THE RANGELAND MANAGEMENT AND SOIL HEALTH CONNECTION

A NATIONAL PERSPECTIVE
CALIFORNIA PACIFIC SECTION, SOCIETY FOR RANGE MANAGEMENT
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SOIL HEALTH IS NOT NEW

"the capacity of a soil to function as a vital, living ecosystem that sustains plants, animals, and humans" (USDA NRCS 2014)

- Homer, the Bible, Chief Seattle, FDR all talked about soil as the basis for human existence

- Soil Quality-conceptual development and investigations and through the 90s

"the challenge for the future is to develop sustainable management…soil quality indicators are merely a means toward this end." Doran and Zeiss 2000

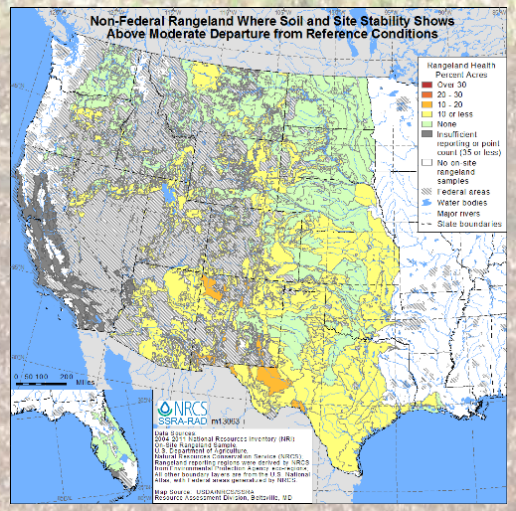
IS SOIL HEALTH A MOVEMENT, A MOTIVE OR A SCIENCE?

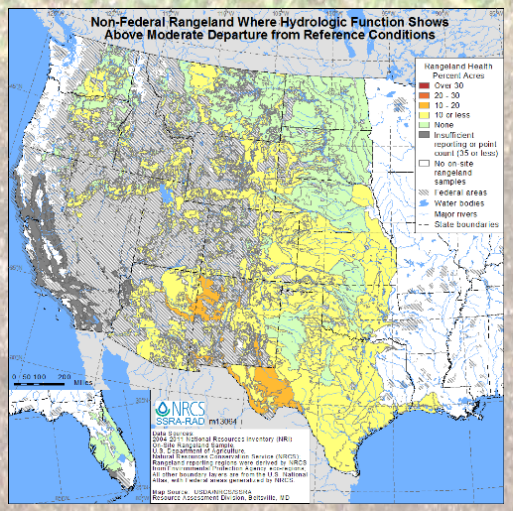
- MOVEMENT-A GROUP OF PEOPLE WORKING TOGETHER TO ADVANCE THEIR SHARED POLITICAL, SOCIAL OR ARTISTIC IDEAS
- MOTIVE-REASON FOR DOING SOMETHING; THE GOAL OR OBJECT OF AN ACTION
- SCIENCE-A SYSTEMATIC ENTERPRISE THAT ORGANIZES KNOWLEDGE IN THE FORM OF TESTABLE PREDICTIONS

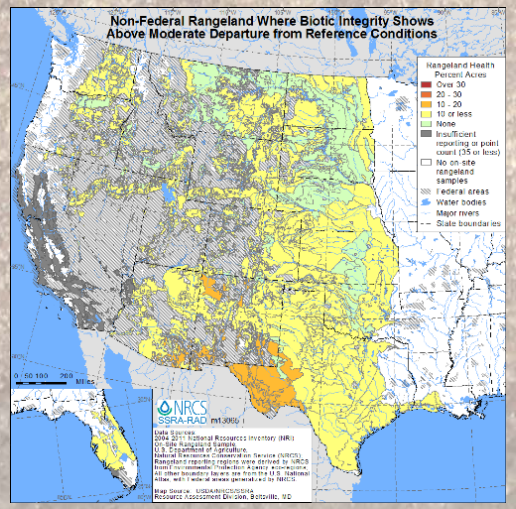
CAN WE IMPROVE RANGELAND SOIL HEALTH (SEQUESTER CARBON) BY MANAGED GRAZING?

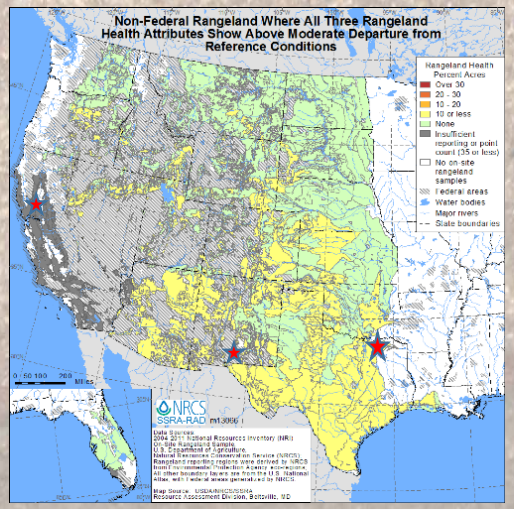
The question of whether we can sequester carbon on rangeland by improving grazing management is important and deserves serious consideration. A 2008 review of 29 rotational grazing experiments by Briske et al (including an NRCS and several ARS authors) concluded unequivocally that rotational grazing management would not increase net primary productivity or animal productivity. Stocking rate was the driving management variable in any biophysical response variable. Moreover, stocking rate was always overridden by weather variability as a factor.

