

Soil Morphology of Canopy and Intercanopy Sites in a Piñon-Juniper Woodland

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ABSTRACT

Piñon (*Pinus edulis* Engelm.)-juniper [*Juniperus monosperma* (Engelm.) Sarg.] woodlands in the semiarid western USA have expanded as much as fivefold during the last 150 yr, often accompanied by losses of understory vegetation and increasing soil erosion. We conducted this study to determine the differences in soil morphology between canopy and intercanopy locations within a piñon-juniper woodland with uniform parent material, topography, and climate. The woodland studied, located near Los Alamos, NM, has a mean tree age of 135 yr. We examined soil morphology by augering 135 profiles in a square grid pattern and comparing soils under piñon and juniper canopies with intercanopy soils. Only two of the 17 morphological properties compared showed significant differences. The B horizons make up a slightly greater proportion of total profile thickness in intercanopy soils, and there are higher percentages of coarse fragments in the lower portions of canopy soil profiles. Canopy soils have lower mean pH and higher mean organic C than intercanopy soils. Regression analysis showed that most soil properties did not closely correspond with tree size, but total soil thickness and B horizon thickness are significantly greater under the largest piñon trees, and soil reaction is lower under the largest juniper trees. Our findings suggest that during the period in which piñon-juniper woodlands have been expanding, the trees have had only minor effects on soil morphology.

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Abbreviations: ANOVA, analysis of variance; CV, coefficient of variation; OC, organic carbon.

PIÑON-JUNIPER WOODLANDS have undergone remarkable increases (as much as fivefold) in both distribution and density during about the last 150 yr, and currently occupy some 20 to 30 million ha throughout the western USA (Miller and Wigand, 1994). Accelerated erosion has accompanied this expansion into grasslands, forests, and shrub-steppes (Burkhardt and Tisdale, 1976; Wilcox et al., 1996), and even existing piñon-juniper woodlands have experienced increasing rates of erosion in the last century (Carrara and Carroll, 1979). The dramatic expansion and accompanying erosion of these woodlands has raised serious questions of how piñon and juniper trees affect the physical and chemical properties of soils. These questions ultimately are related to issues of sustainable use of these important semiarid ecosystems.

Semiarid woodlands and shrublands, including piñon-juniper woodlands, usually consist of a mosaic of tree canopies separated by open intercanopy areas. Chemical differences between canopy and intercanopy soils have been well documented in piñon-juniper woodlands and

through leaf- and litter-fall, thereby creating "islands" of elevated soil fertility. These differences, combined with use of intercanopy soil water by trees (Breshears, 1993; Breshears et al., 1994), have been shown to affect the density of intercanopy vegetation (Pieper, 1990) to the point that ground cover can be severely reduced, possibly causing initiation or acceleration of erosion.

Several environmental conditions that are expected to influence the development of soil morphology (Jenny, 1941) are typically quite different for canopy and intercanopy patches. For example, intercanopy patches receive more direct solar radiation (Rich et al., 1993; Lin et al., 1992; Breshears et al., 1995), and soil temperatures are generally higher and more temporally variable than under canopies (Johnsen, 1962; Burkhardt and Tisdale, 1976). Woody canopies intercept incoming precipitation, thereby reducing inputs of moisture to soils under canopies (Breshears, 1993; Breshears et al., 1995). Deposition of plant litter under canopies adds organic matter and nutrients, and can protect the soil from runoff and erosion. Canopies also tend to intercept and collect eolian dust to a greater extent than intercanopy areas (Barth, 1980; Klopatek, 1986). Due to the presence of trees or shrubs, then, we might reasonably expect to see changes in mineral weathering, translocation of clay and silt, precipitation or dissolution of carbonates and other secondary minerals, and deposition of loess. All of these changes could have profound impacts on soil morphology as well as soil chemistry.

Despite the demonstrated chemical changes brought on by the establishment and growth of piñon and juniper, and the clear potential for physical changes that could increase erosion, few studies have examined the morphology of soils associated with these trees. Barth (1980) and Klopatek (1986) found that A horizons of soils under tree canopies were lower in clay content and higher in sand content than those in shrub-dominated intercanopy areas, and attributed the differences to enhanced accumulation of eolian material beneath the canopies. Klopatek (1986) reported lower bulk densities and higher water-holding capacities under canopies at three sites in piñon-juniper woodlands of northern Arizona. McDaniel and Graham (1992) found differences in soil color and root density between canopy and intercanopy zones of piñon-juniper woodlands in Utah. They also found higher concentrations of coarse fragments in the A horizons of intercanopy soils and attributed these to preferential removal of fine soil particles by erosion. All of these studies provide valuable information, and point to significant physical impacts on soils, but are somewhat limited in terms of both the number of morphological properties analyzed and the number of profiles examined. In addition,

