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ROOT DISTRIBUTION  
OF SOME NATIVE TREES AND UNDERSTORY PLANTS  
GROWING ON THREE SITES WITHIN PONDEROSA PINE WATERSHEDS  
IN COLORADO

by

Herbert W. Berndt and Robert D. Gibbons

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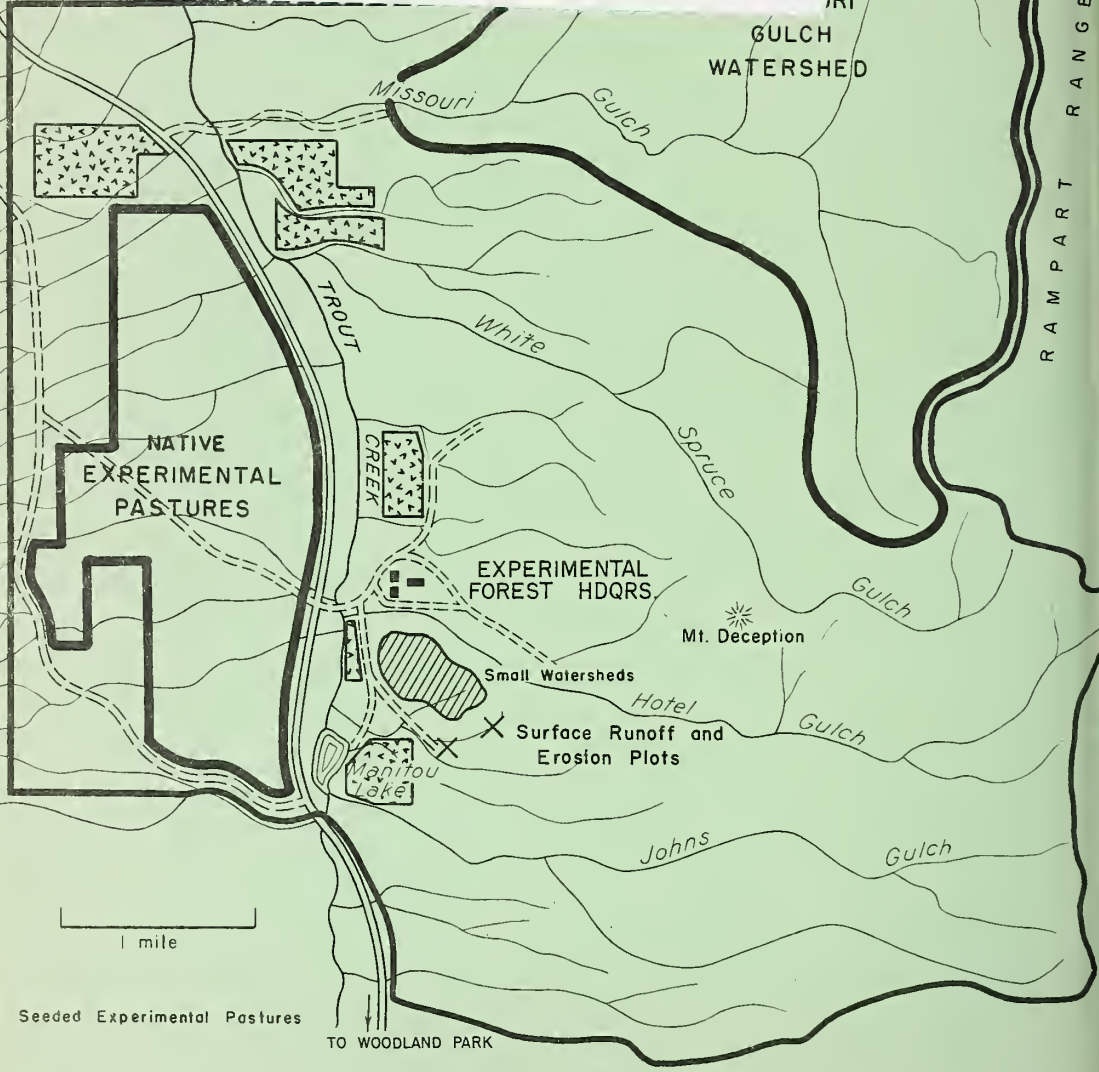
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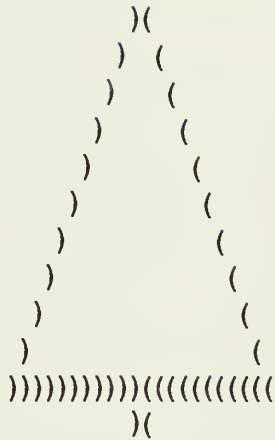
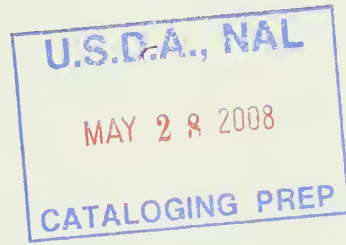
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by

