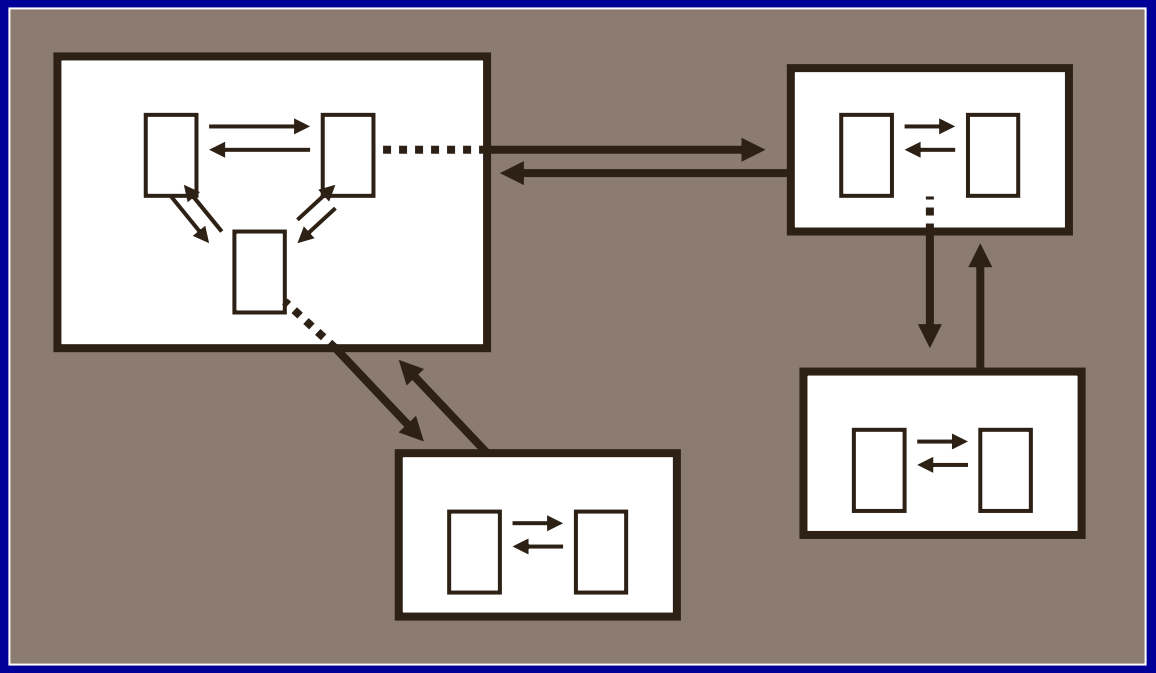
Using State and Transition Models in Soil Change Projects



Arlene J. Tugel, NRCS
Soil Scientist
NSSC Interpretations Staff
Liaison to ARS-Las Cruces, NM

Objective

Illustrate how conceptual process models will be used in comparison studies to document management effects on dynamic soil properties.

What's a comparison study?

1. Soil survey procedure to document dynamic soil properties.
2. Sample two or more different management systems.
3. Document inherent or reference condition.
4. Substitute space-for-time to analyze change. (Pickett, 1989)

What is a conceptual model?

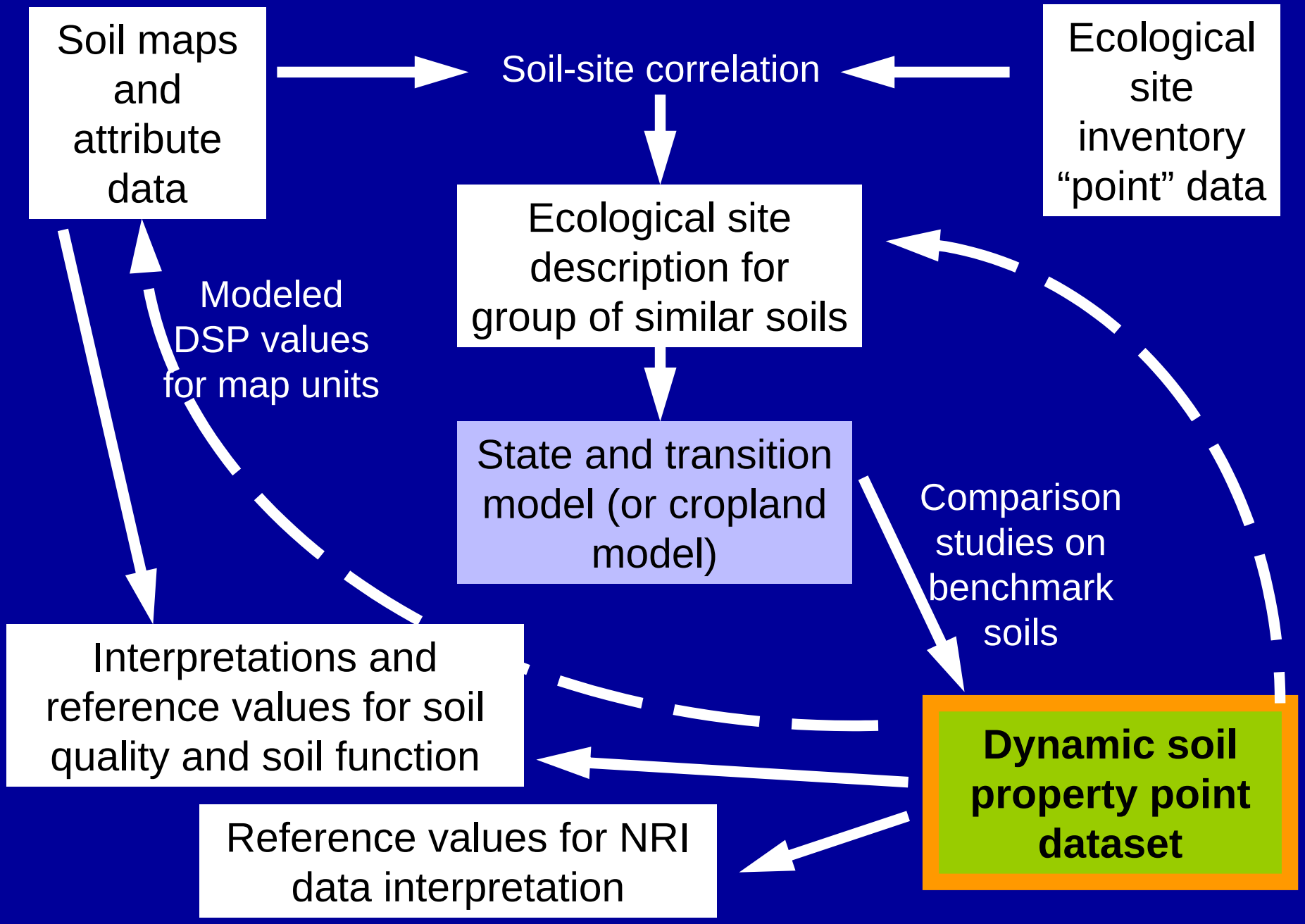
A purposeful representation of reality that provides a mental picture of how something works to communicate that explanation to others.