areas have experienced piñon and juniper expansion with little or no accompanying erosion. Increases in piñon and juniper do not inevitably lead to soil erosion or other forms of land degradation (Belsky, 1996). The reasons for erosion where it is happening in piñon-juniper woodlands are unclear. Possible causes include tree-induced morphological changes leading to increased erodibility, reductions in stabilizing intercanopy-understory vegetation through competitive or allelopathic interactions, overgrazing, and other land use factors. We sought to answer the question of whether changes in soil morphology, other than those caused by erosion, are brought about by the presence of trees.

To effectively determine whether any observed morphological changes were caused by piñon and juniper trees, the study site should be selected to eliminate other potential causes of change to the greatest extent possible. The ideal study site should have uniform parent material, topography, and soil age. The site should not have a history of recent livestock grazing, significant fires or other disturbance. Soil erosion should be minimal, and there should be clearly defined open areas between tree canopies.

We selected a piñon-juniper woodland site on Mesita del Buey near Los Alamos, NM, at which the ideal conditions mentioned above appear to be closely approximated. Casual observations at this site suggested that the presence of trees does influence soil morphology. The soil surfaces under canopies of both piñon and juniper are commonly higher topographically than those in neighboring intercanopy areas, suggesting eolian accumulation under trees, greater erosion of intercanopy areas, or both. In addition, limited observations of soils in trenches suggested a relationship between tree canopies, tree species, and soil morphology. Specifically, it appeared that soils beneath juniper canopies are shallower, are less well developed, have lower clay contents, and show less distinct horizonation than those beneath piñon canopies or in intercanopy areas.

In order to investigate whether piñon and juniper trees effect significant changes in soil morphology, we examined the soil morphology of canopy and intercanopy zones of the Mesita del Buey piñon-juniper woodland. Our working hypotheses were: (i) soils are deeper under canopies, because of loess and litter accumulations; (ii) canopy soils have thicker A horizons, for the same reasons; (iii) canopy soils have lower soil reaction due to dissolution of CaCO_3 under lower pH conditions; (iv) canopy soils have thinner and fewer Bt horizons, because lower soil moisture and infiltration in canopy soils reduces weathering and clay translocation rates; (v) the magnitude of the differences between canopy and intercanopy profiles increases with tree size and tree age.

MATERIALS AND METHODS

Study Area

The study area is located within the Los Alamos National Laboratory Environmental Research Park in northern New Mexico (Fig. 1). The site is atop a narrow mesa at an elevation of 2133 m and has a semiarid, temperate mountain climate,

receiving about 360 mm of precipitation yearly (Bowen, 1990). Vegetation consists primarily of Colorado piñon pine and one-seed juniper, with an understory community composed of mixed grasses (predominantly blue grama [*Bouteloua gracilis* Lag.]), annual forbs, and cryptogamic crusts. Tree canopy covers 50% of the study area, piñons accounting for 35% and junipers for 15% (Padien and Lajtha, 1992).

The soils of the study area developed in Bandelier Tuff derived residuum and alluvium. The Bandelier Tuff is rhyolitic in composition, with a loamy sand particle-size distribution (Davenport et al., 1995). The soil surface has a southeast aspect and a general slope of about 4%.

This area is well suited for testing the influence of trees on soil properties. The parent material consists of a single geologic unit, so parent material characteristics should be virtually uniform. In addition, the small size and mesa-top setting of the study area should ensure homogeneity of climate, topography (geomorphic position), and soil age. In other words, we can reasonably assume that all of the major soil-forming factors (Jenny, 1941) except vegetation (the factor of interest) are constant across the study area. In addition, the site has been documented to be experiencing relatively little erosion (Wilcox, 1994), despite significant patches of bare soil. This ensures that erosion has had little differential effect on soil morphology between canopy and intercanopy sites. There is no evidence of major fires, livestock grazing, or other disturbance in the study area.

Methods

Soils were sampled on a 120 by 120 m grid (1.44 ha) with sample points every 10 m, for a total of 144 points. Nine points fell in disturbed areas, including access roads or ditches, and were discarded, leaving 135 points to be used in analyses. Site characteristics were recorded for a 1-m² area centered on each point, and included slope and visual estimates of percentage and type of ground cover (grass, cryptogams, tree litter, bare ground). Each sampled area was placed in one of three categories on the basis of vegetation type: piñon canopy, juniper canopy, or intercanopy. Five points fell beneath overlapping piñon and juniper canopies; these were not included in the analyses because of their small number and because they could not be clearly categorized with respect to canopy type.