The Carbon Cowboys have proposed to increase soil C on grazing lands via the use of Adaptive Multi Paddock Grazing, which is rotational grazing. NRCS has a long history of promoting and implementing conservative stocking rates, with or without rotational grazing, to achieve landowner objectives. There appears to be no evidence in the literature that would warrant an increased emphasis on anything other than Prescribed Grazing (528) according to current standards. The basis for the assertions regarding increased soil C are from Teague et al 2011, the only published study that addresses the issue. Those results are not supportive of intensified grazing management as a means to increase soil carbon.









Best estimates (NRI) do not indicate that much private rangeland has soil health problems

Table 6
Soil organic matter (%) following heavy continuous, light continuous, heavy multi-paddock grazing and grazing exclosures in Cooke, Parker and Jack counties, Texas.

Soil depth (cm)	Grazing management			
	Heavy continuous	Light continuous	Multi-paddock	Graze exclosure
0–15	3.76_b ★	5.24_a	5.72_a	5.62_a
15–30	2.45_b ★	3.55_a	4.00_a	4.01_a
30–60	1.49_a	2.09_a	2.48_a	2.63_a
60–90	1.78_a	1.67_a	2.00_a	2.34_a
Mean	2.49_c ★	3.24_b	3.61_a	3.59_a

Means differ if they have a different letter ($p < 0.05$).

From USDA National Soil Survey
Kellogg Laboratory Pedon Database

			<20 cm		>30 cm
Series	Surface Texture	% Clay	% Silt	%Clay	% Silt
Aledo	gravelly clay loam	18-20	36-38	21-24	38-50
Anocon	fine sandy loam				
Sanger	clay	41-45	41	48-50	38-42
Thurber	clay loam	37-42	32-45	36-44	31-39
Venus	loam	12-30	22-42	28-35	38-60

Teague et al 2011

Table 4
Soil physical and hydrological parameter values recorded following heavy continuous, light continuous, heavy multi-paddock grazing and grazing exclosures in Cooke, Parker and Jack counties, Texas.

Parameter	Grazing management			
	Heavy continuous	Light continuous	Multi-paddock	Graze exclosure
Aggregate stability (%)	81_b	90_{ab}	93_a	89_{ab}
Bulk density ($g\,cm^{-3}$)	1.06_a	0.98_a	0.91_a	0.9_a
Hydraulic conductivity ($K \times 10^{-4}$)	44_a	53_a	60_a	66_a
Ring infiltrometer ($cm\,h^{-1}$)	4_a	11_a	7_a	26_a
Penetration resistance (Joules)	246_a	212_b	174_{bc}	160_c
Runoff ($cm\,h^{-1}$)	2.0_a	0.3_b	1.4_a	1.8_a
Sediment loss ($g\,m^{-2}$)	18.0_a	2.0_b	4.0_b	4.0_b
Soil moisture (Volumetric %)	15_b	23_a	25_a	24_a

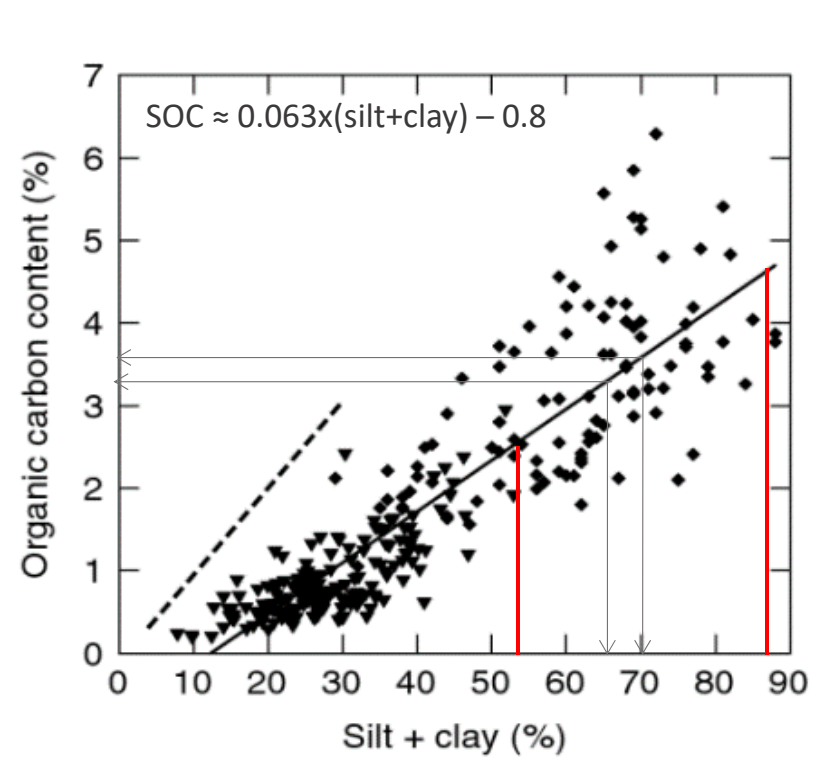
Within row means followed by the same letter are not significantly different ($p < 0.05$).

