Evaluating potential indicators of ecosystem functioning

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USDA Agricultural Research Service

Goal-

Let variation in data reveal the best predictors of ecosystem functioning

Implications-

Efficacy of indicators for rangeland health

Soil stability is routinely measured and interpreted as an indicator of ecosystem function/health

% water stable aggregates (% **WSA**)

Figure 4. Place sample in sieve.

Figure 5. Complete soil stability kit with water and samples.

soil stability (or slack) test

Hypothesis

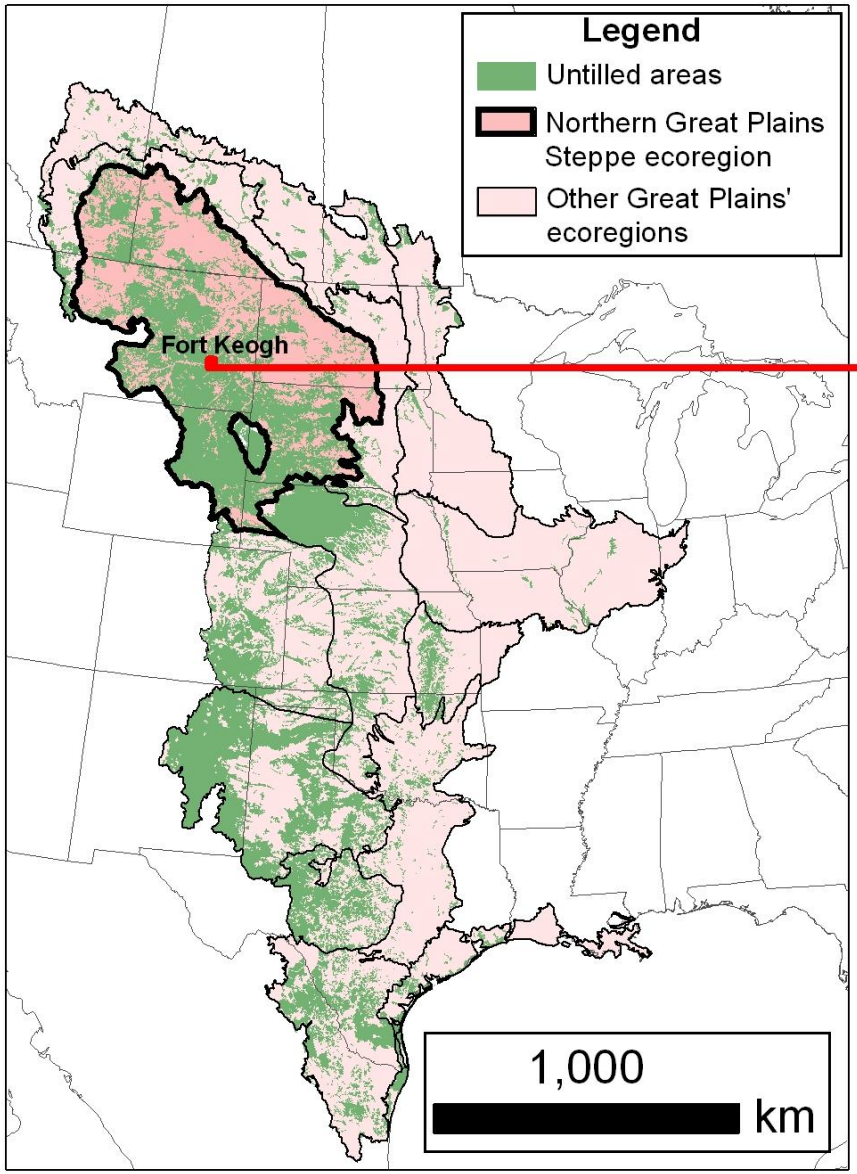
Soil stability will be positively correlated with **plant productivity** and **hydrologic function**

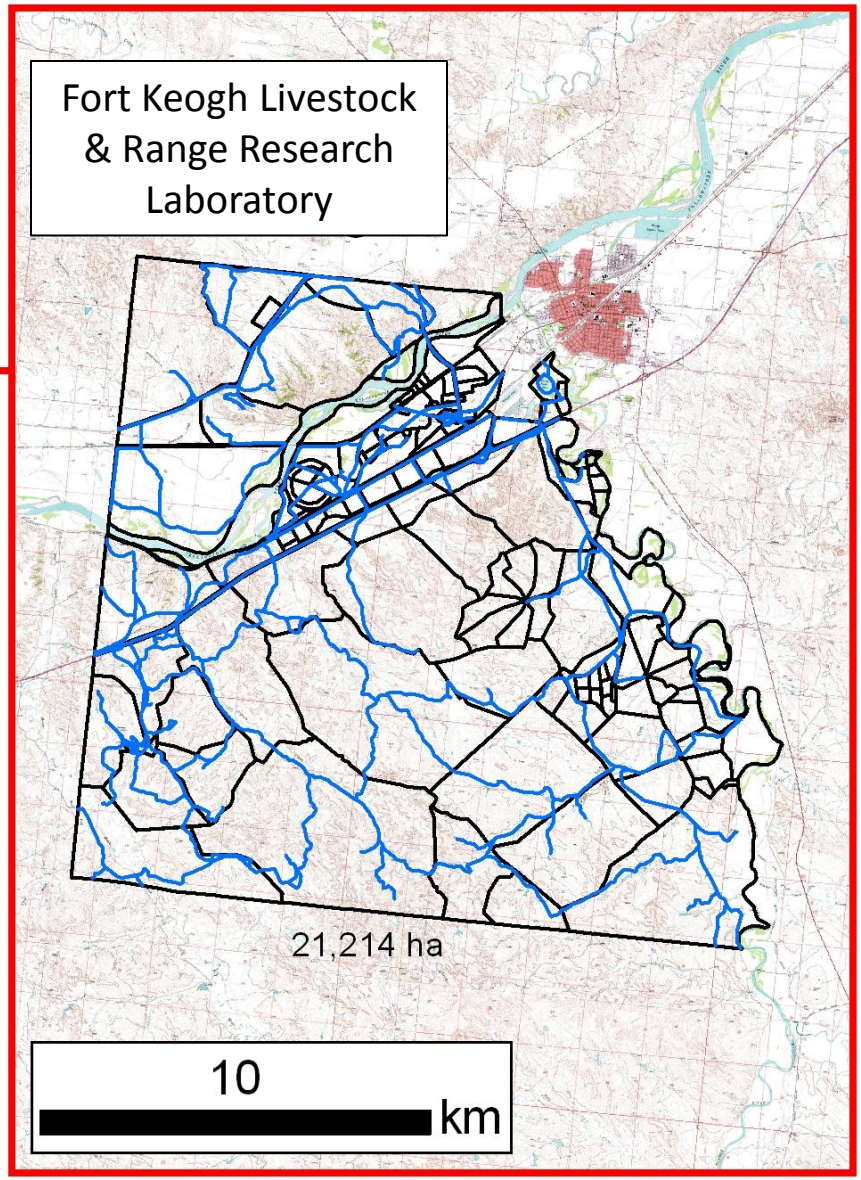
% water stable aggregates (% **WSA**)

Figure 4. Place sample in sieve.

Figure 5. Complete soil stability kit with water and samples.

soil stability (or slack) test


Legend
Untilled areas
Northern Great Plains Steppe ecoregion
Other Great Plains' ecoregions
Fort Keogh
1,000
km


Fort Keogh Livestock & Range Research Laboratory
21,214 ha
10
km

Measurements

Elevation

Plant measurements

- annual net primary productivity (ANPP)
  - ➢ clipped and sorted plant biomass into 8 groups

Soil measurements

- % soil moisture (June 5-13)
- soil structure (i.e. physical properties)
  - ➢ water infiltration (sorptivity and field-saturated infiltrability)
- soil stability
  - ➢ % water stable aggregates (WSA) (2 size classes of macroaggregates [0.25-1mm and 1-2mm], 0-10cm depth)
  - ➢ rangeland health soil stability tests (subsurface soil stability)