Soils were described in the field, using samples obtained by hand augering in 10-cm increments to the depth at which unweathered massive tuff was encountered. Data recorded at each sampling point included, for each soil horizon, the following: depth, texture (field estimate), moist Munsell color, moist consistence, degree of reaction to dilute HCl, coarse fragments (estimated percentage by volume), and any unusual or distinguishing characteristics. These data were obtained for a total of 640 horizons. Soils were classified according to Soil Survey Staff (1992). Separate indices were calculated for the texture, color, and reaction of each profile, using methods similar to those of Harden (1982), Meixner and Singer (1981), and Bilzi and Ciolkosz (1977). For each horizon in a profile, the value of each property was compared with that for the assumed parent material (unweathered Bandelier tuff). The differences for all horizons in a profile were then summed, and the sums were normalized to eliminate differences resulting from variations in profile thickness. The indices are a rough measure of the degree of soil development, larger values indicating more change from the initial (parent material) condition.

Samples for laboratory analysis were collected at roughly 10-cm depth intervals from auger holes in eight profiles, two from piñon canopy areas, two from juniper canopy areas, and

four from intercanopy areas. These samples (43 total) were air dried, sieved to obtain the <2-mm fraction, and analyzed for particle-size distribution (by hydrometer), OC content (by chromic acid digestion [Nelson and Sommers, 1982]), pH (using saturated pastes), and electrical conductivity (using saturated paste extracts [U.S. Salinity Laboratory Staff, 1954]). These analyses were performed as a means of comparing, at least qualitatively, our soils with those reported by other researchers.

Statistical analysis included comparison of means using one-way ANOVA, using Fisher's protected least significant difference with $\alpha = 0.05$ (Snedecor and Cochran, 1980). Separate ANOVAs were performed using two treatments (canopy and intercanopy) and three treatments (piñon canopy, juniper canopy, and intercanopy). Regression analyses were performed using Kaleidagraph data analysis software (Synergy Software, Reading, PA).

RESULTS

Vegetation

On the basis of results from the 135 points analyzed in this study, we estimated that tree canopy covers 45% of our 1.4-ha study area. Piñons accounted for 69% of the canopy points, junipers for 25%, and overlapping piñon and juniper for 6%. Ground cover, including live vegetation, rocks, and debris, averaged 48% at intercanopy points. Vegetation in intercanopy areas consists mainly of blue grama and cryptogams, with scattered annual forbs and cacti. Ground cover under tree canopies consisted mainly of tree litter.

The piñon trees have basal trunk diameters ranging from 4 to 50 cm, with a mean of 25 cm (CV = 42%). Most of the junipers have multiple trunks; the effective diameter of all trunks combined range from 10 to 101 cm in diameter, with a mean of 42 cm (CV = 57%). Using tree-ring data obtained previously (Mark Fulton, 1992, unpublished data) from a subset of trees within the study area, we were able to show a reasonably strong relationship between piñon trunk diameter and number of rings, an index of tree age (Fig. 2). On the basis of this relationship, we estimated that the piñon trees in our study range in age from about 50 to >230 yr in age, with a mean age of about 135 yr. The mean age shows that this woodland was established within the approximate period when piñon and juniper were experiencing major expansions across the western USA (Miller and Wigand, 1994). Age estimates of junipers are problematic because of multiple trunks and numerous false rings; for this reason we did not attempt to determine juniper ages. We assumed, however, that the effective trunk diameter increases with age, and that the largest junipers are the oldest.

Soil Morphology

Most of the soils at the study site fall into two major categories. Fifty-five percent of the soils are Typic Haplustalfs, and 34% are Typic Ustochrepts (Soil Survey Staff, 1992). Also present, at 5% or less each, are Lithic Haplustalfs, Lithic Ustochrepts, Typic Paleustalfs, and Typic Ustorthents. Table 1 presents descriptive statistics

for soil properties of the two dominant types. The distinguishing characteristic between the two is the presence or absence of an argillic horizon, whereas they are very similar with respect to total thickness and horizon thicknesses.

