Soil health and grazing – Can they co-exist?

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1942-2017
Born and raised in Clinton, Iowa

Integrated systems

Grazing of crop residues

Sod-based crop rotations

Livestock grazing of cover crops within cash-crop rotations

Sod intercropping

Farm trading of products and by-products

Leasing by cattlemen of grain stubble fields or cover crops for grazing

Animal manure application to cropland

Dual-purpose cereal crops

Grain-fish pond-animal manure systems

Integrated systems

Sod-based crop rotations

Livestock grazing of cover

Sod intercropping

...acts

Grain

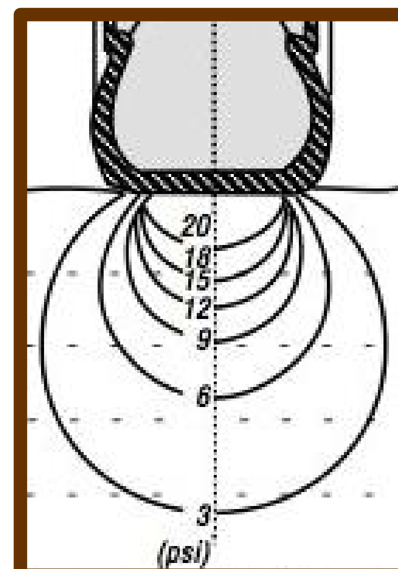
world congress on integrated
crop-livestock-forest systems
3rd International Symposium on Integrated Crop-Livestock Systems
...ds sustainable intensification • brasilia • brazil

Ruminant livestock – *pressure points of concern to cropland farmers*

<u>Ruminant livestock</u> – *pressure points of concern to cropland farmers*

Small footprint of a large-bodied animal exerts considerable pressure on the soil

- **Hoof pressure of 19-51 psi for cattle** (Willatt and Pullar, 1983; Scholefield and Hall, 1986; Nie et al., 1997)
- **Hoof pressure of 12-18 psi for sheep** (Cohron, 1971; Willatt and Pullar, 1983)
- **Actual pressure depends on type and age of animal, land slope, and extent of movement**
- **Ground pressure from contemporary tractor tire of 15-30 psi** (Schjønning et al., 2006)



References
Cohron (1971) In: Barnes et al. Compaction of Agricultural Soils, St. Joseph MI, p. 106-124.
Nie et al. (1997) Plant and Soil, v. 197, p. 201-208.
SchjØnning et al. (2006) Advances in Geoecology, v. 38, p. 38-46.
Scholefield & Hall (1986) European Journal of Soil Science, v. 37, p. 165-176.
Willattt & Pullar (1983) Australian Journal of Research, v. 22, p. 343-348.

Animal traffic impacts on soil bulk density

Soil depth (inches)	Grazed ?	At end of 1 yr	At end of 2 yr	At end of 3 yr	At end of 5 yr
		------------- g/cc -------------			
0-1.2	No	0.97	0.96	1.12	0.96
	Yes	0.99	1.04	1.14	1.05
					*
1.2-2.4	No	1.37	1.40	1.45	1.37
	Yes	1.38	1.40	1.45	1.41
2.4-4.7	No	1.50	1.51	1.56	1.51
	Yes	1.52	1.54	1.53	1.51

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

From North Georgia

Animal traffic impacts on soil bulk density

✓ Poaching of soil with heavy animal traffic can damage forage and cause soil compaction leading to reduced infiltration, greater water runoff, and contamination of receiving water bodies with nutrients and fecal-borne pathogens

✓ In a review of grazing effects on bulk density [Greenwood and McKenzie (2001) Aust. J. Exp. Agric. 41:1231-1250], an increase in bulk density was observed with animal treading in most studies:

0.12 $\pm$ 0.12 g/cc (n = 46)

✓ This situation represents an extreme treading condition, not what would be envisioned for an integrated crop-livestock system

Animal traffic impacts on soil bulk density

✓ On Mollisols in Argentina, soil bulk density increased with winter grazing of corn and soybean residues, but it depended on tillage system:

	Ungrazed		Grazed
		g/cc	
CT	1.17	<	1.34
NT	1.25		1.27

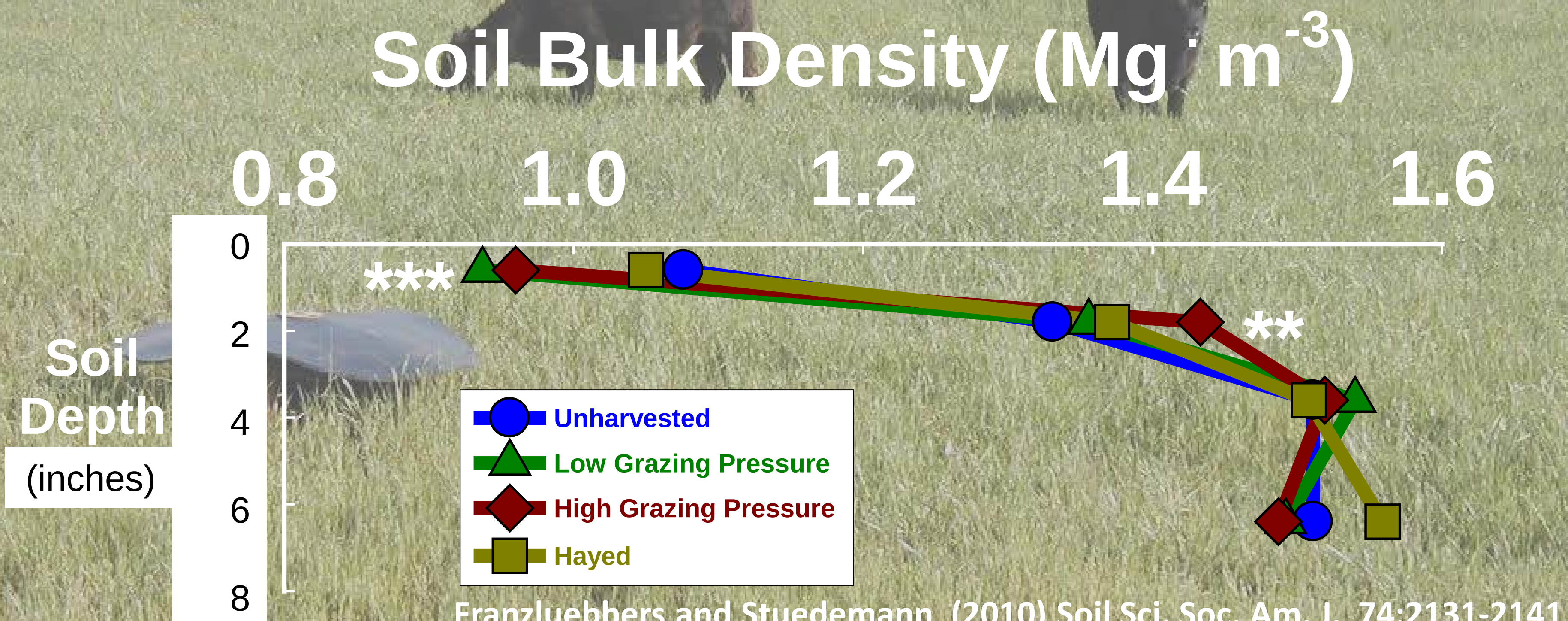
Diaz-Zorita et al. (2002) Soil Till. Res. 65:1-18

✓ On silt loam and silty clay loam soils (Mollisols) in Iowa, soil bulk density was not affected by monthly rotational grazing of corn stalks during the winter, irrespective of whether soil was frozen or not [Clark et al. (2004) Agron. J. 96:1364-1371].

Do cattle always compact soil?

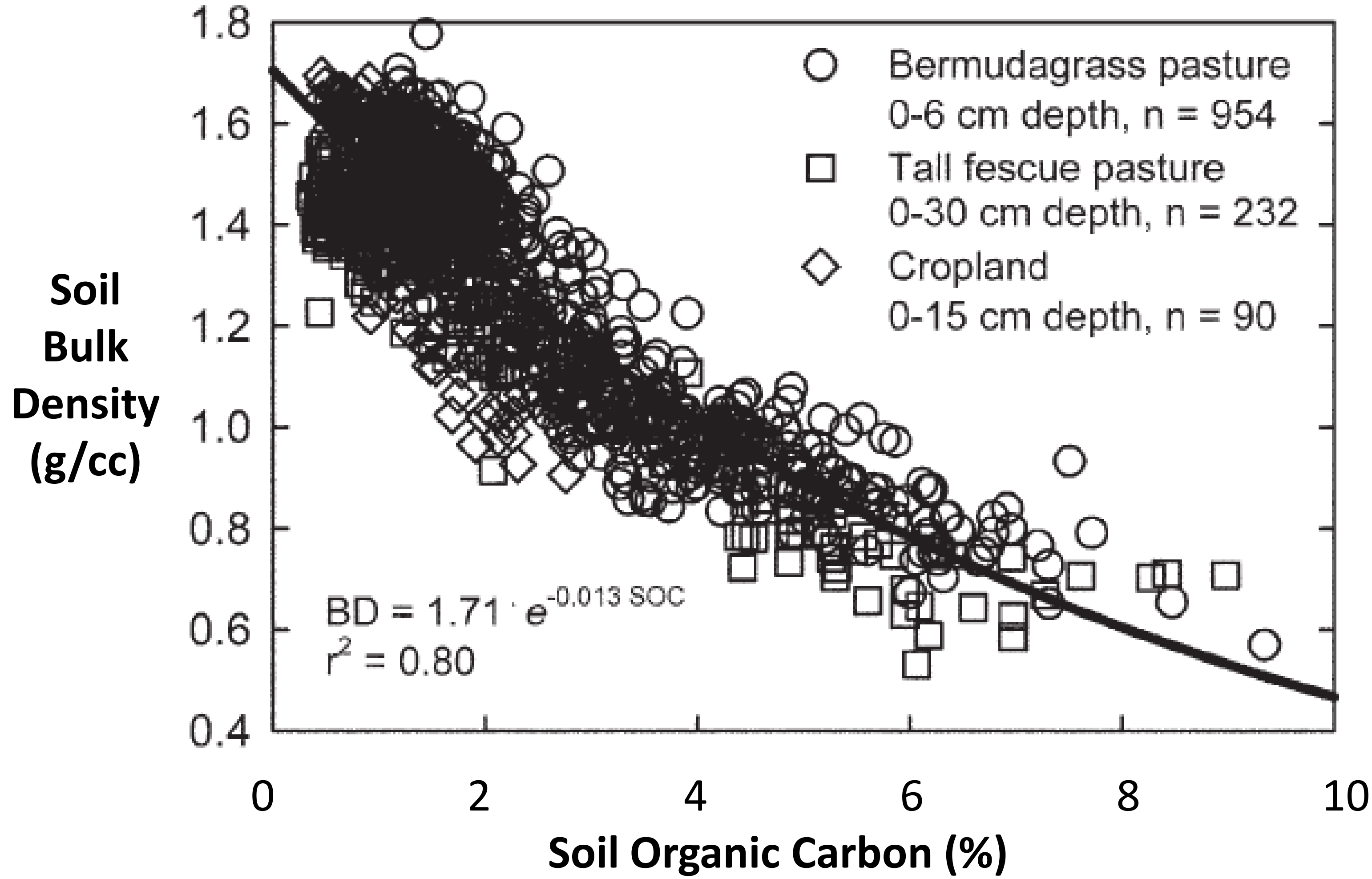
End of 12 years of bermudagrass / tall fescue management in Georgia

Soil Bulk Density (g/cc or Mg m^{-3}) 0-8” depth	Unharvested	Low Grazing Pressure	High Grazing Pressure	Hayed
	1.42	1.40	1.41	1.44



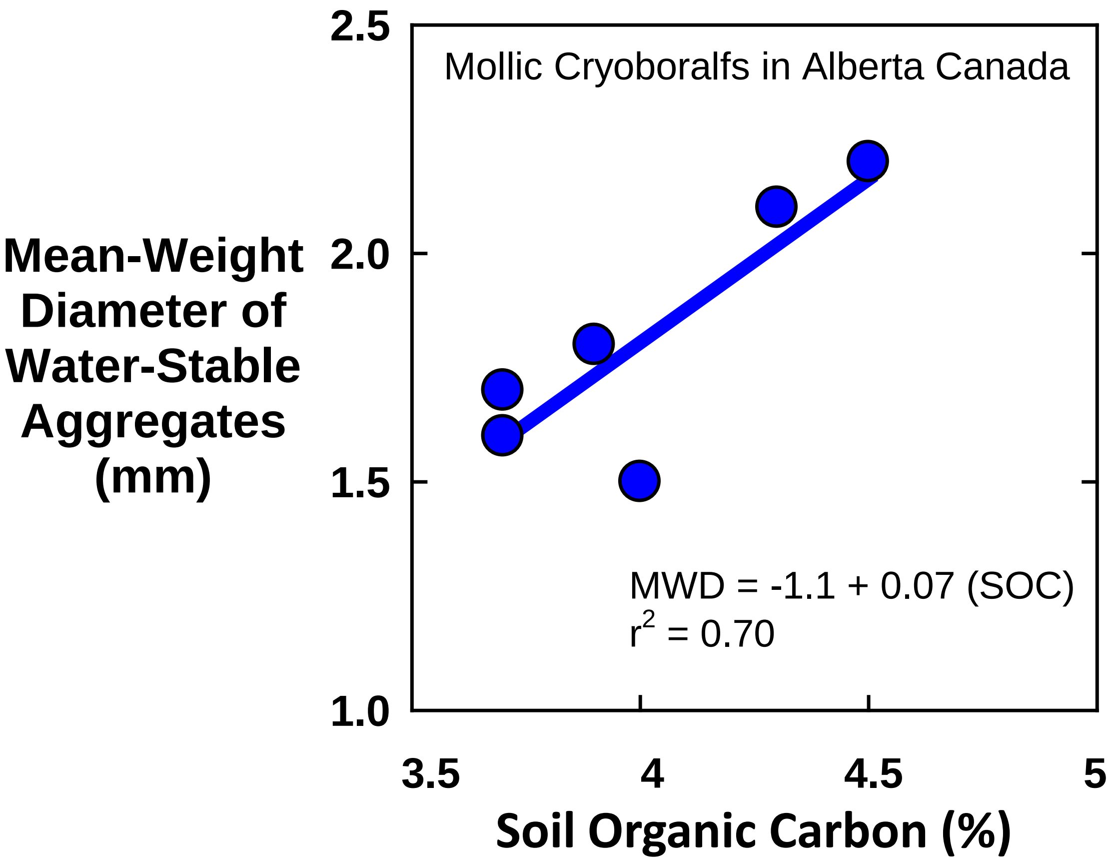
Franzluebbers and Stuedemann (2010) Soil Sci. Soc. Am. J. 74:2131-2141

