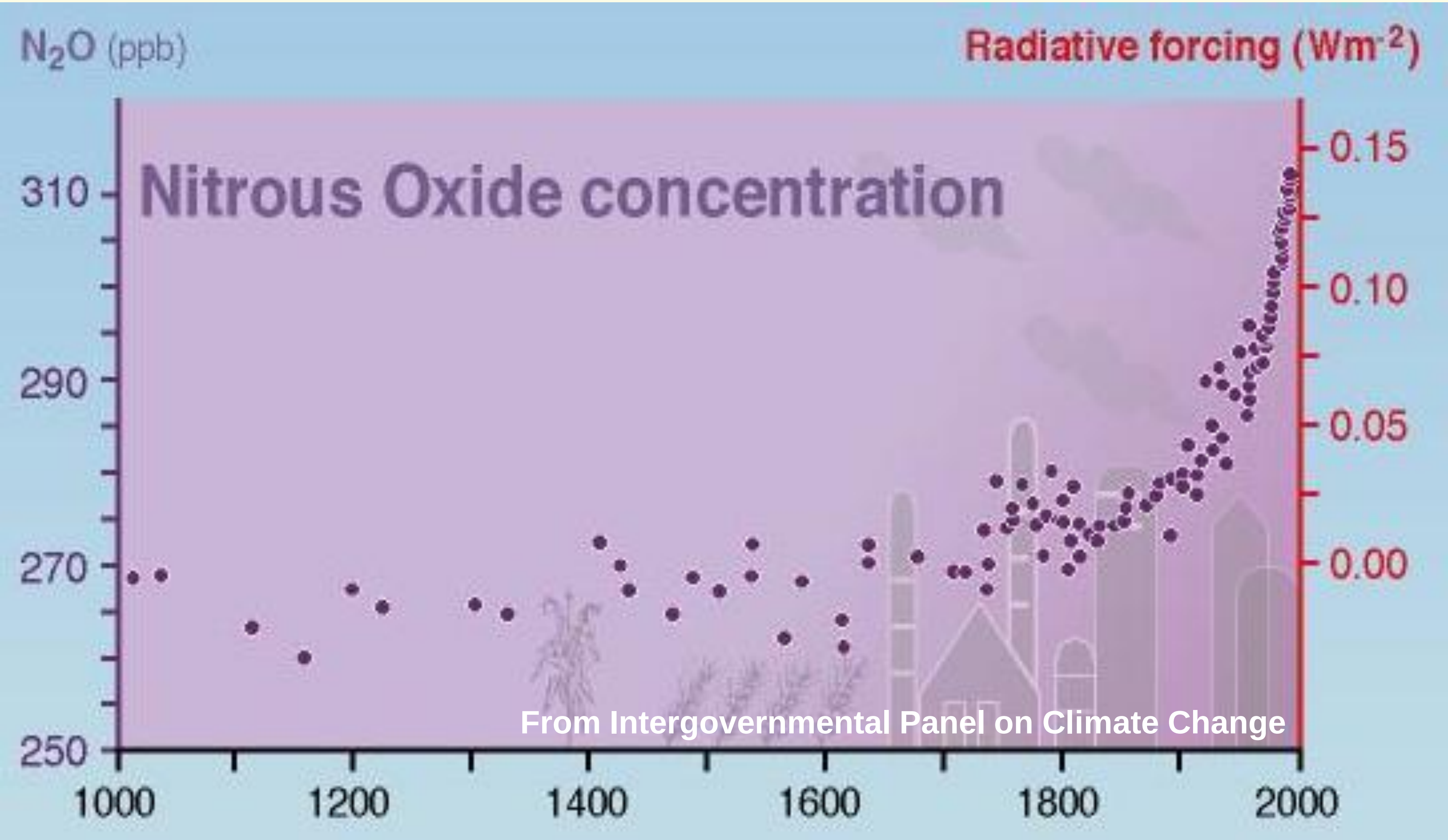
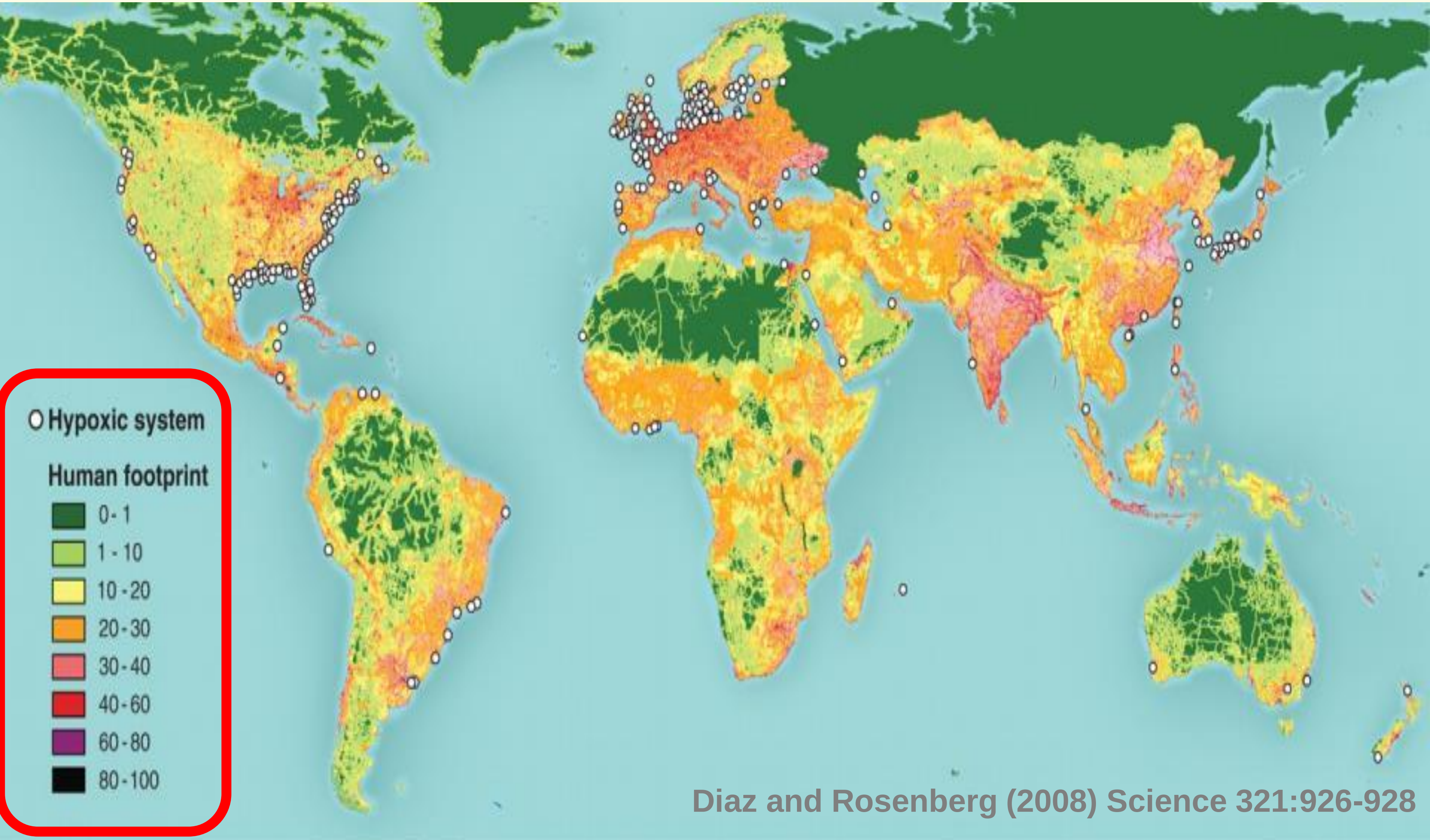
Nitrogen – national and global issue