Only two of the morphological properties we measured are significantly different between canopy and intercanopy locations (Table 2). One is a greater B horizon thickness in the intercanopy (when the B horizon is expressed as a percentage of the total soil thickness). The second is a greater percentage of coarse (>2-mm) fragments in canopy soils. Each of these differences is significant in the two-treatment ANOVA (canopy vs. intercanopy; Table 2), but not in the three-treatment ANOVA (intercanopy vs. piñon vs. juniper; Table 3). The Bt horizons are present in 64% of the profiles examined, Bw (cambic) horizons in 34%, and a transitional BC horizon in only 2%. When the profiles are separated by cover type, the piñon canopy and the intercanopy soils show distributions of Bt and Bw horizons very similar to the overall distribution: piñon canopy = 68% Bt, 28% Bw, 4% BC; and intercanopy = 67% Bt, 33% Bw. The juniper canopy soils show a different distribution: 48% Bt and 52% Bw horizons, indicating that soils under juniper trees are less well developed and have a tendency toward lower clay contents. Although the distribution for juniper is not significantly different from those for piñon and intercanopy ($P = 0.14$), it is consistent with our observation, from soil trenches, that juniper canopy soils are shallower and show a lesser degree of development than either piñon canopy or intercanopy soils.

It is interesting that soil depth does not differ significantly between canopy and intercanopy locations, considering the wide range of depths observed — from 33 to 125 cm — and that soils as little as 10 m apart vary in thickness by as much as 55 cm. As previously mentioned, mounding was observed under some trees, but this phenomenon clearly does not account for the enormous variations in soil thickness. A factor that may explain some of the variability is vertical offsets of as much as 25 cm across fractures in the tuff bedrock. Observations in trenches showed that these offsets produce abrupt lateral changes in soil depth. The origin of these offset fractures is not clear, but they may be associated with movement on minor faults in the area (Gardner and House, 1987). In any case, our observations in trenches indicated that the offsets do not account for the variation in soil thickness in all locations.

The A horizon thicknesses, surprisingly, are not significantly greater under canopies. Similarly, color indices show that A horizons are not significantly darker under canopies than in intercanopy soils. Many of the canopy soils include a thin (2–4 cm) O horizon, however, confirming the fact that tree litter is being added to the soil.

A few of the soil properties measured vary with trunk diameter of piñons and effective trunk diameter of junipers. Regression analysis shows that A horizon thickness is positively correlated with the trunk diameter of piñons ($r^2 = 0.19$, $P = 0.01$), but not with that of junipers ($r^2 = 0.07$, $P = 0.77$). No other significant relationships

were indicated by regression analysis, but analysis of variance yielded a further piece of information: when each tree species is separated into two size classes by median trunk diameter, both total soil thickness and B horizon thickness are greater for soils under large piñons, and soil reaction (carbonate content) is lower in soils under large junipers (Table 4).

Soil Chemistry

Soil chemical properties correlate with cover type at the most general level of comparison (canopy vs. intercanopy, Table 2), but not at the more specific level of juniper canopy vs. piñon canopy vs. intercanopy (Table 3). Mean soil pH is lower in canopy areas, although this is largely a surface effect, with generally lower values in the upper 15 cm (mean = 6.5, minimum 5.4) of canopy soils. At depth, pH values for all soils analyzed converge near 8.0. Depth trends for pH in piñon and juniper canopy sites and grassy and bare intercanopy sites are shown in Fig. 3. Both mean OC content and electrical conductivity are higher in canopy soils, also largely reflecting elevated levels in the upper 15 cm. Depth trends for OC are shown in Fig. 4 (electrical conductivity was analyzed only in the upper 10 cm). The lowest levels of OC were found in bare intercanopy soils, and grassy intercanopy sites are intermediate between bare sites and canopy sites.

DISCUSSION

Our data show that few of the soil morphological properties measured are significantly different between canopy and intercanopy sites in the piñon-juniper woodland study site. Of our initial hypotheses, only that predicting fewer and thinner Bt horizons in canopy soils (Hypothesis iv) is supported by our data. Comparisons of soils under large and small trees suggests that total soil thickness and soil reaction begin to show significant differences within about 135 yr of tree establishment. These findings tend to support our Hypotheses i, iii, and iv. Soils thicken with time under piñon canopies, probably because of trapping ofolian material and continual additions of tree litter to the A horizons. The additions of tree litter also tend to acidify the soil, reducing the soil reaction as seen under the large junipers.

Surprisingly, total soil thickness does not vary significantly between canopy and intercanopy soils, contrary to our expectations prior to the study (Hypothesis i). It is possible that our initial expectations were biased by observations of the sometimes large topographic variations between adjacent canopy and intercanopy areas. A different approach to the study, in which canopy soils were compared only with adjacent intercanopy soils, might yield significant differences in soil thickness.