Soil organic C counteracts soil compaction



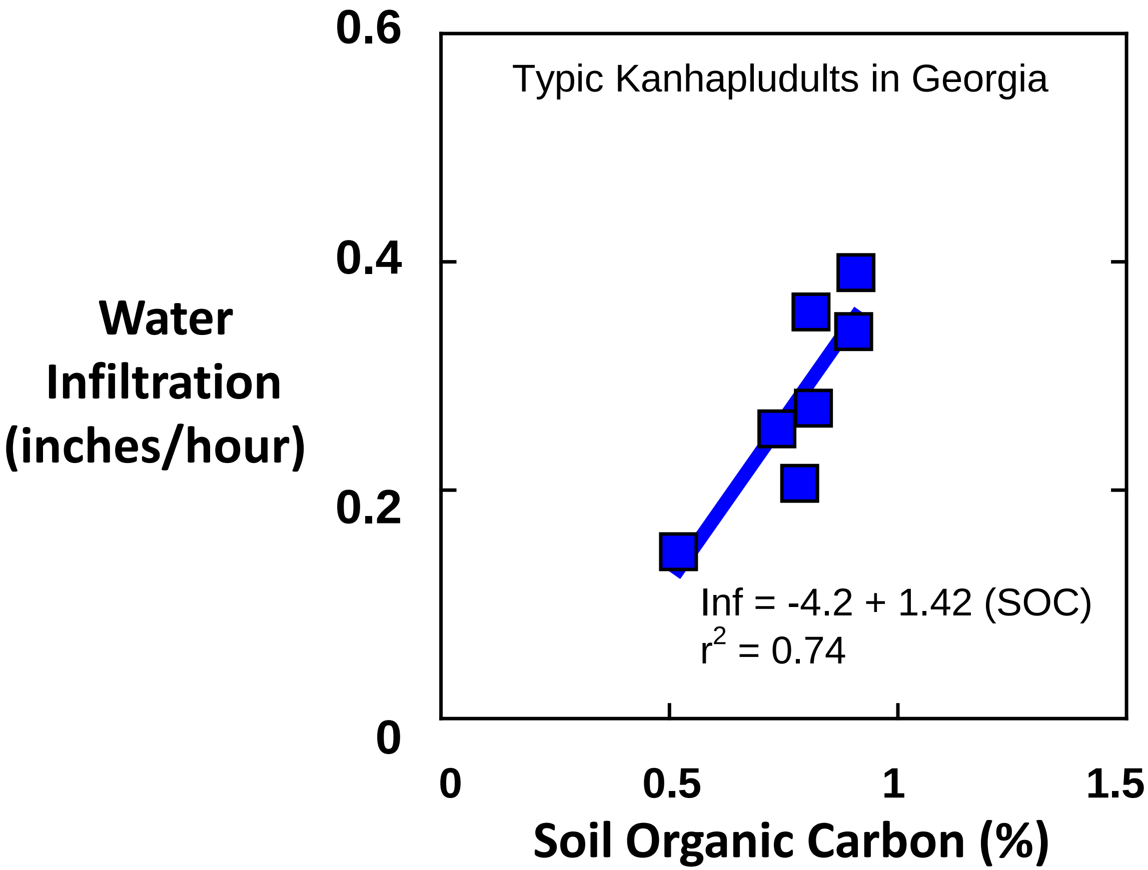
Franzluebbers (2010) Soil Sci. Soc. Am. J. 74:347-357

Soil organic C affects water cycling



Data from Arshad et al. (2004) Soil Till. Res. 77:15-23
Carreker et al. (1977) USDA-ARS S-160

Soil organic C affects water cycling



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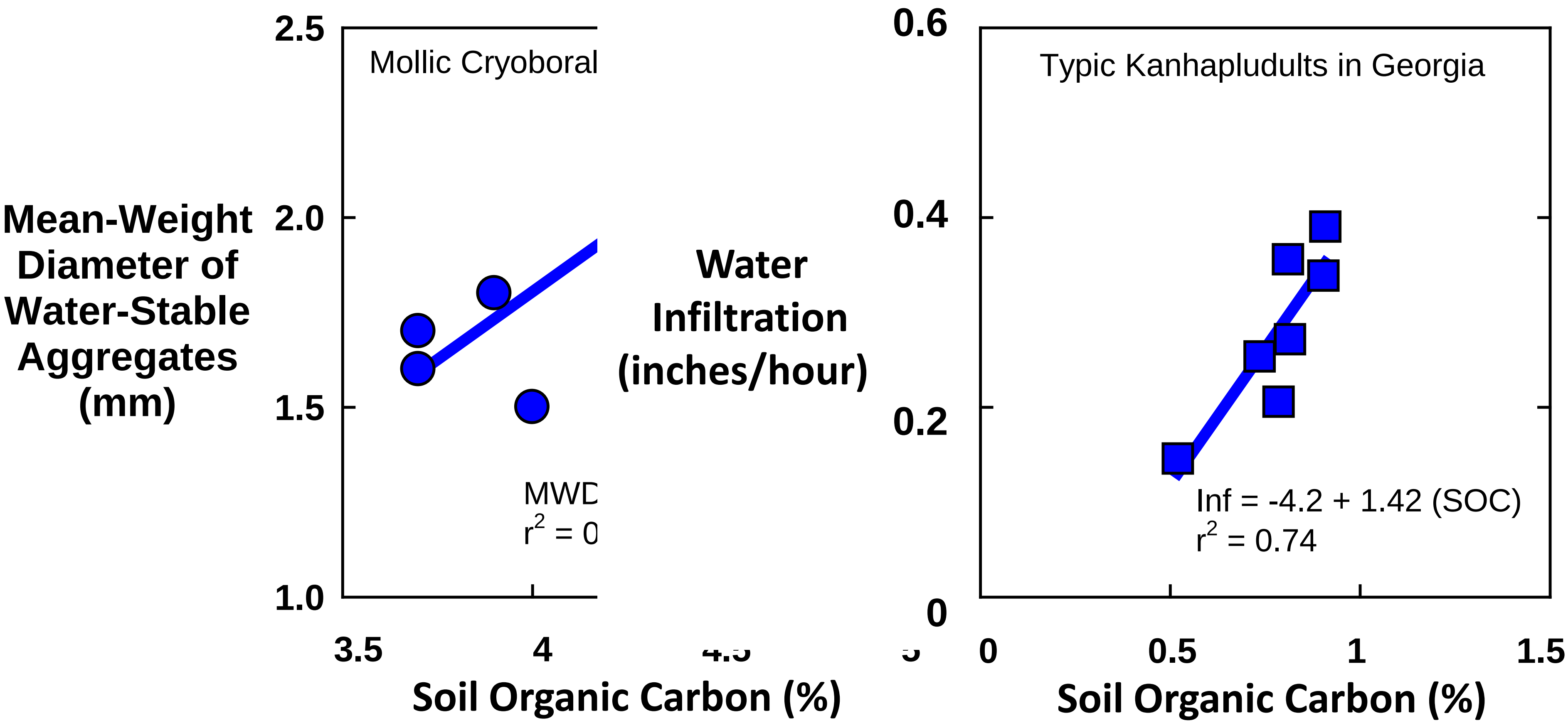
Soil organic C affects water cycling



Soil organic matter improves surface conditions to get more water into soil

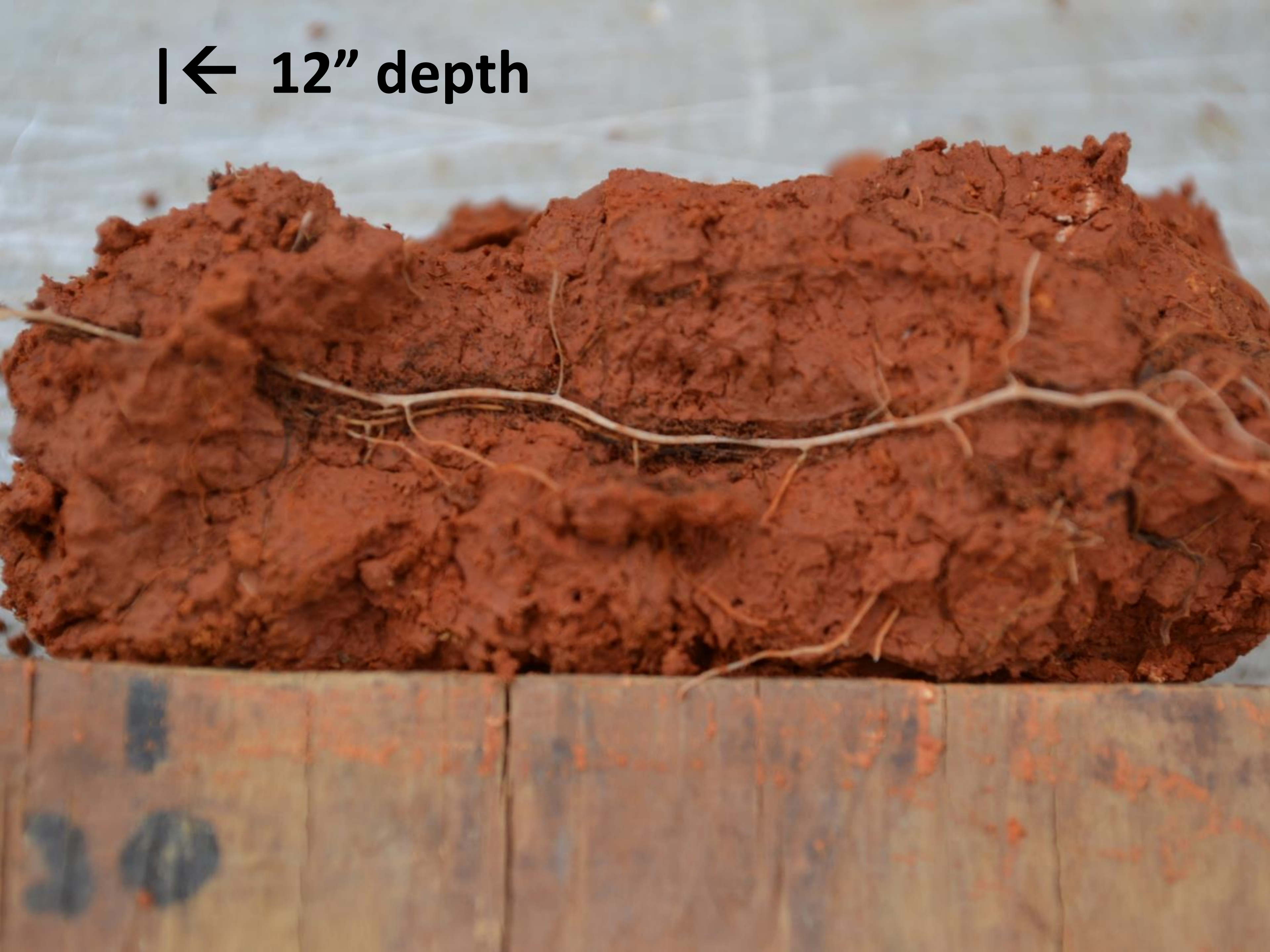
Data from Arshad et al. (2004) Soil Till. Res. 77:15-23
Carreker et al. (1977) USDA-ARS S-160