From Intergovernmental Panel on Climate Change

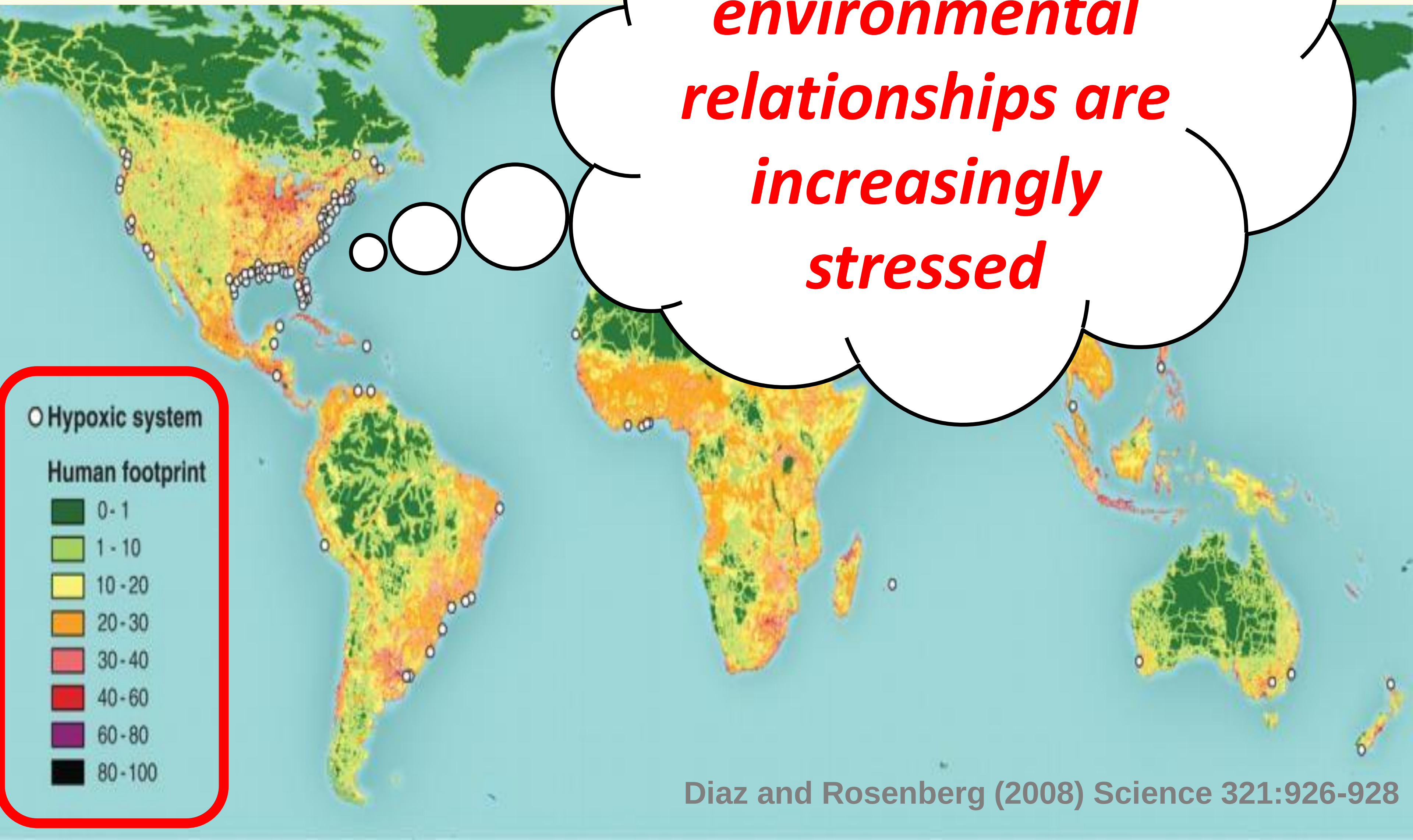
Nitrogen – national and global issue



Diaz and Rosenberg (2008) Science 321:926-928

Nitrogen – national and global issue

Human – environmental relationships are increasingly stressed



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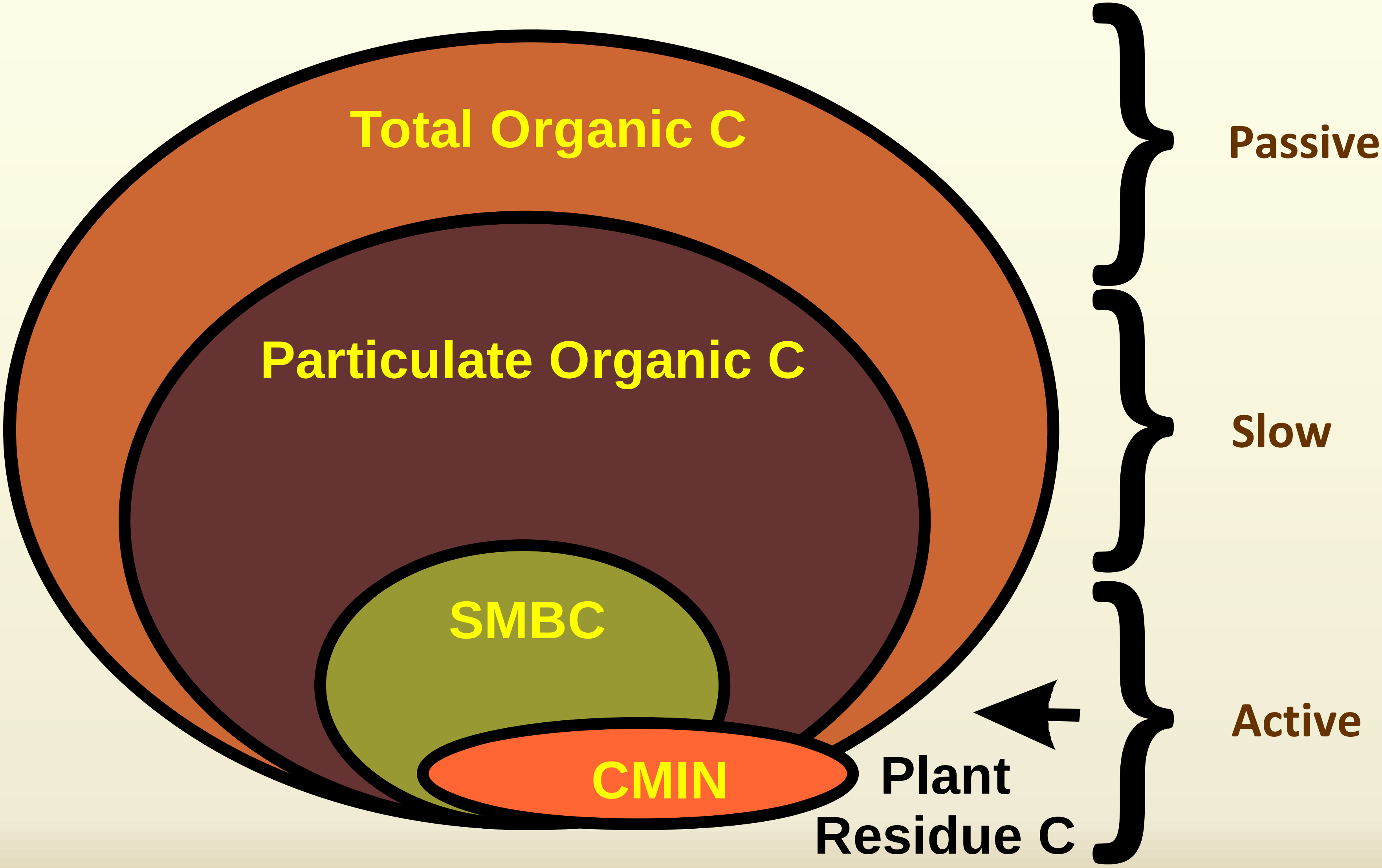
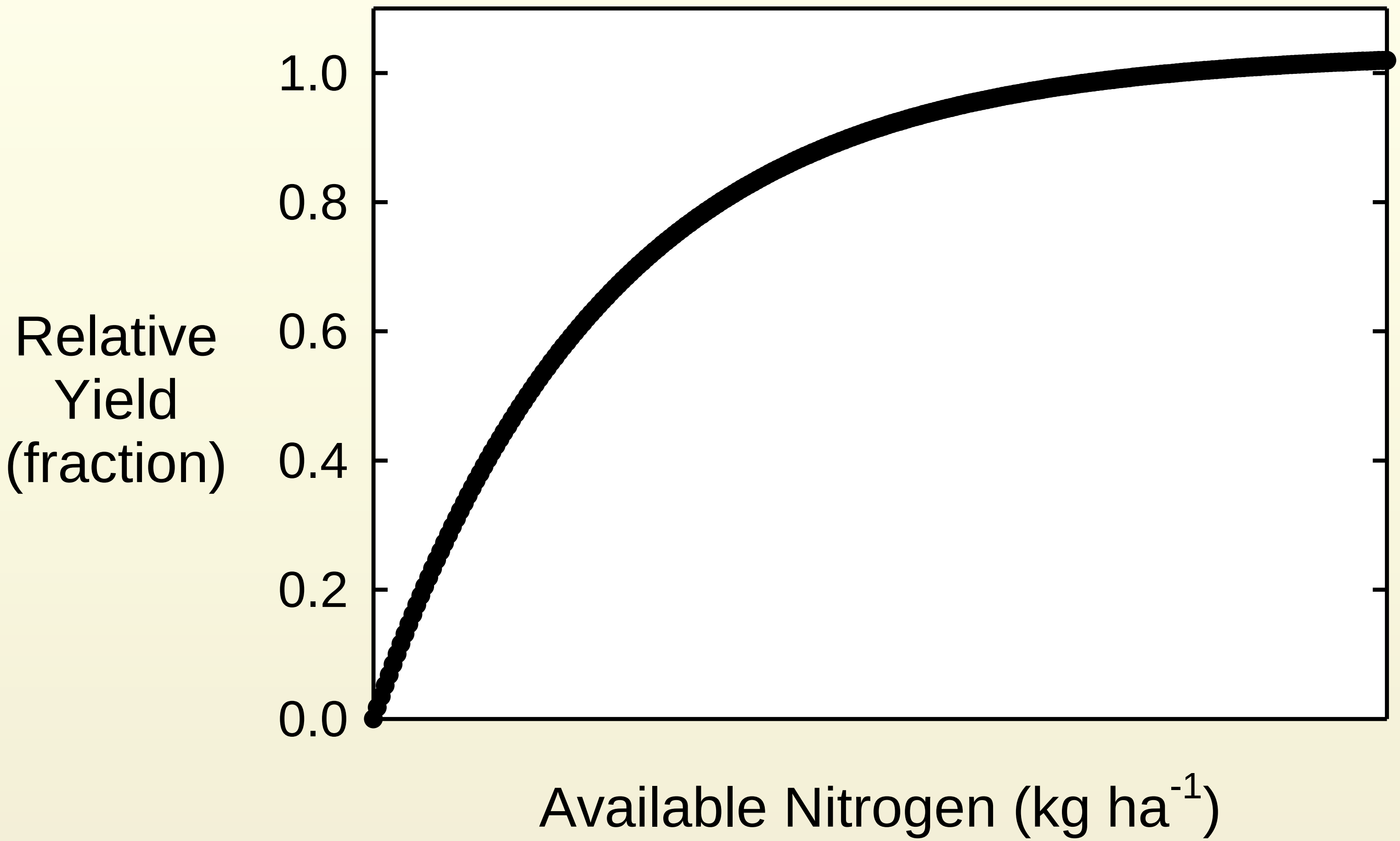
- ✓ **Limiting disturbance of soil will preserve soil pores and organic residues for soil faunal and microbial development**
- ✓ **Adding C- and N-rich organic amendments (e.g. crop residues, leys, animal manures) will enhance microbial activity and diversity**