Table 7
Soil microbial biomass and mycorrhizal root colonization recorded following heavy continuous, light continuous, heavy multi-paddock grazing and grazing exclosures in Cooke, Parker and Jack counties, Texas.

Parameter	Grazing management			
	Heavy continuous	Light continuous	Multi-paddock	Graze exclosure
Total bacteria ($g\,m^{-2}$)	82_a	74_a	78_a	98_a
Active bacteria ($g\,m^{-2}$)[a]	5_a	7_a	5_a	4_a
Total fungi ($g\,m^{-2}$)	97_b	98_b	174_a	105_{ab}
Active fungi ($g\,m^{-2}$)	1.1_a	0.8_a	1.0_a	0.7_a
Endo-mycorrhizal fungi (Infection %)	4_b	3_b	6_{ab}	12_a
Ratio of total fungi to total bacteria	1.2_b	1.1_b	3.1_a	0.7_b
Nematodes ($g\,m^{-2}$)	0.25_b	0.40_a	0.25_a	0.27_a
Protozoa ($g\,m^{-2}$)	0.8_a	0.9_a	0.5_a	0.5_a

Within row means followed by the same letter are not significantly different ($p < 0.05$).

[a] To 60 mm depth.



0.58 x(3.61-3.24%SOC)/0.063= 3.4% clay difference between tmts can explain measured difference in SOM. Higher runoff in MP vs LC suggests clay higher in MP.

0.58 is the conversion from SOM (reported in the 2011 study) to SOM.

From Magdoff & Weil 2004. Soil Organic Matter in Sustainable Agriculture *CRC Press*

CAN WE IMPROVE RANGELAND SOIL HEALTH (SEQUESTER CARBON) BY ADDING CARBON ?

Finally, there is a suggestion that the addition of organic wastes (compost) to rangeland would dramatically increase soil carbon. There is a limited amount of research on the subject and the studies to date are small-plot, short-term biogeochemistry and not land management.

Beyond the broader questions of adding potential pollutants to steep slopes, shallow soils in a Mediterranean climate zone where water quality is a multi-decade concern and program priority, the question of efficacy should be examined. Does the data really support increasing soil carbon storage via the addition of organic waste products?