Herbert W. Berndt and Robert D. Gibbons, Foresters



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INTRODUCTION

Knowledge of the depth and extent of plant root systems is basic to watershed management. From such knowledge it may be possible to select plants most useful for soil stabilization, flood control, or for minimum transpiration.

This report presents information on root distribution of eight native plant species studied at the Manitou Experimental Forest.

The experimental forest lies northwest of Colorado Springs, Colorado, on the west side of the Rampart Range, and has a forest of ponderosa pine, Douglas-fir, and aspen, with an understory of shrubs and grasses. Lodgepole and limber pine grow near the mountain crests. Base rock of the area is Pikes Peak granite, overlain by the three sedimentary formations: Sawatch quartzite, Madison limestone, and Fountain arkose. Residual soils have developed from weathering of the parent formations, and along the streams there are alluvial deposits derived mainly from granites.

METHODS OF STUDY

Root systems of eight species were examined at three study sites selected to represent three residual soils<sup>1/</sup> -- Edloe gravelly sandy loam, Chubbs stony loam, and skeletal soil from sandstone.<sup>2/</sup> Roots were exposed by digging back with hand tools from a trench excavated by a tractor-mounted back hoe. Species studied were:

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<sup>1/</sup> Soil names used are tentative and subject to final correlation.

<sup>2/</sup> These skeletal or lithosol soils have many characteristics of the Travessilla soils.

1. Lodgepole pine (Pinus contorta Dougl. )
2. Douglas-fir (Pseudotsuga menziesii (Mirb. ) Franco)
3. Quaking aspen (Populus tremuloides Michx. )
4. Ponderosa pine (Pinus ponderosa Laws. )
5. Mountainmahogany (Cercocarpus montanus Raf. )
6. Kinnikinnick (Arctostaphylos uva-ursi (L. ) Spreng. )
7. Arizona fescue (Festuca arizonica Vasey)
8. Mountain muhly (Muhlenbergia montana (Nutt. ) Hitchc. )

At each study site two trenches were dug - - one to observe tree roots and the other to study roots of understory species. Tops of the plants were removed, and root crowns were anchored to retain their positions throughout the hand digging (fig. 1). The exposed roots were sketched periodically as the digging progressed.



Figure 1. --Exposed root systems at Edloe gravelly sandy loam site.



Information gathered for each site included: (1) soil character and depth; (2) age and condition of tree species; (3) condition of understory species; and (4) length, depth, and configuration of root systems.

## RESULTS

Findings from each site are presented by means of drawings of root distributions, with a discussion of the individual root systems and a tabular comparison.

### EDLOE GRAVELLY SANDY LOAM

The single site for excavation of lodgepole pine was chosen at 9,300 feet elevation on a 15-percent northwest slope. A well-developed 2-inch needle litter covered the soil surface. The grayish-brown surface soil was a coarse, gravelly loam 8 inches deep. Fine clays were not noticeable in this layer. Subsoil exhibited no profile development. Parent material was a coarse gravel resulting from disintegration of granite bedrock from which the Edloe soils have developed. This layer was penetrable to a depth of 4 feet. Dense overstory consisted of lodgepole pine, with scattered aspen. Sparse understory was mainly kinnikinnick, with a few grasses.