http://www.fao.org/docrep/007/y5104e/y5104e08.htm

Soil organic matter is a key



Idealized response of yield to N



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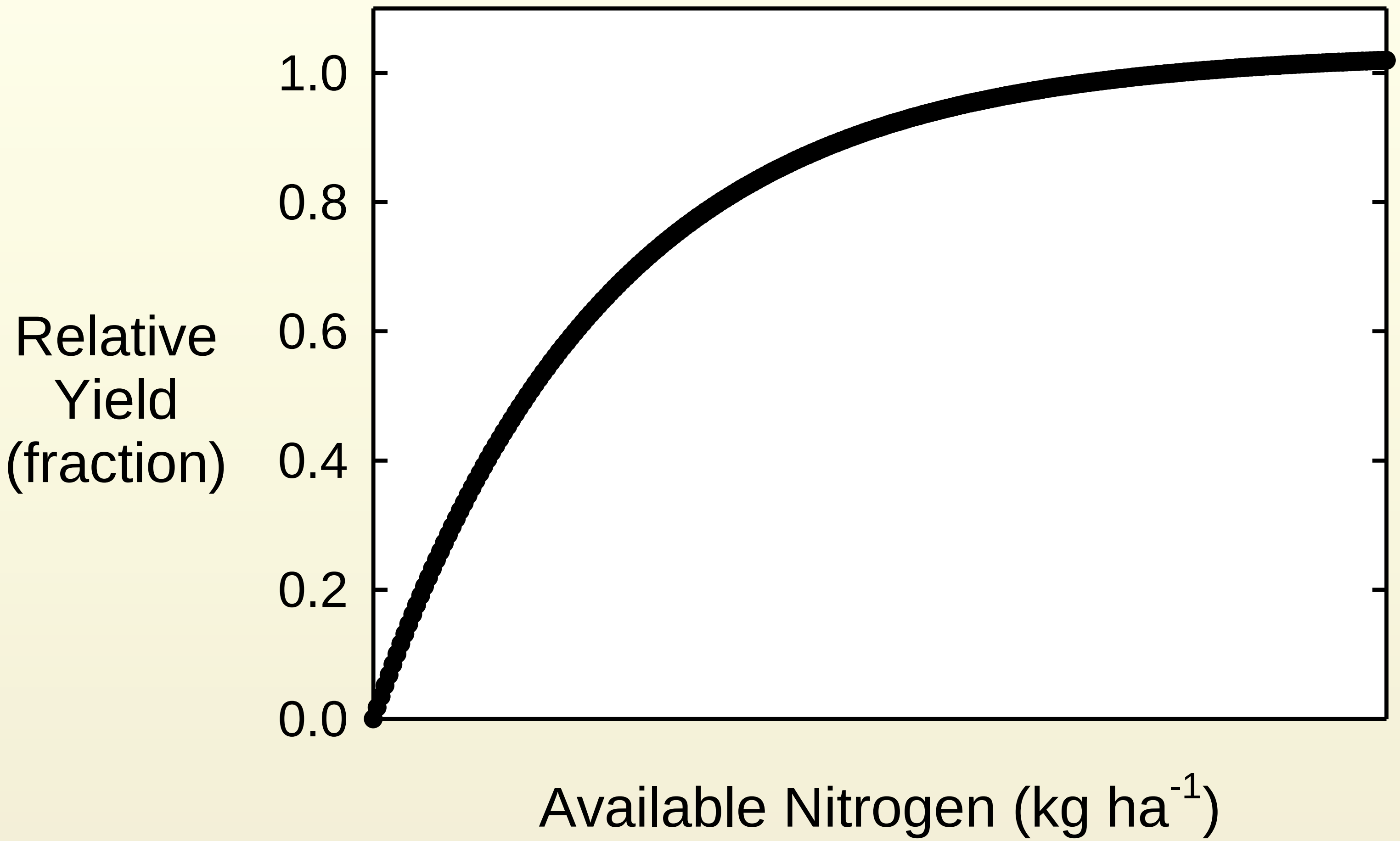

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- **Surface soil**
- **Residual in profile**

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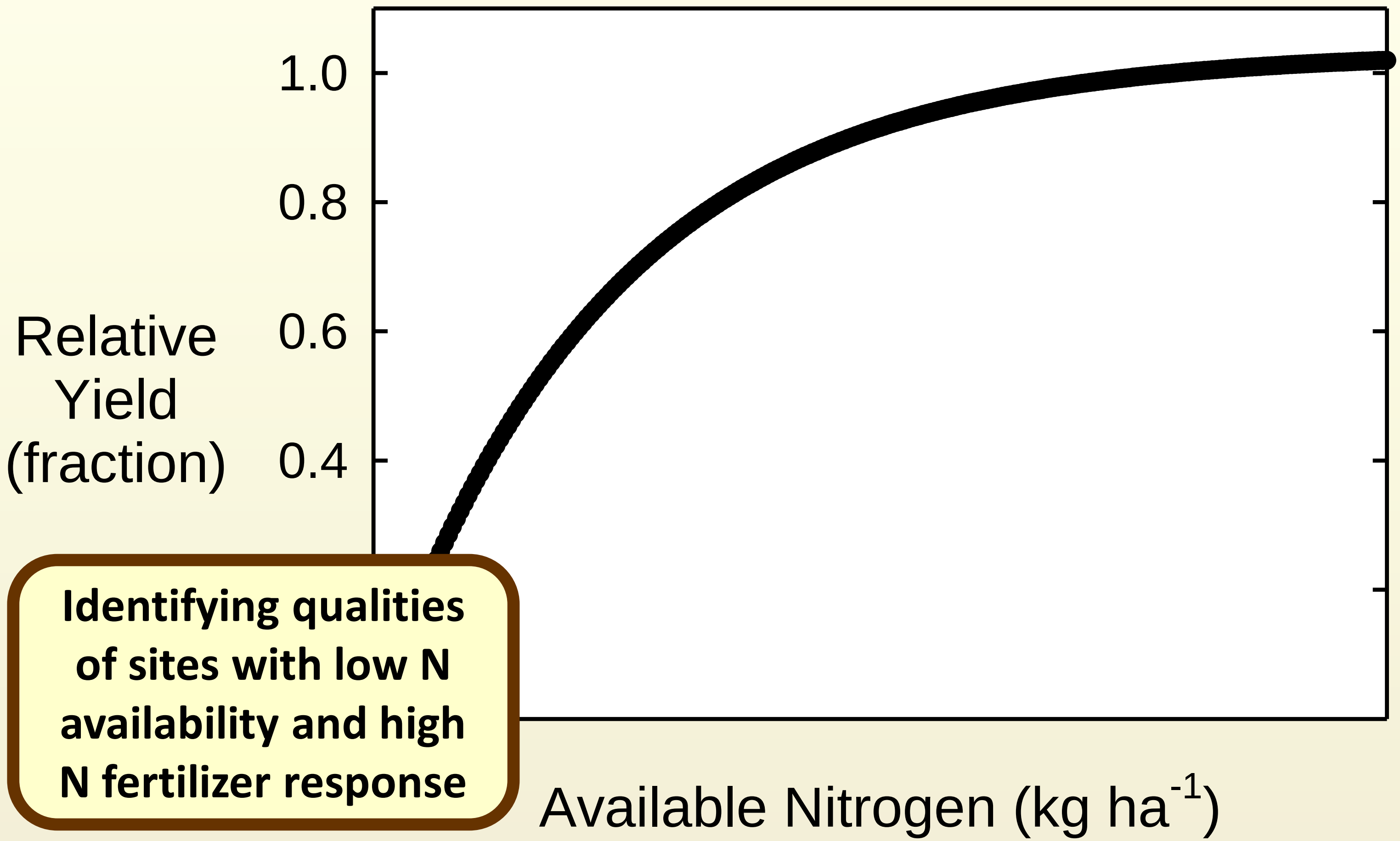

Identifying qualities of sites with low N availability and high N fertilizer response

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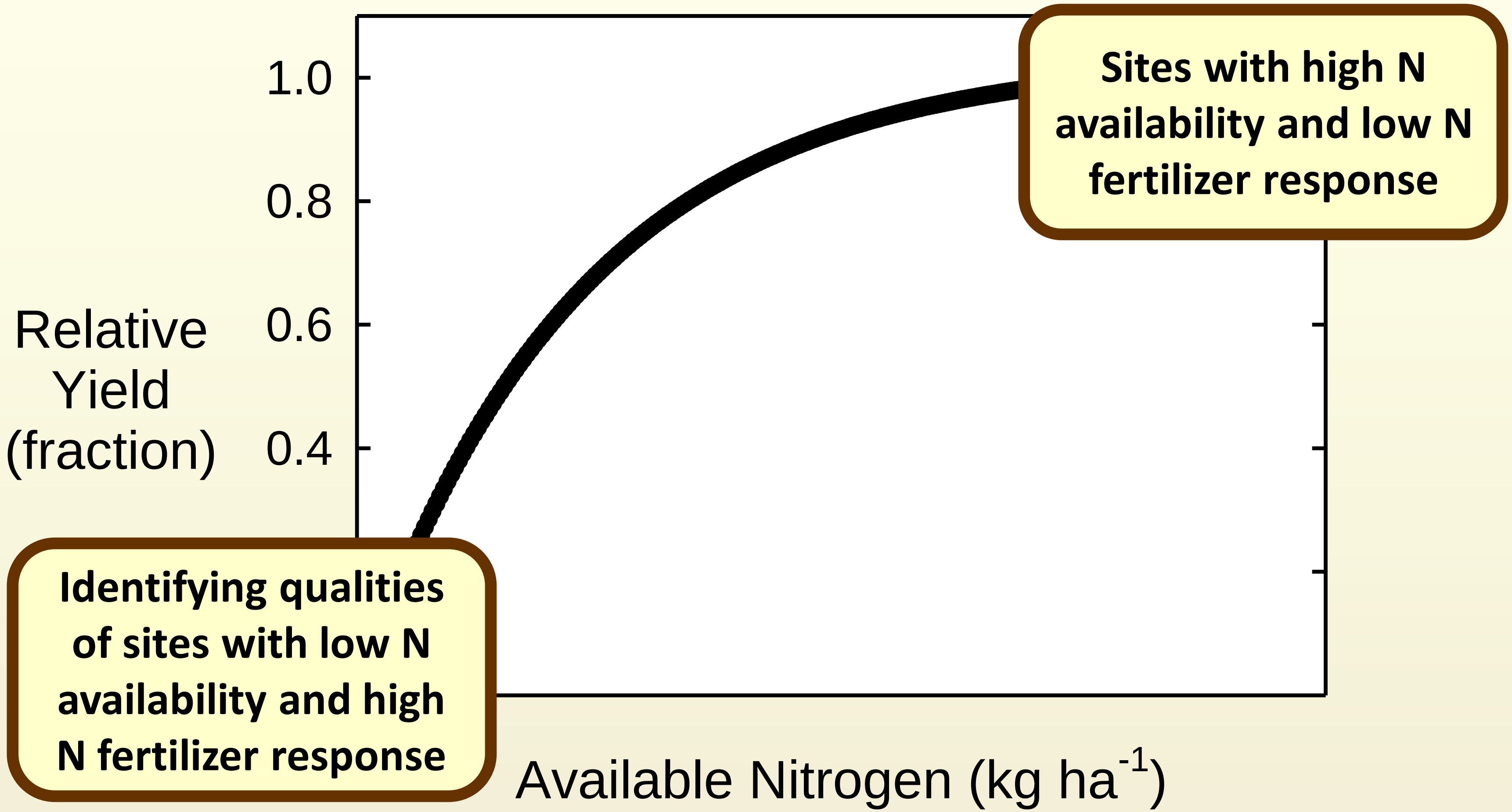