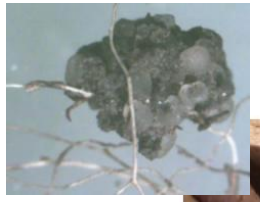
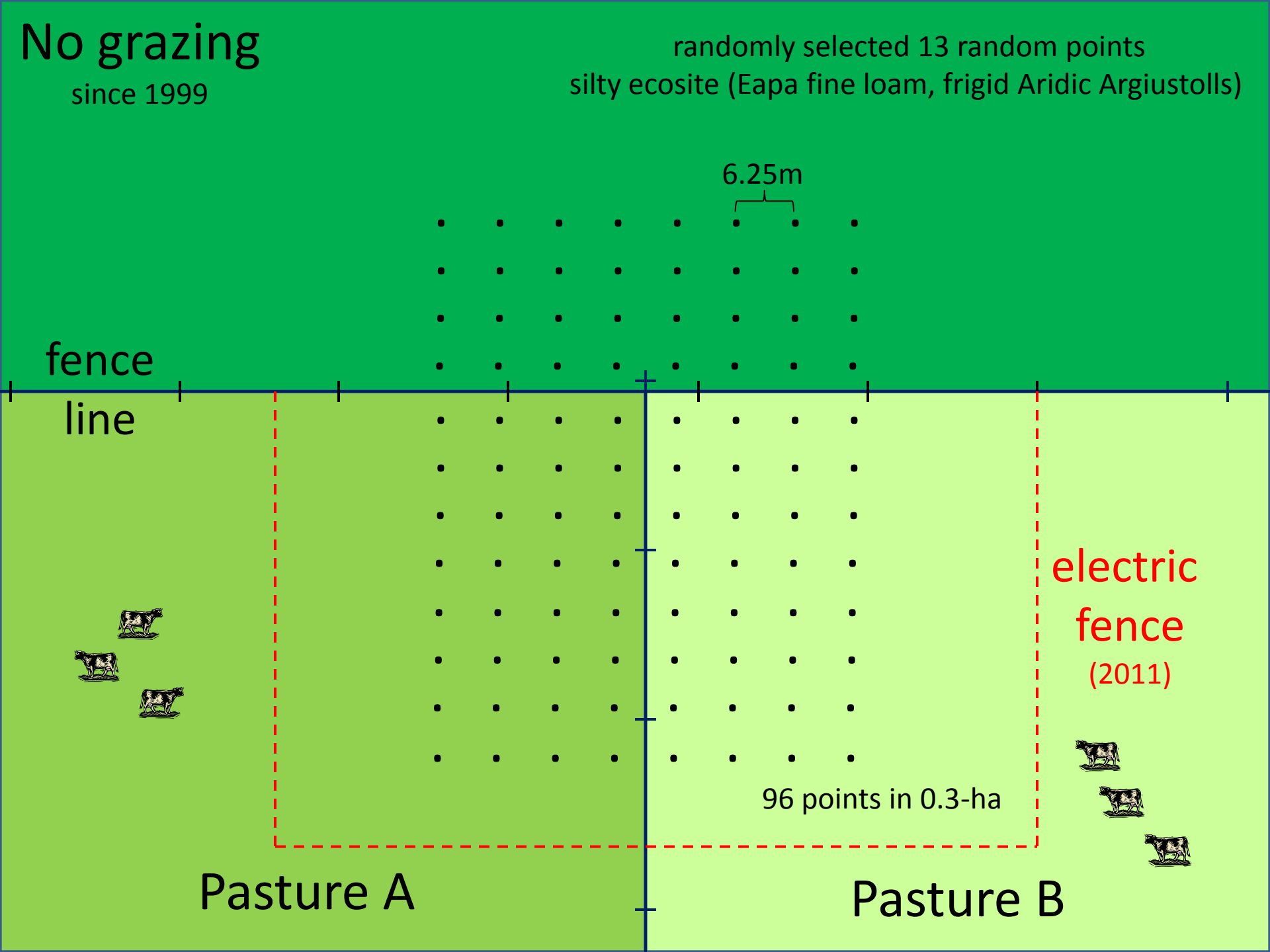
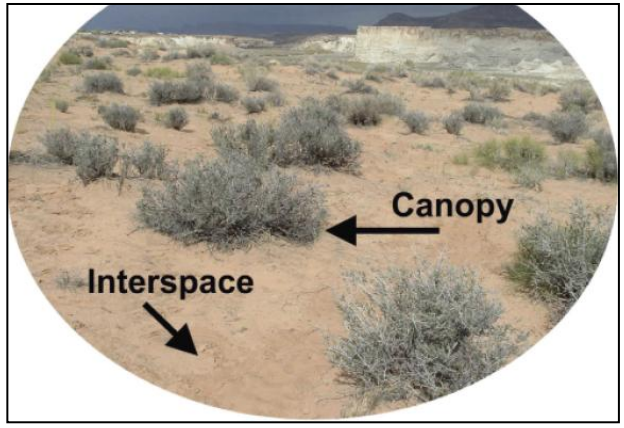


Figure 4. Place sample in sieve.


No grazing
since 1999
randomly selected 13 random points
silty ecosite (Eapa fine loam, frigid Aridic Argiustolls)
6.25m
fence line
electric fence
(2011)
96 points in 0.3-ha
Pasture A
Pasture B

Unique aspects of our study

1. all sampled areas were **vegetated**
2. sampled across **local gradients** (0.3ha)



Utah

Correlates with ANPP

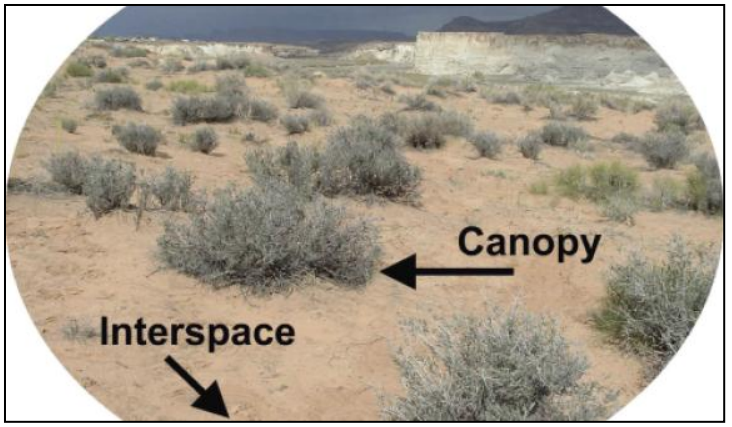
	ANPP
ANPP	
infiltrability	**0.39 (0.02)**
sorptivity	0.10 (0.54)
soil moisture	0.23 (0.16)
smWSA	0.26 (0.12)
medWSA	0.03 (0.85)
subsurface soil stability	0.28 (0.14)
elevation	-0.26 (0.13)

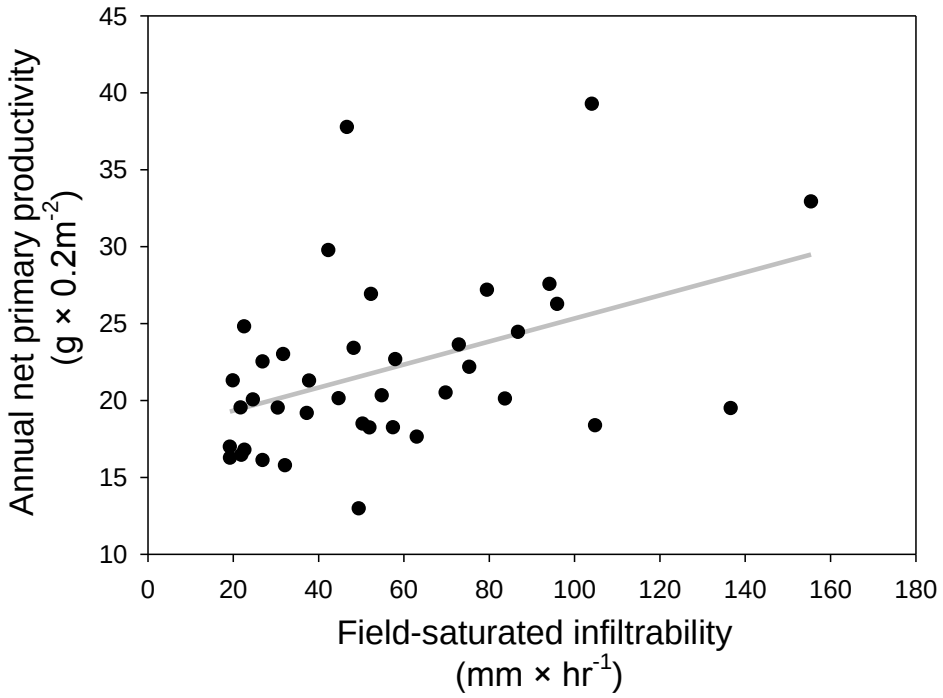
Dependent variable

r

(p-value)

* **Independent variables**





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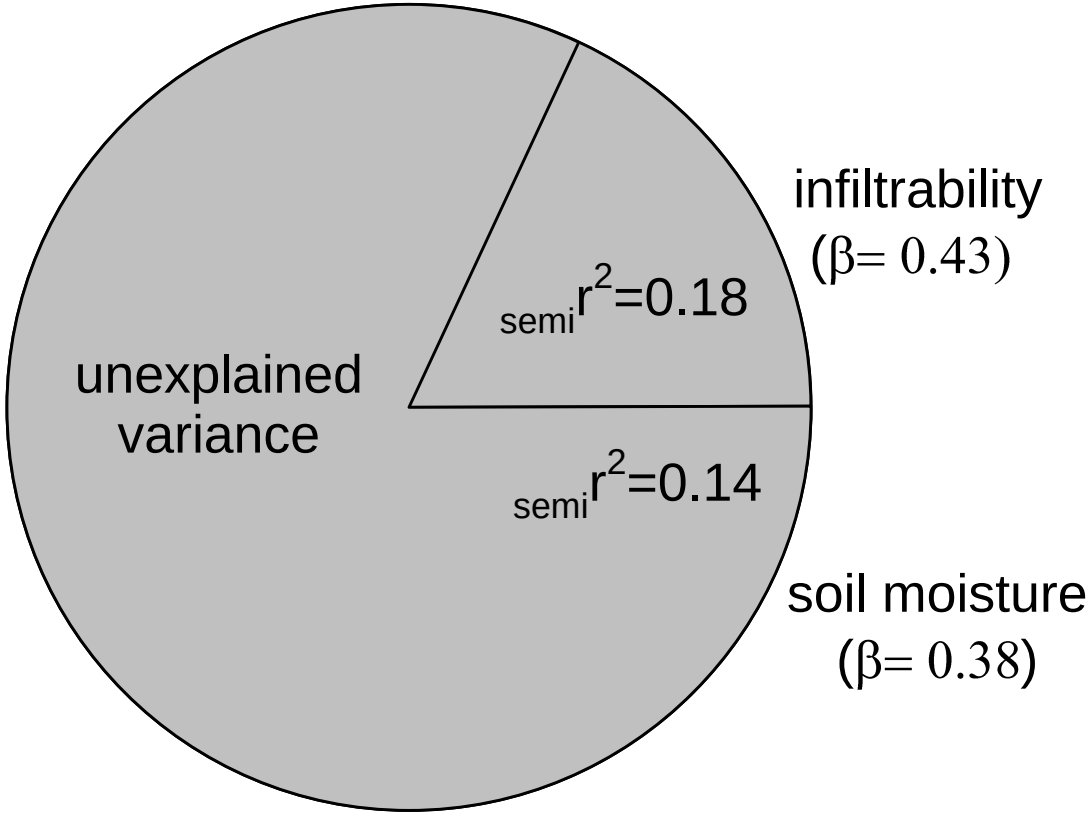
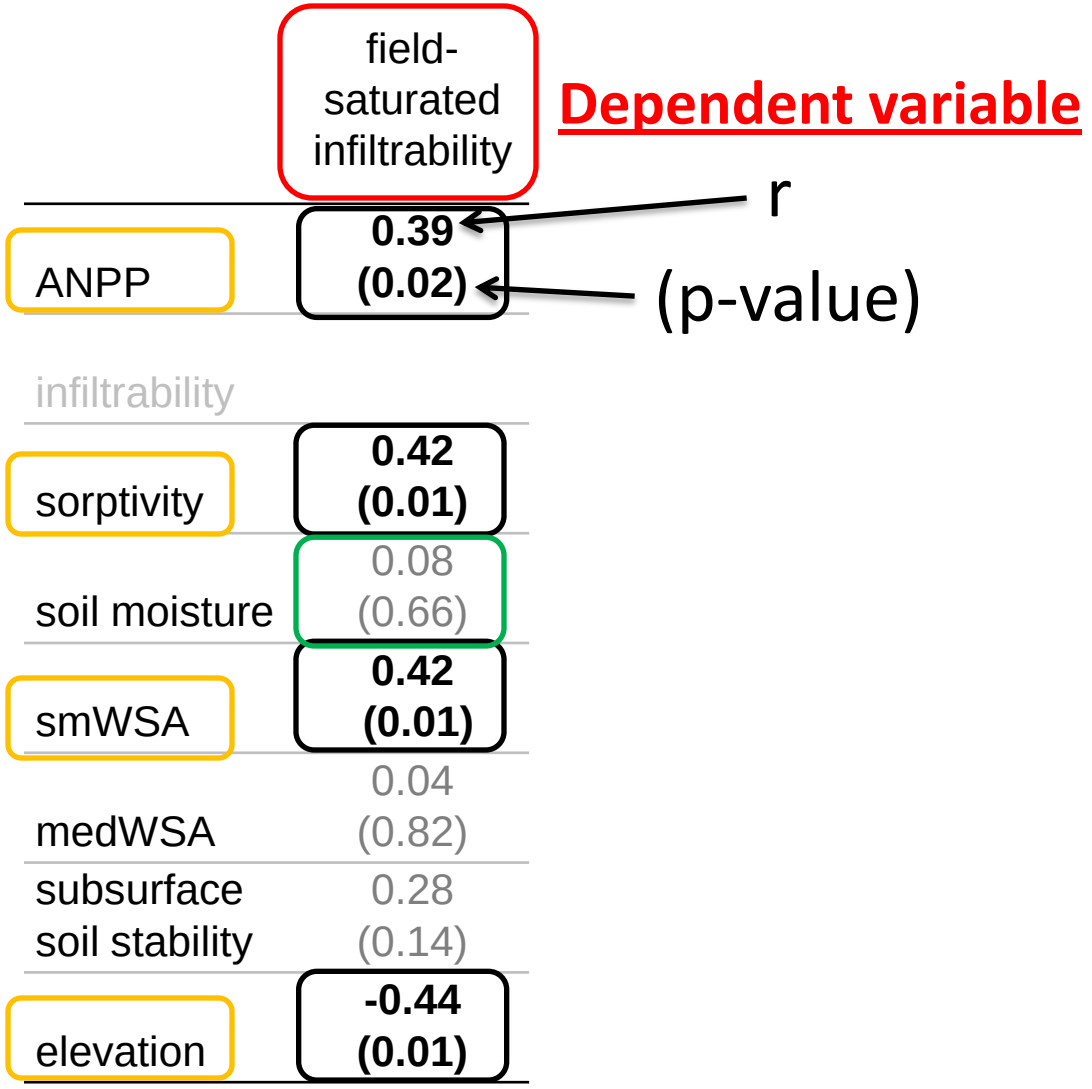
elevation	-0.26 (0.13)

