Assessing Soil Quality in Ancient Agricultural Landscapes of Southern Arizona

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Introduction

Ancient farmers of the Southwest used a variety of agricultural strategies (irrigation, floodwater, runoff, and rock mulch) to cope with environmental vagaries. Fields in bottomlands are better watered and more fertile than more elevated landscape positions but are prone to salinization and damaging floods, whereas fields on higher terraces and in ephemeral drainageways are more drought-prone, but avoid the effects of flooding and cold air drainage. Ancient farmers managed agricultural risk by using a variety of soil and water conservation measures and by spreading their fields across many different landscape positions. As a way to assess and model soil quality and land suitability for different agricultural systems, we integrated soil, physiographic, and archaeological data in southern Arizona.

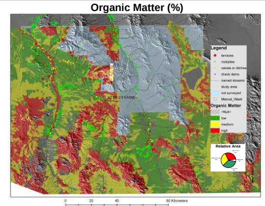
Methods

- Soil, physiographic, and archaeological data were compiled for the study area:-
  - Digital soil maps and a soil database were obtained from the USDA Natural Resources Conservation Service (NRCS).
  - Digital elevation model (DEM) data were obtained from the U.S. Geological Survey.
  - Archaeological site data were obtained from AZSITE site database, including locational data for sites with canals (n = 56), checkdams (n = 66), terraces (n = 69), and rock piles (n = 780).
- Spatial distributions of different soil and physiographic properties were used to model agricultural soil quality and suitability for different types of farming systems.
- The distributions of ancient agricultural fields and other types of archaeological sites were then evaluated in relation to a spatial model of agricultural soil quality.

Research Objectives

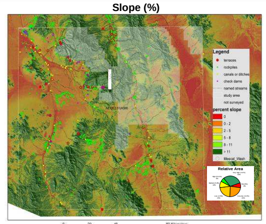
- **Model agricultural soil quality and suitability in southern Arizona in order to evaluate potential uses of the Mescal Wash site (AZ EE:2:51 ASM)**
- **Assess agricultural feature distributions relative to a spatial model of agricultural soil quality and suitability**

Organic Matter (%)



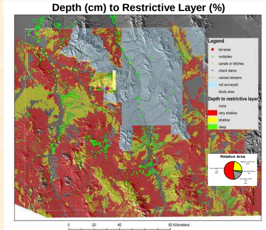
Soils with higher organic matter contents are the most productive agricultural soils. Organic matter content is typically low in the study area because of high oxidation rates and relatively low rates of biomass production. Soils with the highest organic matter contents are mainly in the mountains at elevations too high for agriculture, in *bajadas* flanking the uplands, and along the Santa Cruz River floodplain.

Slope (%)



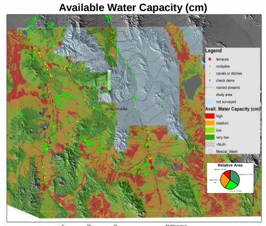
All agricultural systems are concentrated on gently sloping terrain where water could be controlled and conserved. Most agricultural features were built on slopes less than about 8 percent. Irrigated and floodwater fields were mainly established on floodplains, runoff fields in and at the mouths of ephemeral drainageways on alluvial fans, and rockpile fields on cobbly ridges and fan terraces.

Depth (cm) to Restrictive Layer (%)



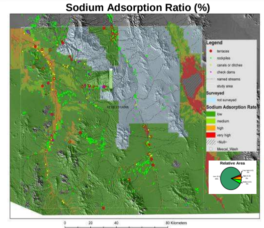
The shallowest soils occur in upland settings and the deepest in bottomlands. The depth to restrictive layers, especially bedrock and petrocalcic horizons, limits the volume available to plants for water and nutrient uptake. Shallow soils are advantageous to shallow-rooting crops such as agave because moisture is conserved in the root zone. Most crops, however, are more productive in the deeper soils.

Available Water Capacity (cm)



Available water capacity is critical for agricultural sustainability in desert settings. Although floodplains along the major rivers are the best-watered locales, the loamy soils on alluvial fans tend to have the highest available water capacities. Upland soils tend to have the lowest available water capacities because of shallow bedrock.

Sodium Adsorption Ratio (%)

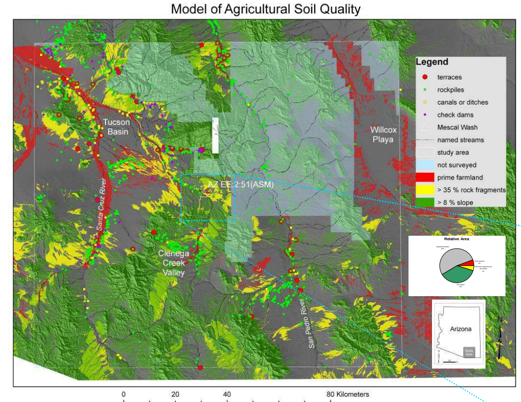


Sodium adsorption ratio (SAR) is a measure of the proportion of sodium ions to the concentration of calcium plus magnesium ions. High to very high SAR levels cause soils to become hard and cloddy when dry, to develop crusts and to take in water very slowly. They limit the ability of plants to absorb water. High to very high SAR levels occur in 7 percent of the study area, mainly in low landscape positions around the Wilcox Playa and along the Santa Cruz River. SAR hazards can be managed by flushing salts below the root zone in irrigated soils.