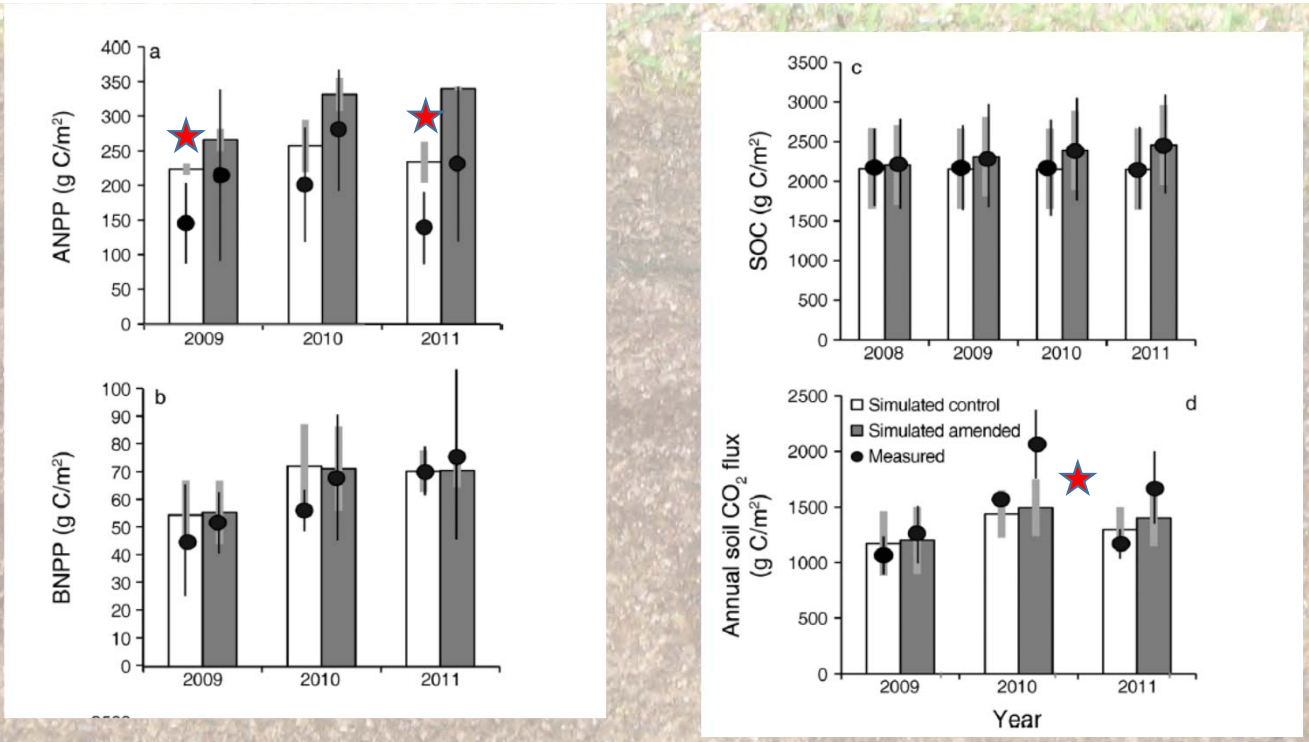


FIG. 2. Relationships between modeled and measured data (a) aboveground net primary production (ANPP), (b) belowground net primary production (BNPP), (c) 0–20 cm soil organic C, and (d) annual soil respiration (heterotrophic + autotrophic components) from 2009 to 2011. Bars are model averages of the three site characterizations with light gray bars representing ±SD. Black circles are average measured values with black lines representing ±SD.

Ryals et al 2015 characterized the soils of their study as Auburn-Sobrante complex

SERIES	Slope	Surface Texture	Depth to Bedrock	% Clay (13 records)
Auburn*	Undulating 2-75%	Silt loam	25 – 60 cm	14-45%
Sobrante*	2-75%	Silt Loam	50-100 cm	10-25 %

* OSD- very high variability over short distances

From the Kellogg National Soil Survey Center database and Official Series Descriptions
https://soilseries.sc.egov.usda.gov/OSD_Docs
https://ncsslabdatamart.sc.egov.usda.gov

ASSESSING AND MANAGING SOIL HEALTH ON RANGELANDS

- CAPACITY IS DIFFICULT TO DEFINE
- VERY DIFFICULT TO MEASURE SOIL HEALTH ATTRIBUTES DIRECTLY
- CHANGES IN HUMAN DESIRES MAY NOT AFFECT SOIL HEALTH ATTRIBUTES
- RESTORATION IS OFTEN MULTI-DECADAL

42 - SOUTHERN DESERTIC BASINS, PLAINS, AND MOUNTAINS

42.2 - Chihuahuan Desert Shrubs

(R042XB023NM) – **Clayey**

Tobosa

- Tobosa / burrograss mosaic, a few mesquite. Low diversity community.
- Few small bare ground patches, usually associated with burrograss.

- Species Cover (LPI average)
  - 40% ± 2.8 SE - Bare Ground
  - 8% ± 2.1 SE - Burrograss
  - 8% ± 1.2 SE - Tarbush
  - 26% ± 4.6 SE - Tobosa

Burrograss

- Burrograss, ear muhly dominate, some tarbush encroachment.
- Frequent bare ground patches of moderate size, but grass cover appears continuous.

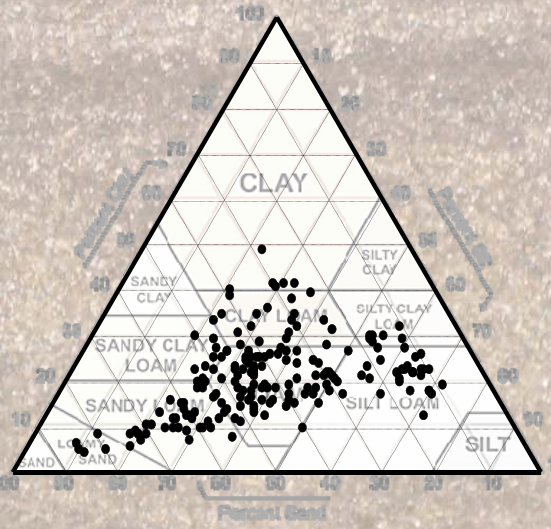
- Species Cover (LPI average)
  - 51% ± 1.8 SE - Bare Ground
  - 5% ± 1.3 SE - Soaptree yucca
  - 6% ± 0.9 SE - Tobosa grass
  - 29% ± 2.7 SE - Burrograss