- (Starfield et al., 1993)

A model that represents key processes, interactions, and feedbacks.

- (Gross, 2003)

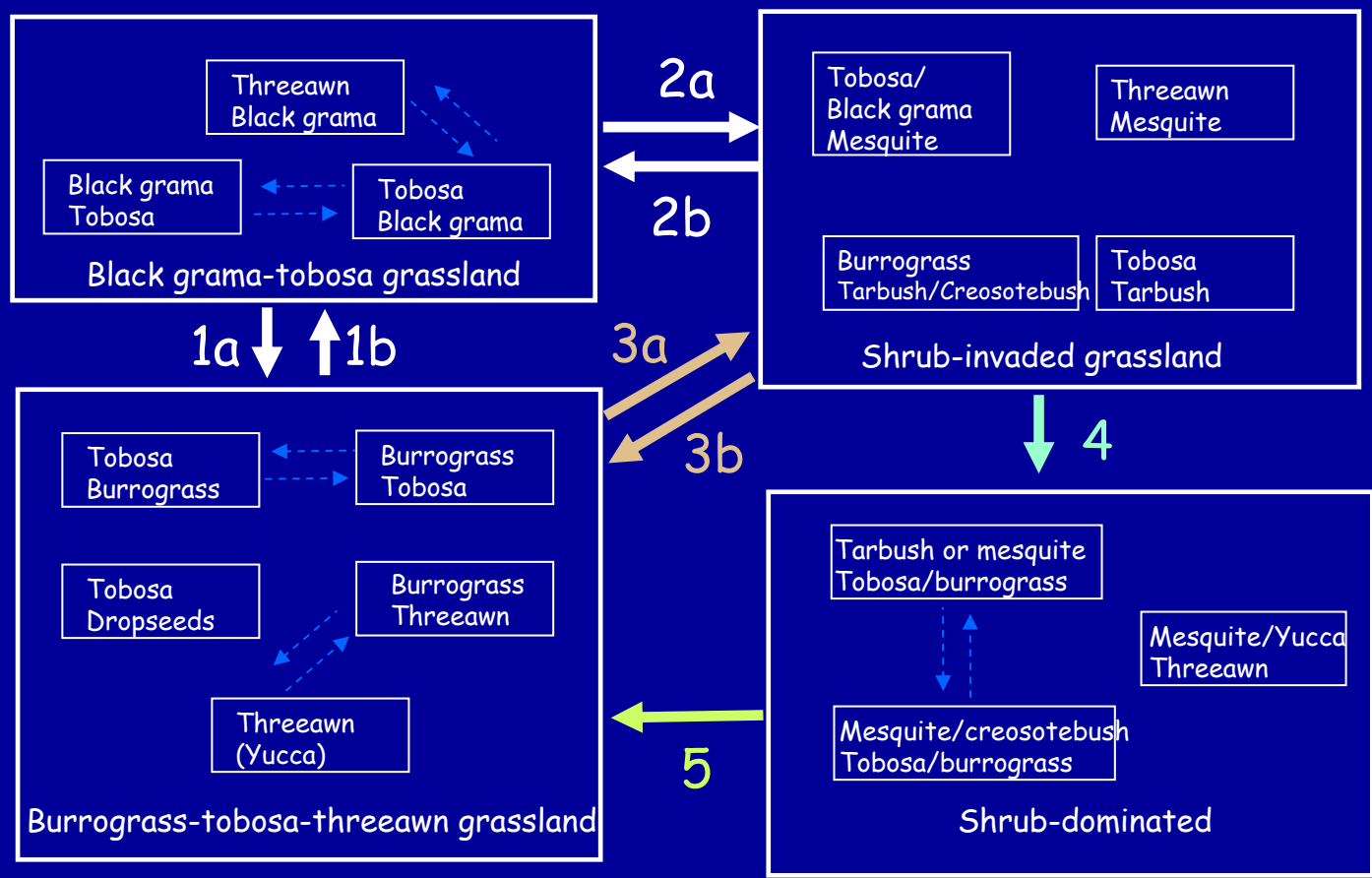
What's the Soil Survey - Ecological Site Linkage?



Uses of models in soil survey comparison studies

1. Show cause and effect relationships.
2. Stratify the soil map unit component (phase).
3. Help identify sample locations (plant community characteristics).
4. Provide a framework to organize and communicate management information and dynamic soil property data.
5. Develop hypotheses for testing (research) and development of interpretations.
6. Extend data and relationships to other similar soils, Ecological Sites or crop management zones.

Loamy SD-2 State and transition model



1a. Continuous heavy grazing, soil fertility loss, erosion.
1b. Soil stabilization, soil amendments

3a. Shrub invasion. **3b**. Shrub removal

Bestelmeyer, 2003

2a. Shrub invasion due to overgrazing and/or lack of fire.
2b. Shrub removal, restore grass cover