Best predictors of variation in **ANPP** ($P=0.002$, $R^2=0.33$)

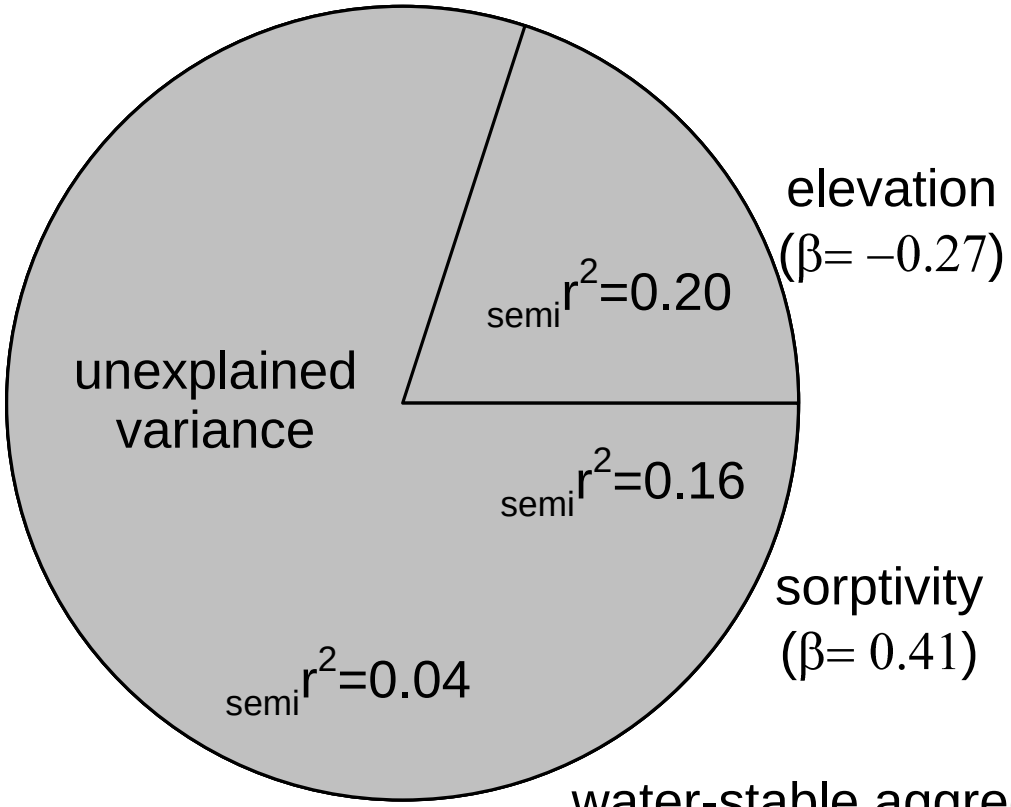


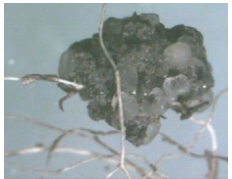
AIC, $_{semi}r^2$=squared semi-partial correlation coefficients

Correlates with field-saturated infiltrability



Best predictors of variation in **field-saturated infiltrability** ($P<0.001$, $R^2=0.39$)





ANPP not include in model selection

AIC, $_{semi}r^2$=squared semi-partial correlation coefficients

Summary

- ANPP was positively correlated with field saturated-infiltrability but the two form a positive feedback

- useful pr
r function i e
r

roots affect preferential flow

but systems quantifying rangeland health routinely measure soil stability…

Australia

(Tongway and Hindley 2004)

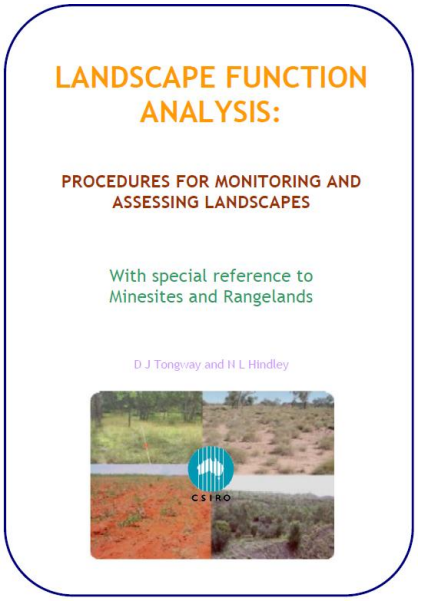
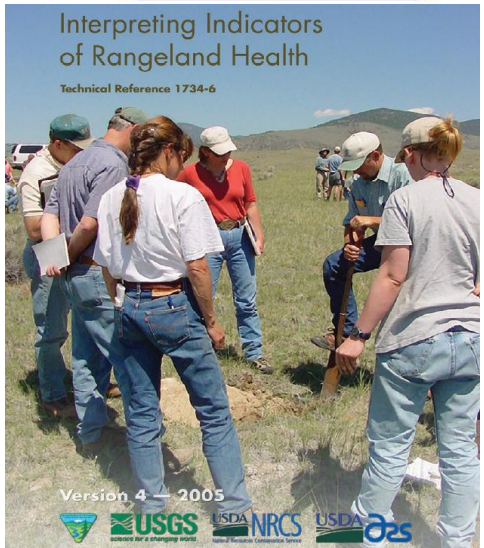


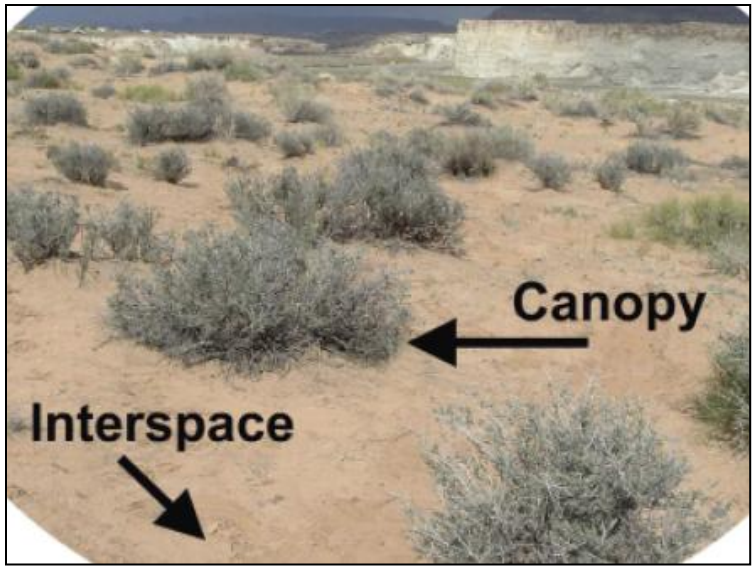
Figure 4. Place sample in sieve.

U.S.A.

(Pellant et al. 2005)



Should rangeland health assessments continue measuring soil stability?



Utah

Montana

What do you think?