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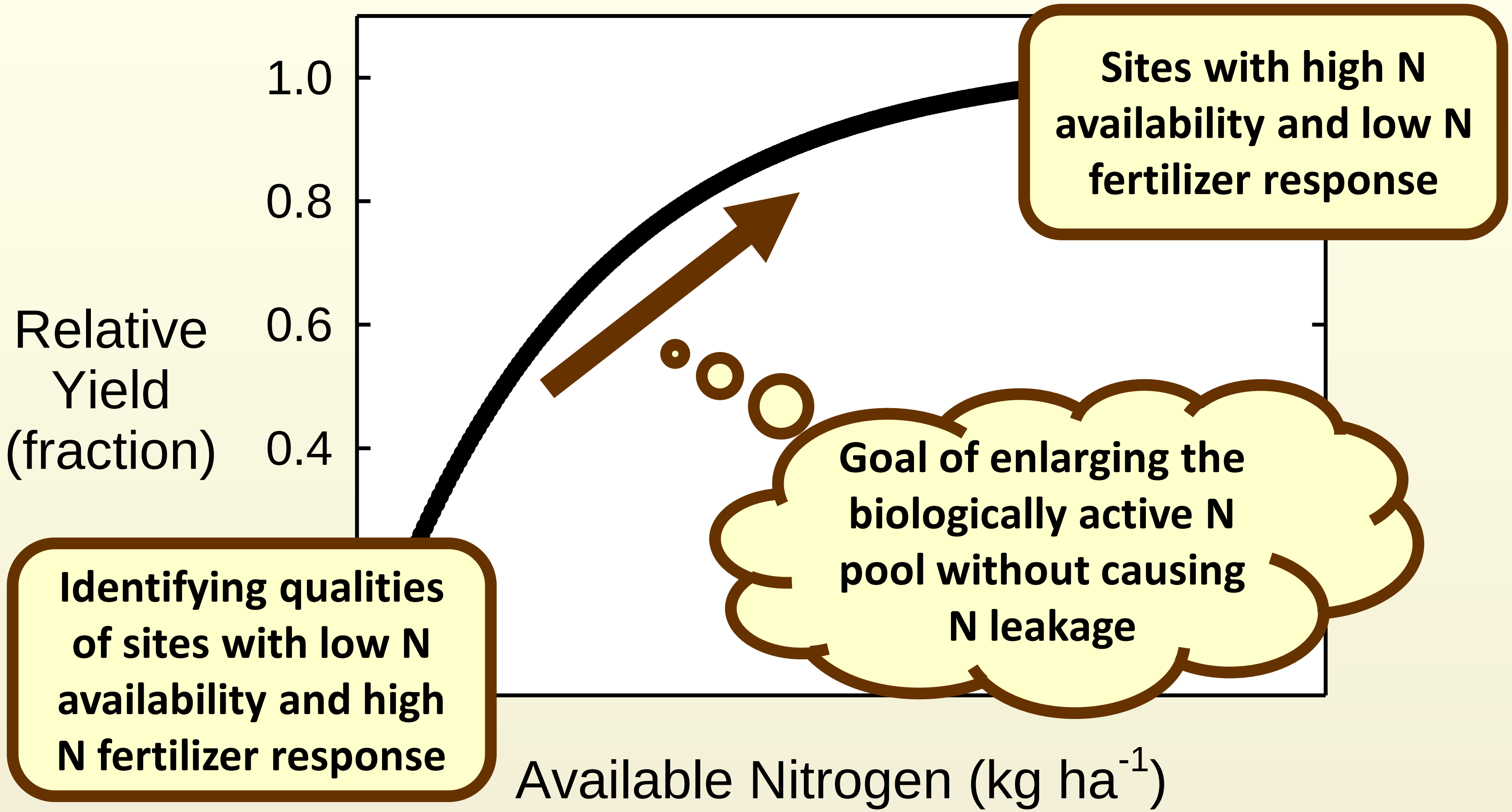

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Some history

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Soil Science:
February 1924 - Volume 17 - Issue 2 - ppg 141-162
Original Articles: PDF Only

MICROBIOLOGICAL ANALYSIS OF SOIL AS AN INDEX OF SOIL FERTILITY: VII. CARBON DIOXIDE EVOLUTION1.

WAKSMAN, SELMAN A.; STARKEY, ROBERT L.

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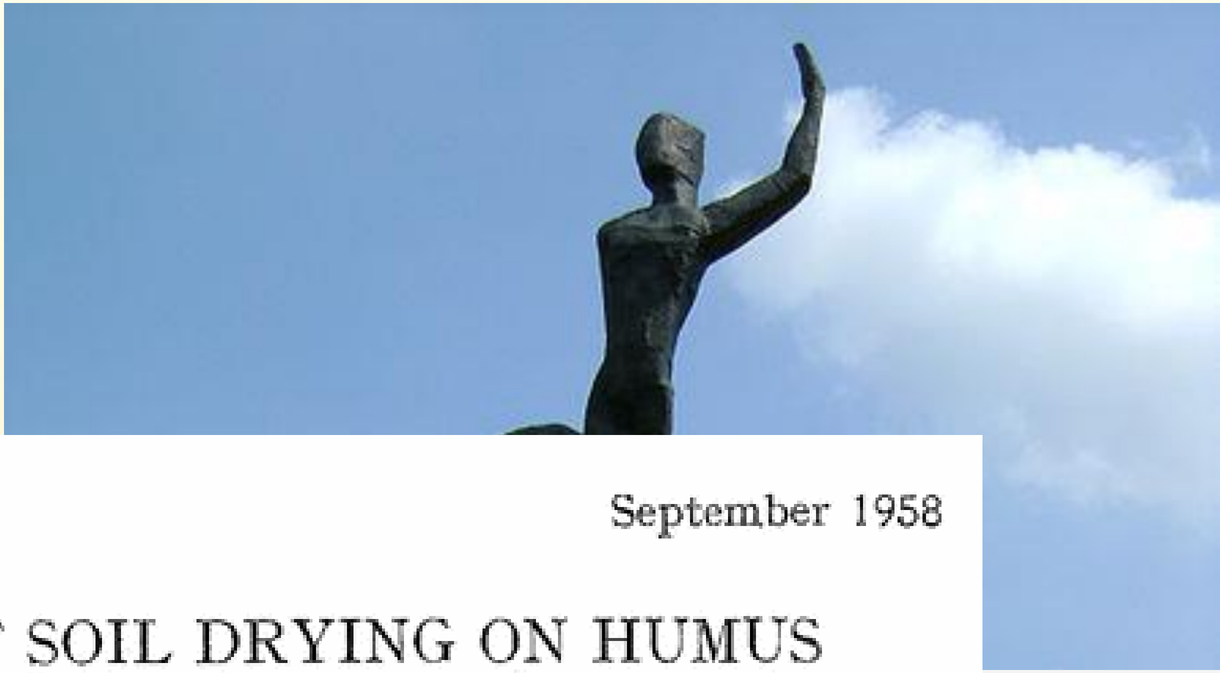

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The search for rapid tests to predict N continues…

Assessing Indices for Predicting Potential Nitrogen Mineralization in Soils under Different Management Systems

Schomberg et al. (2009)
Soil Sci. Soc. Am. J. 73:1575-1586

Table 1. Laboratory methods used for determining potential N mineralization.