4. Persistent reduction in grasses, competition by shrubs, erosion and soil truncation

5. Shrub removal with soil addition?

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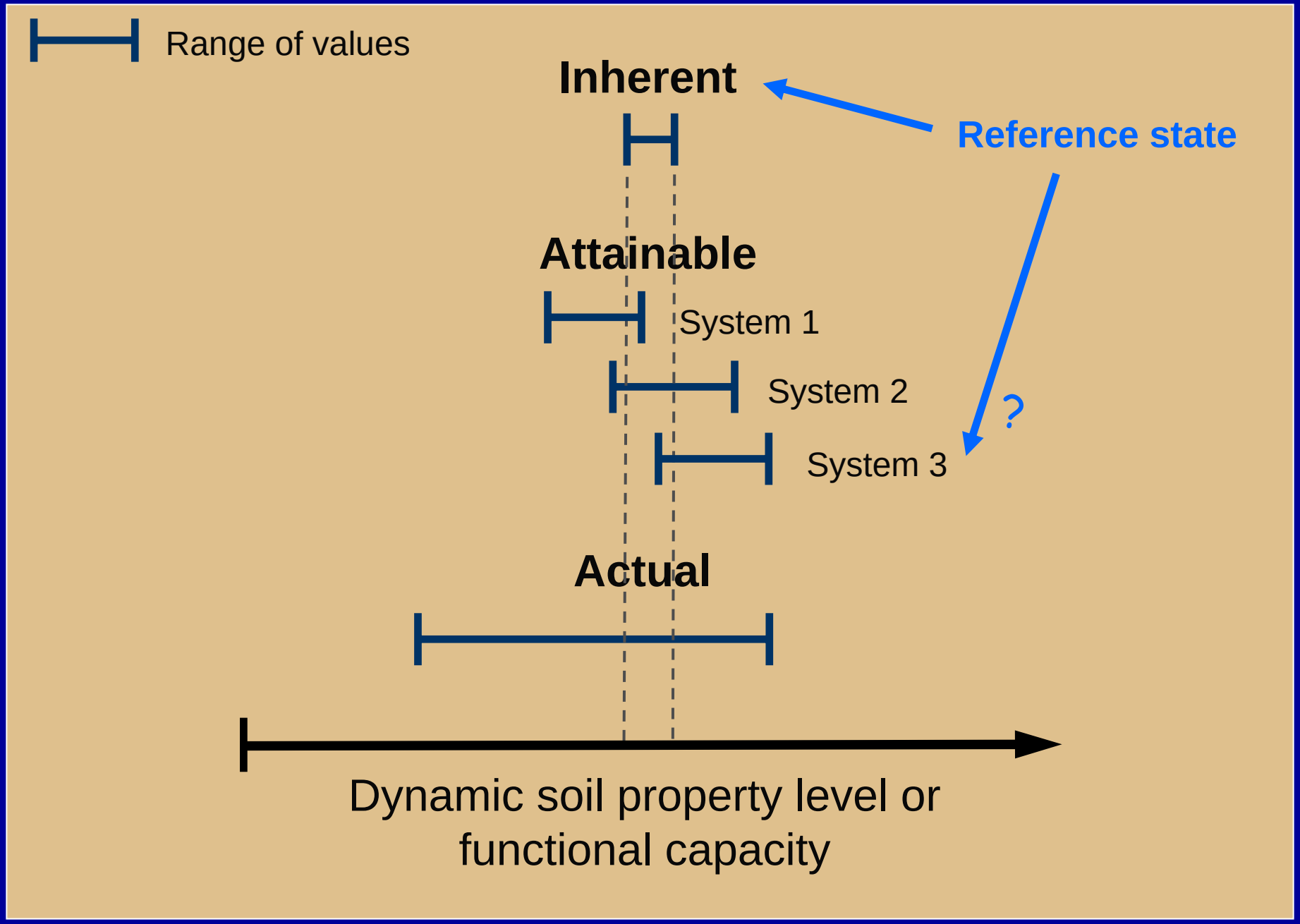
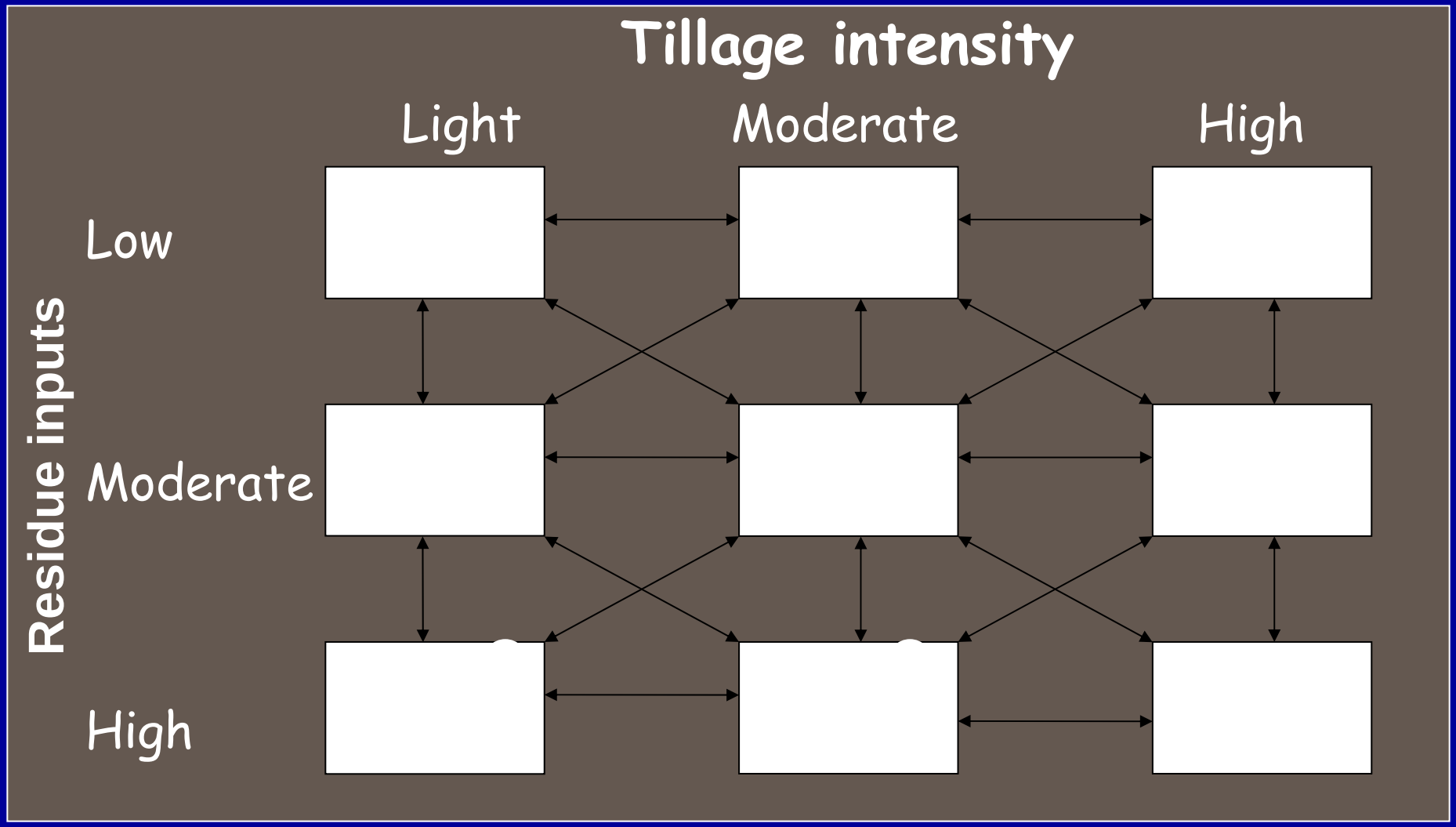

Range of values
Inherent
Reference state
Attainable
System 1
System 2
?
System 3
Actual
Dynamic soil property level or functional capacity

Stratify cropland (initial draft)