Fort Keogh Livestock & Range Research Laboratory

USDA Agricultural Research Service

Pearson correlation coefficients (r) among factors

	sorptivity
ANPP	0.10 (0.54)
infiltrability	0.42 (0.01)
sorptivity	
soil moisture	-0.40 (0.013)
smWSA	0.02 (0.89)
medWSA	-0.20 (0.22)
subsurface soil stability	0.13 (0.49)
elevation	0.05 (0.76)

Dependent variable

r

(p-value)

* **Independent variables**

Pearson correlation coefficients (r) among factors

Dependent variable

	soil moisture
ANPP	0.23 (0.16)
infiltrability	0.08 (0.66)
sorptivity	**-0.40 (0.013)**
soil moisture	
smWSA	**0.34 (0.034)**
medWSA	-0.02 (0.92)
subsurface soil stability	0.29 (0.12)
elevation	**-0.56 (<0.001)**

* **Independent variables**

Pearson correlation coefficients (r) among factors

Dependent variable

	smWSA (0.25-1mm)
ANPP	0.23 (0.16)
infiltrability	0.08 (0.66)
sorptivity	**-0.40 (0.013)**
soil moisture	**0.34 (0.034)**
smWSA	
medWSA	0.13 (0.44)
subsurface soil stability	**0.47 (0.01)**
elevation	**-0.59 (<0.001)**

*** Independent variables**

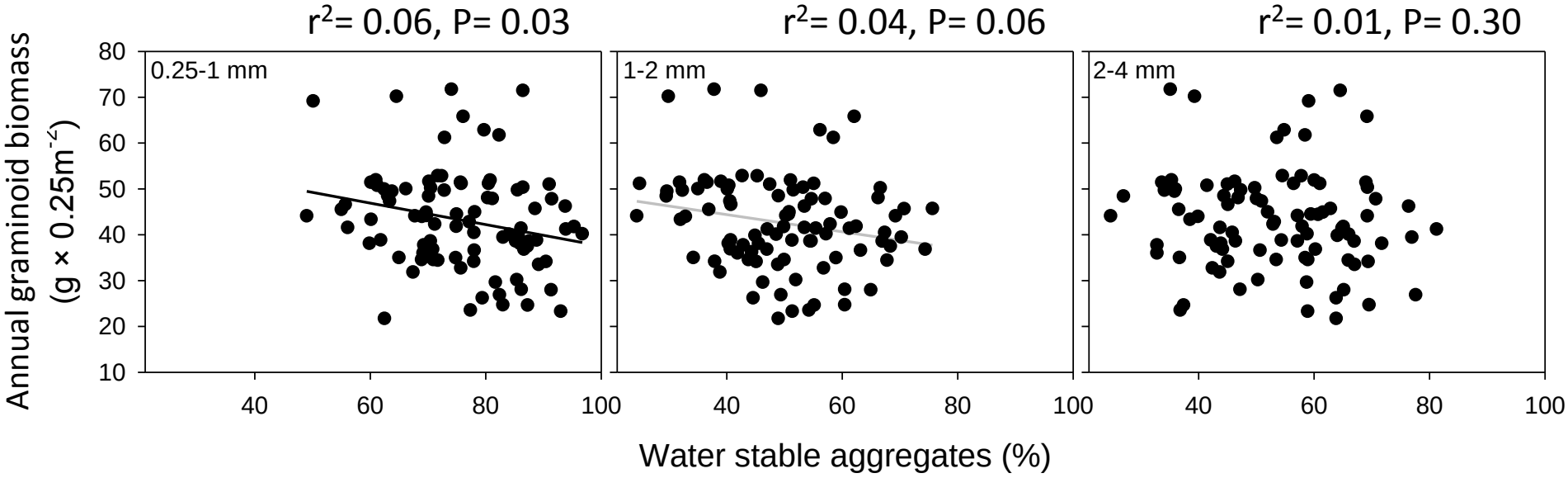
Pearson correlation coefficients (r) among factors

Dependent variable

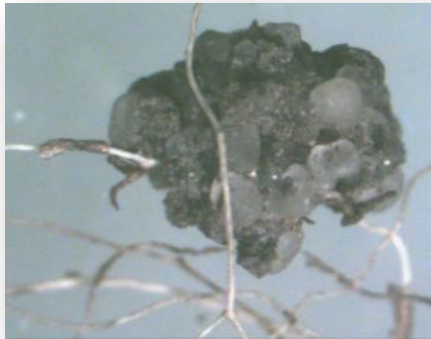
	Elevation
ANPP	-0.26 (0.13
infiltrability	**-0.44 (0.01)**
sorptivity	0.05 (0.76)
soil moisture	**-0.56 (<0.001)**
smWSA	**-0.59 (<0.001)**
medWSA	-0.10 (0.55)
subsurface soil stability	**-0.46 (0.01)**
elevation	

*** Independent variables**

Negative or no correlation between WSA and **graminoid production**



soil stability



Negative or no correlation between WSA and **total root biomass**

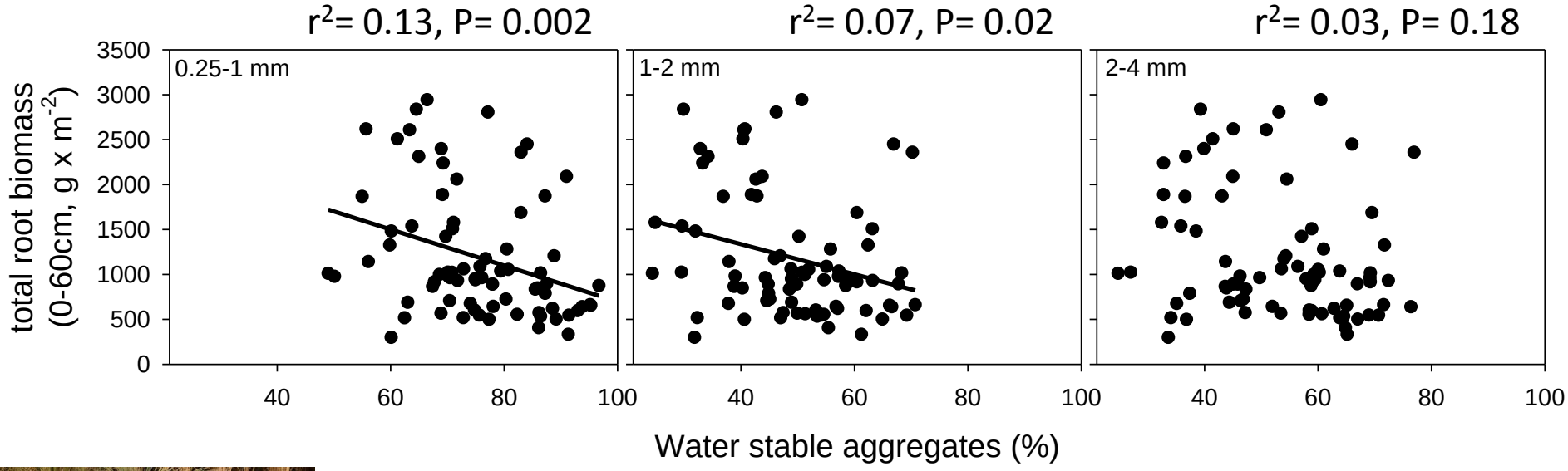
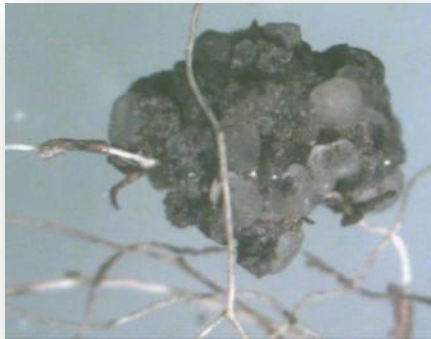


Photo credit: Jim Richardson, Nat. Geo.

soil stability



Do perceptions on links between soil stability and ecosystem function match empirical evidence?

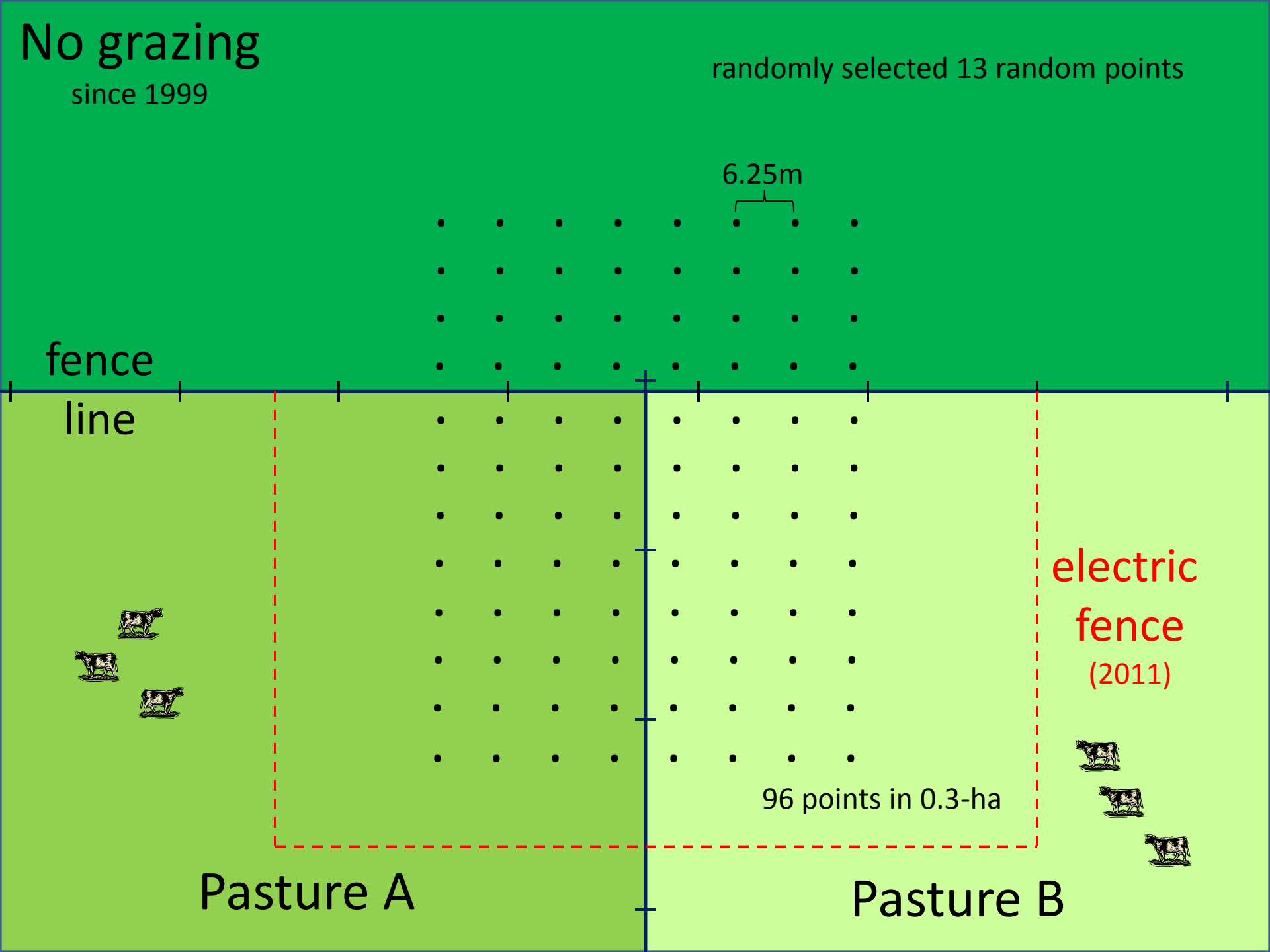
Literature search details:

- Web of Science
  - terms- soil aggregate*, water stable aggregat*, macroaggregat*, or soil stability
  - years- 2001-2010
  - journals- *Ecological Application*, *Plant & Soil*, or *Soil Biology & Biochemistry*

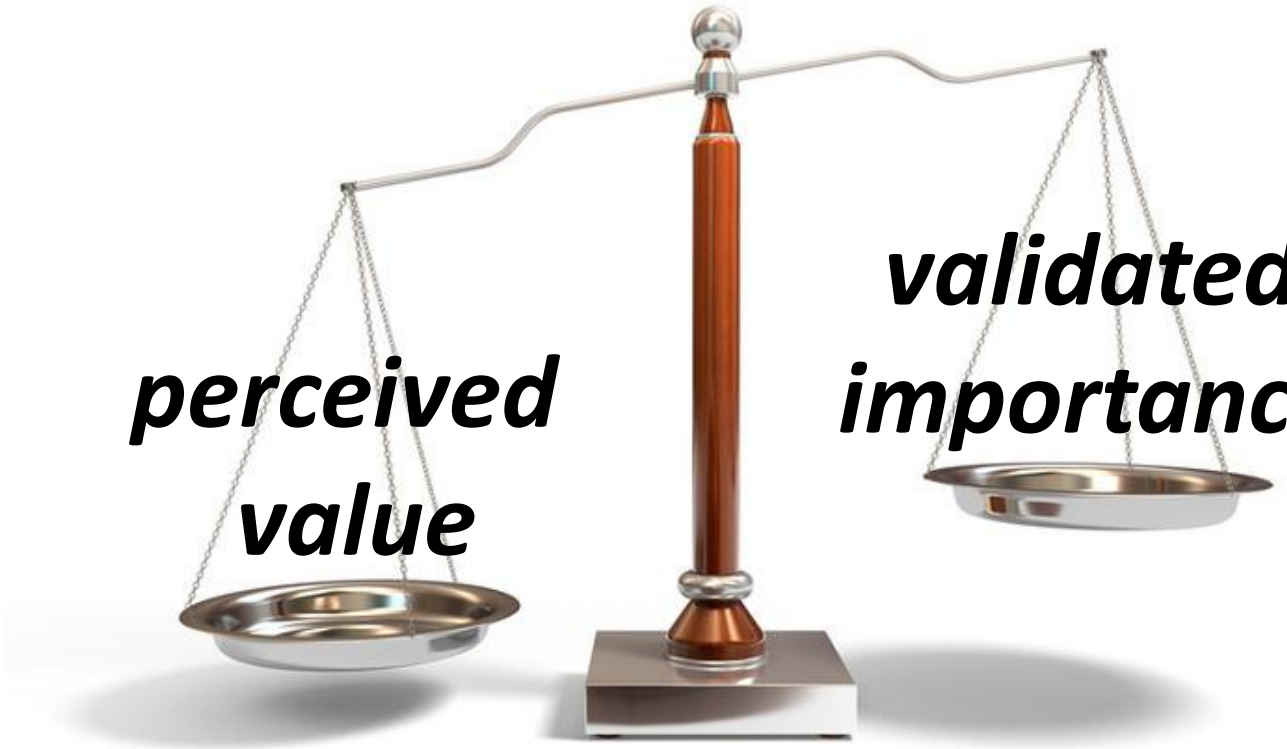
- Results
  - 112 papers
  - 19 (17%) papers included the term [water] “infiltration”
    - soil stability was linked to hydrologic function

- Any empirical support for statements linking soil stability to water infiltration?

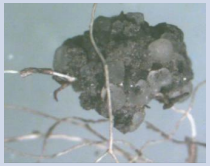
Many of the relevant statements either 1) lacked reference to direct empirical support, 2) lacked a supporting citation, or 3) most common citation (Oades 1984)


No grazing
since 1999
randomly selected 13 random points
6.25m
fence line
electric fence
(2011)
96 points in 0.3-ha
Pasture A
Pasture B

Is the robustness of soil stability as a indicator of ecosystem functioning context dependent



Discussions on the use of WSA as an indicator of soil process functions

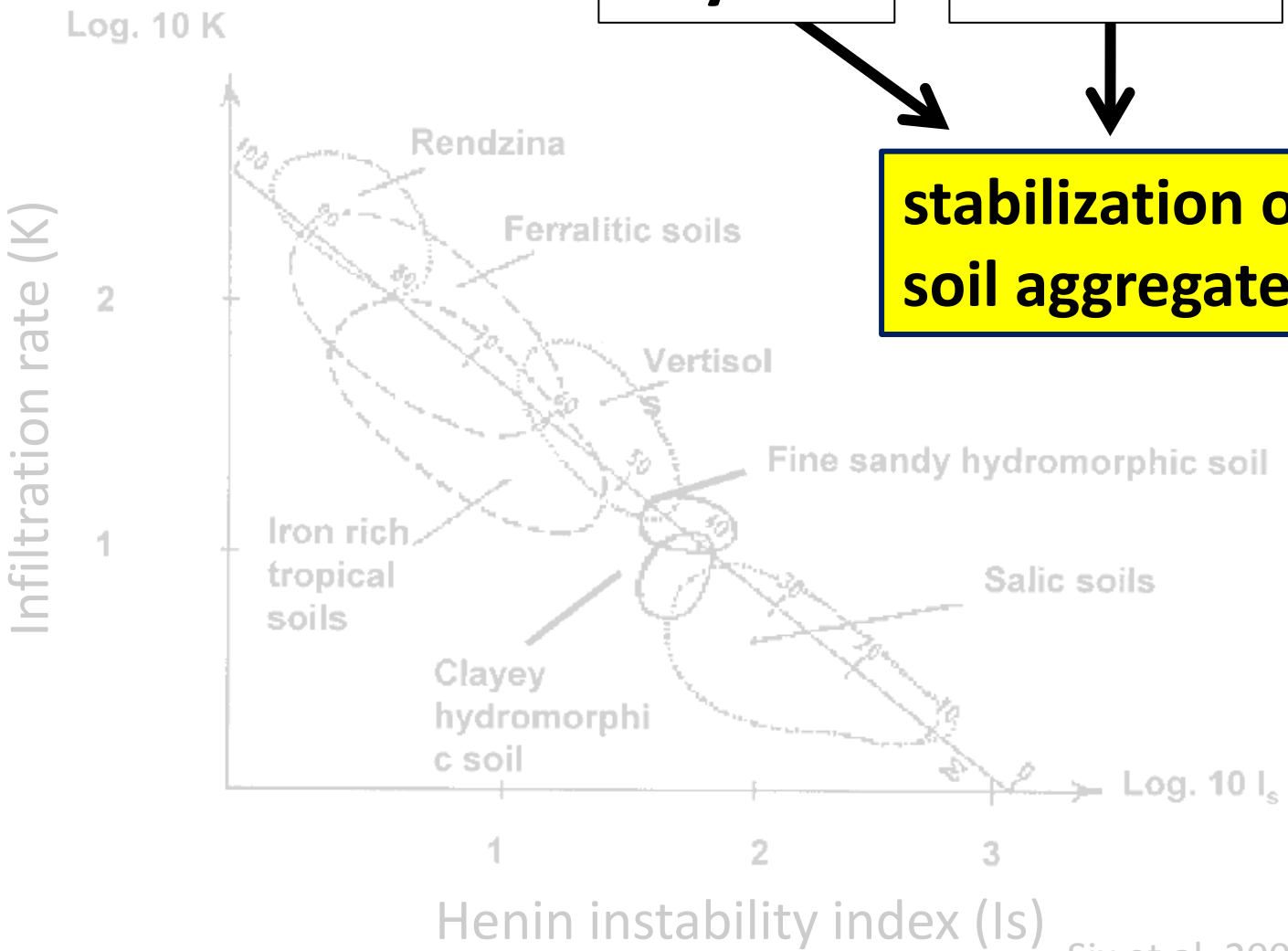
Soil processes	Indicators	References
structural stability	WSA 	Karlen et al. (1994), Doran & Jones (1996), Moebius et al. (2007), Gugino et al. (2009)
runoff & erosion	WSA 	“”
crusting	WSA 	“”
shallow rooting	WSA 	“”
aeration	WSA 	“”
water infiltration & transmission	WSA 	“”

row crop agriculture

Links between soil properties and functions are often discussed but are rarely supported by empirical evidence