The slightly increased relative thickness of B horizons in intercanopy soils could be related to differences in water budgets between canopy and intercanopy areas caused by canopy interception of precipitation, which significantly reduces the input of moisture to canopy soils (Breshears et al., 1995). This reduction in water

movement into and through the soil could slow the processes of weathering and translocation of clay, thus decreasing Bt horizon development. This mechanism is apparently contradicted, however, by the fact that soils under the larger half of the piñon population have thicker B horizons than soils under the smaller half. It is possible that the trees have not influenced the B horizon thickness, but that the nature and thickness of the B horizons have influenced the establishment and survival of trees (Burkhardt and Tisdale, 1969, 1976; Pieper, 1993).

We expected to find thicker A horizons in canopy soils (Hypothesis ii), but did not. The presence of O horizons in many canopy soils confirms that tree litter is being added to the soil surface. This is a significant qualitative difference between canopy and intercanopy soils, and one that would have been statistically significant had we chosen to perform an ANOVA with O horizon thickness as the factor of interest (intercanopy O horizon thickness = 0, with variance = 0). In the period in which trees have been growing in their present locations, however, the addition of organic litter has apparently not translated into thicker A horizons in canopy soils. Our data suggest that such a change should take longer than an average of 135 yr in this semiarid climate.

The higher percentage of coarse fragments in canopy soils is attributable to the disruption of bedrock by the growth of tree roots. This is a reasonable explanation in this case, because we found differences in the coarse fragment concentrations in the lower soil horizons only and virtually no coarse fragments in surface horizons.

The chemical differences we observed between canopy and intercanopy are consistent with reports by other workers. Soil pH is lower under canopies, probably due to additions of organic acids through tree litter decomposition. Organic C contents are higher under canopies, also because of additions of plant litter to the soil.

We have shown that morphological differences between canopy and intercanopy soils (exclusive of erosion-induced differences) are minor in a woodland with an average tree age of about 135 yr. This is an important finding because roughly half the piñon-juniper woodlands in the USA were established in about the last 150 yr (Tausch et al., 1981; West and Van Pelt, 1986). Previous reports indicate that piñons and junipers extract nutrients and moisture from intercanopy soils (Barth, 1980; McDaniel and Graham, 1992; Breshears, 1993; Breshears et al., 1994), and this may limit growth of understory-intercanopy vegetation, contributing to increasing heterogeneity of soil resources. This heterogeneity is likely to be more pronounced on shallower soils where piñon and juniper use a greater portion (or all) of the available soil water, excluding intercanopy vegetation entirely. Soil resource heterogeneity is cited by Schlesinger et al. (1990) as part of a feedback mechanism that is likely to lead to degradation and even desertification of semiarid regions. Our findings suggest that, on the time scale that encompasses much of the piñon-juniper woodland expansion in the western USA, tree-induced heterogeneity in soil morphology is minimal and, alone, is not a significant factor in initiating or controlling soil erosion.

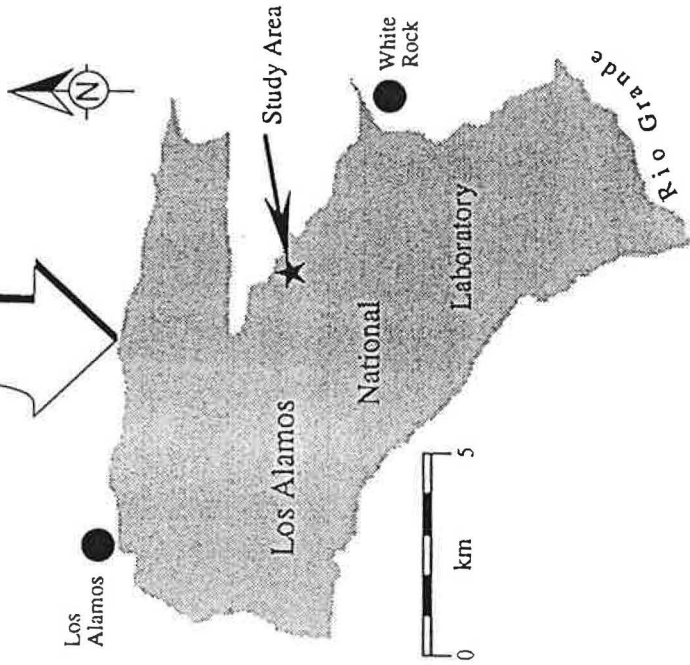
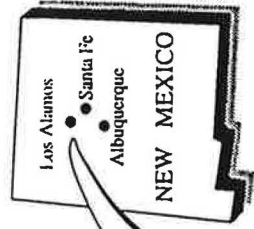
Thus, in the absence of accelerated erosion caused by other contributing factors such as competitive plant interactions or overgrazing, the physical impact of piñon and juniper on soil morphology should be negligible, and sustainable use of these woodlands may be possible.