Develop for groups of similar soils in a cropland management zone

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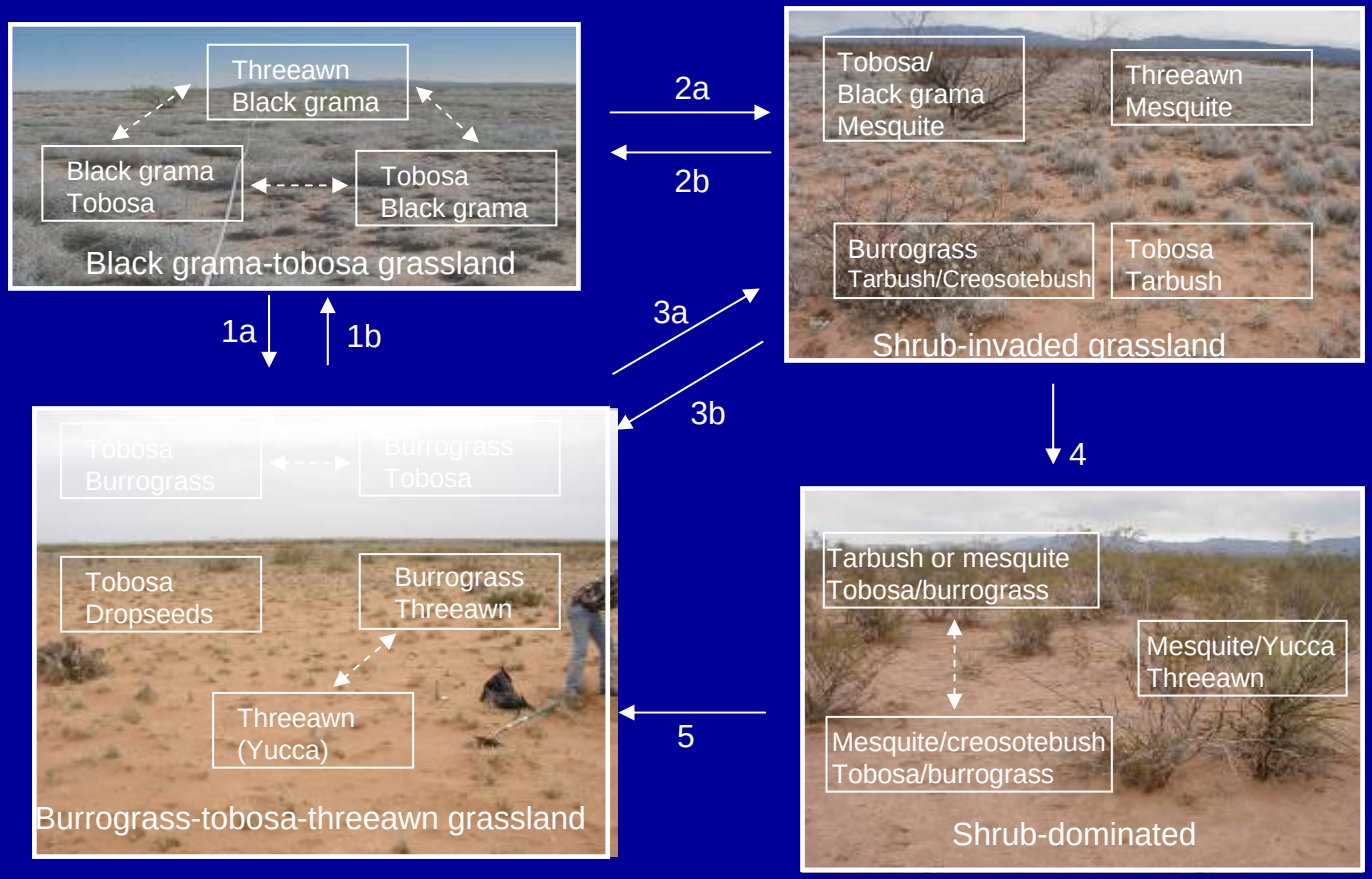
Loamy SD-2 MLRA 42



1a. Continuous heavy grazing, soil fertility loss, erosion and sand loss. **1b**. Soil stabilization, soil amendments

2a. Shrub invasion due to overgrazing and/or lack of fire. **2b**. Shrub removal, restore grass cover

3a. Shrub invasion. **3b**. Shrub removal

4. Persistent reduction in grasses, competition by shrubs, erosion and soil truncation

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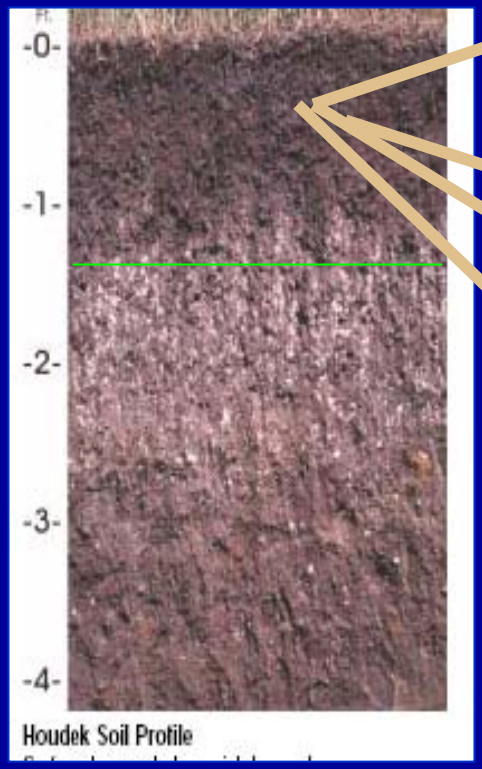
Future point data structure will include multiple values based on management (states)