The site where the other species were studied was at 8,400 feet elevation on a 25-percent north slope. The soil was similar to that described above. The surface layer was noticeably darker and the subsoil was unconsolidated gravels. Hard granite was found at 4.5 to 6 feet. Timber overstory was an open stand of ponderosa pine and Douglas-fir, with scattered aspen. Mountainmahogany occupied most openings. Dense understory was made up of kinnikinnick, low juniper (Juniperus communis L.), Arizona fescue, mountain muhly, and numerous annual forbs.

These extensive Edloe soils have only a weak profile development. Made up of only about 20 to 30 percent silt plus clay, they are, nevertheless, highly erosive. Relatively low fertility retards plant growth.

Root distribution of the species studied on the Edloe soil are shown in the figures that follow (figs. 2, 3, 4, 5, 6, 7). Grid scale equals 1 foot.

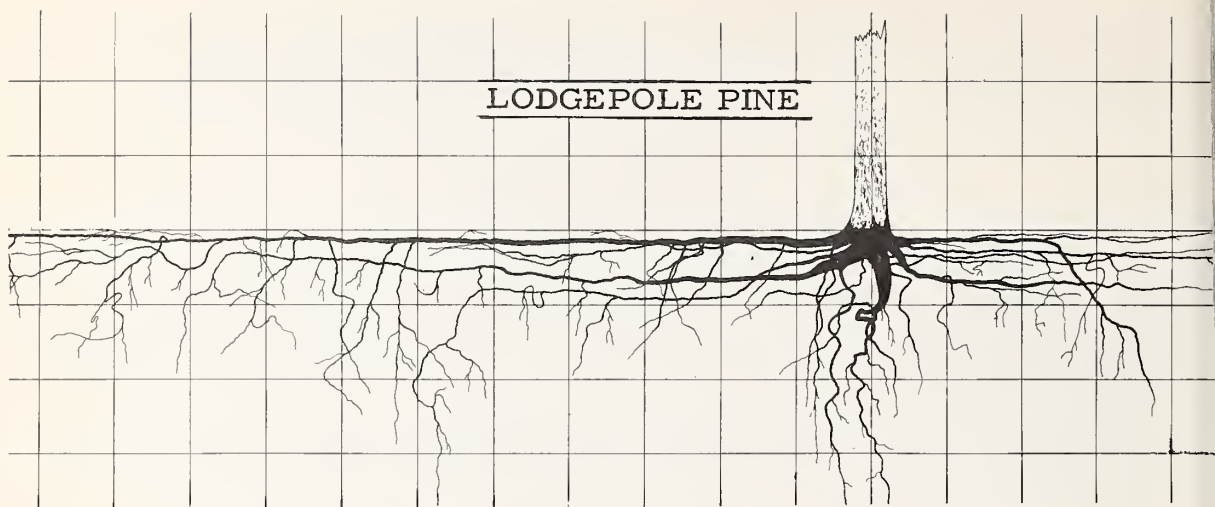


Figure 2. -- This root system is from a tree that was 90 years old, 23 feet high, and 5 inches d.b.h. Maximum root penetration was 4 feet and maximum lateral spread was 16 feet. Although roots frequently penetrated 4 feet, most of the system was in the upper 2 feet of soil. The main laterals branched frequently into feeder roots and formed a matlike system (see fig. 3).



Figure 3. -- View of exposed lodgepole pine roots, Edloe gravelly sandy loam.