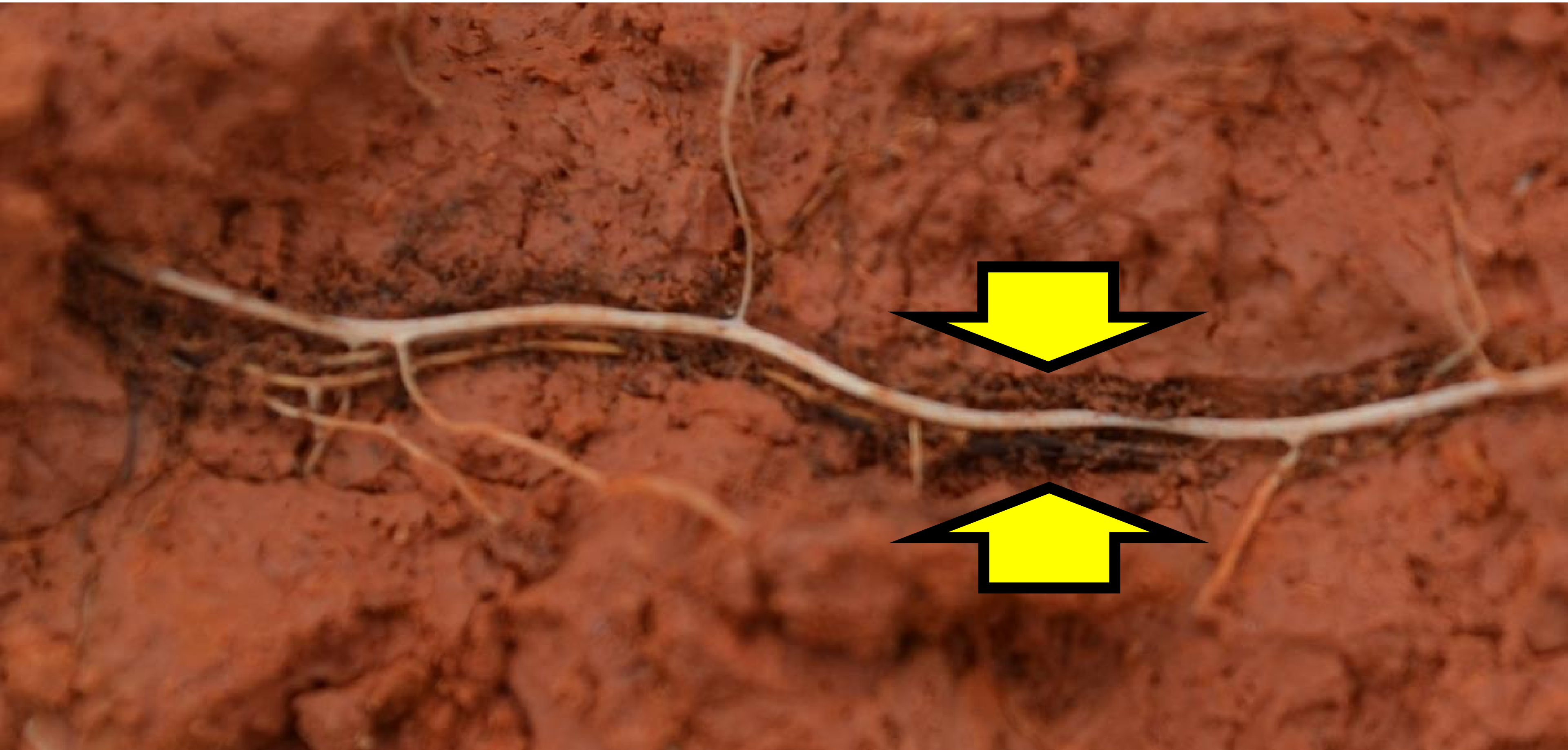

FRANK LEE
FARMS
CONSERVATION
FARM FAMILY
2011
STANLY S&WCD
Whitley

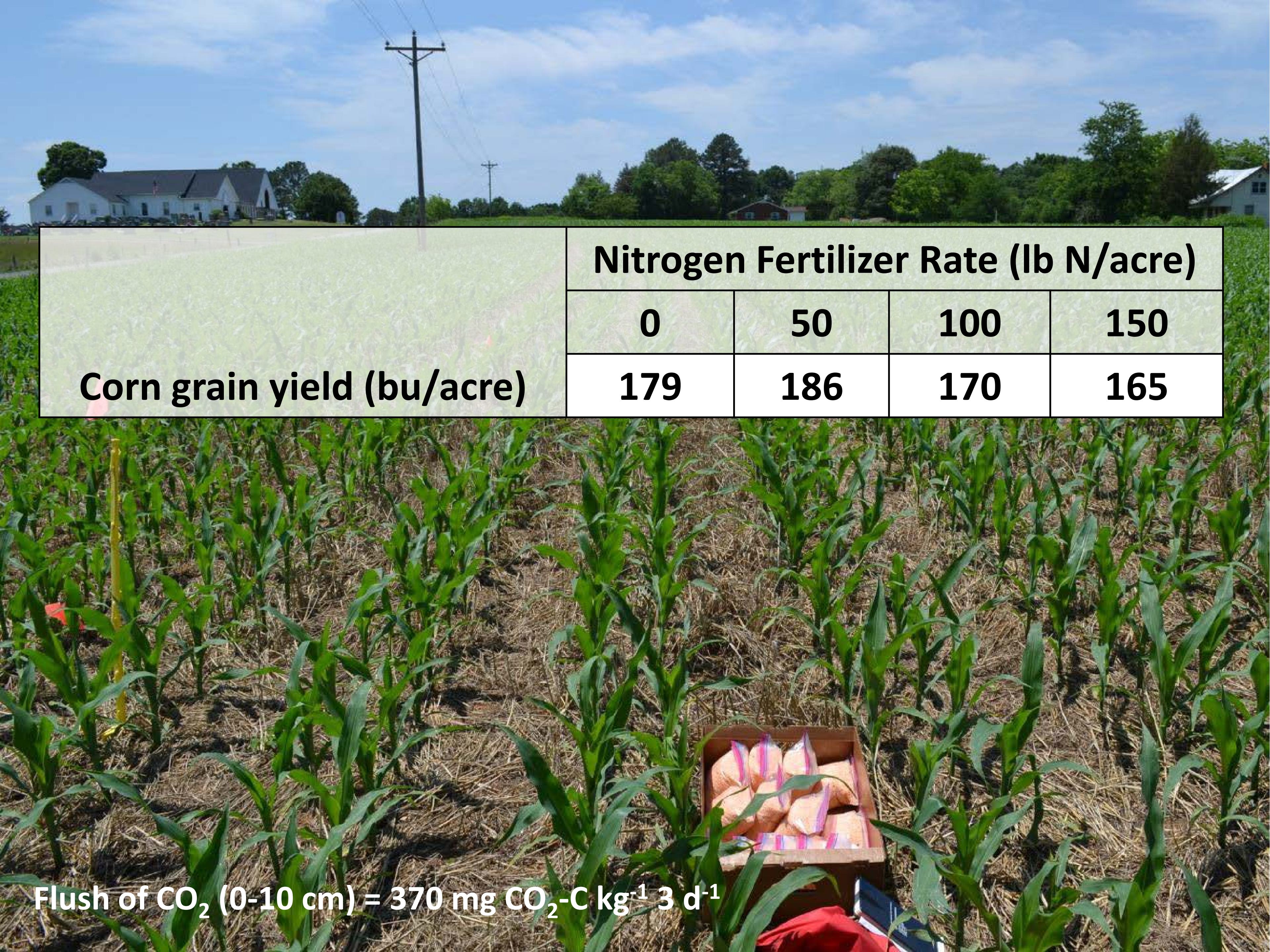

Triticale-crimson clover-winter pea cover crop
grazed moderately
and recently sprayed prior to planting corn

| ← 0-4" → | ← 4-8" → | ← 8-12" → |

| ← 4-8” depth → |


|← 12” depth





	Nitrogen Fertilizer Rate (lb N/acre)			
	0	50	100	150
Corn grain yield (bu/acre)	179	186	170	165

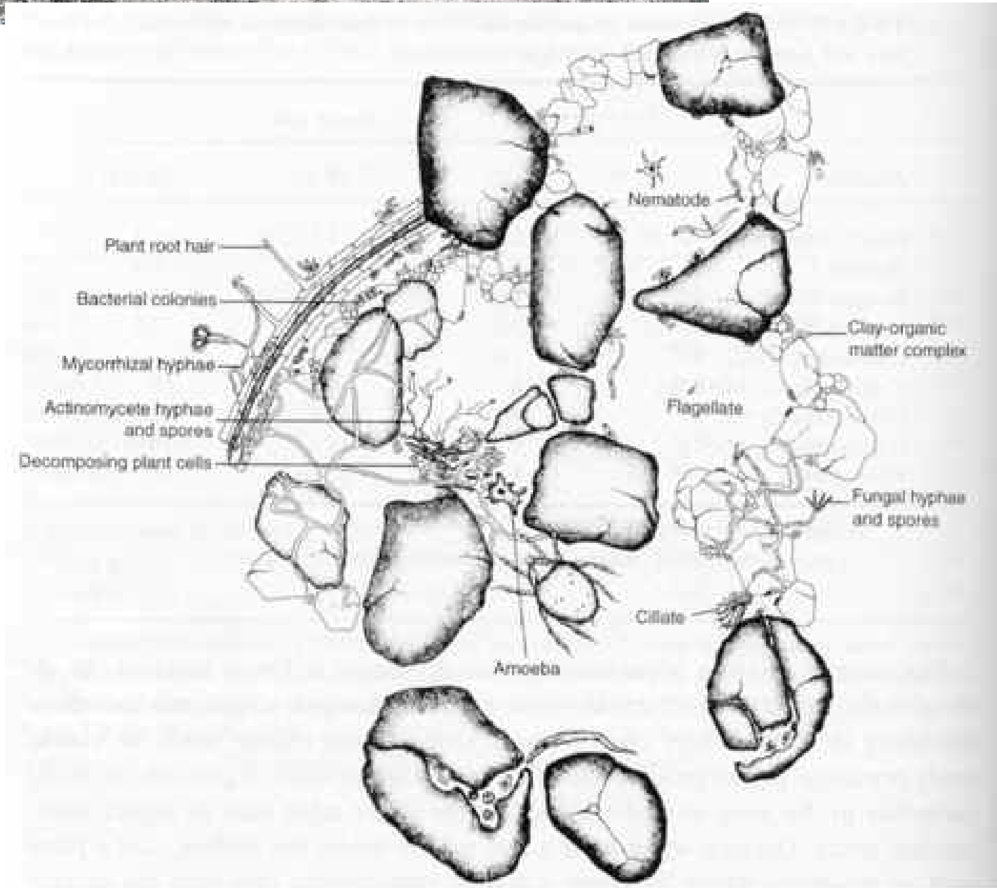
Flush of CO_2 (0-10 cm) = 370 mg CO_2-C kg^{-1} 3 d^{-1}

Soil aggregation

✓ **Stabilizes soil surface against the energy input of rainfall and traffic (equipment and animals)**

✓ **Creates sufficient porosity for retention and transport of water and air**

✓ **Protects soil organisms from predation and rapid decomposition of organic matter**



Animal traffic impacts on macro-aggregate stability

Under No-Till Management

Soil depth (inches)	Grazed?	At end of 1 yr	At end of 2 yr	At end of 3 yr
		------ g_{wet} / g_{dry} ------		
0-1.2	No	0.94	0.96	0.94
	Yes	0.94	0.99	0.98
1.2-2.4	No	0.96	0.99	0.94
	Yes	0.93	1.00	0.98
				*
2.4-4.7	No	0.94	0.98	0.96
	Yes	1.02	0.99	0.99
				*

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

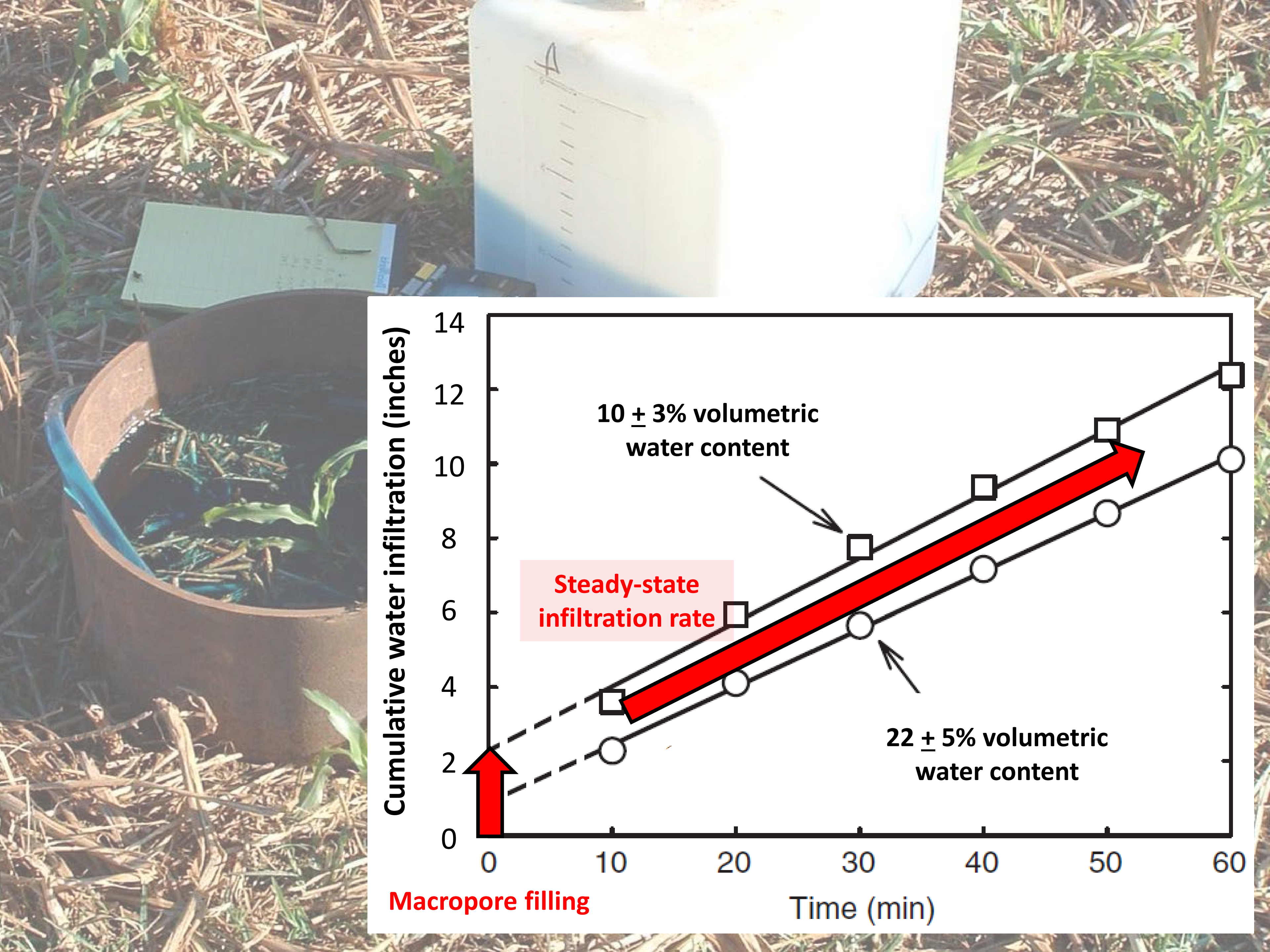
From
North Georgia

Animal traffic impacts on mean-weight diameter stability of aggregates

Soil depth (inches)	Grazed?	Under No-Till Management		
		At end of 1 yr	At end of 2 yr	At end of 3 yr
		---- mm $_{wet}$ / mm $_{dry}$ ----		
0-1.2	No	0.90	0.95	0.92
	Yes	0.91	1.01	0.96
			*	
1.2-2.4	No	0.93	0.98	0.90
	Yes	0.88	1.02	0.97
				*
2.4-4.7	No	0.86	0.94	0.89
	Yes	0.95	0.96	0.94
				*

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

From
North Georgia



Cumulative water infiltration (inches)
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
Time (min)
10 + 3% volumetric water content
22 + 5% volumetric water content
Steady-state infiltration rate
Macropore filling