Conclusions

- **Digitized soil maps and databases are useful for modeling soil quality in ancient agricultural landscapes in southern Arizona.**
- **The model of soil quality generally conforms well to locations where archaeological traces of agriculture have been identified in association with irrigation, runoff, and rock mulch systems.**
- **Prime farmland and rocky soils suitable for floodwater, runoff, and rock mulch systems occur near AZ EE:2:51 (ASM). Other portions of the study area, however, contain much broader expanses of prime farmland.**

Model of Agricultural Soil Quality

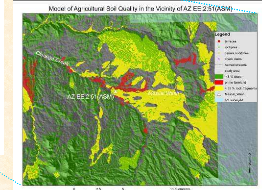


This soil quality map integrates properties in the model of agricultural landscapes (see table at right). Land identified as prime farmland by the NRCS is concentrated in well-watered, fertile soils along perennial drainages, where irrigation agriculture is best suited, and in smaller pockets of land flanking these drainages. Rockpile fields are strongly associated with very to extremely gravelly and cobbly soils on the terraces of alluvial fans and streams. Areas best suited to runoff farming include landforms with 2–8 percent slopes. Most rugged and mountainous terrain is unsuited for agriculture.

Soil Properties Used in Soil Quality Model in Relation to Ancient Agricultural Features

Soil Property	Description	Range	Relative Area (%)	Agricultural Features (%) Canals	Check Dams	Terraces	Rockpiles
A Horizon (cm)	Thin	0 - 25	77	46	71	78	86
	Medium	25 - 50	15	34	8	9	8
	Thick	> 50	8	20	21	13	6
Available Water Capacity (AWC) (cm³/cm³)	Very low	0-0.05	32	4	21	43	26
	Low	0.05-0.10	23	38	38	23	32
	Medium	0.1-0.15	29	16	36	29	32
	High	0.15-0.20	16	43	5	4	11
Total AWC (cm)	Very low	0-8	34	4	33	51	31
	Low	8-16	25	45	32	23	32
	Medium	16-24	28	32	33	23	32
	High	24-32	13	20	2	3	4
Bulk Density (g/cm3)	Restricted	Depends on texture	41	4	36	28	34
	Somewhat restricted	Depends on texture	44	70	38	41	49
	Unrestricted	Depends on texture	15	27	26	32	17
Calcium carbonate (%)	Very calcareous	>10	25	14	32	14	27
	Calcareous	5-10	19	18	26	42	22
	Slightly calcareous	2-5	22	41	17	22	25
	Slightly calcareous	1-2	8	16	8	3	17
	Very slightly calcareous	0.5-1	8	9	6	1	4
	Noncalcareous	<0.5	18	2	12	17	5
Cation exchange capacity (meq/100g)	Low	0-10	53	59	42	65	39
	Medium	10-20	34	41	50	33	51
	High	>20	13	0	8	1	9
Depth to Bt horizon (cm)	Very shallow	0-15	54	0	73	0	58
	Shallow	15-50	10	18	14	51	11
	Deep	50-150	4	5	0	3	1
	Very deep	>150/absent	31	77	14	46	29
Depth to Restrictive Layer (cm)	Very shallow	0 - 15	55	14	68	51	48
	Shallow	15 - 50	24	11	23	3	30
	Deep	50-150	3	2	0	0	2
	Very deep	>150	18	73	9	46	21
Electrical Conductivity (dS/m)	Strongly saline	≥16	1	0	0	0	0
	Moderately saline	8-16	0	0	2	4	3
	Slightly saline	4-8	1	0	17	7	1
	Very slightly saline	2-4	4	13	2	6	7
	Non saline	0-2	93	88	80	83	90
Organic Matter (%)	Low	0-0.5	35	32	62	64	60
	Medium	0.5-1.0	30	18	21	19	20
	High	>1.0	29	27	12	9	6
	Undetermined	—	5	23	5	9	15
pH	Poor	<6.0/>8.4	3	0	0	0	0
	Fair	7.9-8.4	43	80	62	62	56
	Good	7.4-7.8	33	16	29	28	35
	Optimal	6.1-7.3	21	4	9	10	9
Sodium Adsorption Ratio (proportion of Na to Ca + Mg)	Very high	>12	2	0	0	0	1
	High	6-12	5	54	68	17	8
	Medium	3-6	5	0	23	0	4
	Low	0-3	87	46	0	83	87
Texture	poor	sand, loamy sand	4	5	11	22	11
	fair	non-loamy & non-sandy	46	29	47	54	33
	good	loamy	51	66	42	25	56
Rock Fragments (%)	Not rocky	0 - 15 %	56	61	33	42	31
	Rocky	15 - 35 %	31	27	42	26	36
	Very rocky	35 - 60 %	8	9	9	14	18
	Extremely rocky	> 60 %	5	4	15	17	15
Aspect (degrees)	N	337.5-22.5	19	29	10	17	18
	NE	22.5-67.5	13	7	3	9	6
	E	67.5-112.5	12	5	10	10	12
	SE	112.5-157.5	10	4	13	22	10
	S	157.5-202.5	10	2	16	12	12
	SW	202.5-247.5	11	11	23	14	11
	W	247.5-292.5	11	18	12	7	15
	NW	292.5-337.5	14	25	13	9	16
Slope (%)	Flat	0	8	18	1	1	4
	Very low	0-2	23	41	29	13	24
	Low	2-5	23	30	39	22	39
	Medium	5-8	10	9	20	16	16
	High	8-11	6	0	0	19	8
	Very high	>11	30	2	10	29	9

Model of Agricultural Soil Quality in the Vicinity of AZ EE:2:51(ASM)



Substantial areas of prime farmland and soils with more than 35 percent rock fragments occur in the immediate vicinity of the Mescal Wash site (AZ EE:2:51 ASM). These data suggest that local farmers could have used a mix of rock mulch, runoff, and floodwater agriculture along Mescal Wash and Cienega Creek. Prime farmland, however, is more restricted than along larger drainages, such as the Santa Cruz River in the Tucson Basin.

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