Measurement	Type	Units	Reference
Total Carbon	Chemical	g kg^{-1}	Bremner, 1996
Total Nitrogen	Chemical	mg kg^{-1}	Nelson and Sommers, 1996
Particulate organic matter C	Chemical	mg kg^{-1}	Franzluebbers et al., 2000
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KCl extractable NO_3–N	Extraction	mg kg^{-1}	Mulvaney, 1996
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Sodium Hydroxide distillable N	Distillation	mg kg^{-1}	Sharifi et al., 2007
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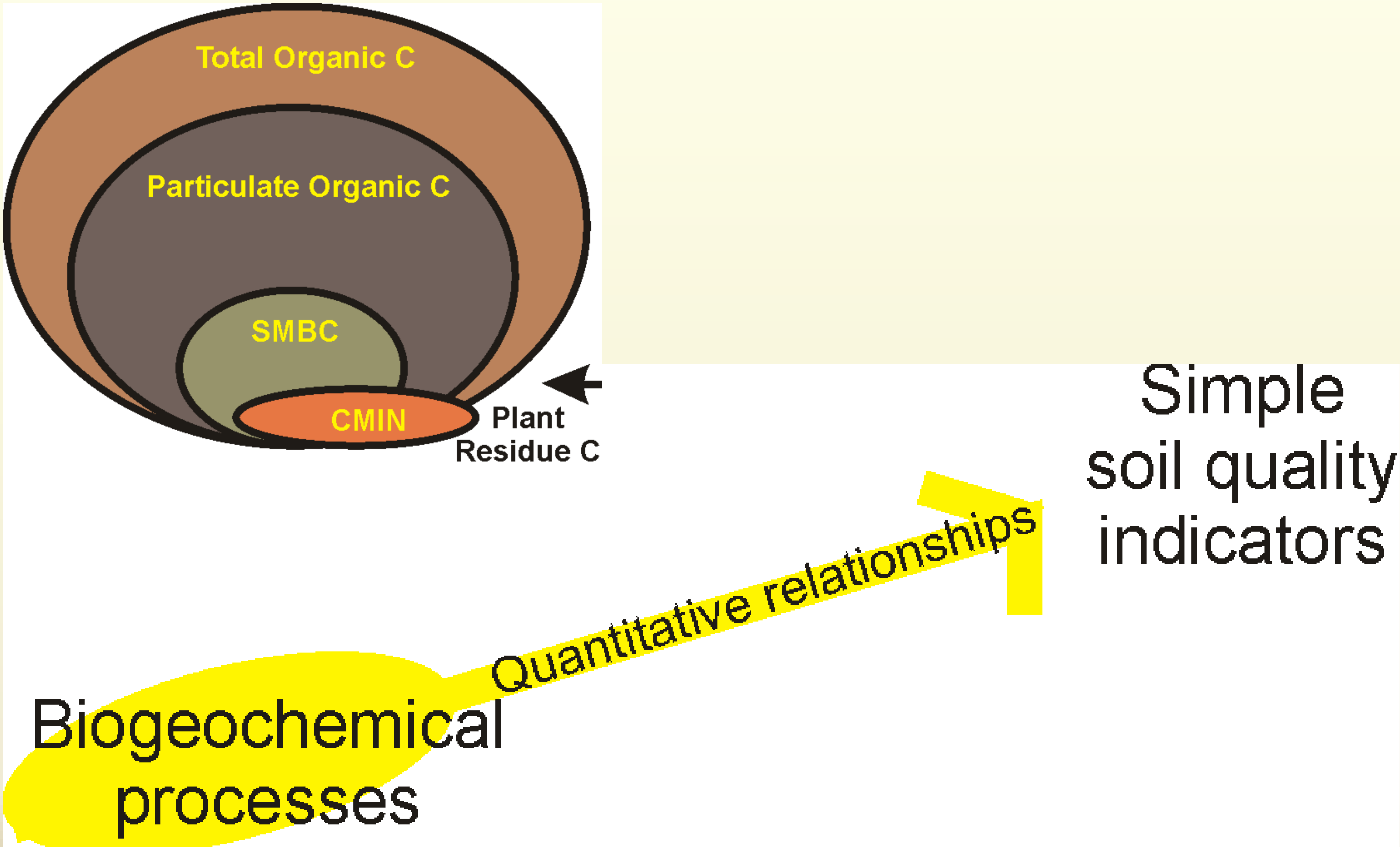
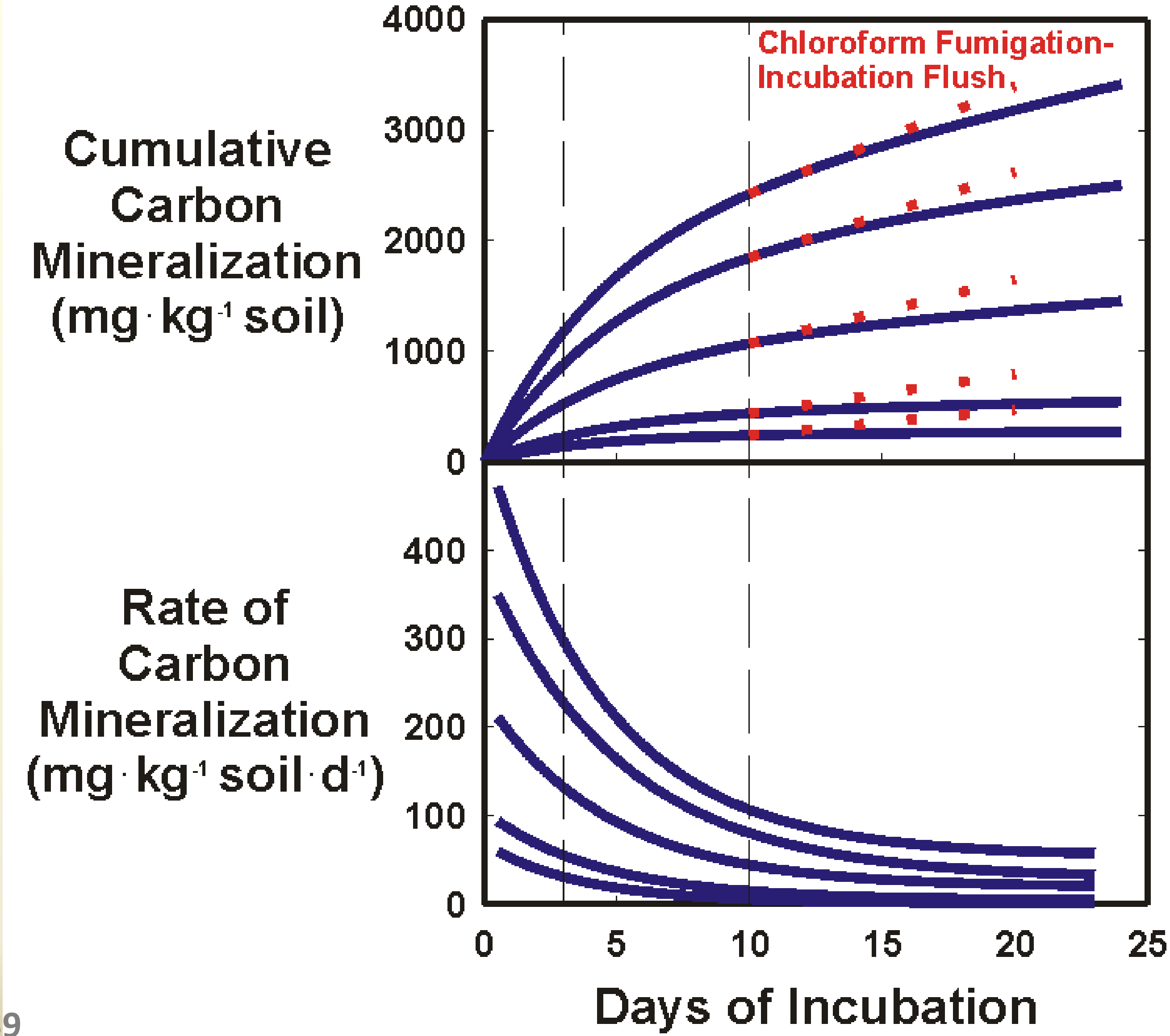
Urgent need for robust soil health indicators



Flush of CO_2 following rewetting of dried soil



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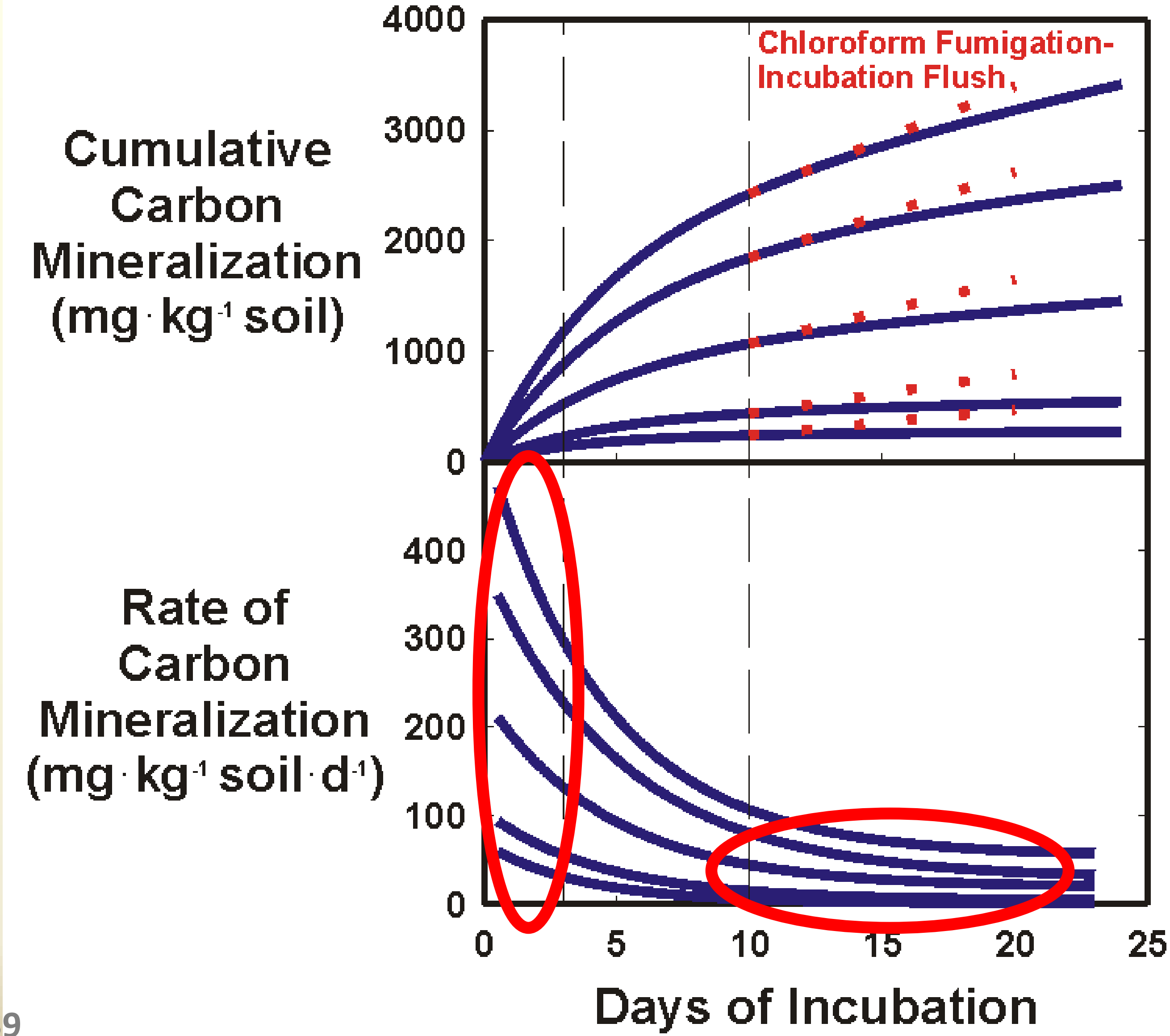