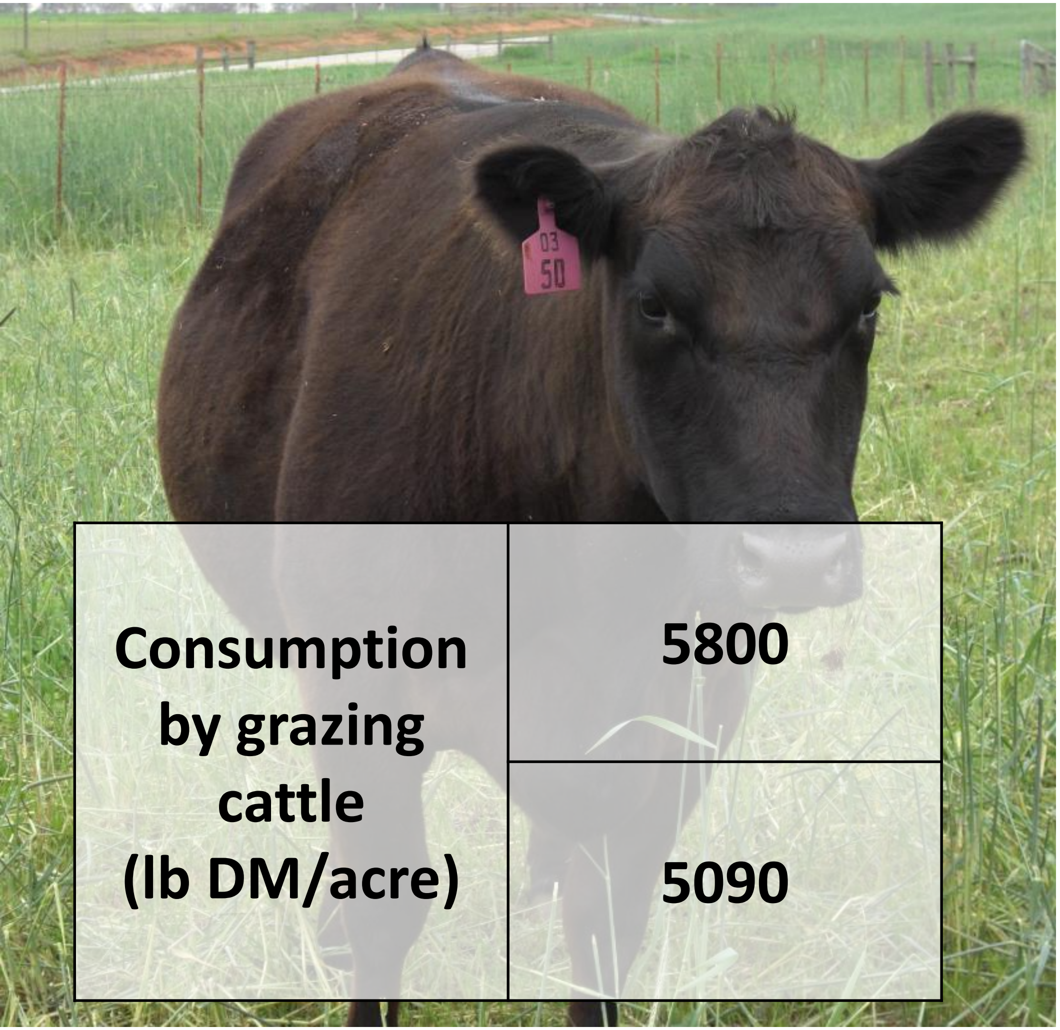
Animal traffic impacts on soil penetration resistance

Resistance in top 4” of soil (Joules)	
No tillage	
Ungrazed	109
Grazed	122
Conventional tillage	
Ungrazed	70
Grazed	110

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

<u>Ruminant livestock</u> – *pressure points of concern to cropland farmers*

Consumption of high-quality, cover-crop forage



Consumption by grazing cattle (lb DM/acre)	5800
	5090

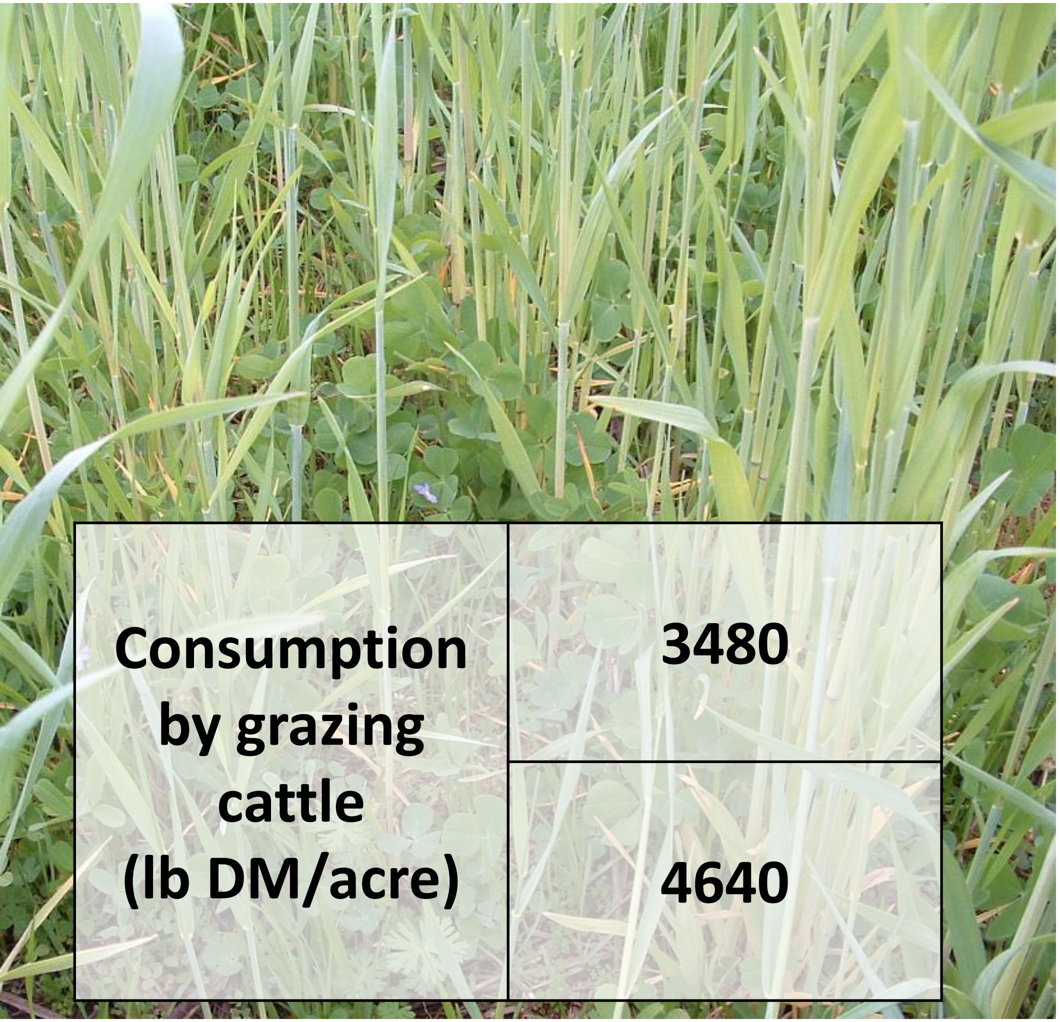
3 years of data in north Georgia

Cereal rye as winter cover crop following corn or sorghum

Dry matter remaining (lb/a)	
No tillage	
Ungrazed	6250
Grazed	450
Conventional tillage	
Ungrazed	5360
Grazed	270

Franzluebbers and Stuedemann (2007) Renewable Agric. Food Syst. 22:168-180

Consumption of high-quality, cover-crop forage



Consumption by grazing cattle (lb DM/acre)	3480
	4640

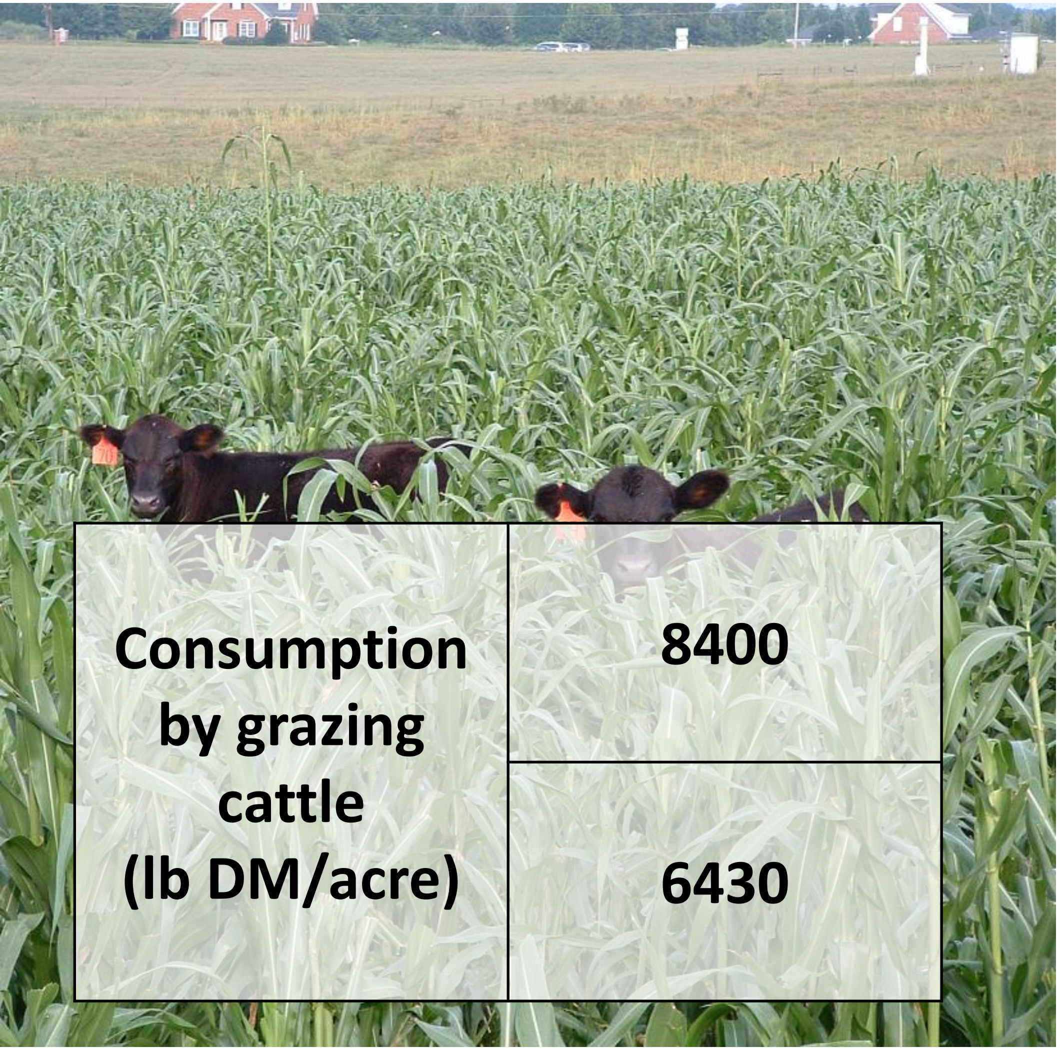
3 years of data in North Georgia

Winter cover crops following NT corn or soybean

Dry matter remaining (lb/a)	
Crimson clover/rye (0 lb N/a)	
Ungrazed	3930
Grazed	450
Ryegrass/rye (40 lb N/a)	
Ungrazed	5270
Grazed	630

Franzluebbers and Stuedemann (2014) Eur. J. Agron. 57:62-70

Consumption of high-quality, cover-crop forage



Consumption by grazing cattle (lb DM/acre)	8400
	6430

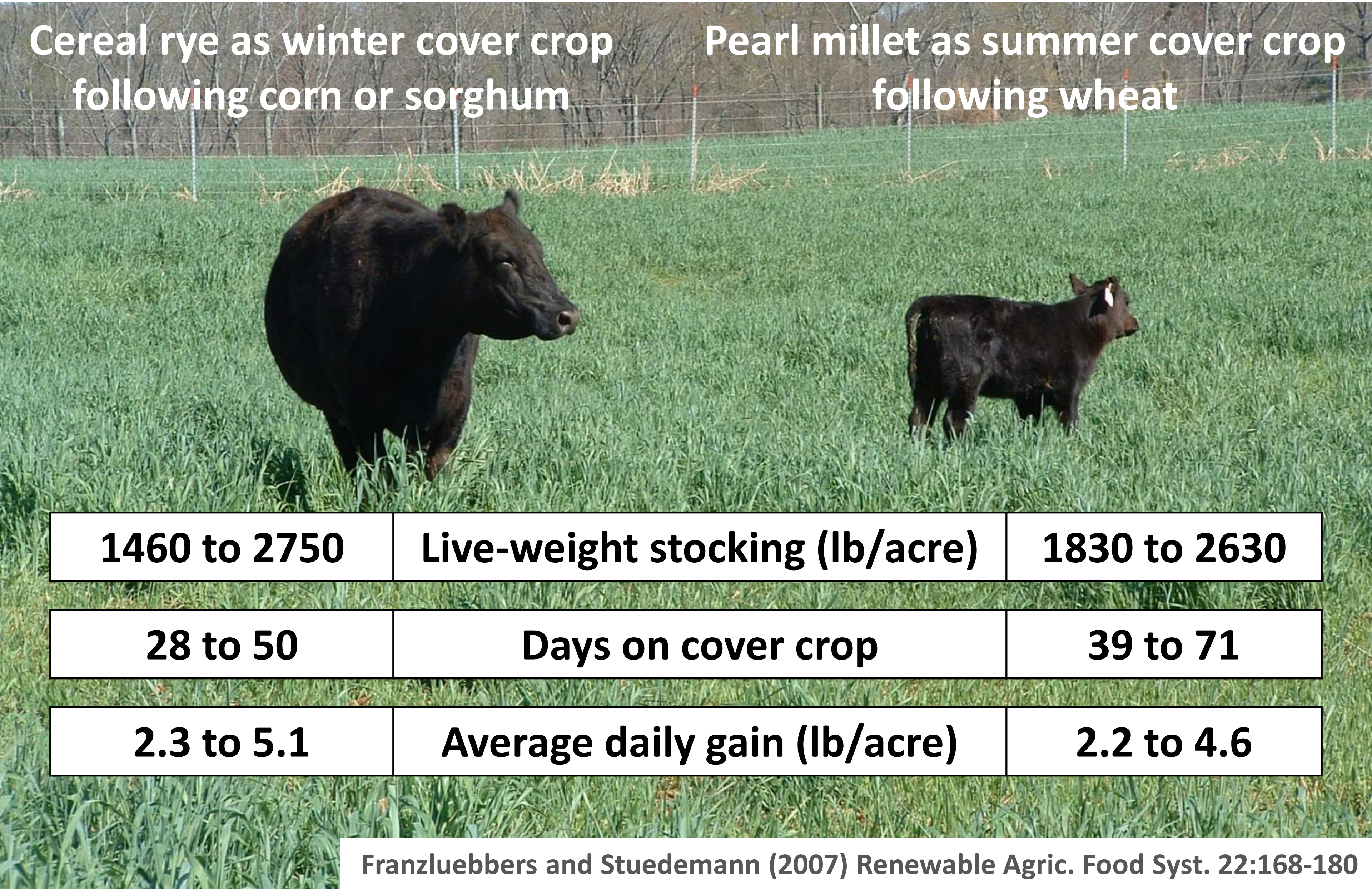
4 years of data in North Georgia

Pearl millet as summer cover crop following wheat

Dry matter remaining (lb/a)	
No tillage	
Ungrazed	9110
Grazed	710
Conventional tillage	
Ungrazed	6790
Grazed	360