42 - SOUTHERN DESERTIC BASINS, PLAINS, AND MOUNTAINS

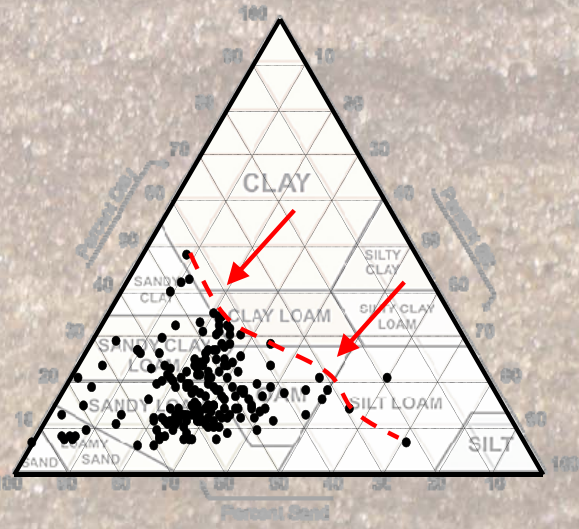
42.2 - Chihuahuan Desert Shrubs

(R042XB023NM) – **Clayey**

Clayey (Tobosa State)



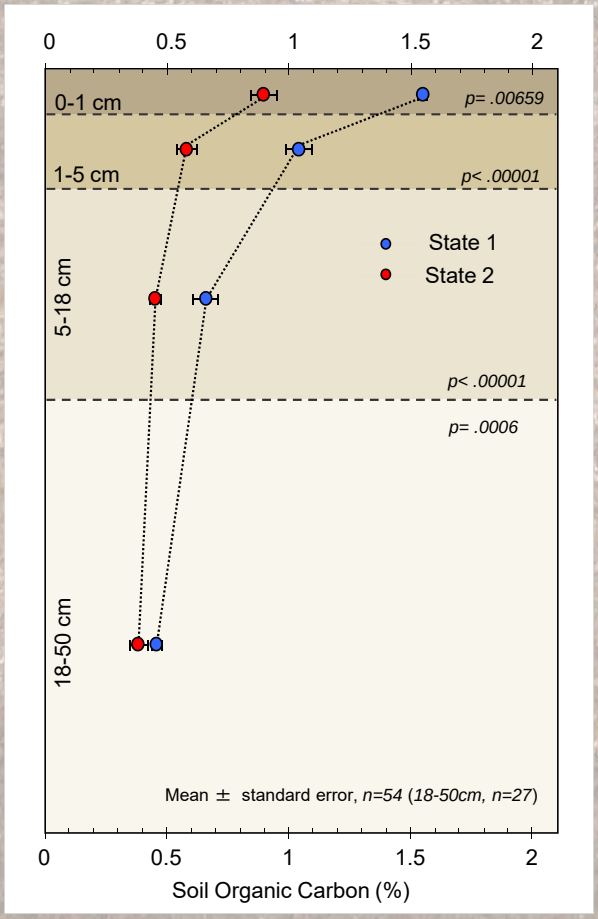
Clayey (Burrograss State)



MLRA 42 CHIHUAHUAN DESERT

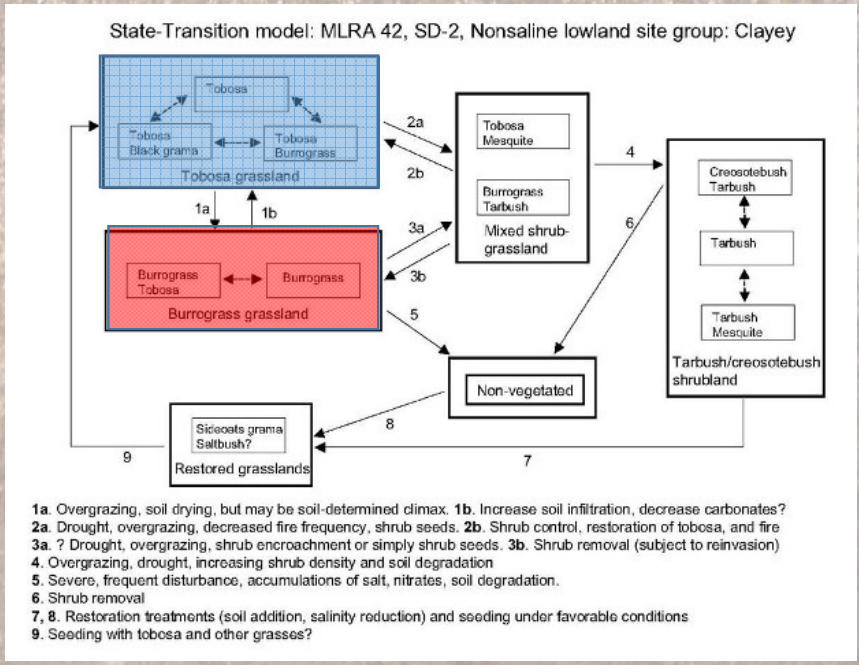
Clayey Ecological Site R042XB023NM

Soil Organic Carbon (%)