Near surface dynamic soil properties

Static properties

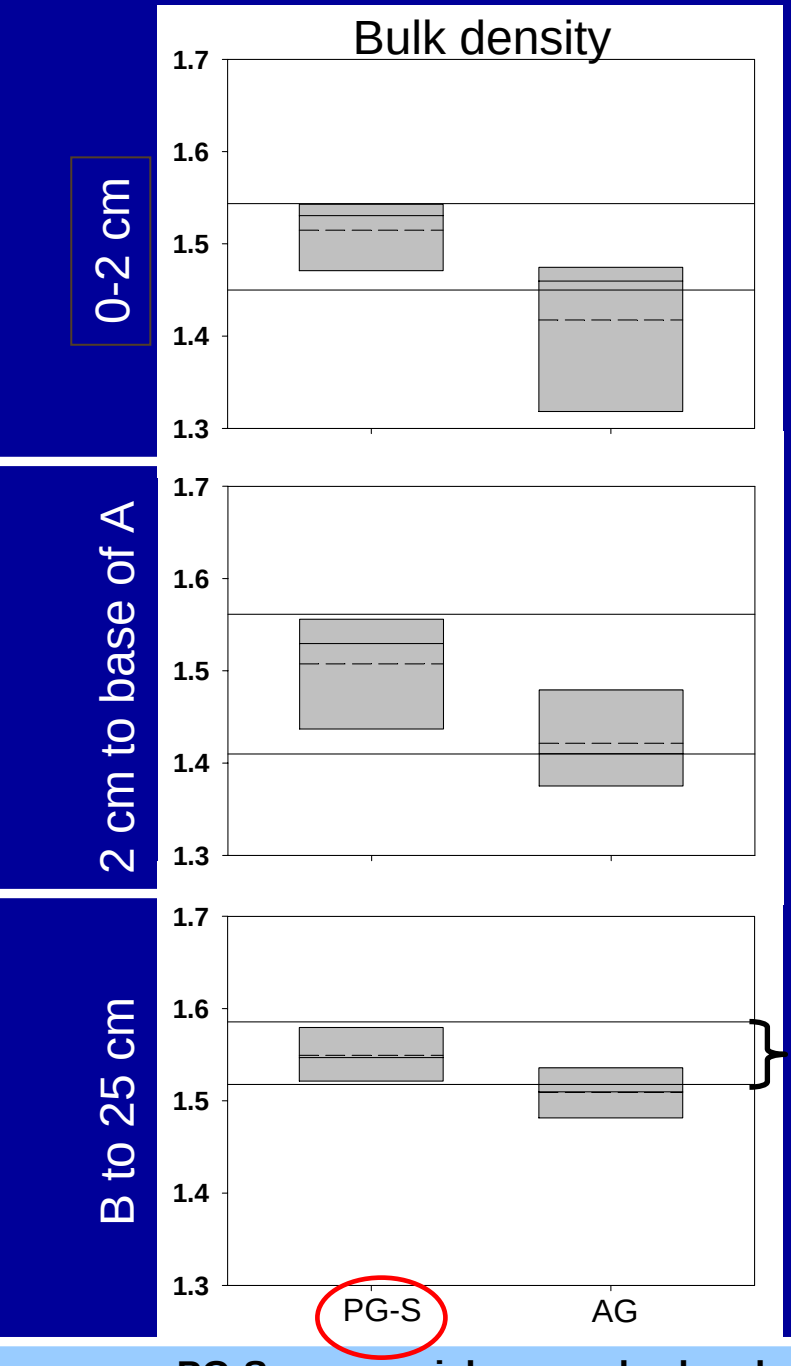


Inherent
native plant community
3.5% organic carbon

Managed
plant community
3.4% OC

Tilled
Cropland
2.5% OC

No-till
Cropland
2. 9% OC



High and low values of reference state

Illustrate change or departure from the inherent condition or reference state.

PG-S = perennial grass-shrub sub-state; AG = Annual grass (cheat grass) sub-state; n=4

——— = Median - - - - - = Mean

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SSSA symposium, October 2008
S6 and S5, S3, S7

Pedology, Soil Change and Management Effects on Soil Quality

Organizers:
Susan Andrews, Arlene Tugel and Larry West

MULTI-SCALE ECOSYSTEM PROCESS MODEL

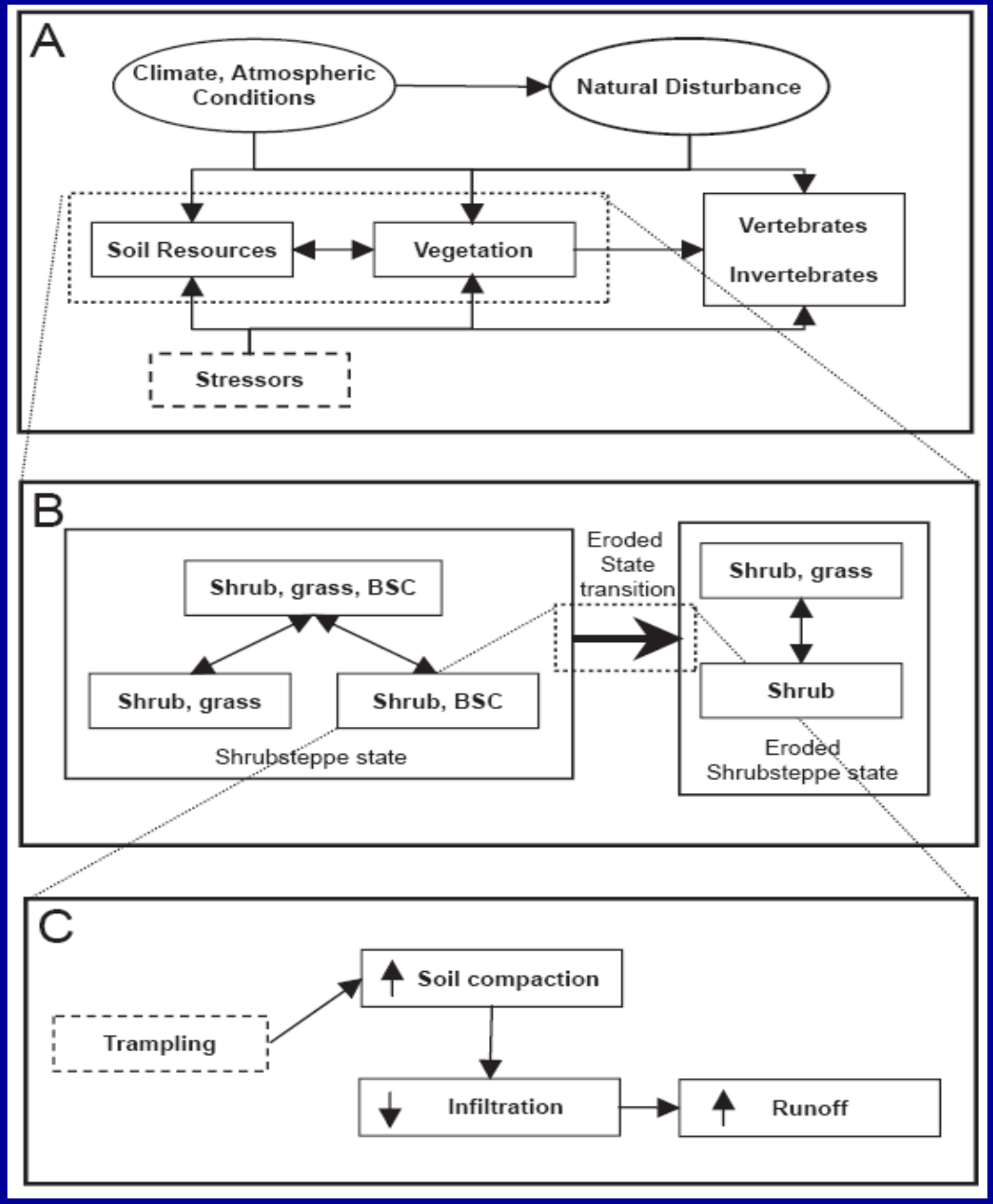
NORTHERN COLORADO PLATEAU NETWORK

A. The global model shows the larger scale controls (drivers) that affect the system.

B. Submodels convey more detailed processes with state and transition models.

C. Associated transition-causes (stressors) are in mechanistic models.

(O'Dell et al. 2005)