Franzluebbers and Stuedemann (2007) Renewable Agric. Food Syst. 22:168-180

Daily gain on high-quality, cover-crop forage



Cereal rye as winter cover crop following corn or sorghum		Pearl millet as summer cover crop following wheat
1460 to 2750	Live-weight stocking (lb/acre)	1830 to 2630
28 to 50	Days on cover crop	39 to 71
2.3 to 5.1	Average daily gain (lb/acre)	2.2 to 4.6

Franzluebbers and Stuedemann (2007) Renewable Agric. Food Syst. 22:168-180

Animal gain on cover crops

Year	Grazing days	Spring Grazing		Grazing days	Summer Grazing	
		CT	NT		CT	NT
		----- lb/acre -----			----- lb/acre -----	
2002	0	-	-	485	221	288
2003	252	196	261	191	265	299
2004	211	345	463	200	141	162
2005	117	68	146	144	223	289
2006	172	101	97	0	-	-
2007	81	71	214	0	-	-
2008	157	299	199	0	-	-
Mean	**165**	**179**	**230**	**255**	**213**	**260**
Gross return ($/acre)		**138-276**			**156-312**	

Franzluebbers and Stuedemann (2007) Renewable Agric. Food Syst. 22:168-180

Excessive consumption of forage on cropland nearly eliminates surface cover and potentially risks negative soil impacts…

Grazing of winter cover-crop pasture in Rio Grande do Sul, Brazil

Years	Characteristic	Grazing Height (inches)				
		4	8	12	16	Ungrazed
14	Forage production (ton/acre)	2.9	3.2	3.3	3.5	2.9
14	Surface residue (lb/acre)	1340	3030	4020	5090	5800
9	Soil organic carbon (ton/acre)	23.0	26.3	26.3	26.3	26.3
14	Soybean yield (bu/acre)	43.2	43.2	41.7	46.1	44.6
15	Stocking weight (lb/acre)	1190	846	580	336	--
16	Animal daily gain (lb/day)	1.8	2.3	2.4	2.4	--
15	Live weight gain (lb/acre)	455	382	278	163	--
14	Net economic return ($/acre)	278	253	227	215	171

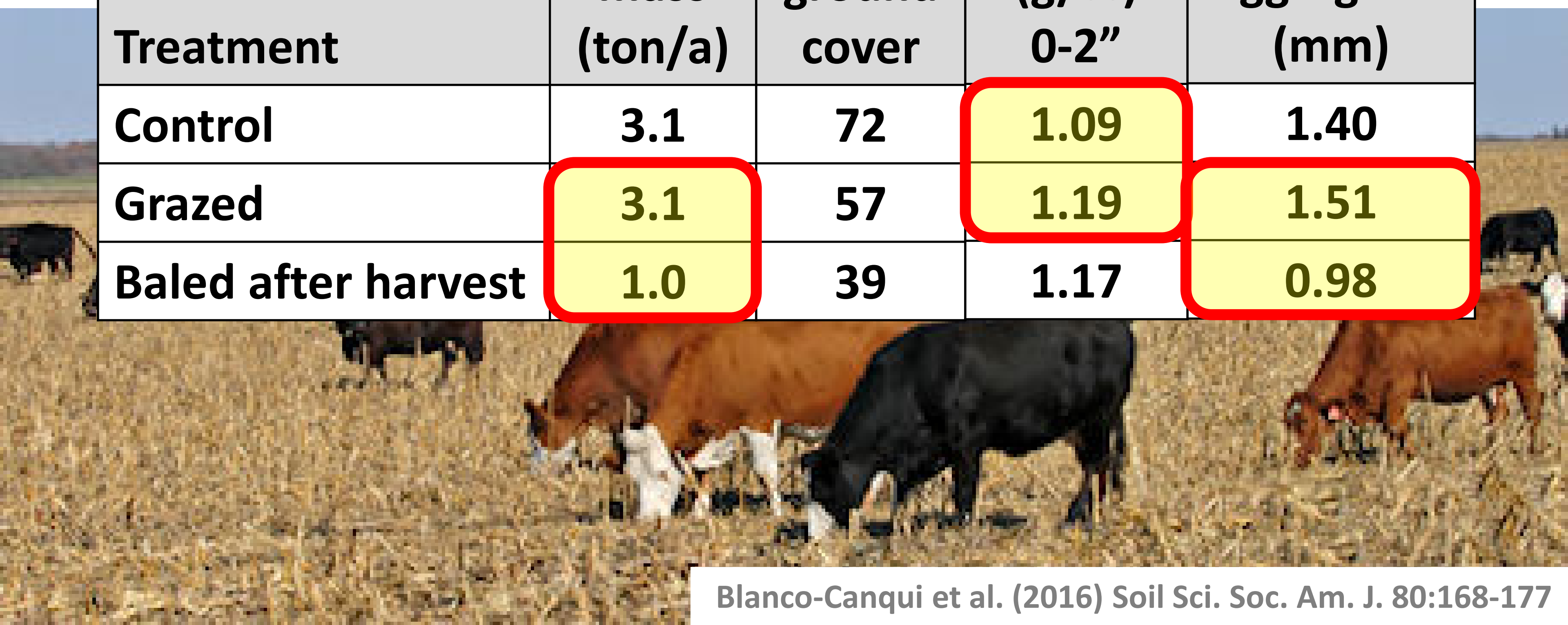
Assmann et al. (2014), Martins et al. (2015), Carvalho et al. (2018)

Grazing corn stalks

- Two studies from Nebraska

1-year dryland study in southeastern Nebraska

- ✓ **87 days of grazing from Oct 25 to Jan 20**

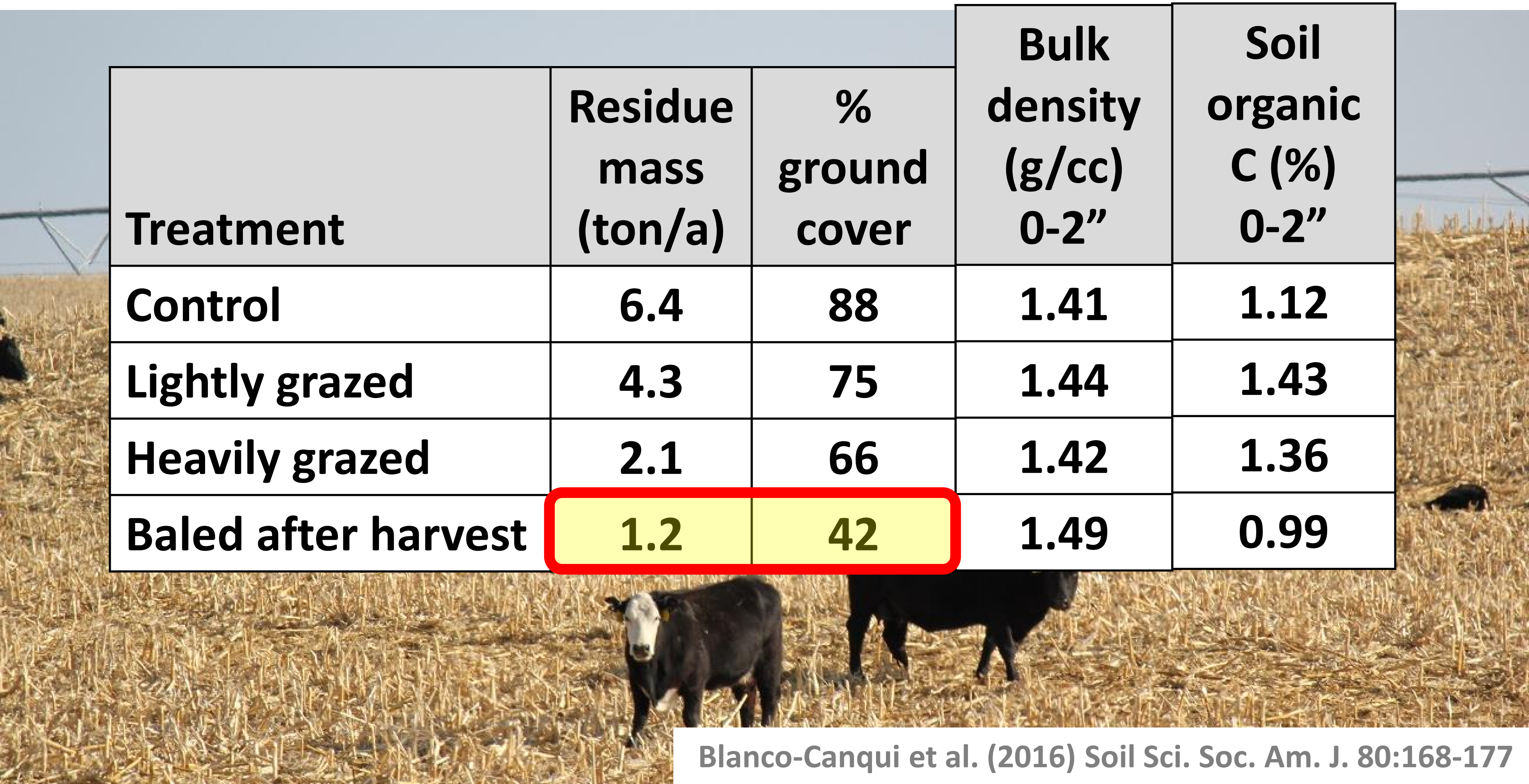


Treatment	Residue mass (ton/a)	% ground cover	Bulk density (g/cc) 0-2”	MWD of aggregates (mm)
Control	3.1	72	1.09	1.40
Grazed	3.1	57	1.19	1.51
Baled after harvest	1.0	39	1.17	0.98

Blanco-Canqui et al. (2016) Soil Sci. Soc. Am. J. 80:168-177

7-year irrigated study in west-central Nebraska

✓ ~62 days of grazing from Dec to early Feb

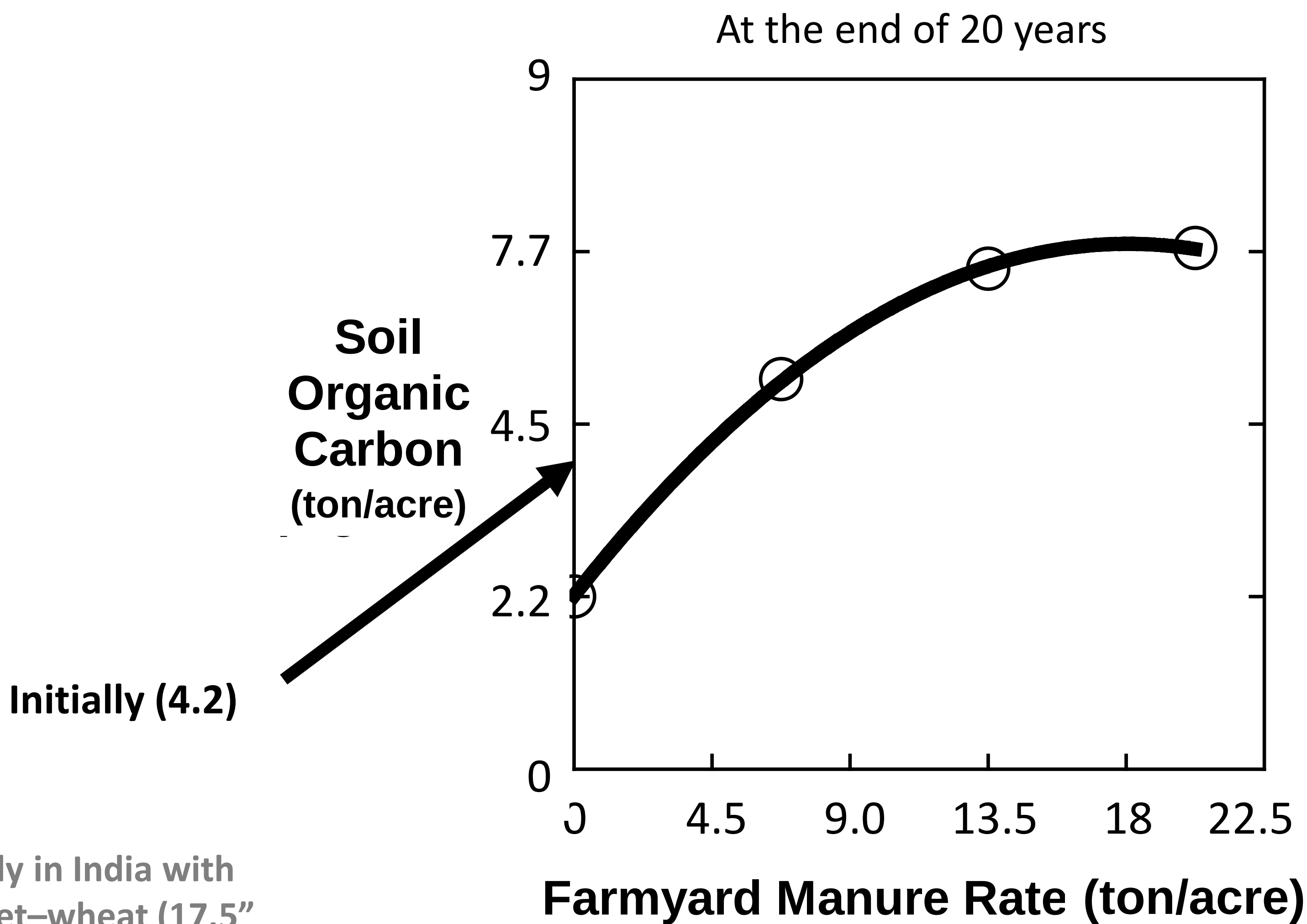


Treatment	Residue mass (ton/a)	% ground cover	Bulk density (g/cc) 0-2”	Soil organic C (%) 0-2”
Control	6.4	88	1.41	1.12
Lightly grazed	4.3	75	1.44	1.43
Heavily grazed	2.1	66	1.42	1.36
Baled after harvest	1.2	42	1.49	0.99