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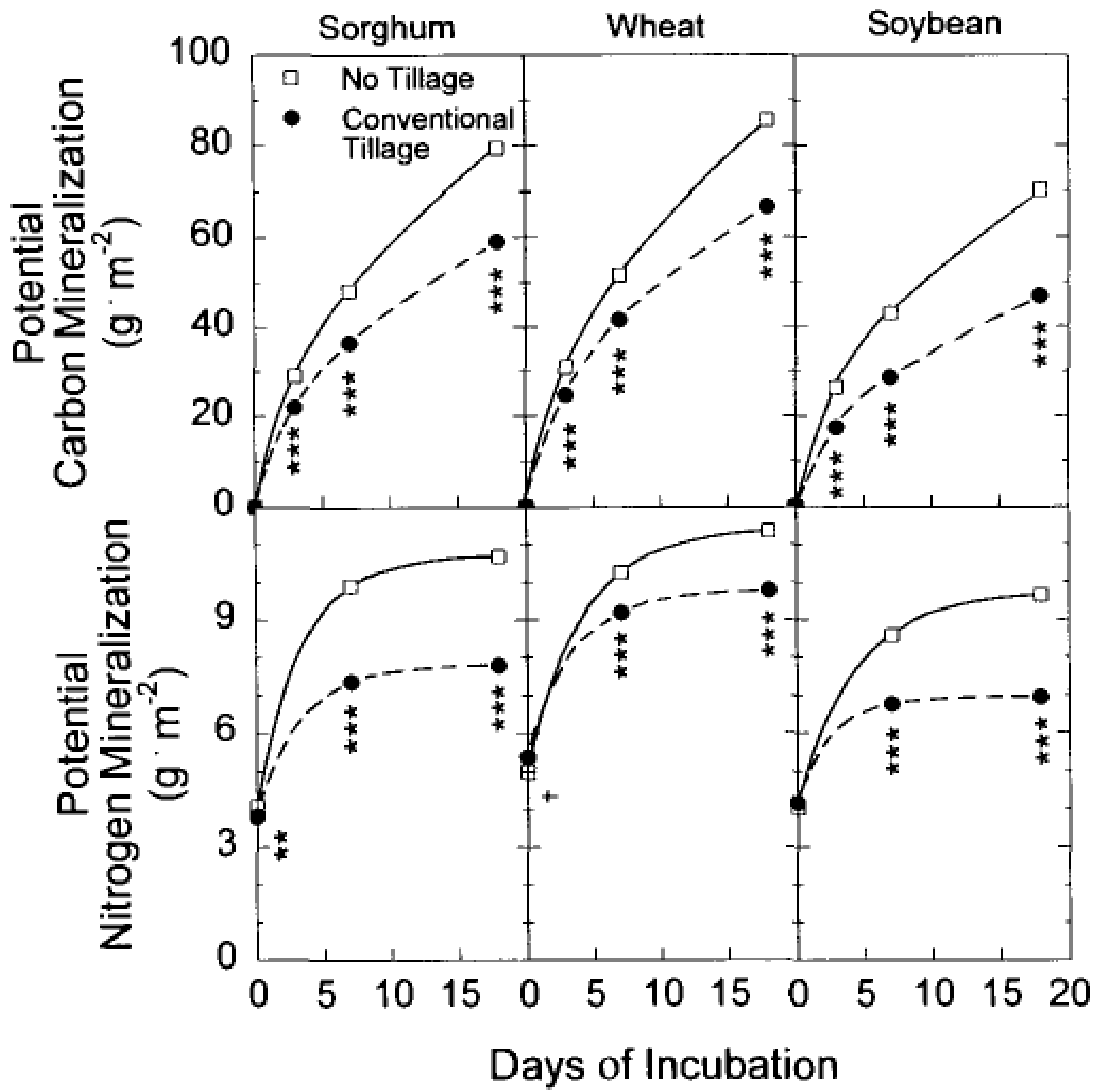

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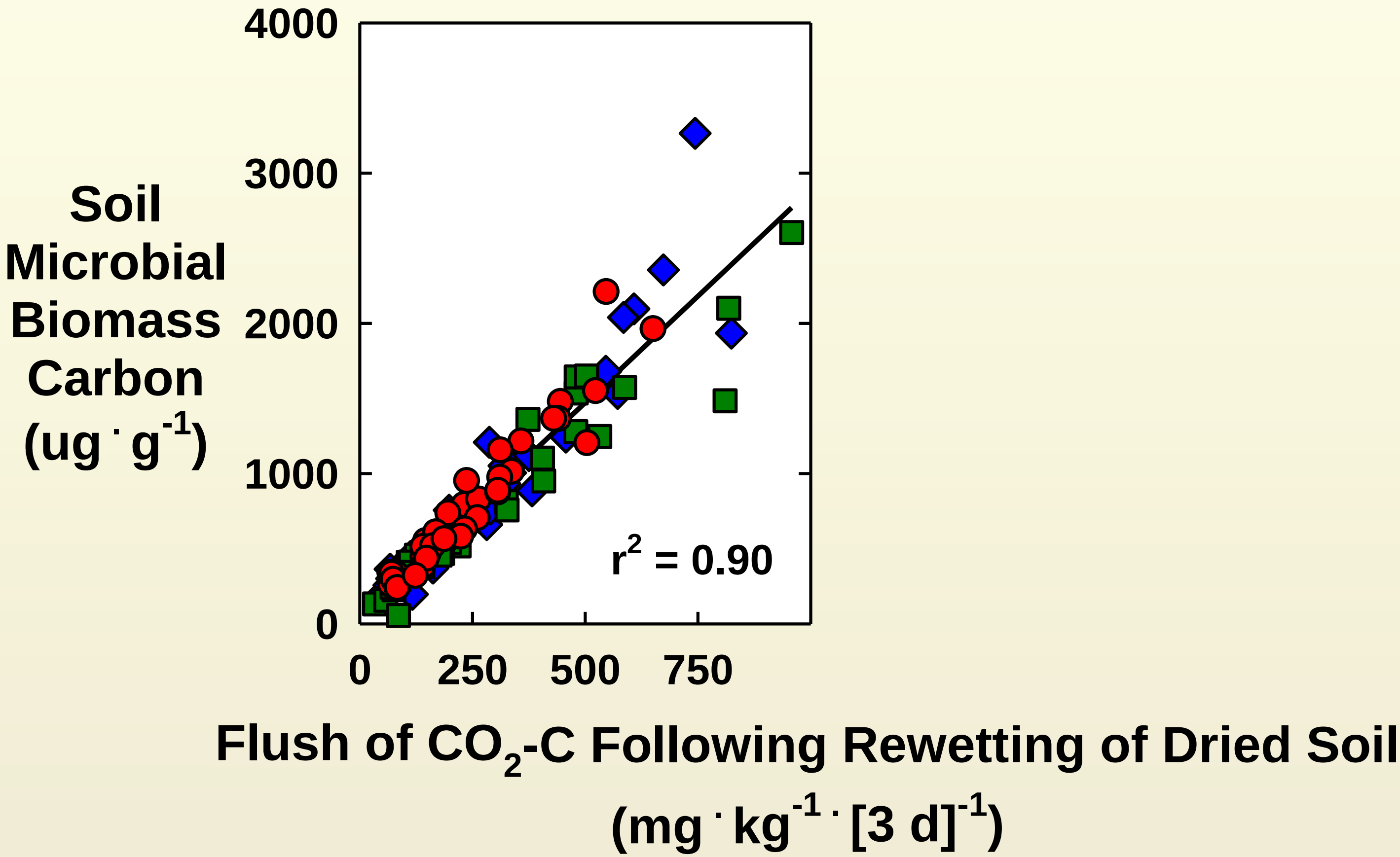
Flush of CO_2 – Relation to active organic matter