Physical **Chemical** **Biological**

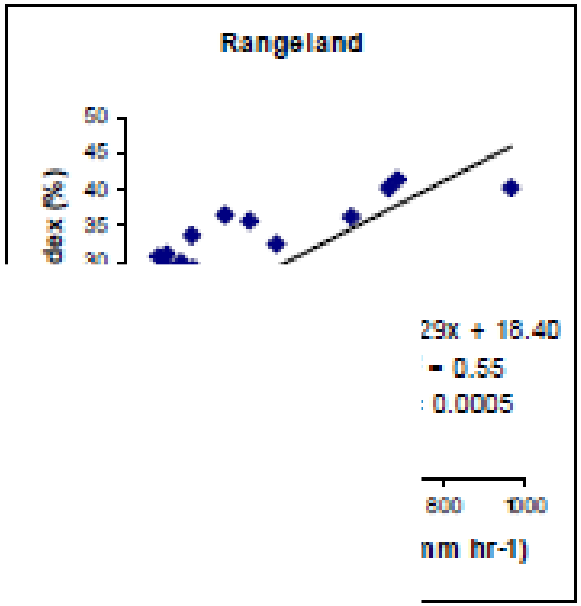
stabilization of soil aggregates

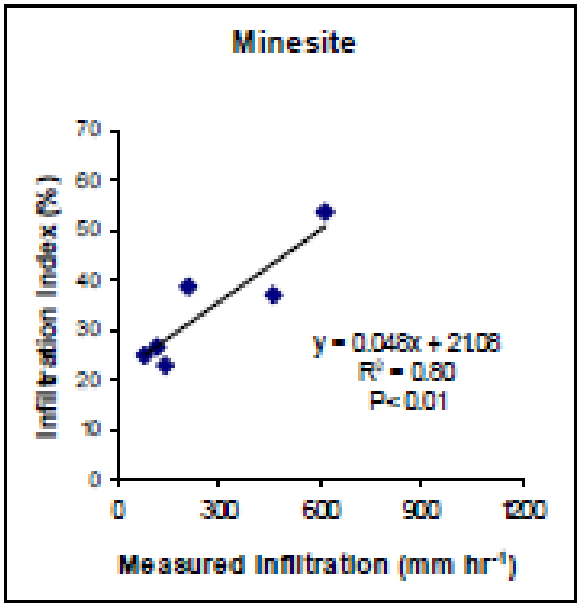


Six et al. 2002 *Agronomie*

Indicator
1. Soil Cover
2. Perennial grass basal and tree and shrub foliage cover
3a. Litter cover
3b. Litter cover, origin and degree of decomposition
4. Cryptogam cover
5. Crust broken-ness
6. Erosion type & severity
7. Deposited materials
8. Surface roughness
9. Surface resistance to disturb.
10. Slake test
11. Soil texture

Soil stability test

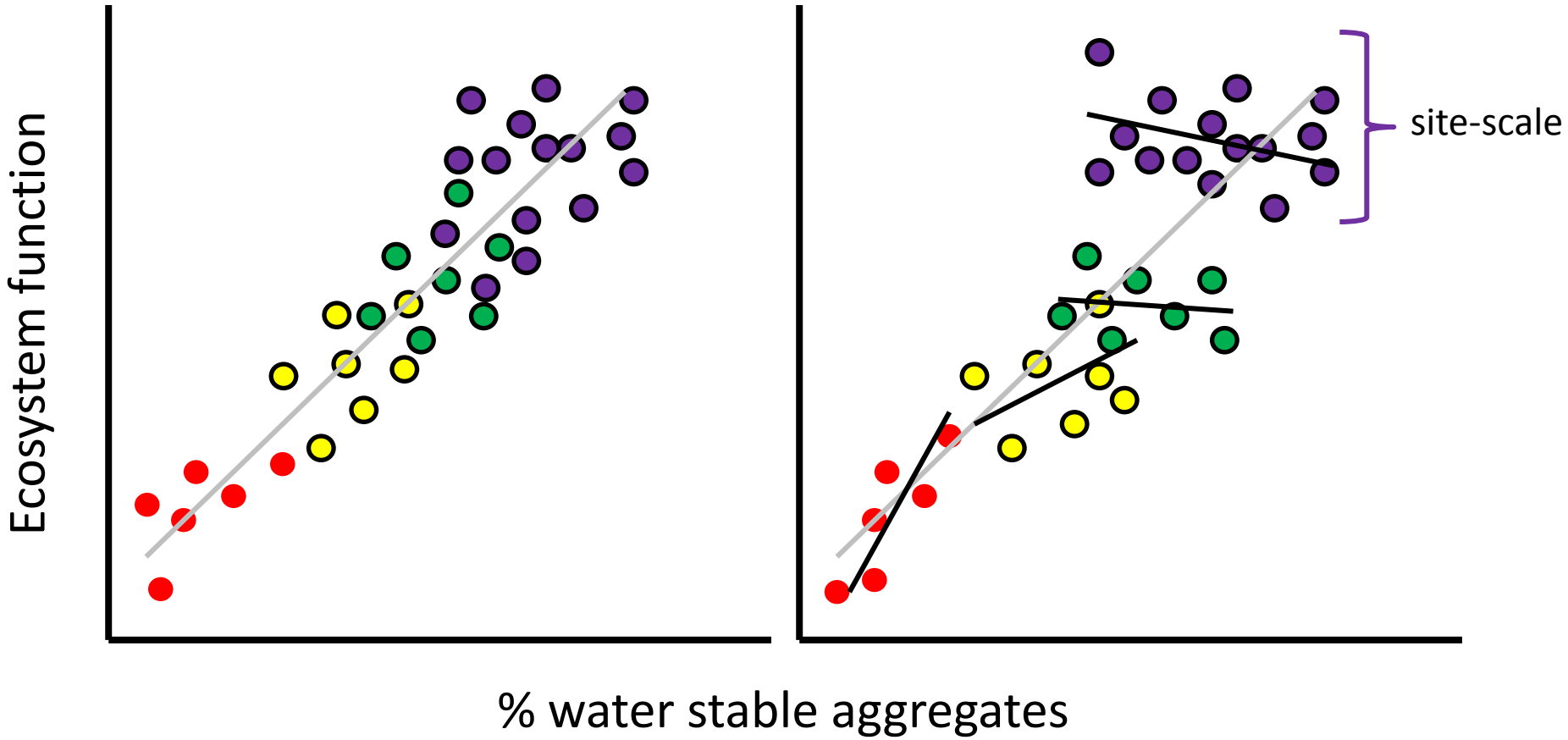


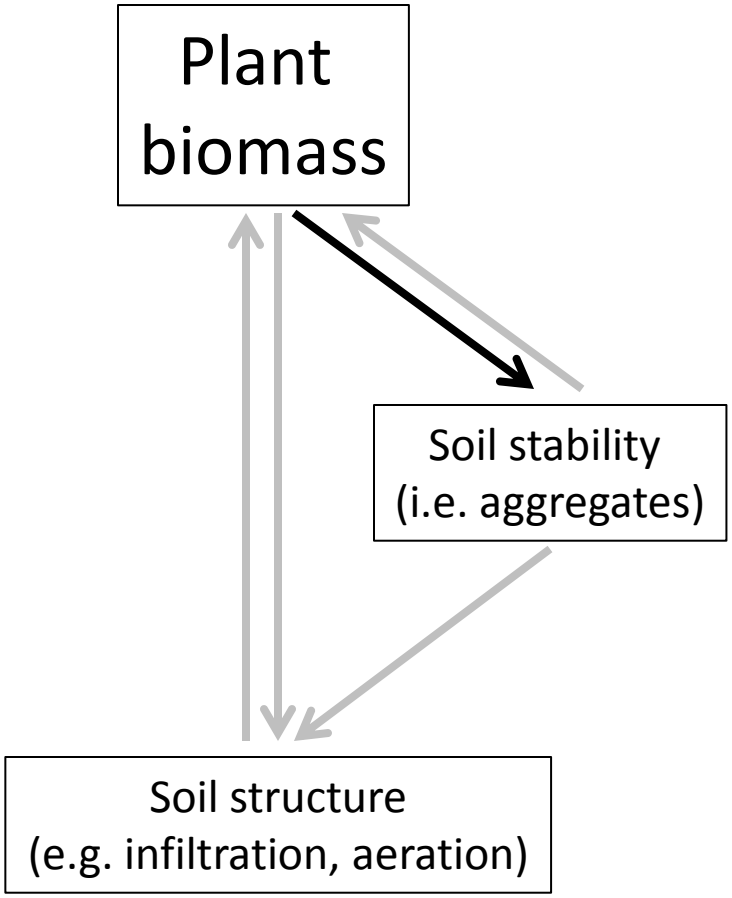


D J Tongway and N L Hindley

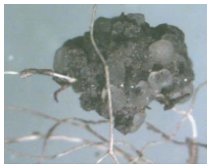
Landscape Function Analysis manual

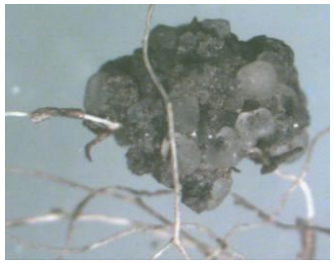
Do patterns across local gradients mirror those across the broader landscape?

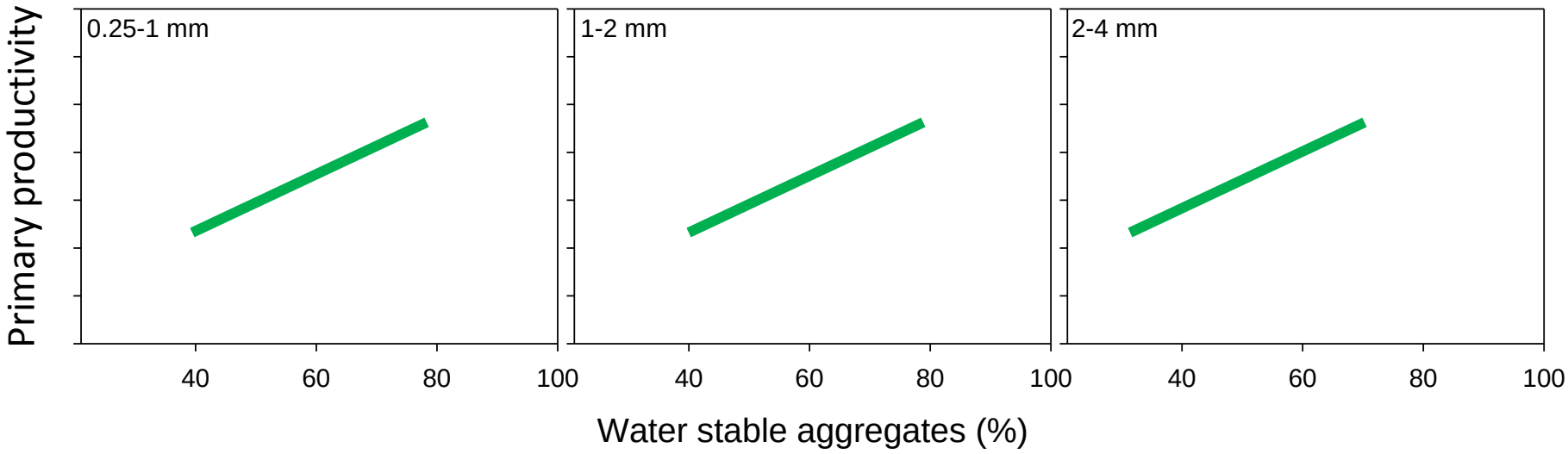



Plant biomass
Soil stability (i.e. aggregates)
Soil structure (e.g. infiltration, aeration)