Blanco-Canqui et al. (2016) Soil Sci. Soc. Am. J. 80:168-177


Ruminant livestock – pressure points of concern to cropland farmers
Feces deposition impacts

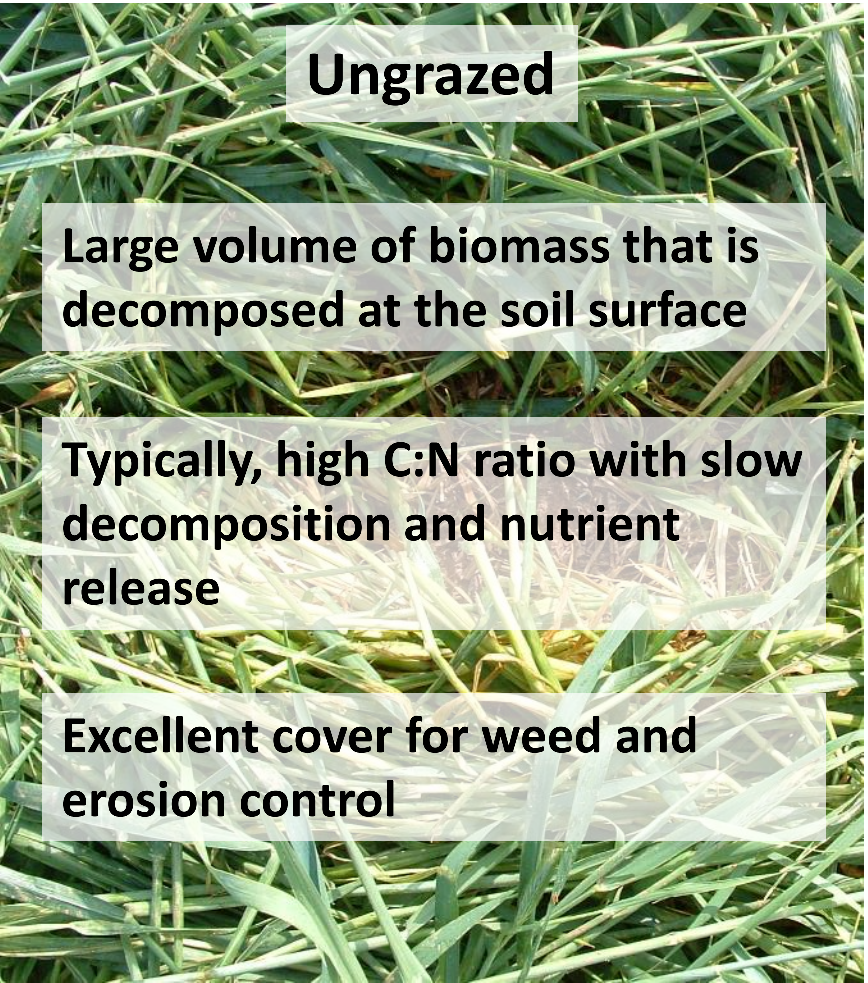
Animal manure has long been known for its beneficial effects on soil fertility



20-yr study in India with pearl millet–wheat (17.5" annual rainfall)

Gupta et al. (1992) Arid Soil Res. Rehabil. 6:243-251

In integrated crop-livestock system, plant biomass is transformed into feces (importantly, after feeding livestock)

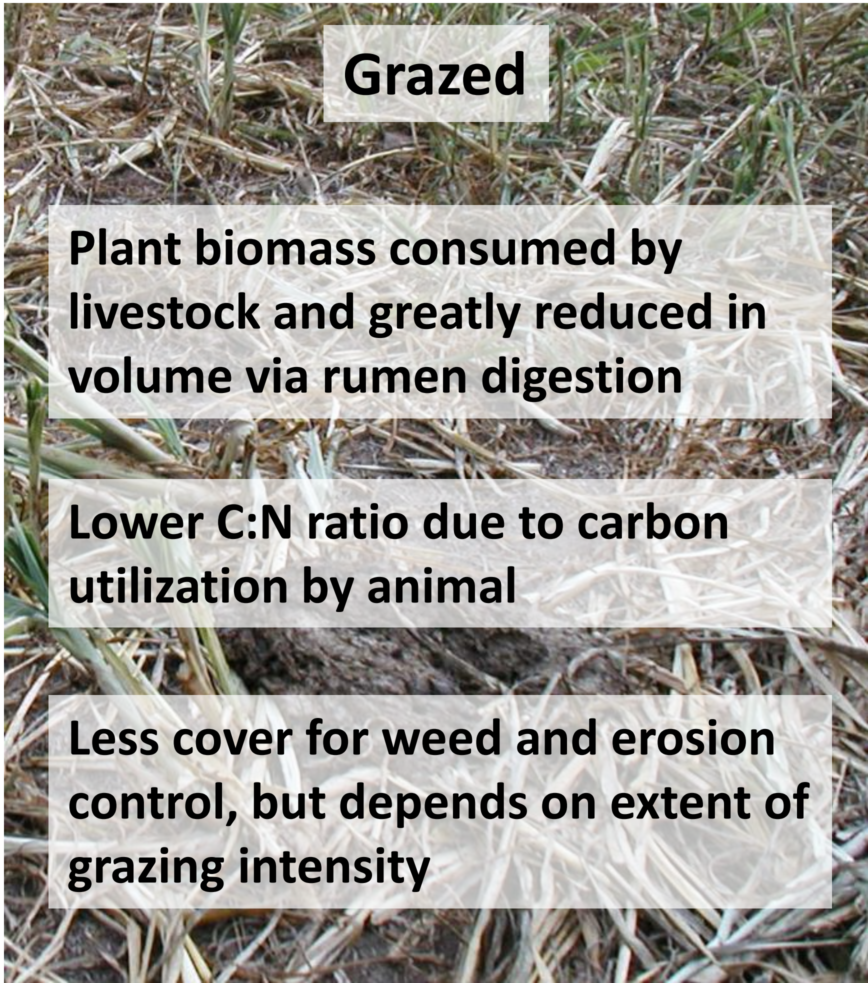


Ungrazed

Large volume of biomass that is decomposed at the soil surface

Typically, high C:N ratio with slow decomposition and nutrient release

Excellent cover for weed and erosion control

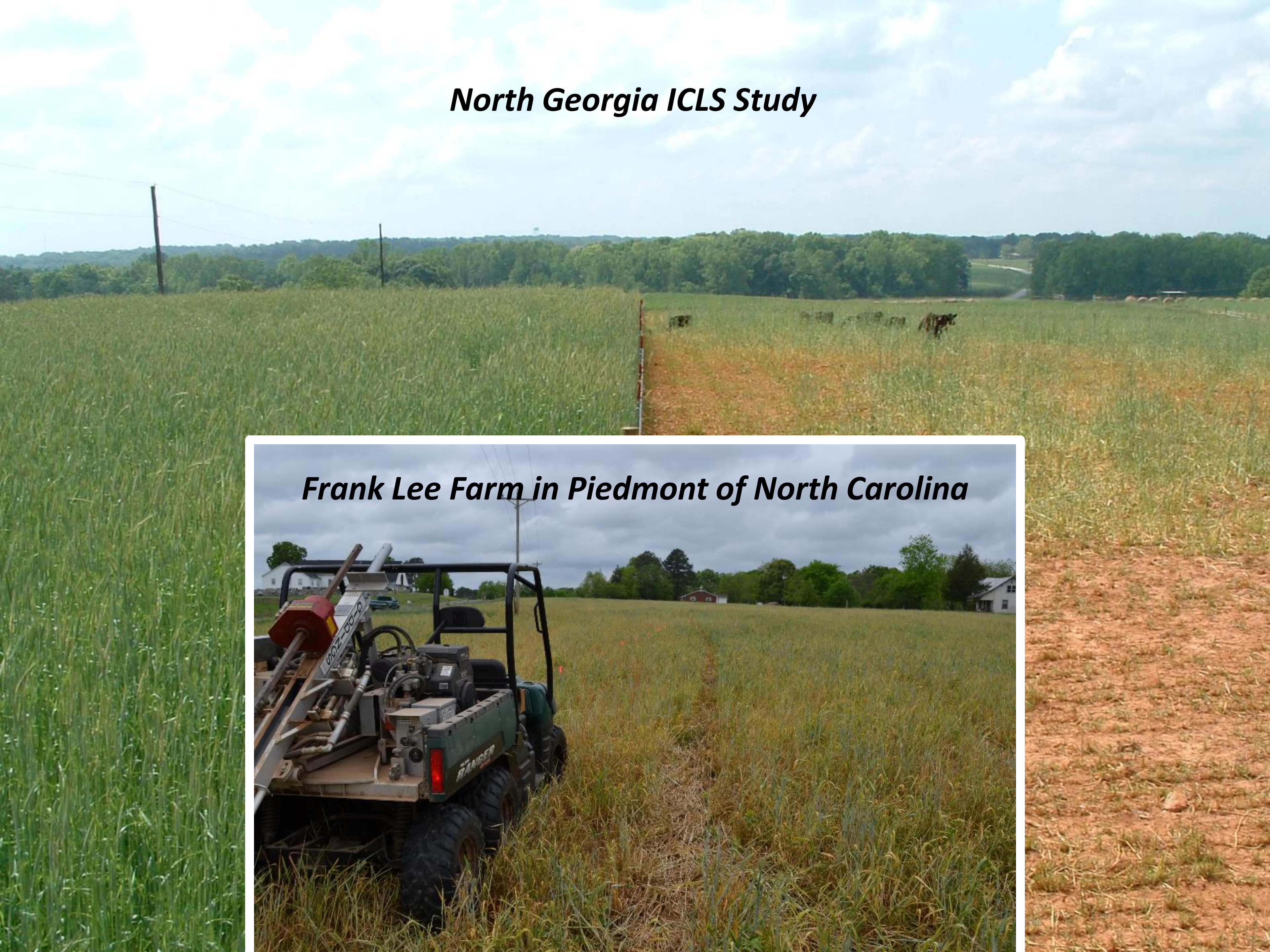


Grazed

Plant biomass consumed by livestock and greatly reduced in volume via rumen digestion

Lower C:N ratio due to carbon utilization by animal

Less cover for weed and erosion control, but depends on extent of grazing intensity


North Georgia ICLS Study
Frank Lee Farm in Piedmont of North Carolina

Grazing-induced change in soil microbial biomass in an integrated crop-livestock system

5 years of data in North Georgia

Soil microbial biomass C (lb/acre)		
Soil depth (inches)	No-Till Management	
	Ungrazed	Grazed
0-1	394	430
1-2	243	265
2-5	293	285
5-8	245	265
8-12	234	229
0-12	1408	1475

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

Effect of grazing cover crops on soil organic matter

North Georgia
Average of 1, 3, 5, and 7 years
under no-tillage management

Total soil nitrogen (lb/acre)		
Soil depth	Ungrazed	Grazed
0-2”	1429	1438
0-12”	3402	3438
Soil organic C (ton/acre)		
Soil depth	Ungrazed	Grazed
0-2”	9.7	9.6
0-12”	22.4	22.5
Particulate organic C (ton/acre)		
Soil depth	Ungrazed	Grazed
0-2”	3.3	3.3
0-12”	5.6	5.7

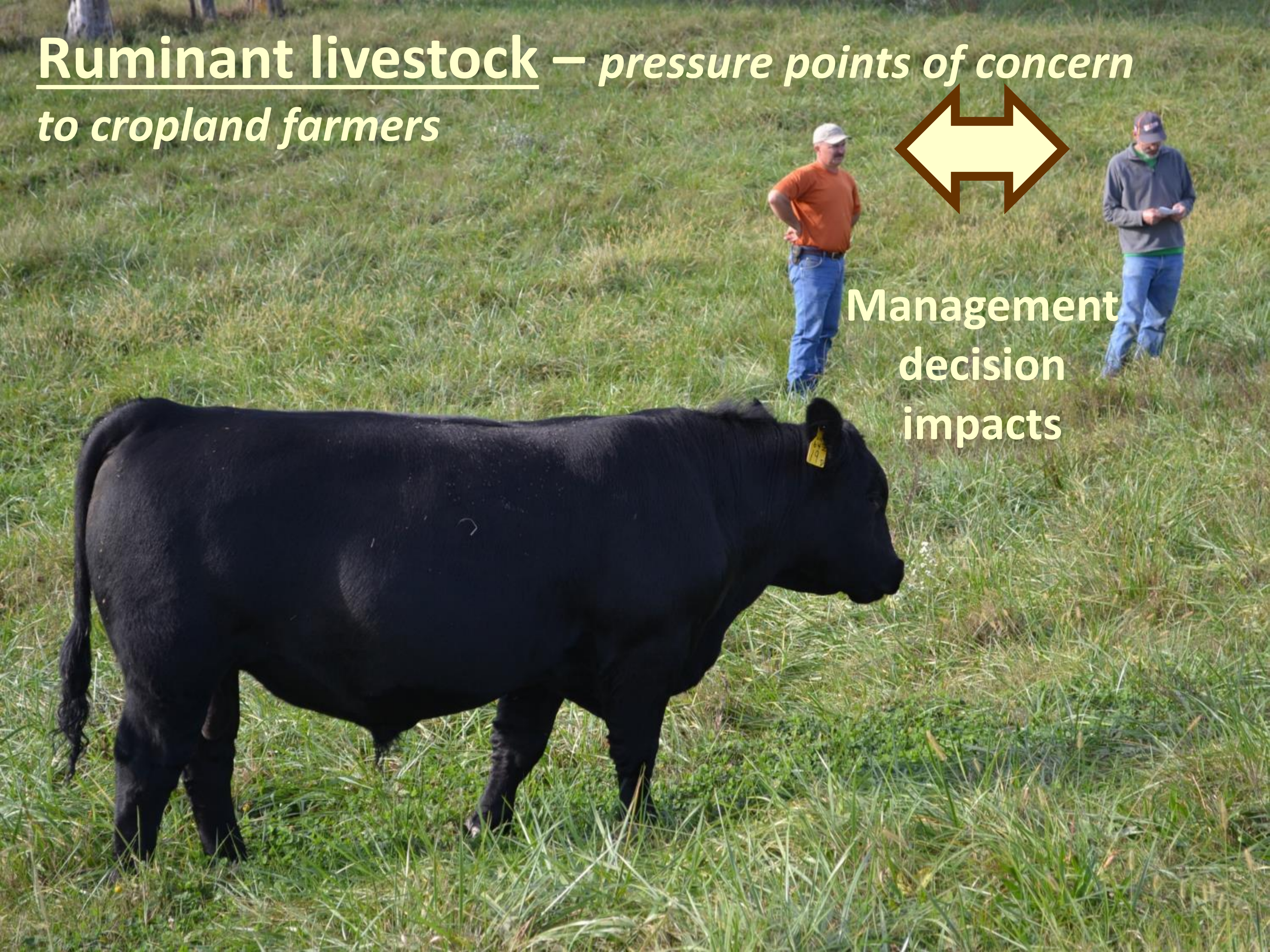
Franzluebbers and Stuedemann (2014) Soil Sci. Soc. Am. J. 78:1404-1413