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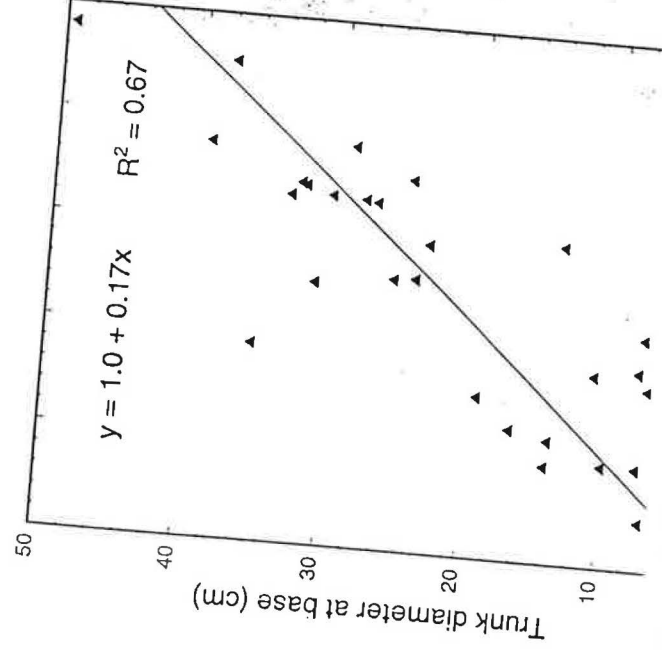
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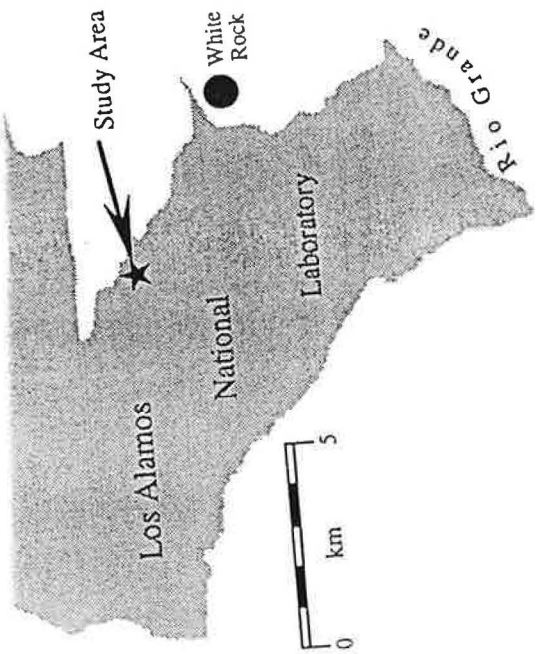
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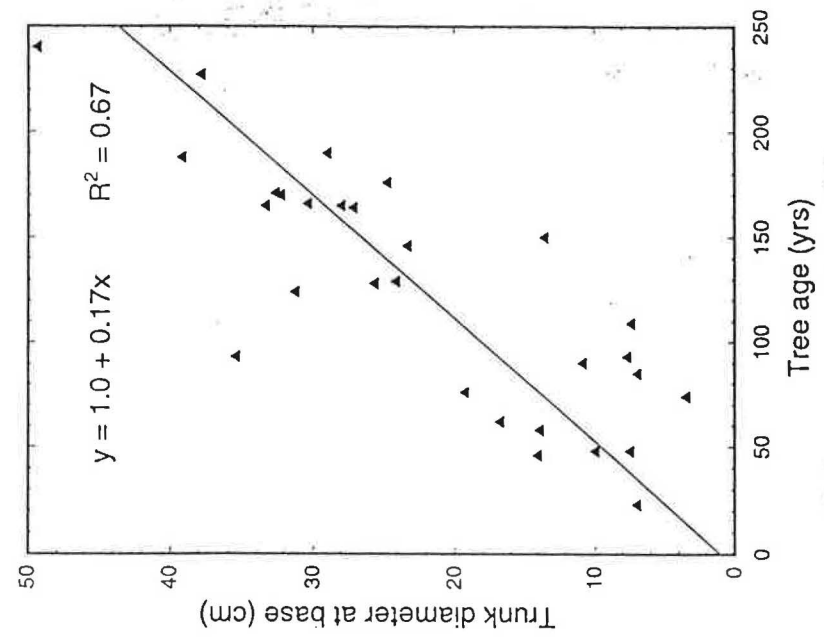