Predicted relationships

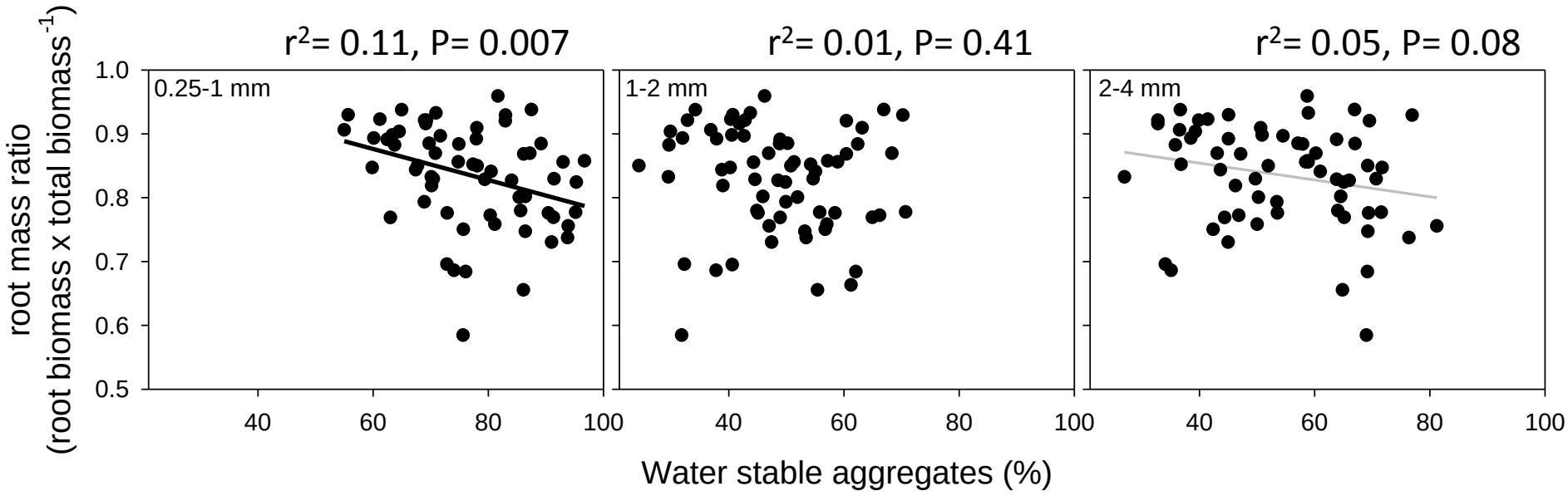


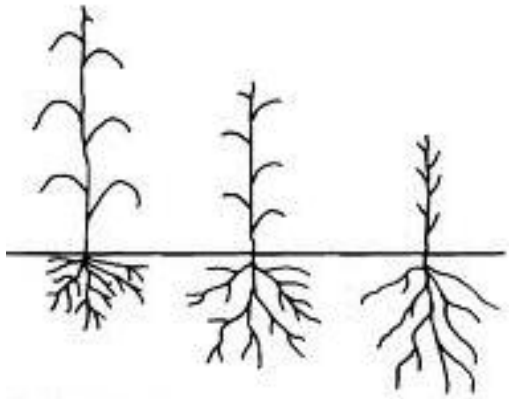




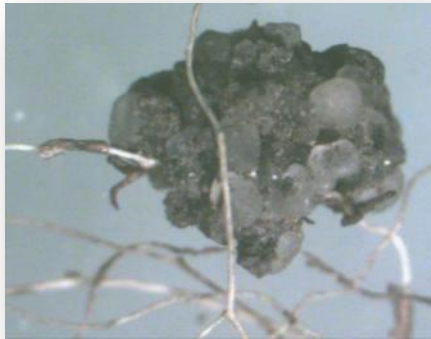
soil stability

Negative or no correlation between WSA and **root mass ratio**

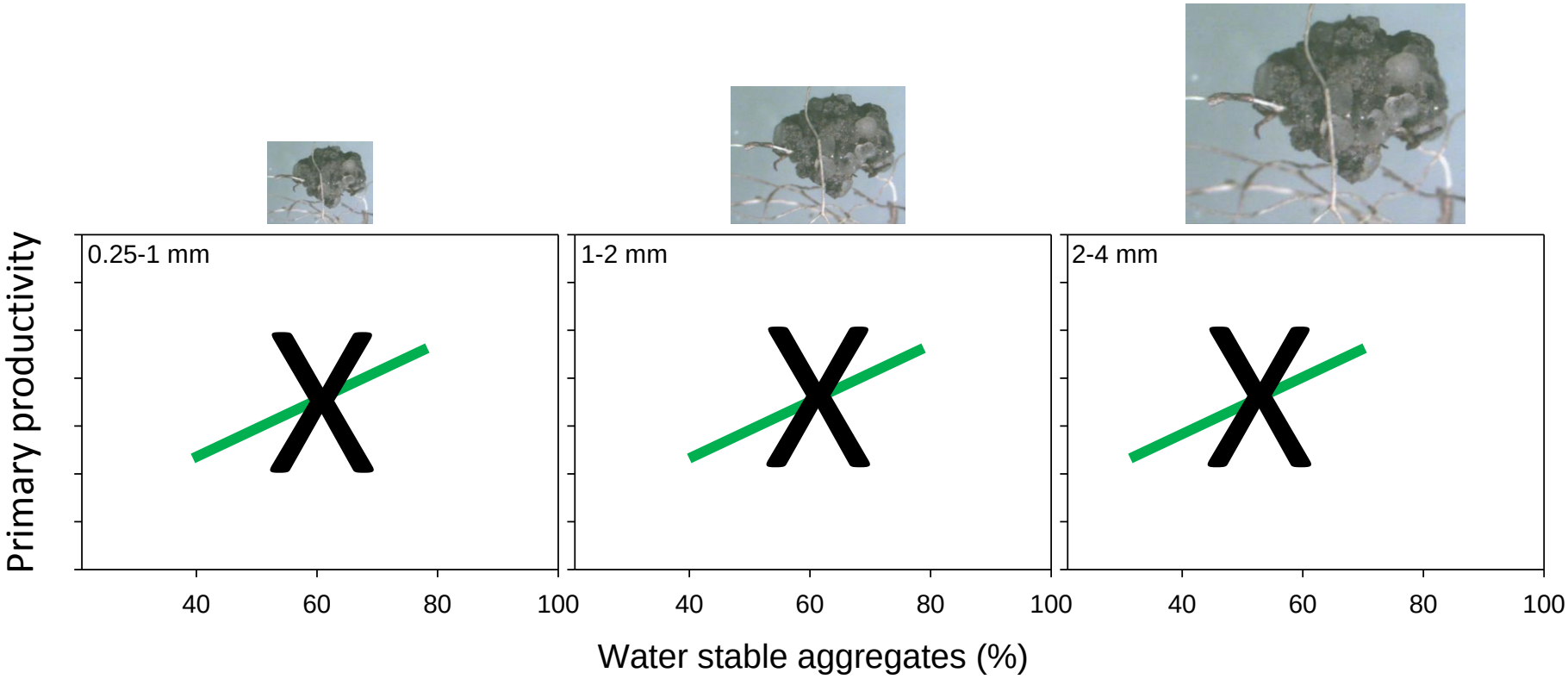




soil stability



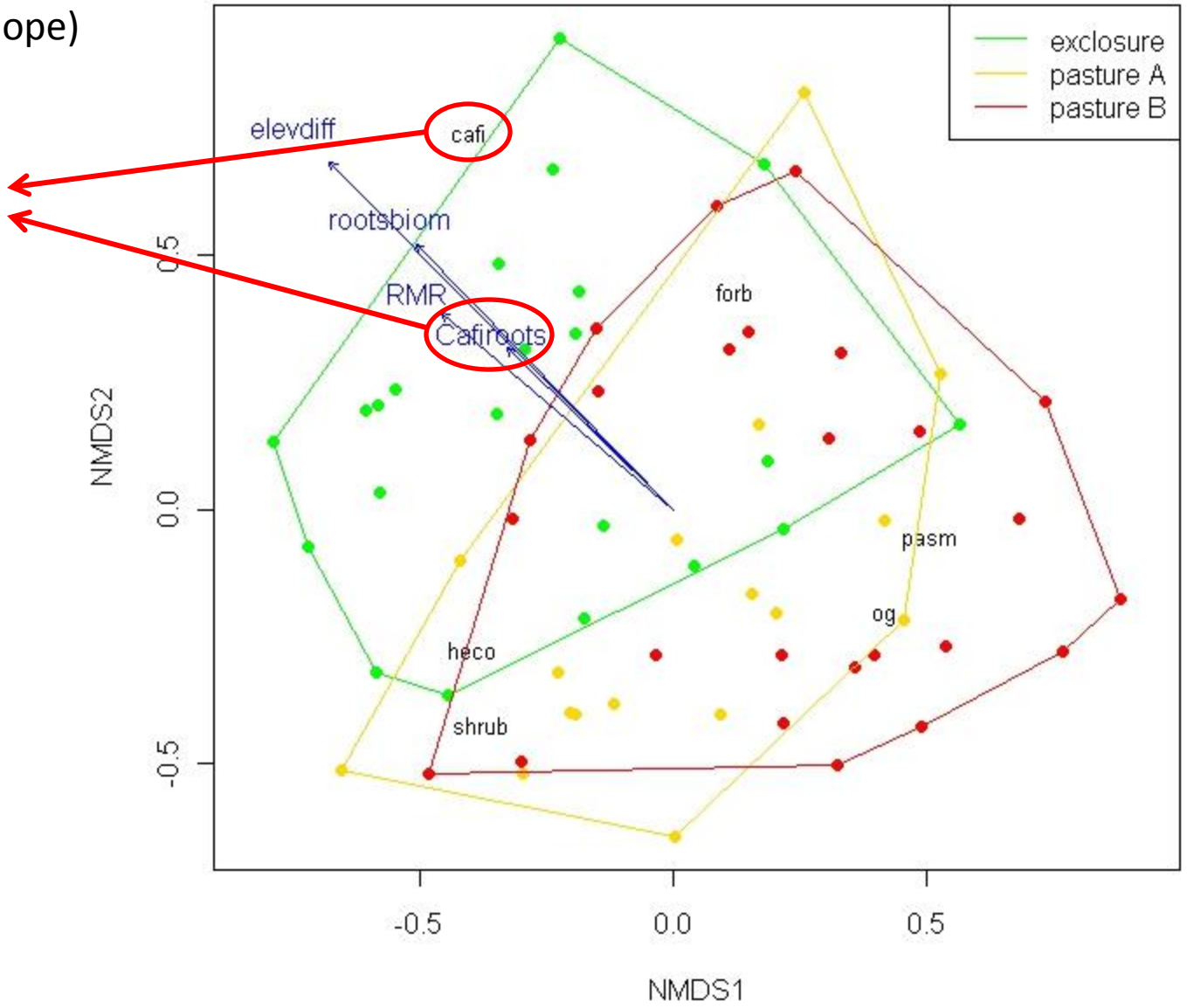
So what is going on?