Effect of grazing cover crops on active fractions of SOM

North Georgia
Average of 1, 3, 5, and 7 years under no-tillage management

N mineralization (lb/acre/24d)		
Soil depth	Ungrazed	Grazed
0-2”	49	50
0-12”	96	97
Flush of CO_2 (lb/acre/3d)		
Soil depth	Ungrazed	Grazed
0-2”	234	238
0-12”	463	464
C mineralization (lb/acre/24d)		
Soil depth	Ungrazed	Grazed
0-2”	667	694
0-12”	1317	1327

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


Ruminant livestock – pressure points of concern to cropland farmers
Management decision impacts

Ruminant livestock – *pressure points of concern to cropland farmers*

Management decision impacts

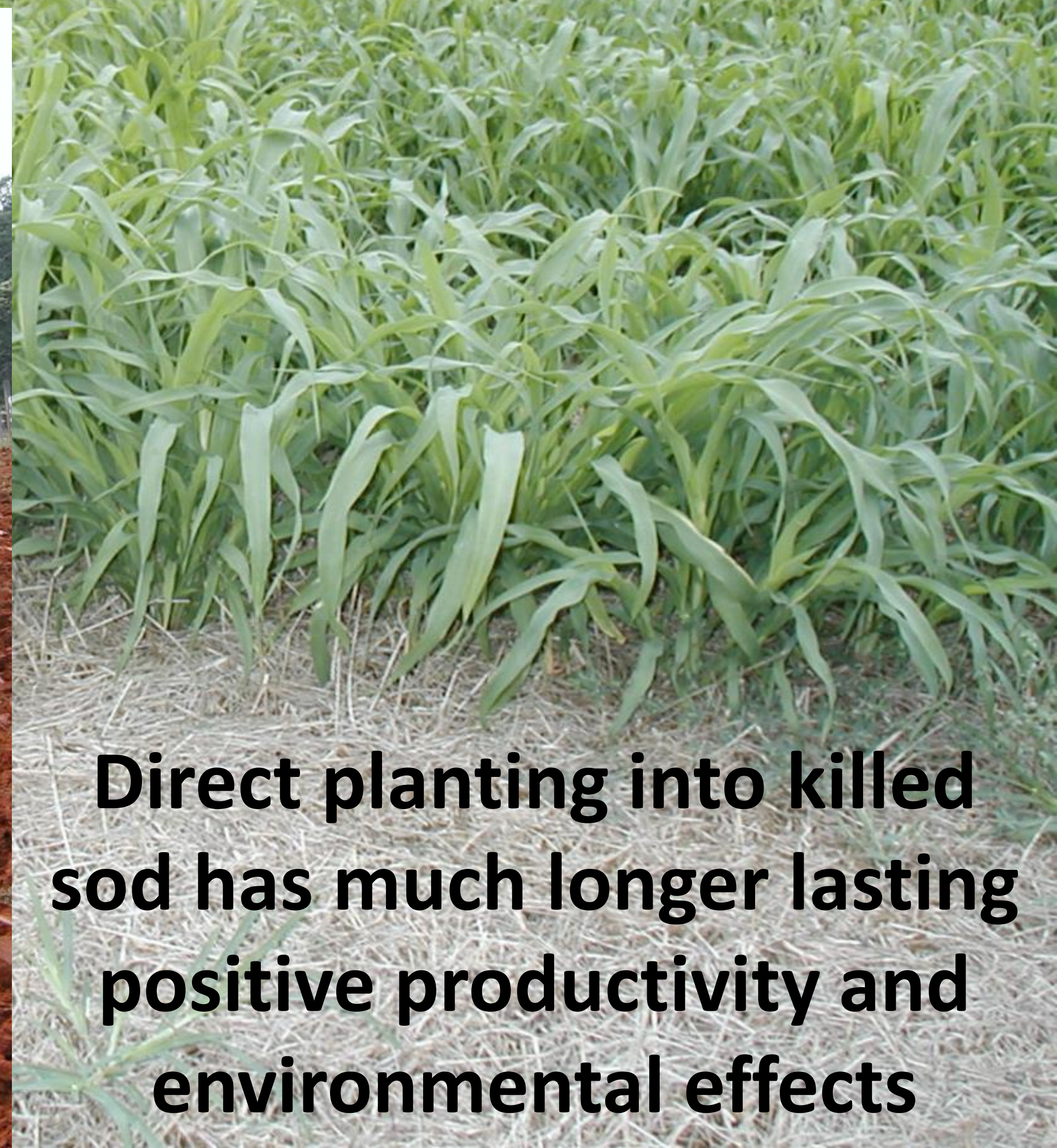
Short-term

1. What class of livestock/how many?
2. What type of cover is best?
3. Will fertilization and weed control be different?
4. How to allocate forage/move cattle?
5. Available water?

Long-term

1. Which parcels of land are most appropriate?
2. How does the annual forage fit within the whole-farm operation?
3. Will grazing affect crop rotation?
4. Sustainability goals?

Pasture-crop rotations (long-term integration strategy)

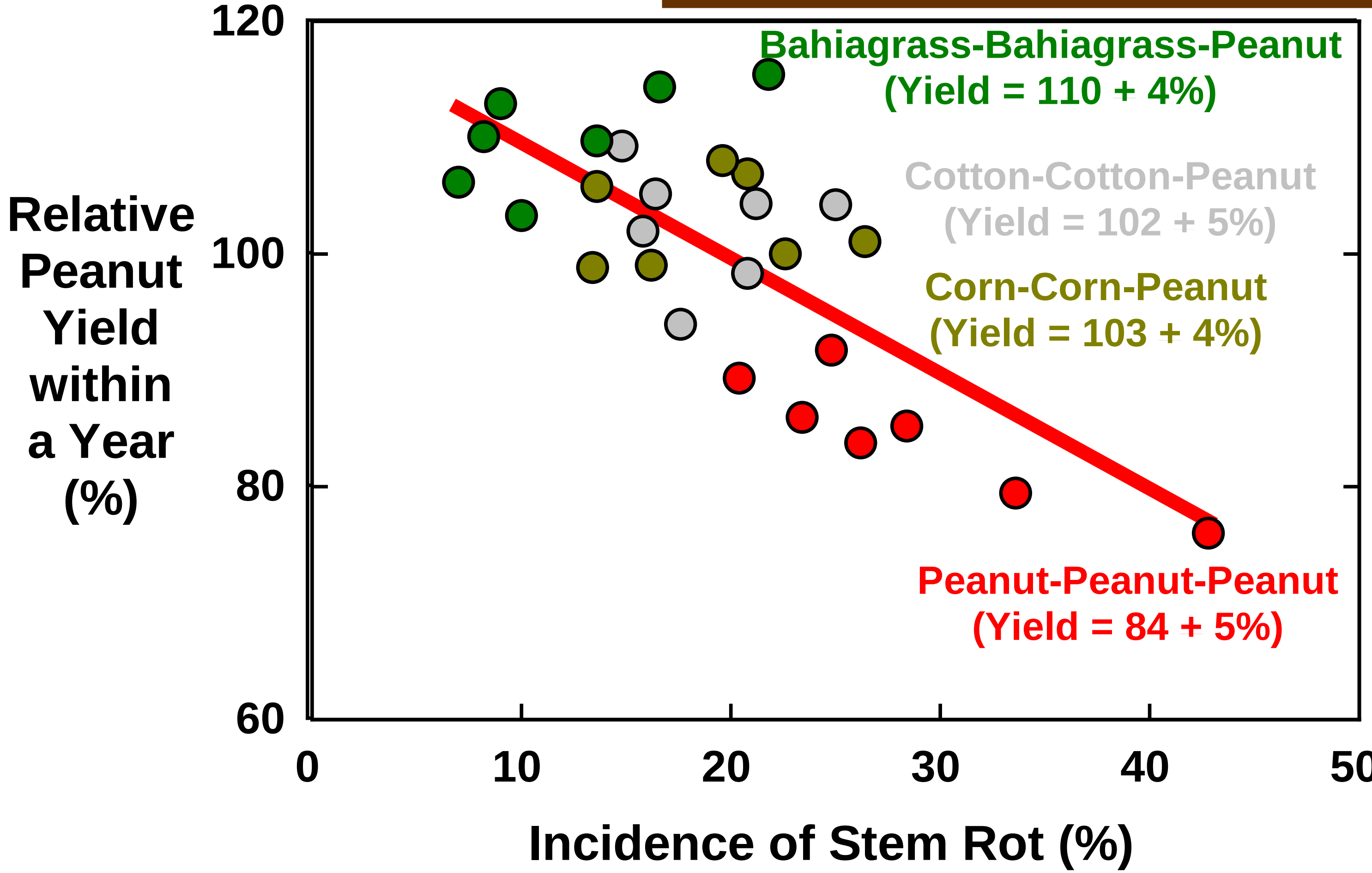


Direct planting into killed sod has much longer lasting positive productivity and environmental effects

Crop rotations and yield

— Disease suppression

Crop-specific responses to rotations and integrated systems will be important



Data from Brenneman et al. (2003) Proc. Sod-Based Crop. Syst. Conf., Quincy FL, p. 59-65

Yield responses to perennial rotations

Eastern Nebraska (Varvel, 2000; Agron. J. 92:938-941)

Crop rotation	Precipitation use efficiency (lb/acre/inch)	Yearly yield variation (relative)
Continuous corn	190	Higher
Soybean-corn-oat/clover-corn	235	Lower

Central Iowa (Davis et al., 2012; Agron. J. 92:938-941)

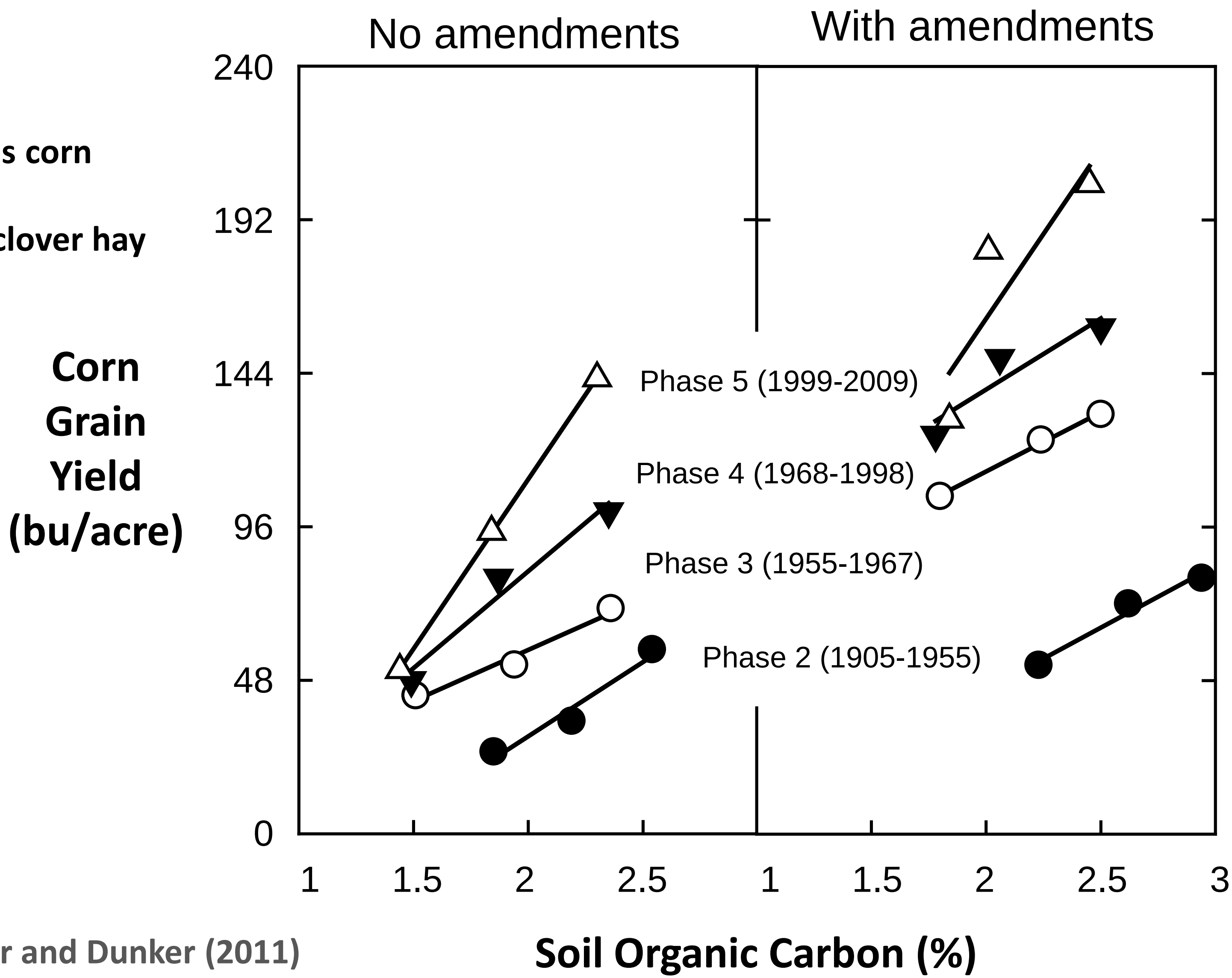
Crop rotation	Corn yield (bu/acre)	Soybean yield (bu/acre)	Economic return ($/acre)
Corn-soybean	195	51	278
Corn-soybean-oat-alfalfa	205	57	283

Pennsylvania (Grover et al., 2009; Agron. J. 101:940-946)

- ✓ Corn grain yield 10-12% greater under longer rotations [4-yr corn-oat/wheat-timothy/red clover hay; 8-yr corn (4)-alfalfa (4)] than cont. corn
- ✓ Longer rotations with lower intra-annual variation than continuous corn