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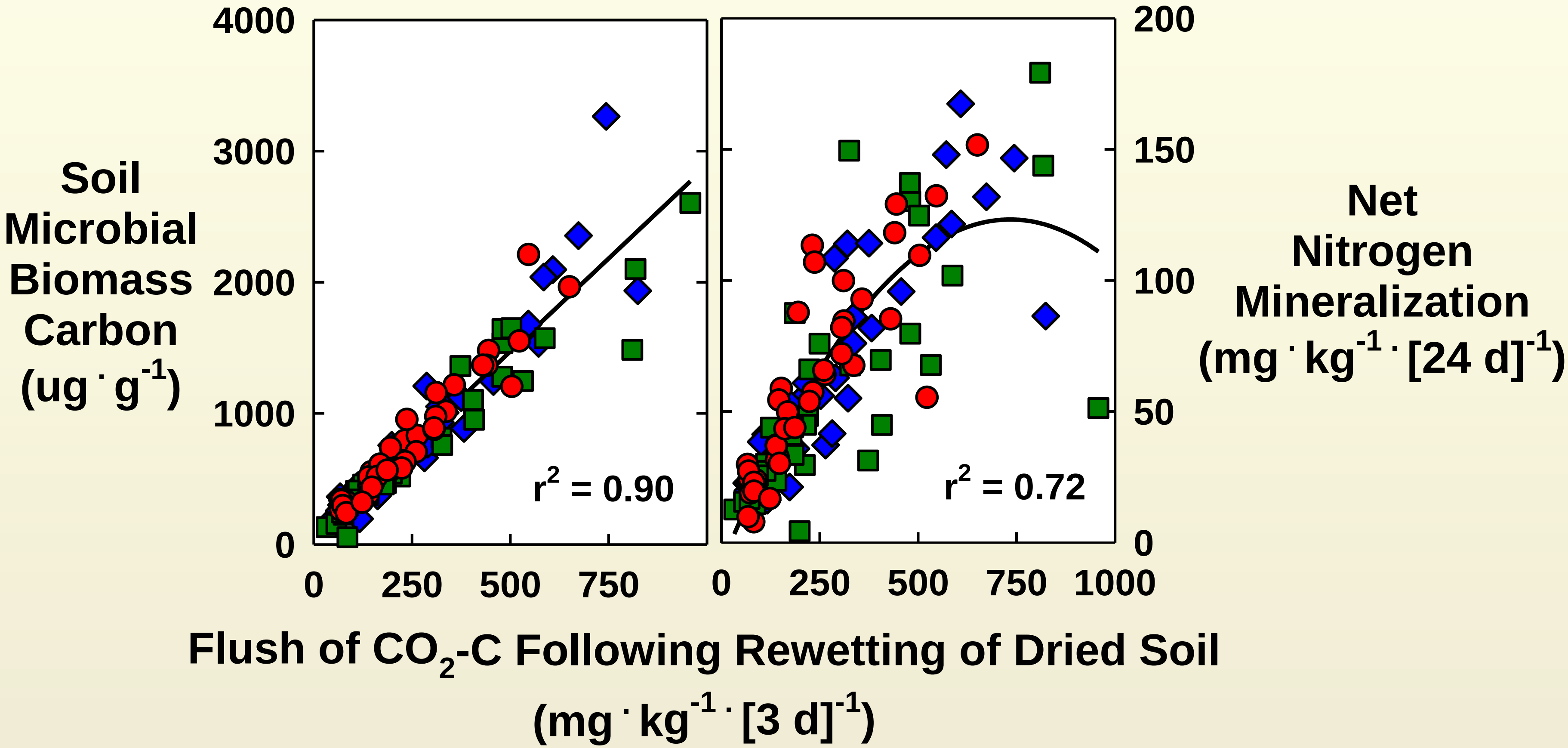

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Mean values from 1, 3, 5, and 7 years after converting pasture to cropping system with cover crop management **(mg N kg^{-1} 24 d^{-1})**

Franzluebbers and Stuedemann (2015) J. Soil Water Conserv. 70:365-373

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	Conventional Tillage	
Depth (cm)	**Ungrazed**	**Grazed**
0-3	**33**	**34**
3-6	**38**	**35**
6-12	**29**	**28**
12-20	**25**	**27**
20-30	**20**	**20**
0-30	**112**	**111**

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Flush of CO_2

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	Conventional Tillage		No Tillage		
Depth (cm)	Ungrazed	Grazed	Ungrazed	Grazed	Significance
0-3	218	227	524	530	CT < NT
3-6	193	193	253	238	
6-12	150	139	104	105	CT > NT
12-20	112	113	66	64	CT > NT
20-30	74	75	52	50	CT > NT
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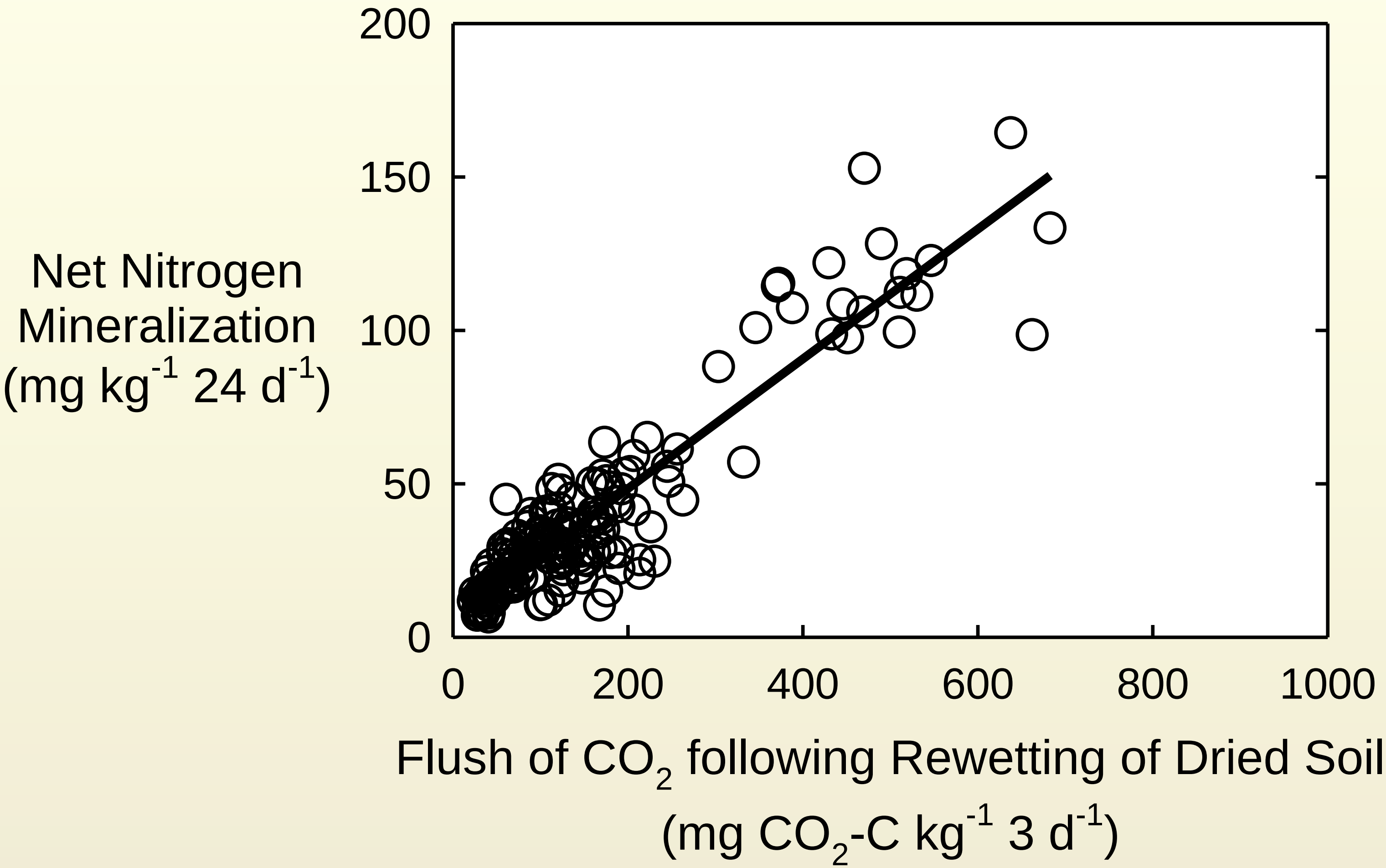