Mechanisms of soil change

Anthropogenic stressors

Cultivation, heavy equipment, amendments, pesticides, irrigation

Heavy continuous grazing, catastrophic fire, absence of fire, invasive species

Heavy equipment, catastrophic fire, absence of fire, invasive species, insects, disease

Transitions

- Change in soil cover
- Erosion
- Nutrient depletion
- Organic matter loss
- Reduced biological activity
- Structural degradation
- Salinization
- Change in base status/Acidification

Properties impacted

- Organic matter
- Aggregate stability
- Structure
- pH
- Salinity
- Infiltration
- Penetration resistance
- Topsoil depth
- Biological crusts

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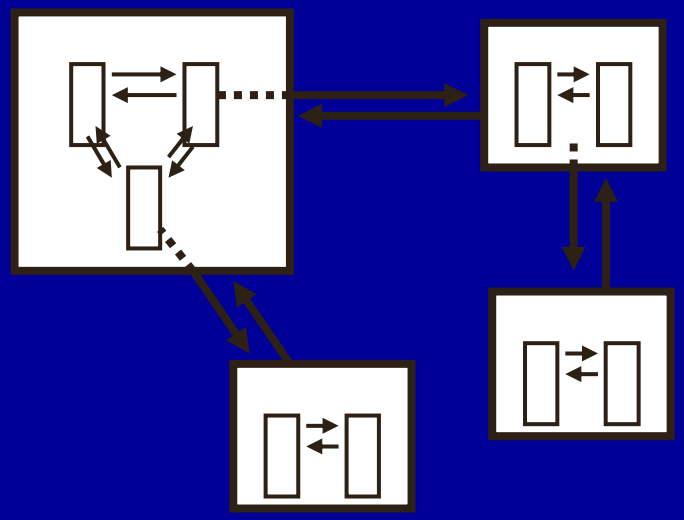
Extending the data



- Similar soils
  - Soil-site correlation
  - Benchmark soils
  - Benchmark Ecological Sites
- Pedotransfer functions, simulation models

Summary of soil survey strategy

1. Select priority benchmark soils and reference states.
2. Gather dynamic soil property and vegetation data (using the GUIDE).
3. Populate a point database.
4. Develop interpretations of management effects on soil function and the consequences of change.
5. Use models and pedotransfer functions to populate the soil map unit data base.

References for process models

Gross, John E. 2003. Developing Conceptual Models for Monitoring Programs, NPS Inventory and Monitoring Program, http://science.nature.nps.gov/im/monitor/docs/Conceptual_Modelling.pdf

National Park Service Vital Signs Monitoring. http://science.nature.nps.gov/im/monitor/index.cfm

Ross, 1989. Soil Processes. 444p. Routledge. London. England.

Starfield, A. M., D. H. M. Cumming, R. D. Taylor , and M. S. Quadling. 1993. A frame-based paradigm for dynamic ecosystem models. Ai applications 7:1-13.

Tugel, A.J., J.E. Herrick, J.R. Brown, M.J. Mausbach, W. Puckett, and K. Hipple. 2005. Soil change, soil survey, and natural resources decision making: A blueprint for action. Soil Sci. Soc. Am. J. 69:738-747. http://soil.scijournals.org/content/vol69/issue3/#PEDOLOGY

Ad-hoc Committee on Soil Change

• Soil Survey updates. The Soil Change Guide: Procedures for Soil Survey and Resource Inventory	A. Tugel
• Soil Change Strategic Plan	K. Hipple
• Cooperator and Agency Needs for Dynamic Soil Property Data	P. Biggam
• Group Discussion	All

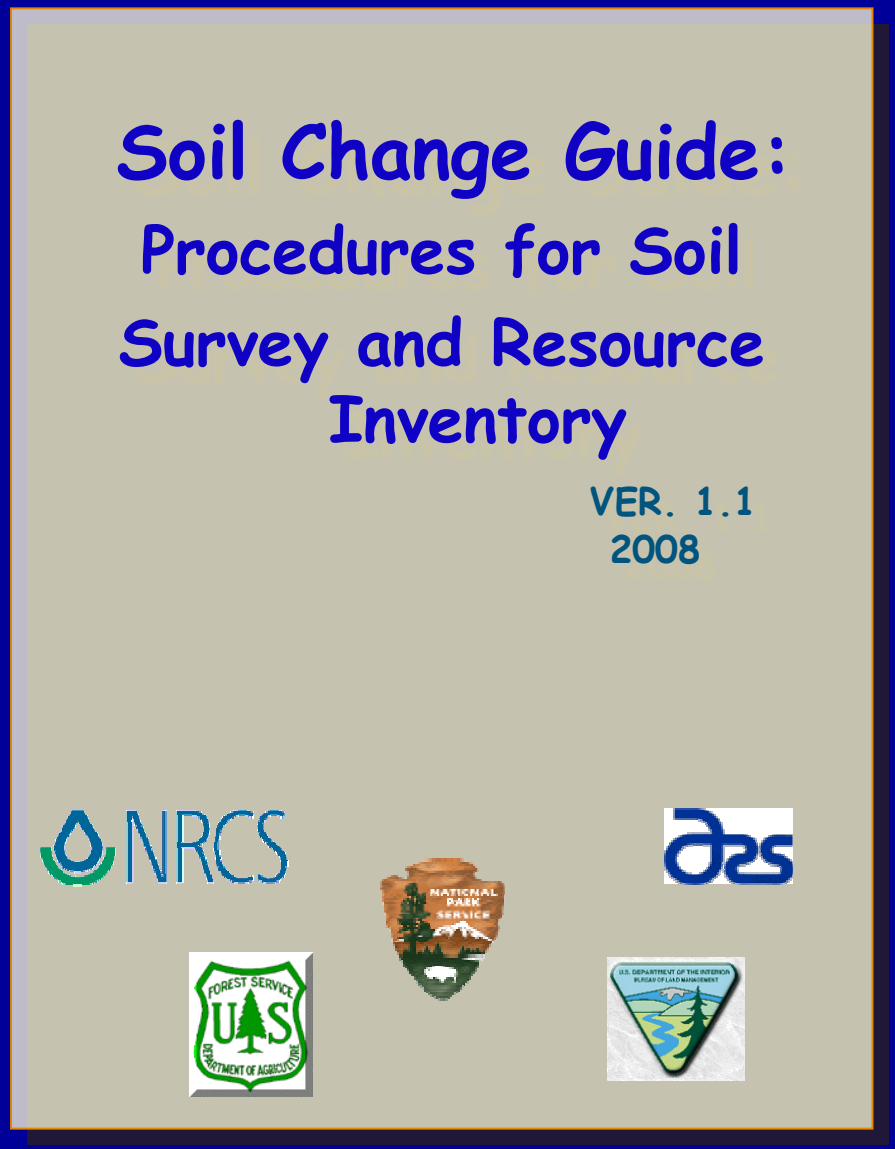
Discussion and Work Session

1. Identify environmental, productivity and resource management issues that involve management-induced changes in soil properties and function.