Yield responses to perennial rotations

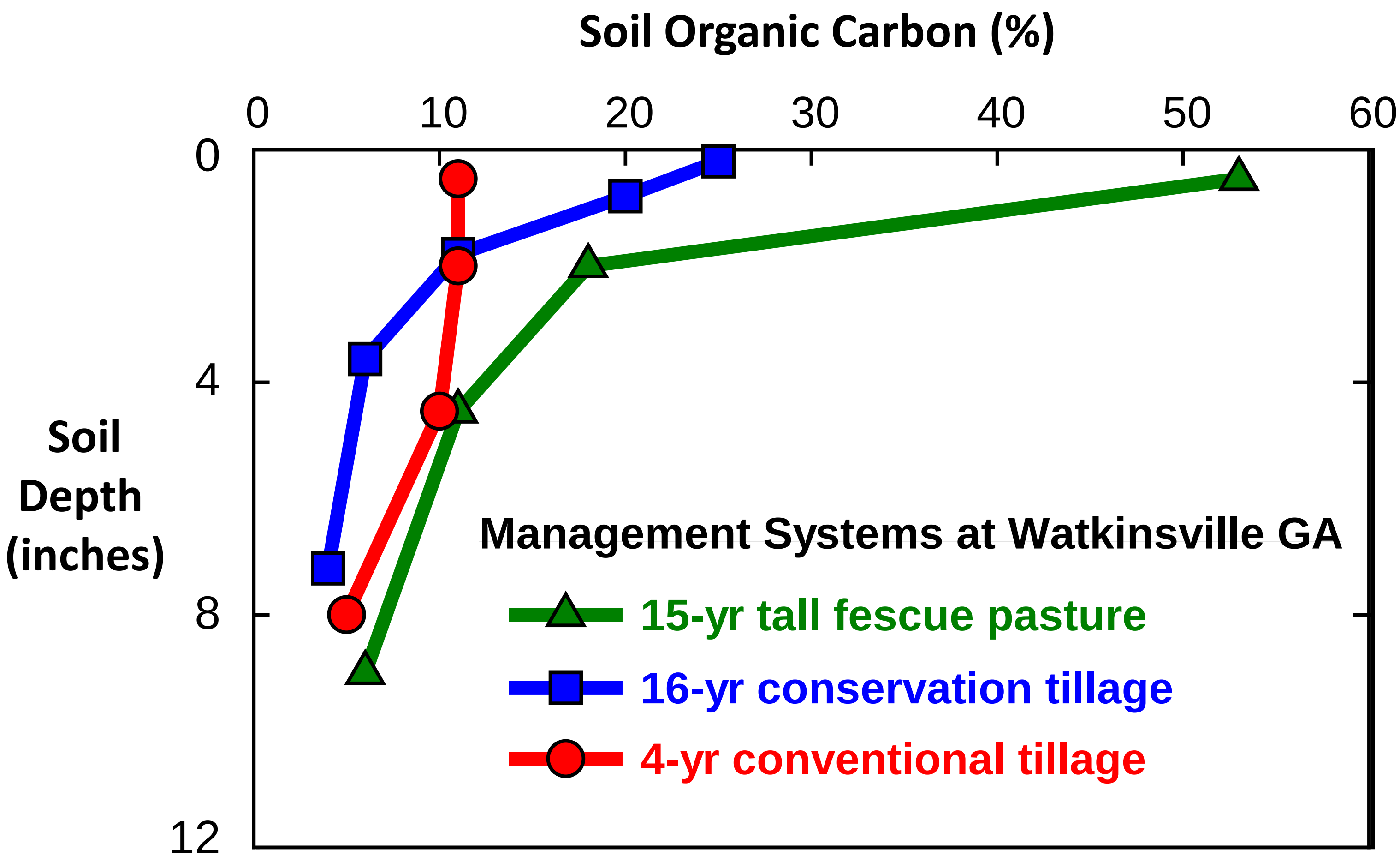
Rotations
1-yr continuous corn
2-yr corn-oat
3-yr corn-oat/clover hay



Data from Nafziger and Dunker (2011)
Agron. J. 103:261-267

Soil organic C accumulates near the soil surface

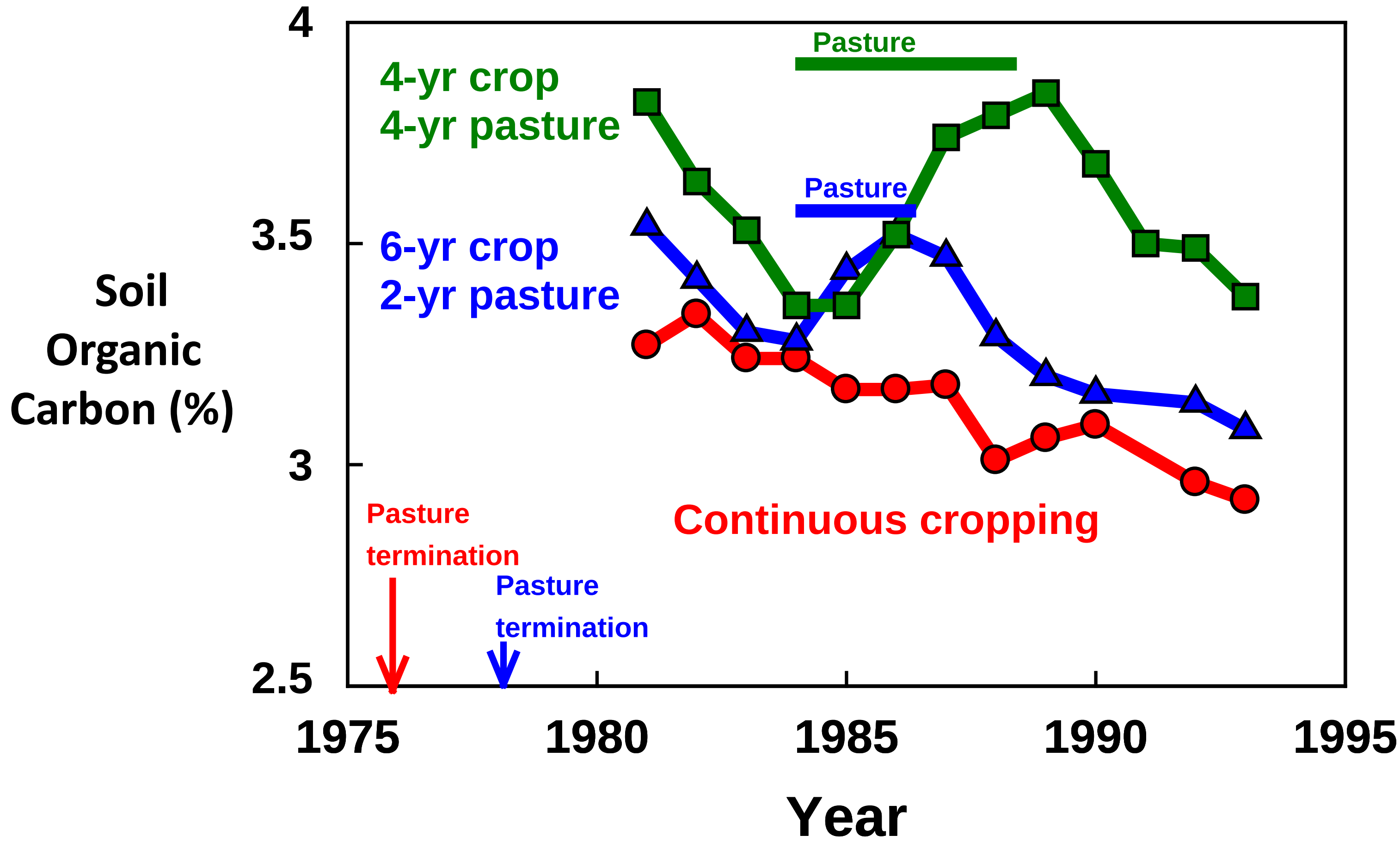
- ***Lack of disturbance and perennial systems key!***



Data from Franzluebbers et al. (1999) Soil Sci. Soc. Am. J. 63:349-355,
Franzluebbers et al. (1999) Soil Sci. Soc. Am. J. 63:1687-1694,
and Bruce and Langdale (1997) SOM in Temp. Agroecosyst., p. 247-261

Soil organic carbon

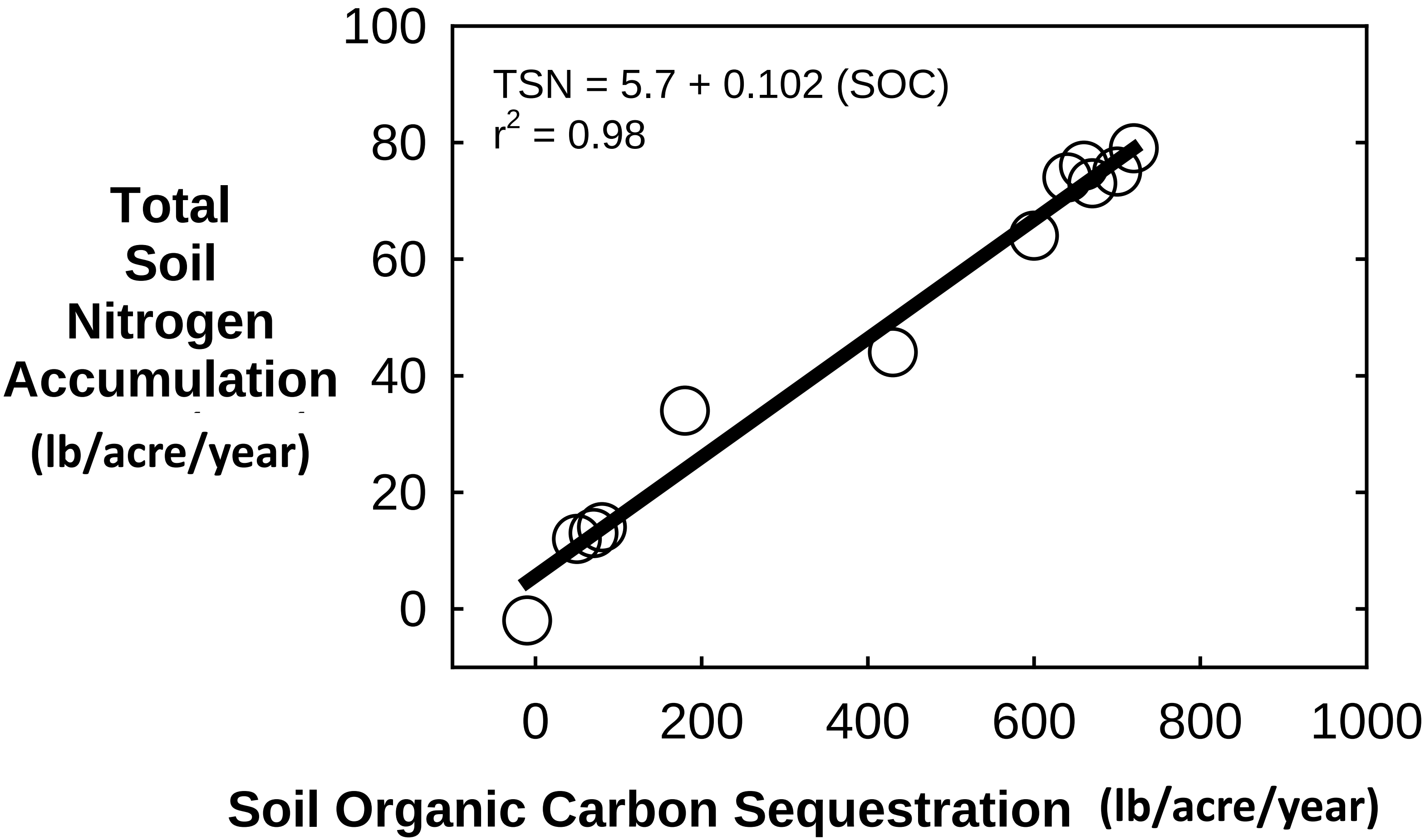
— Crop rotation effects – Argentina



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

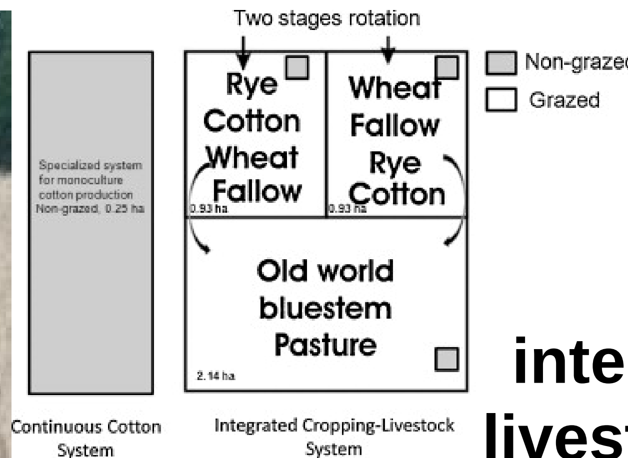
Soil productivity

— Relationship between C and N



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

Conservation agricultural systems for the future



No tillage

\+ cover crops

Corn-Wheat/clover-Cotton/rye-peanut

\+ diverse rotations

\+ sod rotations

\+ integrated crop-livestock systems

\+ agroforestry and/or silvopasture

Time →

Sustainability goals →

Sulc and Franzluebbers (2014) Eur. J. Agron. 57:21-30

Summary

Grazing of cover crops does indeed have impacts on soil, but the measured responses were small in the North Georgia study, which is the longest replicated study of relevance in the US literature. There was an occasional yield drag on summer grain crops, but this study was not in a true "corn environment".

- ✓ **Grazing had little effect on bulk density under either tillage system – much less than lack of tillage when switching from conventional to no tillage**
- ✓ **Grazing had essentially no effect on soil organic C content and depth distribution**
- ✓ **Grazing increased penetration resistance of the surface 10 cm of soil – discernible only under wet soil conditions**
- ✓ **Grazing reduced single-ring water infiltration – discernable only under wet soil conditions**

Conclusions

Integrated crop-livestock systems that are productive and environmentally friendly can be best developed with:
(for the warm-moist southeastern USA)

- ✓ **NT-management to preserve SOM and buffer against animal traffic**
- ✓ **Strategic stocking of livestock on high-quality cover crops and crop residues**
- ✓ **When starting from high-surface SOM condition following perennial pasture**