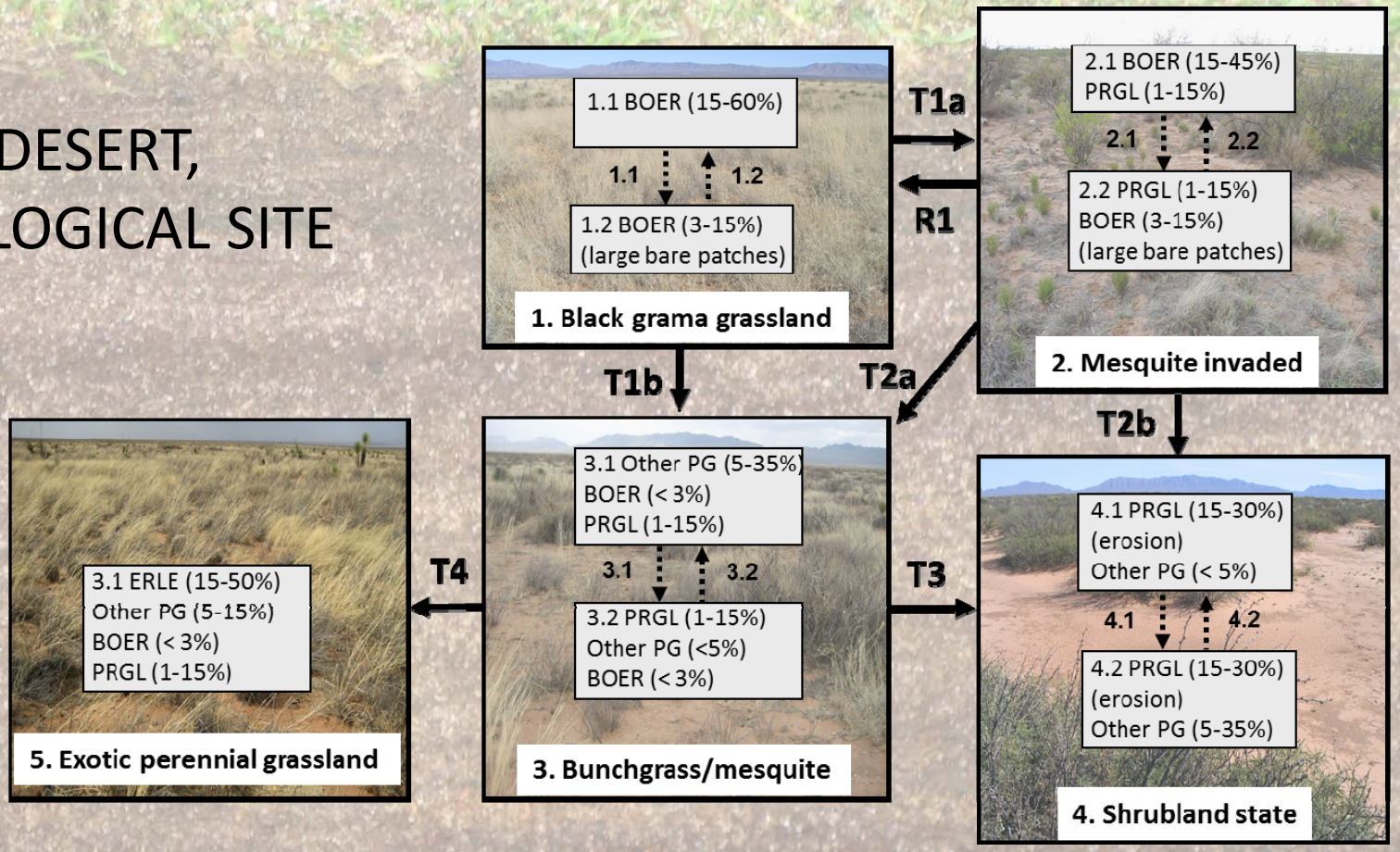
- Large differences in
  Tobosagrass (State 1)
  vs.
  Burrograss (State 2)

- Differences most pronounced
  in upper 5- cm of soil



1a. Overgrazing, soil drying, but may be soil-determined climax. **1b**. Increase soil infiltration, decrease carbonates?
2a. Drought, overgrazing, decreased fire frequency, shrub seeds. **2b**. Shrub control, restoration of tobosa, and fire
3a. ? Drought, overgrazing, shrub encroachment or simply shrub seeds. **3b**. Shrub removal (subject to reinvasion)
4. Overgrazing, drought, increasing shrub density and soil degradation
5. Severe, frequent disturbance, accumulations of salt, nitrates, soil degradation.
6. Shrub removal
7, 8. Restoration treatments (soil addition, salinity reduction) and seeding under favorable conditions
9. Seeding with tobosa and other grasses?