2. Provide input to the NCSS Soil Change Strategic Plan.

3. ??? Recommend a Soil Change Standing Committee and charges for regional and national conferences????

Soil Survey Procedures



Contents

1. Background on comparison studies and conceptual models
2. 6 steps to conduct a project
3. Soil and vegetation data is collected together
4. Cropland sampling design to be added

Developed by NRCS, ARS, and NPS with review by BLM and FS

Six steps of a comparison study

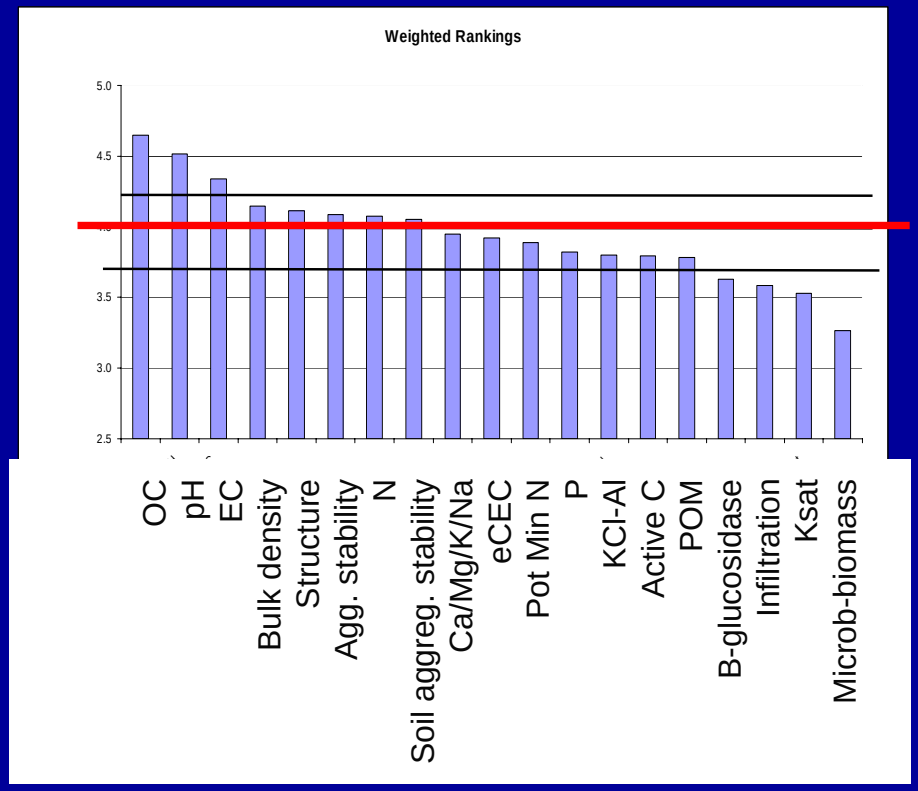
1. Project planning---objectives
2. Sampling design---what to compare
3. Sampling requirements---distribution and how many
4. Field work
5. Data preparation
6. Data analysis, interpretation, and reports

What properties do we measure?

Answer: Minimum data set

(March 15, 2008)

- Organic C
- pH
- EC
- Bulk density/Soil porosity
- Structure and macro-pores
- Aggregate stability (wet)
- Total N (for C:N ratio)
- Soil aggregate stability (field kit)

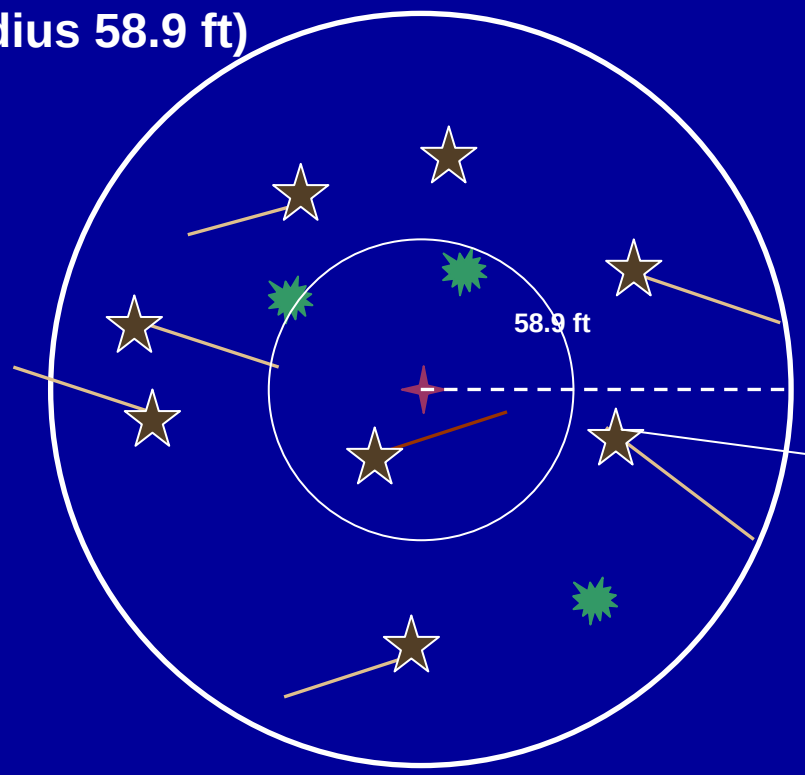


Wills, et al, in prep.
Administered by ARS, Las Cruces, NM

Also: Particle size
Rock fragments

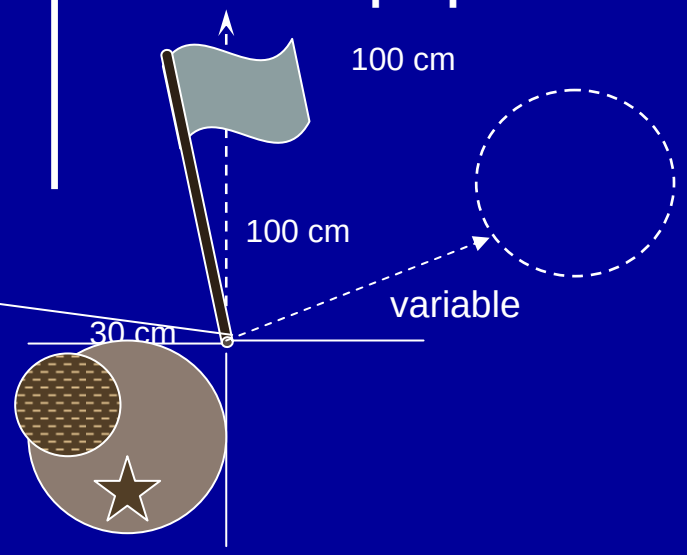
Forestland Ecosystem Plot

¼ acre plot (radius 58.9 ft)