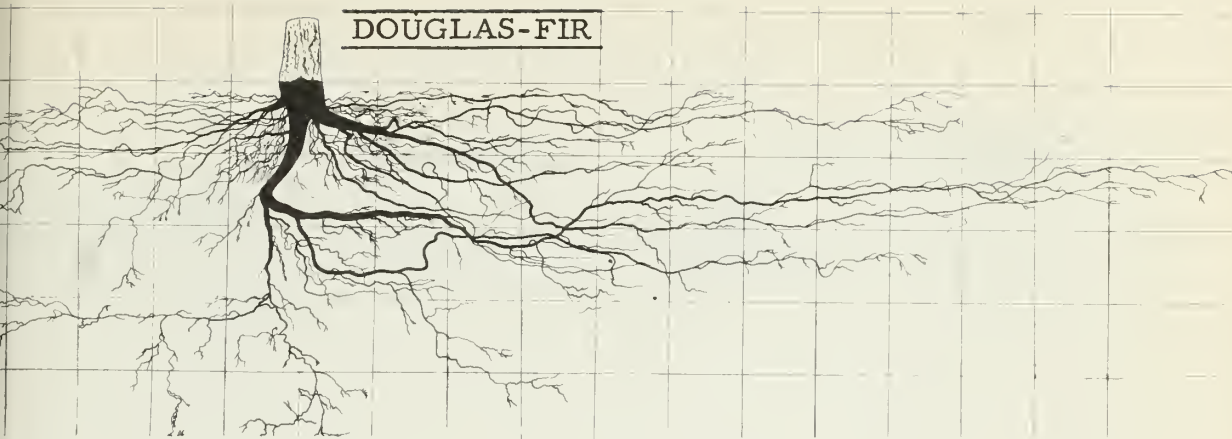


Figure 4. --This root system is from a tree that was 80 years old, 21 feet high, and 5.5 inches d. b. h. Maximum root penetration was 5 feet and maximum lateral spread was 13 feet. This root system had isolated concentrations of fine roots. None were more than 0.2 inch in diameter; many were 0.1 inch or less. The pit used to excavate this tree was oriented up and down the slope (see fig. 1). Most of the roots were downslope from the base of the tree.