MLRA 42, SOUTHERN DESERT, SANDY ECOLOGICAL SITE



T1a. Mesquite establishment facilitated by seed transport by cattle, bare patches > 50 cm, and relatively wet springs
R1. Shrub removal via herbicide or fire followed by black grama recovery to > 15%
T1b, T2a. Black grama is reduced below ca. 3% cover by heavy grazing in drought
T2b, T3. At perennial grass cover < 5%, wind and storm events, trigger deep, spreading soil erosion
T4. Invasion by Lehmann's lovegrass, dominance increased by fire

From Bestelmeyer et al 2010

Management/Restoration Options for Increasing Soil Carbon

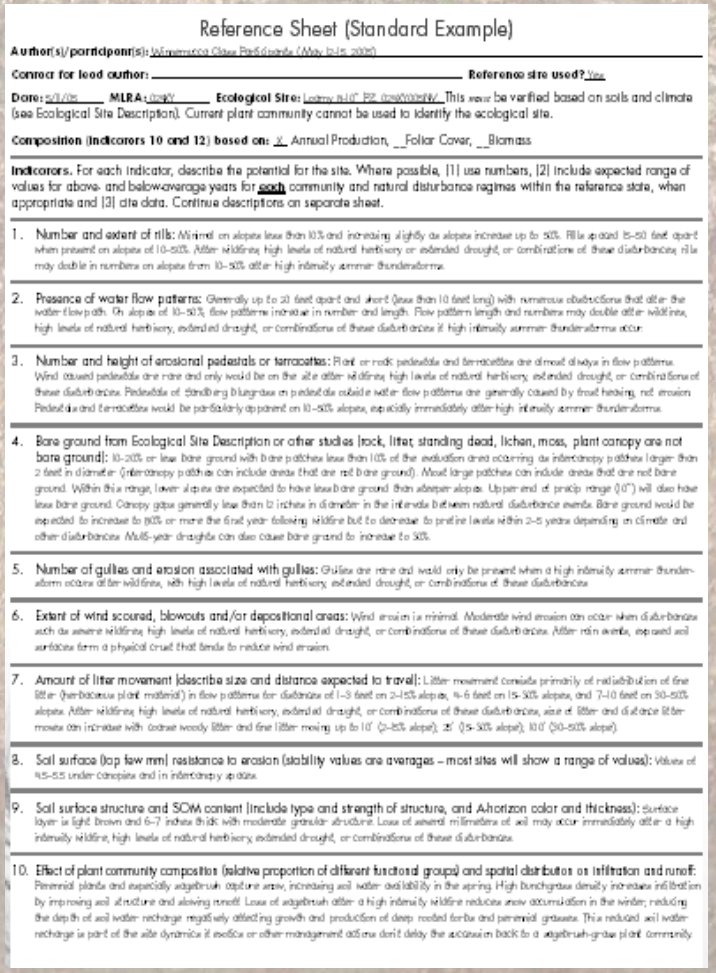
- Sandy Ecological Site
  - Mesquite to Black grama (0.29% C to 0.37% C)
    - Convert to bunchgrass then to black grama grassland
      - Destroy dune, remove mesquite, stabilize soil, add nutrients, Reseed, replant with restoration of soil fertility
      - Large cost associated with this type of restoration
- Shallow Sandy Ecological Site
  - Bunchgrass to Black grama (0.88% C to 0.98% C)
    - Reseed, replant with restoration of soil fertility
- Clayey Ecological Site
  - Burrograss to Tobosagrass (0.74% C to 1.29% C)
    - Further work needed to assess management options

Ecological Site Information, Rangeland Health, Soil Health

- An Ecological Site is the basis for Rangeland Health Assessment, it follows that soil health can be assessed on a similar basis
- A State and Transition Model identifies unique ecological configurations with different ecological processes, rates and magnitudes
- An Ecological Site also provides a basis for implementing management to improve rangeland health
- Investigations of soil health change should focus on ecological state change rather than arbitrary treatment levels

DEVELOPING A REFERENCE SHEET

- A RANGELAND HEALTH REFERENCE SHEET
  - Explicitly defines the values and ranges for each of the 17 indicator attributes for each site



Reference Sheet (Standard Example)

Author(s)/participant(s): [illegible]

Contact for lead author: _____ **Reference site used?** Yes

Date: 5/1/05 **MLRA:** 034X **Ecological Site:** Loamy 8-10" PZ (provisional) This must be verified based on soils and climate (see Ecological Site Description). Current plant community cannot be used to identify the ecological site.

Composition (Indicators 10 and 12) based on: X Annual Production, __Foliar Cover, __Biomass

Indicators. For each indicator, describe the potential for the site. Where possible, [1] use numbers, [2] include expected range of values for above- and below-average years for each community and natural disturbance regimes within the reference state, when appropriate and [3] cite data. Continue descriptions on separate sheet.

1. **Number and extent of rills:** Minimal on slopes less than 10% and increasing slightly as slopes increase up to 30%. Rills spaced 15-30 feet apart when present on slopes of 10-30%. After wildfires, high levels of natural herbivory or extended drought, or combinations of these disturbances, rills may double in numbers on slopes from 10-30% after high intensity summer thunderstorms.