North

Soil sample location for dynamic soil properties



Plot center

Soil sample location

Vegetation understory/groundcover sample location

Woody debris transect

Interior circle = 1/20 acre understory fixed plot; Radius = 26.3 ft

Soil visual disturbance class

Forest floor sample

Soil sample location

Root biomass (supplemental)

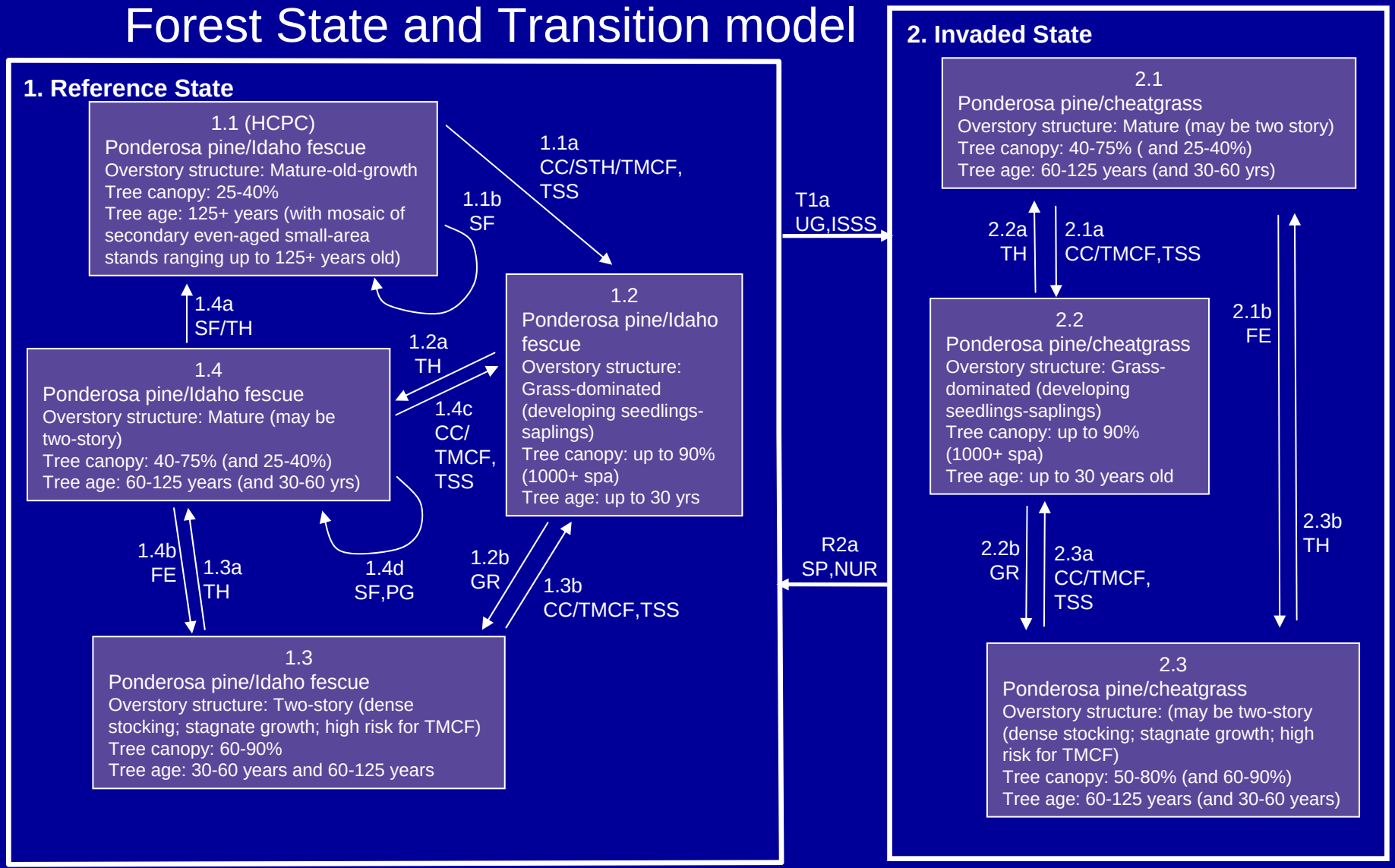
Document the central tendency and range of variation

				Bulk density			
				Central tendency of plot means		**Central range**	**Variation**
		Depth/ horizon	full state phase range	Mean	Median	Interquartile range of plot means	CV
Begay fsl, 0-6%	PGS	0 - 2 cm	1.27 - 1.91	1.51	1.53	1.47 - 154	2.7
		A not 0-2	1.27 - 1.68	1.51	1.53	1.44 - 1.56	4.5
		B	1.46 - 1.62	1.55	1.55	1.52 - 1.58	2.0
	AG	0 - 2 cm	1.01 - 1.68	1.42	1.46	1.32 - 1.47	6.9
		A not 0-2	1.29 - 1.54	1.42	1.41	1.38 - 1.48	3.9
		B	1.42 - 1.59	1.51	1.51	1.48 - 1.54	2.0

How will we select benchmark soils for a comparison study project?

1. Experiencing critical resource management problems or opportunities.
2. Management history and other data available (soil and vegetation).
3. Existing long-term study project underway.
4. Mechanisms of change represent those of other similar soils.
5. Extensive.
6. Benchmark Ecological Site.

Forest State and Transition model



Legend: CC=clearcut harvest; FE=fire exclusion; GR=growth; HCPC=Historic Climax Plant Community; ISSS=invasive species seed source; NUR=native understory restoration; PG=prescribed grazing; SF=surface fire (recurring); SP=site preparation; spa=stems per acre; STH=seed-tree harvest; TH=thinning (prescribed); TMCF=total mortality crown fire; TSS=tree seed source present; UG=uncontrolled grazing. Symbols: **"/"** = and/or; **","** = and; **"-"** = or.

→ Community pathway
← Restoration pathway
→ Transition pathway

(Pinus ponderosa/Idaho fescue; Rev. 1May2007) from L Townsend, NRCS

Pedogenesis

Ecological processes

- Energy capture and flow
- Hydrologic cycle
- Nutrient cycling

Capacity to function