Co-dominant graminoid is autocorrelated with factors negatively related with WSA

1.25m gain (~1.05° slope)

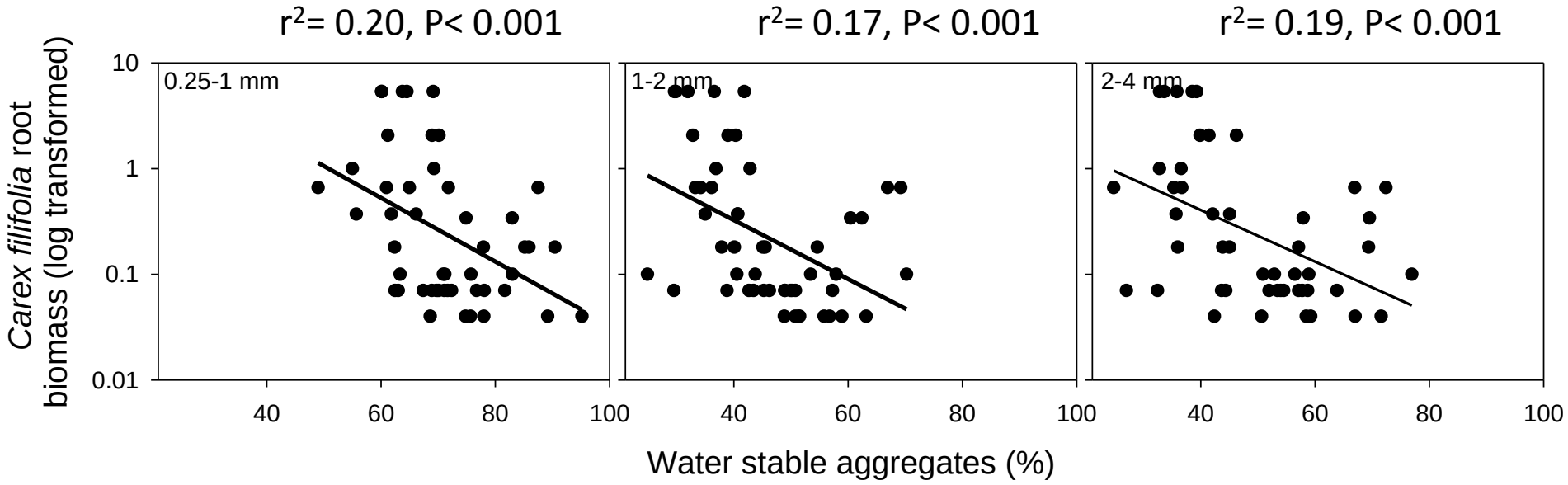
Carex filifolia



Correlations are sensitive to variation in plant community composition

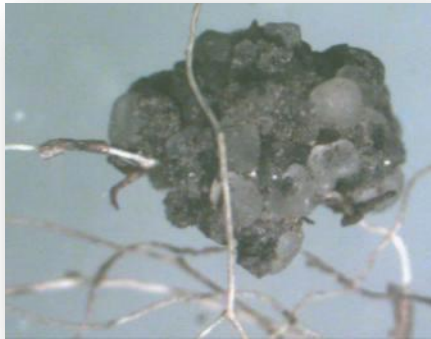
Predictor variables	Response variables	Full data set	Reduced data set
WSA, 0.25-1mm	grass ANPP	$F_{1,83}$= 4.9, P= **0.03**	$F_{1,69}$= 2.54, P= 0.12
WSA, 0.25-1mm	root biomass	$F_{1,70}$= 10.1, P= **0.002**	$F_{1,59}$= 6.46, P= **0.01**
WSA, 1-2mm	root biomass	$F_{1,75}$= 6.0, P= **0.02**	$F_{1,64}$= 3.00, P= 0.09
WSA, 0.25-1mm	root mass ratio	$F_{1,61}$= 7.7, P= **0.007**	$F_{1,50}$= 4.97, P= **0.03**

Negative correlation between WSA and biomass of darkly pigmented roots (*Carex filifolia*)



Carex filifolia- "good forage"
Taylor & Lacey 2007

soil stability



Pearson correlation coefficients (r) among factors

	field-saturated infiltrability	sorptivity	smWSA (0.25-1mm)	medWSA (1-2mm)	soil moisture	Elevation
ANPP	**0.39 (0.02)**					
sorptivity	**0.42 (0.01)**					
smWSA	**0.42 (0.01)**	0.02 (0.89)				
medWSA	0.04 (0.82)	-0.20 (0.22)				
soil moisture	0.08 (0.66)	-0.40 (0.013)				
elevation	**-0.44 (0.01)**	0.05 (0.76)				
subsurface soil stability	0.28 (0.14)	0.13 (0.49)	(0.01)	(0.17)	(0.12)	(0.01)

Dependent variable

* **Independent variable**

Pearson correlation coefficients (r) among factors

	ANPP	infiltrability	sorptivity	smWSA (0.25-1mm)	medWSA (1-2mm)	soil moisture	Elevation
infiltrability	**0.39 (0.02)**						
sorptivity	0.10 (0.54)	**0.42 (0.01)**					
smWSA	0.26 (0.12)	0.42 (0.01)	0.02 (0.89)				
medWSA	0.03 (0.85)	0.04 (0.82)	-0.20 (0.22)				
soil moisture	0.23 (0.16)	0.08 (0.66)	**-0.40 (0.013)**				
elevation	-0.26 (0.13)	-0.44 (0.01)	0.05 (0.76)				
subsurface soil stability	0.28 (0.14)	0.28 (0.14)	0.13 (0.49)				

Dependent variable

* **Independent variable**

Pearson correlation coefficients (r) among factors

	ANPP	field-saturated infiltrability	sorptivity	smWSA (0.25-1mm)	medWSA (1-2mm)	mc
ANPP						
infiltrability	**0.39 (0.02)**					
sorptivity	0.10 (0.54)	0.42 (0.01)				
smWSA	0.26 (0.12)	0.42 (0.01)	0.02 (0.89)			
medWSA	0.03 (0.85)	0.04 (0.82)	-0.20 (0.22)	0.13 (0.44)		
soil moisture	0.23 (0.16)	0.08 (0.66)	-0.40 (0.013)	0.34 (0.034)	-0.02 (0.92)	
elevation	-0.26 (0.13)	-0.44 (0.01)	0.05 (0.76)	-0.59 (<0.001)	-0.10 (0.55)	- (<
subsurface soil stability	0.28 (0.14)	0.28 (0.14)	0.13 (0.49)	0.47 (0.01)	0.26 (0.17)	(

Dependent variable

* **Independent variable**

Pearson correlation coefficients (r) among factors

	ANPP	field-saturated infiltrability	sorptivity	smWSA (0.25-1mm)	medWSA (1-2mm)	mc
ANPP						
infiltrability	**0.39 (0.02)**					
sorptivity	0.10 (0.54)	0.42 (0.01)				
smWSA	0.26 (0.12)	0.42 (0.01)	0.02 (0.89)			
medWSA	0.03 (0.85)	0.04 (0.82)	-0.20 (0.22)	0.13 (0.44)		
soil moisture	0.23 (0.16)	0.08 (0.66)	-0.40 (0.013)	0.34 (0.034)	-0.02 (0.92)	
elevation	-0.26 (0.13)	-0.44 (0.01)	0.05 (0.76)	-0.59 (<0.001)	-0.10 (0.55)	- (<
subsurface soil stability	0.28 (0.14)	0.28 (0.14)	0.13 (0.49)	0.47 (0.01)	0.26 (0.17)	(

Dependent variable

* **Independent variable**

Pearson correlation coefficients (r) among factors

	ANPP	infiltrability	sorptivity	smWSA (0.25-1mm)	medWSA (1-2mm)	soil moisture	Elevation
infiltrability	0.39 (0.02)						
sorptivity	0.10 (0.54)	0.42 (0.01)					
smWSA	0.26 (0.12)	**0.42 (0.01)**	0.02 (0.89)				
medWSA	0.03 (0.85)	0.04 (0.82)	-0.20 (0.22)	0.13 (0.44)			
soil moisture	0.23 (0.16)	0.08 (0.66)	-0.40 (0.013)	**0.34 (0.034)**	-0.02 (0.92)		
elevation	-0.26 (0.13)	-0.44 (0.01)	0.05 (0.76)	**-0.59 (<0.001)**	-0.10 (0.55)		
subsurface soil stability	0.28 (0.14)	0.28 (0.14)	0.13 (0.49)	**0.47 (0.01)**	0.26 (0.17)		

Dependent variable

* **Independent variable**

Pearson correlation coefficients (r) among factors

	ANPP	infiltrability	Sorptivity	smWSA (0.25-1mm)	medWSA (1-2mm)	soil moisture	Elevation
infiltrability	0.39 (0.02)						
sorptivity	0.10 (0.54)	0.42 (0.01)					
smWSA	0.26 (0.12)	0.42 (0.01)	0.02 (0.89)				
medWSA	0.03 (0.85)	0.04 (0.82)	-0.20 (0.22)	0.13 (0.44)			
soil moisture	0.23 (0.16)	0.08 (0.66)	-0.40 (0.013)	0.34 (0.034)	-0.02 (0.92)		
elevation	-0.26 (0.13)	**-0.44 (0.01)**	0.05 (0.76)	**-0.59 (≤0.001)**	-0.10 (0.55)	**-0.56 (≤0.001)**	
subsurface soil stability	0.28 (0.14)	0.28 (0.14)	0.13 (0.49)	0.47 (0.01)	0.26 (0.17)	0.29 (0.12)	**-0.46 (0.01)**

Dependent variable

* **Independent variable**