2. **Presence of water flow patterns:** Generally up to 20 feet apart and short (less than 10 feet long) with numerous obstructions that alter the water flow path. On slopes of 10-30%, flow patterns increase in number and length. Flow pattern length and numbers may double after wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances if high intensity summer thunderstorms occur.

3. **Number and height of erosional pedestals or terracettes:** Plant or rock pedestals and terracettes are almost always in flow patterns. Wind caused pedestals are rare and only would be on the site after wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances. Pedestals of standing bunchgrass or pedestals outside water flow patterns are generally caused by frost heaving, not erosion. Pedestals and terracettes would be particularly apparent on 10-30% slopes, especially immediately after high intensity summer thunderstorms.

4. **Bare ground from Ecological Site Description or other studies (rock, litter, standing dead, lichen, moss, plant canopy are not bare ground):** 10-20% or less bare ground with bare patches less than 10% of the evaluation area occurring as interspace patches larger than 2 feet in diameter. (Interspace patches can include areas that are not bare ground). Most large patches can include areas that are not bare ground. Within this range, lower slopes are expected to have less bare ground than steeper slopes. Upper end of precip range (10") will also have less bare ground. Canopy gaps generally less than 12 inches in diameter in the intervals between natural disturbance events. Bare ground would be expected to increase to 80% or more the first year following wildfire but to decrease to pretine levels within 2-5 years depending on climate and other disturbances. Multi-year droughts can also cause bare ground to increase to 50%.

5. **Number of gullies and erosion associated with gullies:** Gullies are rare and would only be present when a high intensity summer thunderstorm occurs after wildfires, with high levels of natural herbivory, extended drought, or combinations of these disturbances.

6. **Extent of wind scoured, blowouts and/or depositional areas:** Wind erosion is minimal. Moderate wind erosion can occur when disturbances such as severe wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances. After rain events, exposed soil surfaces form a physical crust that tends to reduce wind erosion.

7. **Amount of litter movement (describe size and distance expected to travel):** Litter movement consists primarily of redistribution of fine litter (herbaceous plant material) in flow patterns for distances of 1-3 feet on 2-15% slopes, 4-6 feet on 15-30% slopes, and 7-10 feet on 30-60% slopes. After wildfires, high levels of natural herbivory, extended drought, or combinations of these disturbances, size of litter and distance litter moves can increase with coarse woody litter and fine litter moving up to 10' (2-8% slope), 25' (15-30% slope), 100' (30-60% slope).

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):** Values of 4.5-5.5 under canopies and in interspaces.

9. **Soil surface structure and SOM content (include type and strength of structure, and A horizon color and thickness):** Surface layer is light brown and 6-7 inches thick with moderate granular structure. Loss of several millimeters of soil may occur immediately after a high intensity wildfire, high levels of natural herbivory, extended drought, or combinations of these disturbances.

10. **Effect of plant community composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:** Perennial plants and especially sagebrush capture snow, increasing soil water availability in the spring. High bunchgrass density increases infiltration by improving soil structure and slowing runoff. Loss of sagebrush after a high intensity wildfire reduces snow accumulation in the winter, reducing the depth of soil water recharge negatively affecting growth and production of deep rooted forbs and perennial grasses. This reduced soil water recharge is part of the site dynamics if exotics or other management actions don't delay the succession back to a sagebrush-grass plant community.

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Table 4. Example of a revised descriptor for the bare ground indicator.

	Departure from Reference Sheet				
Indicator	**Extreme to Total**	**Moderate to Extreme**	**Moderate**	**Slight to Moderate**	**None to Slight**
4. Bare ground	Greater than 75% bare ground with entire area connected. Only occasional areas where ground cover is contiguous, mostly patchy and sparse.	60-75% bare ground. Bare patches are large (>24" diameter) and connected. Surface disturbance areas becoming connected to one another. Connectivity of bare ground broken occasionally by contiguous ground cover.	45-60% bare ground with much connectivity especially associated with surface disturbance.Individual bare spaces are large and dominate the area.	30-45% bare ground. Bare spaces greater than 12" diameter and rarely connected. Bare areas associated with surface disturbance are larger (> 15") and may be connected to other bare patches.	**Reference Sheet:** 20-30% bare ground; bare patches should be less than 8-10" diameter and not connected; occasional 12" patches associated w/shrubs. Larger bare patches also associated with ant mounds and small mammal disturbances.
Generic Descriptor	Much higher than expected for the site. Bare areas are large and generally	Moderate to much higher than expected for the site. Bare areas are large and occasionally connected	Moderately higher than expected for the site. Bare areas are of moderate size	Slightly to moderately higher than expected for the site. Bare areas are small and rarely	Amount and size of bare areas match that expected for the site.