JOB NAME	SSAJ	VOLUME	60	NUMBER	6	MONTH	Nov-Dec	DENSITY		CHECKED BY	
AUTHOR	Davenport et al.	FIG #	1	FINAL WIDTH	10.5	FINAL HEIGHT	32	SCALE	70		
	S95-262(5)	1:1 B&W			20			LINE	X	HT	
		1:1 COLOR						LI	COMB		
										☐ APPROVED FOR PRESS	☐ SEND PICTURE

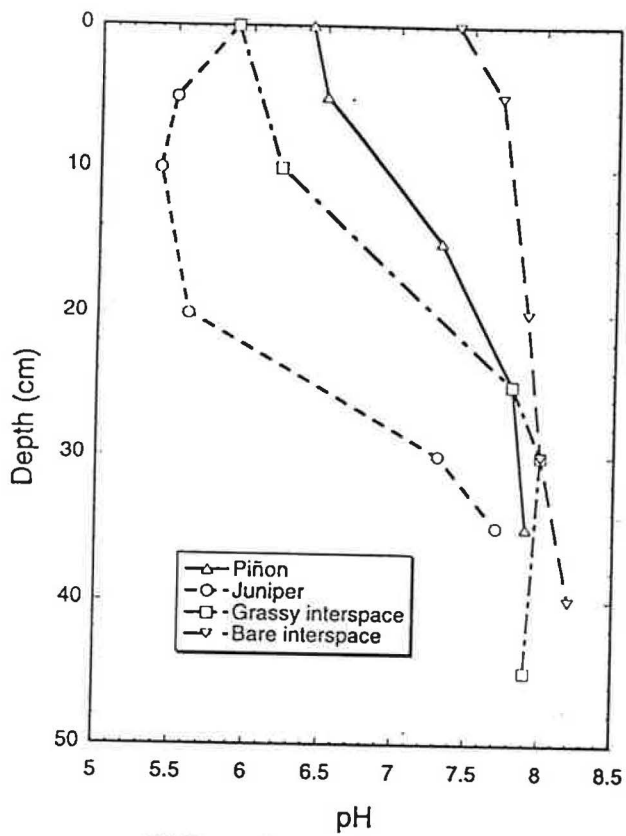




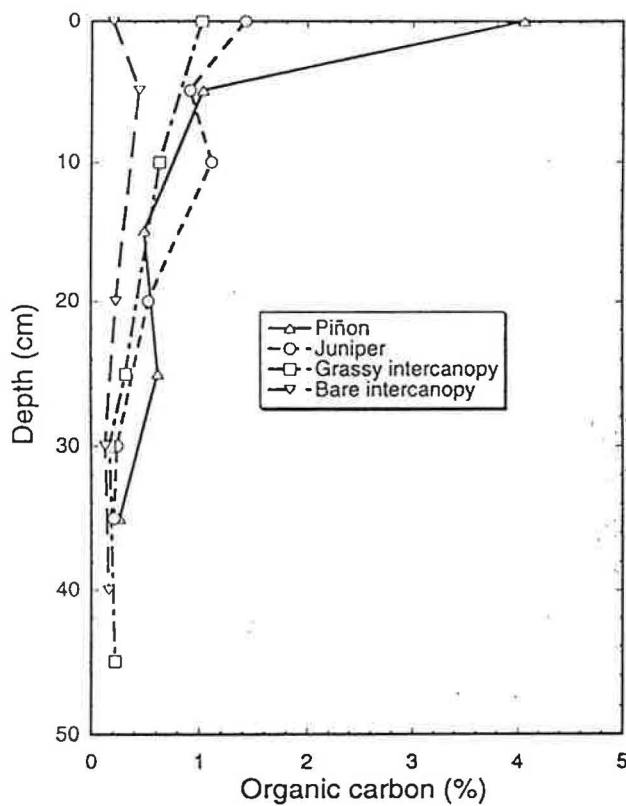
JOB NAME SSSAJ	VOLUME 1	NUMBER 60	MONTH 6	YEAR 1974	COPY#
AUTHOR Davenport et al.	FIG # 1	FINAL WIDTH 20	FINAL HEIGHT 32	SCALE 4x	DENSITY
595-262(5)		☐ APPROVED FOR PRESS ☐ SEND ME VISE ☐ ME VISE			



JOB NAME SSSAJ	VOLUME 2	NUMBER 60	MONTH 6	YEAR 1974	COPY#
AUTHOR Davenport et al.	FIG # 2	FINAL WIDTH 20	FINAL HEIGHT 32	SCALE 4x	DENSITY
595-263(5)		☐ APPROVED FOR PRESS ☐ SEND ME VISE ☐ ME VISE			