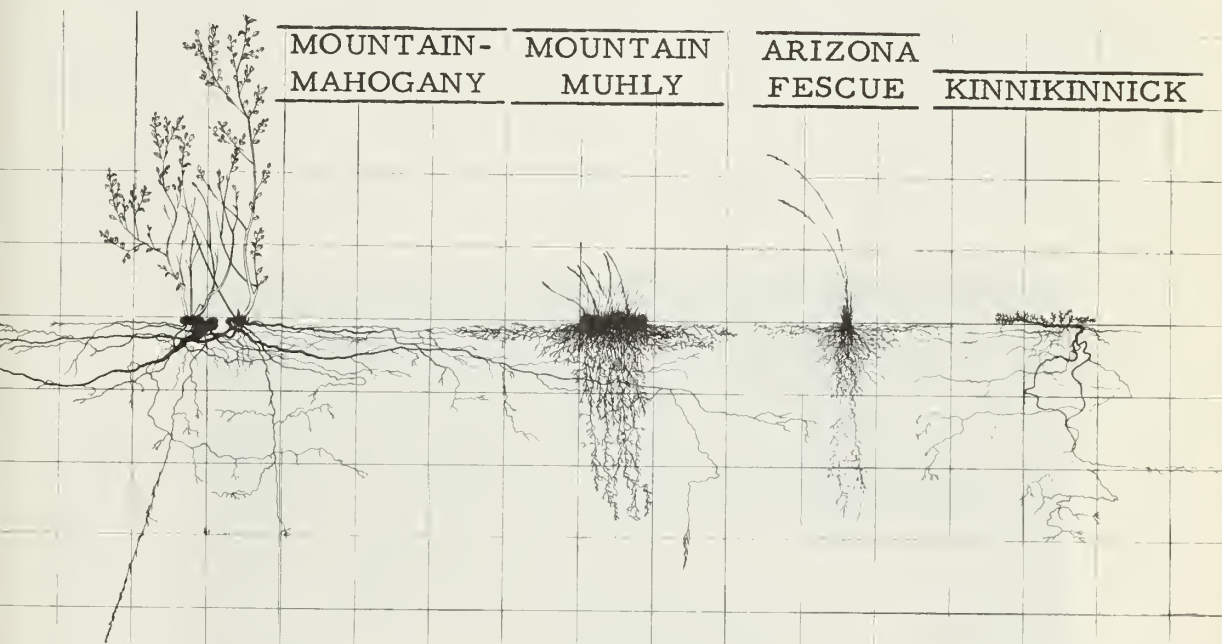


Figure 5. --The mountainmahogany, mountain muhly, and Arizona fescue root systems were from the same pit, while the kinnikinnick system was from a separate trench. The mountainmahogany was 4.5 feet high; maximum root penetration was 5 feet and maximum lateral spread was 8 feet. Mountain muhly had a fibrous root system consisting of 316 individual roots. The grass was 1 foot high, 10 inches in diameter, and its roots had a maximum penetration of 2.8 feet and a maximum lateral spread of 1.7 feet. Arizona fescue also had a fibrous root system, consisting of 290 individual roots. The grass was 2.3 feet high, 4 inches in diameter, and its roots had a maximum penetration of 2.8 feet and a maximum lateral spread of 1.5 feet. Only part of the root system of kinnikinnick was excavated. The main root was a meandering runner just below the surface of the soil. From this runner the plant sent aerial shoots upward and feeder roots downward. Plants forming a dense mat up to 7 feet in diameter were found. Conceivably, these plants could have originated from one rootstock.



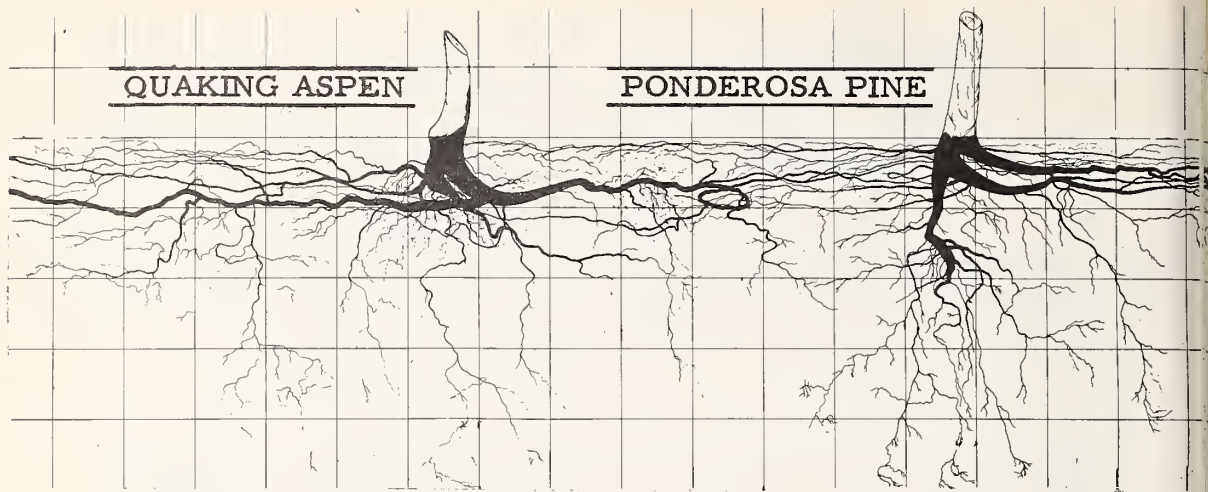


Figure 6. --These root systems were from the same pit as that of Douglas-fir (see fig. 4). The drawing shows the intertwining of the root systems. The aspen root system is from a tree 70 years old, 26 feet in height, and 4.5 inches d. b. h. Maximum root penetration was 5 feet and maximum lateral spread was 31 feet. These aspen roots were rather contorted, often changing direction without apparent cause. Concentrated masses of fine roots, similar to those found in Douglas-fir, were noted (see fig. 7). Root development was mainly downslope. The ponderosa pine was 85 years old, 19 feet high, and 4.5 inches d. b. h. Maximum root penetration was 5 feet and maximum lateral spread was 10 feet. The roots showed downslope development. No fine roots were found as in the systems of Douglas-fir and aspen, nor was the pine root system as finely branched.