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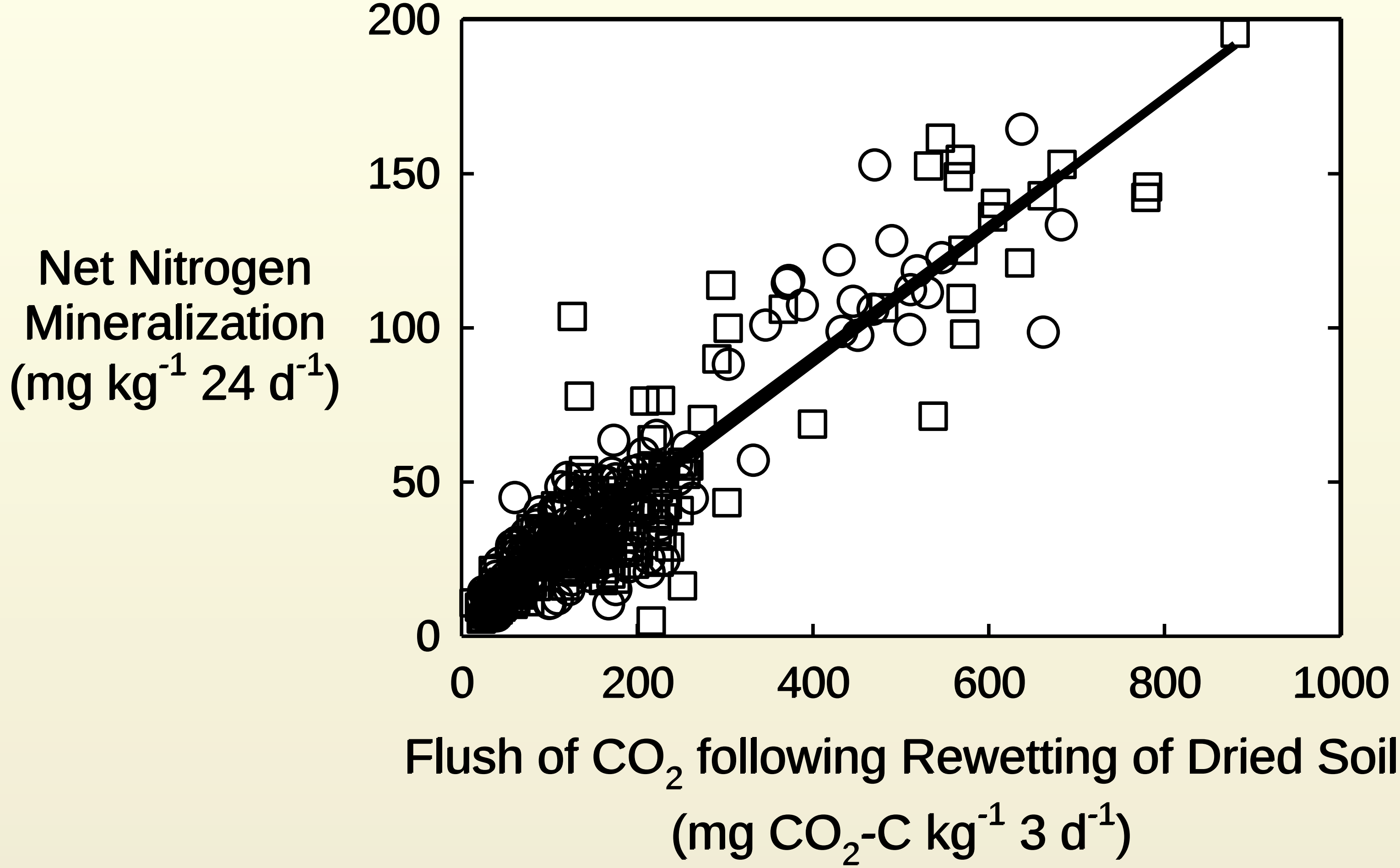

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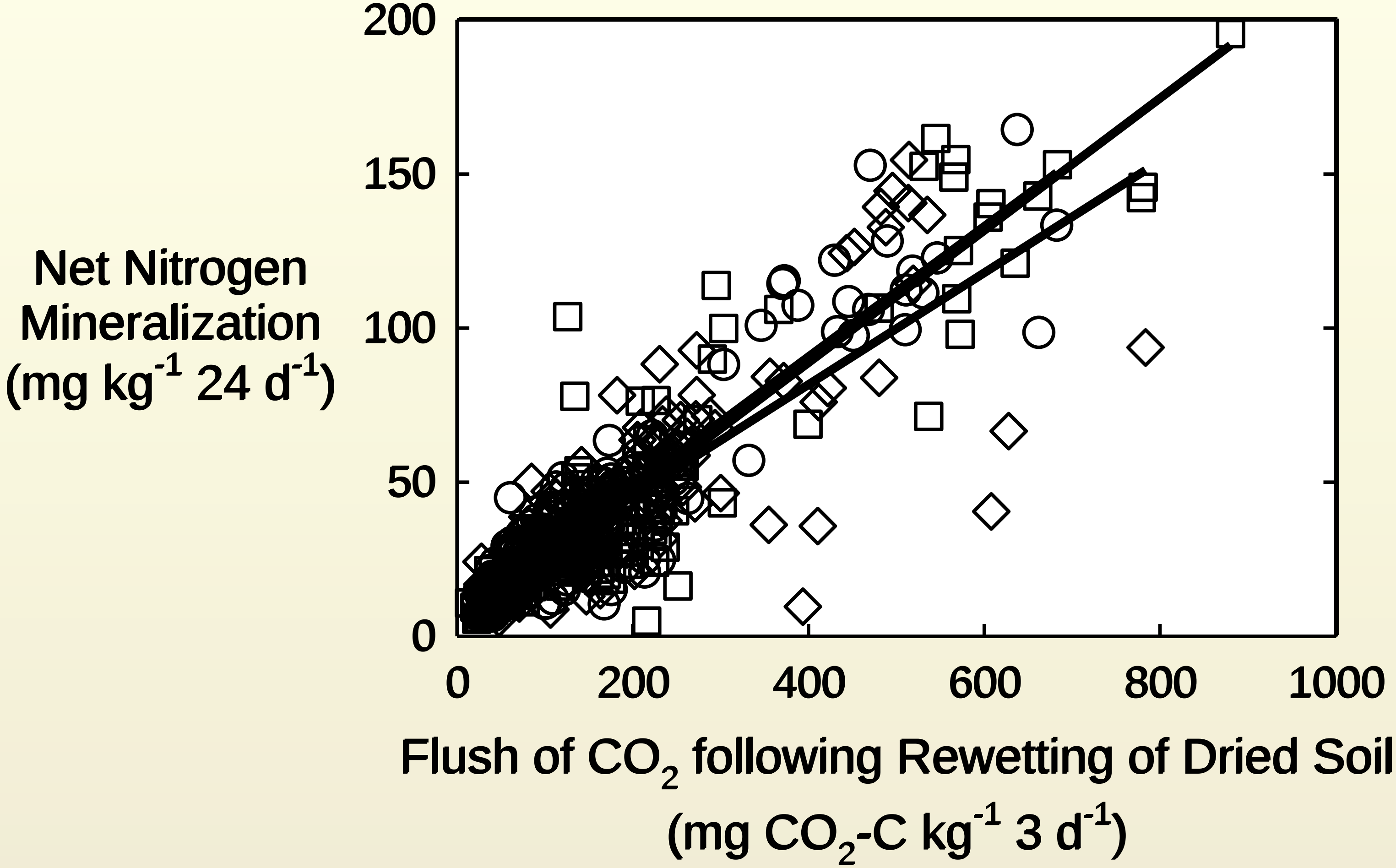

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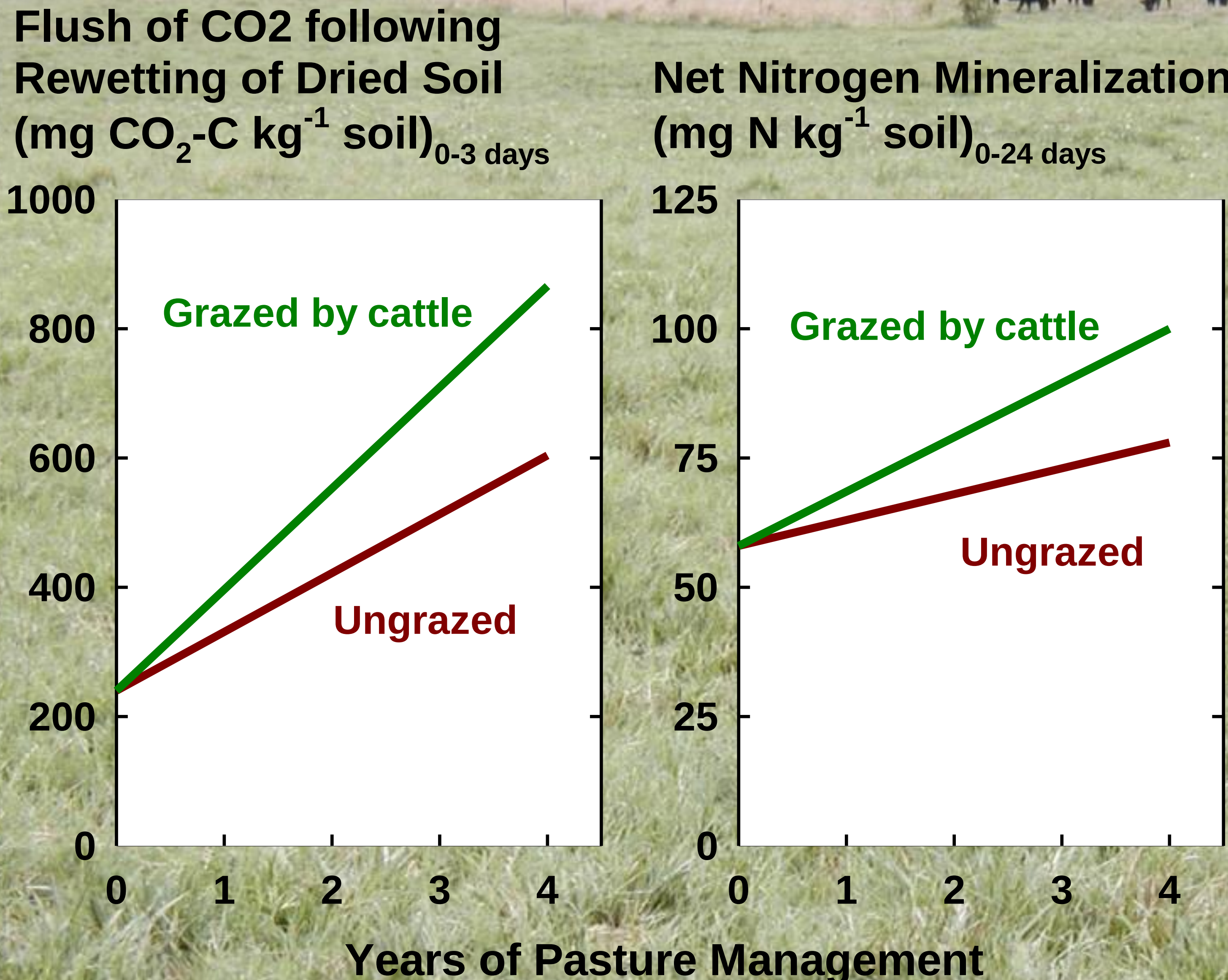

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Summary and conclusions

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- ✓ **Biologically active soil C and N fractions are intimately associated and change both rapidly and gradually with time under ICLS and conservation agricultural systems**
    - **The flush of CO_2 can be a good predictor of N availability**


alan.franzluebbers@ars.usda.gov