JOE NAME	SSSAJ	VOLUME	60	NUMBER	6	MONTH	Nov-Dec	YEAR	1964	CHECKED BY	
PROJECT	Drenpert et al	FIG. #	3	DATE	10/2	SCALE	1:1	DATE	1/4	DATE	
SYMBOL	545-262(s)	DATE	1964	DATE	25	DATE		DATE		DATE	
DATE		DATE		DATE		DATE		DATE		DATE	



JOE NAME	SSSAJ	VOLUME	60	NUMBER	6	MONTH	Nov-Dec	YEAR	1964	CHECKED BY	
PROJECT	Drenpert et al	FIG. #	4	DATE	10/2	SCALE	1:1	DATE	1/4	DATE	
SYMBOL	545-262(s)	DATE	1964	DATE	25	DATE		DATE		DATE	
DATE		DATE		DATE		DATE		DATE		DATE	

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SOIL SCIENCE — SOIL SCI. SOC. AM. J., VOL. 60, NOVEMBER-DECEMBER 1996
Miles 33 — Davenport
08-19-96 02:51:03

Table 1. Descriptive statistics for selected soil properties of Typic Haplustalfs and Typic Ustochrepts.†

Property	Mean	Median	Minimum	Maximum	CV, %†
cm					
Typic Haplustalfs (n = 74)					
Total soil thickness	83	85	54	120	19
A horizon thickness	10	10	5	20	49
Bt horizon thickness	27	25	7	70	46
Cr horizon thickness	47	48	0	95	44
Typic Ustochrepts (n = 46)					
Total soil thickness	79	80	51	125	25
A horizon thickness	9	8	3	30	85
Bw horizon thickness	24	23	0	62	47
Cr horizon thickness	47	47	14	80	42

† CV = coefficient of variation = (standard deviation/mean)100.

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Table 2. Selected mean physical and chemical properties of canopy and intercanopy soils; summary of one-way ANOVA with two treatments.

Property	Canopy	Intercanopy
Total soil thickness, cm	80	76
A horizon thickness, cm	9	9
A horizon thickness, % of total profile	11	12
B horizon thickness, cm	24	26
B horizon thickness, % of total profile	30	34*
Cr horizon thickness, cm	46	45
Cr horizon thickness, % of total profile	58	59
Texture index (normalized)†	0.55	0.57
Soil color index (normalized)‡	0.59	0.58
Surface elevation, cm§	320	303
Elevation of tuff, cm§	240	260
Coarse fragments, volume %¶	12	10*
Soil pH	6.9	7.4*
Organic C, g kg ⁻¹	25.1	5.6*
Electrical conductivity, dS m ⁻¹ ‡	0.48	0.24
Reaction index (normalized)#	0.34	0.29

* Significantly different at the 0.05 level.

† Higher value indicates greater textural change from parent material; maximum possible = 1.00.

‡ Higher value indicates greater color change from parent material; maximum possible = 1.00.

§ Relative to datum of 2162 m.

¶ Lowest horizons only.

Higher value reflects increasing CaCO₃ equivalent content; maximum possible = 1.00.

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08-16-96 14:34:22

Table 3. Selected mean physical and chemical properties of soils by cover type; summary of one-way ANOVA with three treatments.

Property	Intercanopy	Juniper Canopy	Piñon Canopy
Total soil thickness, cm	76	78	79

Ed: cm or under
cv column?

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Table 4. Selected physical properties of soils under large (upper 50 percentile trunk diameter) and small (lower 50 percentile trunk diameter) piñons and junipers.

Property	Piñon		Juniper	
	Small	Large	Small	Large
Total soil thickness, cm	74	86*	84	73
A horizon thickness, cm	9	10	13	9
B horizon thickness, cm	18	26*	21	27
C horizon thickness, cm	54	50	44	43
Coarse fragments, %†	11	11	13	10
Texture index (normalized)‡	0.6	0.6	0.5	0.5
Soil color index (normalized)§	0.6	0.6	0.6	0.6
Reaction index (normalized)¶	0.4	0.4	0.48	0.21*

* Significantly different at the 0.05 level.

† Lowest horizons only.

‡ Higher value indicates greater textural change from parent material; maximum possible = 1.00.

§ Higher value indicates greater color change from parent material; maximum possible = 1.00.

¶ Higher value reflects increasing CaCO₃ equivalent content; maximum possible = 1.00.