Figure 7. --View of exposed aspen roots, illustrating concentrations of small roots and downslope development; Edloe gravelly sandy loam.



## CHUBBS STONY LOAM

The Chubbs stony loam site was selected on a 20-percent slope facing north at 7,800 feet elevation. This residual soil was developed from Madison limestone. Litter was 1 to 2 inches deep. The dark, reddish-brown surface soil, extending to a 10-inch depth, was a loose, stony loam. Horizon development was pronounced. Subsoil was a reddish-brown loam, lighter in color than the surface soil. Texture graded from a rather heavy clay loam near the top of the layer to a very stony loam near the bottom. Both layers contained great amounts of limestone rock. Parent material, lying 5 to 7 feet deep, consisted of fragmented limestone rock with fine soil material in the fissures.

The dense overstory was predominantly ponderosa pine, with scattered Douglas-fir and aspen. Mountainmahogany occurred in most openings. Dense understory consisted of kinnikinnick, mountain muhly, Arizona fescue, low juniper, and many annual forbs.

Chubbssoils developed from Madison limestone are calcareous, loose, and fertile. They have excellent moisture relations and good plant growth.<sup>3/</sup>

Root distribution of species studied on the Chubbs soil are shown in the figures that follow (figs. 8, 9, 10, 11, 12). Pits for this site were oriented across slopes; hence, no comparisons between upslope and downslope root development could be made. Grid scale equals 1 foot.

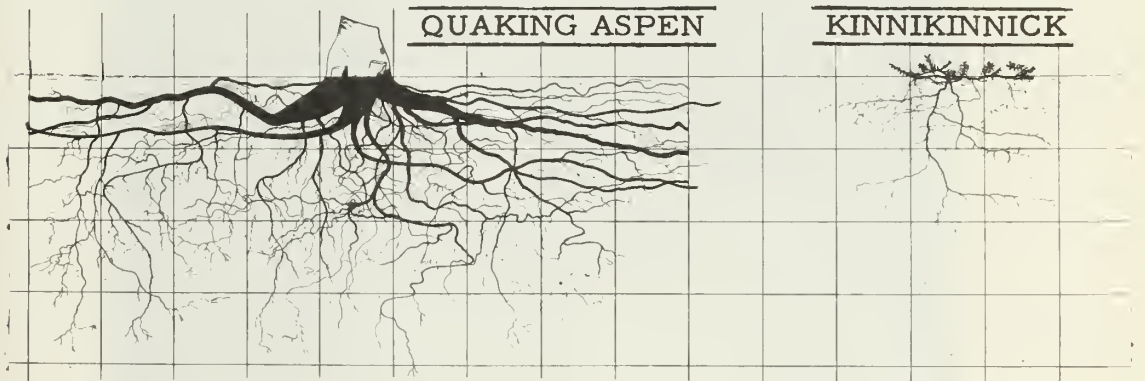


Figure 8. --This root system was from an aspen tree 97 years old, 38 feet high, and 8.5 inches d.b.h. The system was one of the more dense and widespread systems studied. Maximum penetration was 4.2 feet and maximum lateral spread was 48 feet. The small kinnikinnick plant had a root system that penetrated the soil to 2 feet and a lateral spread of 2.6 feet. Most of the roots were close to the surface.

<sup>3/</sup> Retzer, J. L. Soil and physical conditions of Manitou Experimental Forest. U. S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta. 1949. [Processed.]

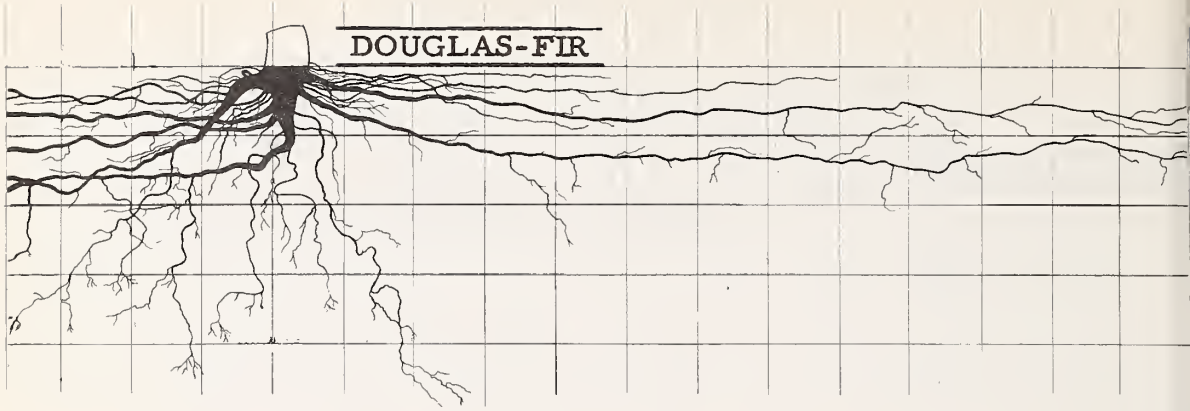


Figure 9. --This tree was 72 years old, 24 feet high, and 5 inches d. b. h. The root system had a maximum penetration of 4.8 feet, and a maximum lateral spread of 21 feet. The tree had a many-branched root system with several lateral roots originating from the root crown (see fig. 10).



Figure 10. --View of Douglas-fir roots, Chubbs stony loam.

PONDEROSA PINE

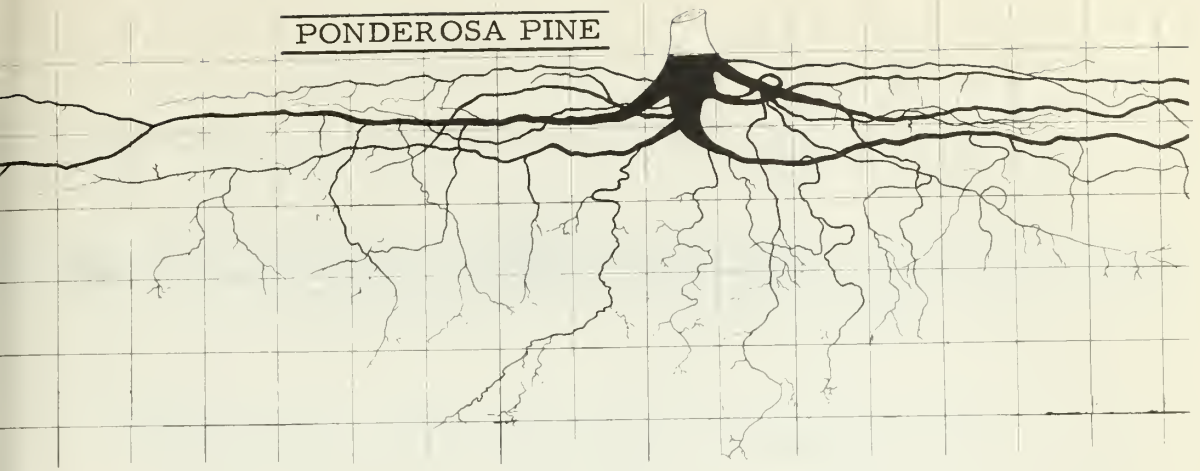


Figure 11. --This root system was from a tree that was 63 years old, 25 feet high, and 5 inches d. b. h. The system exhibited little branching and had a maximum penetration of 5.6 feet and a maximum lateral spread of 20 feet.

MOUNTAIN  
MUHLY

MOUNTAIN-  
MAHOGANY

ARIZONA  
FESCUE

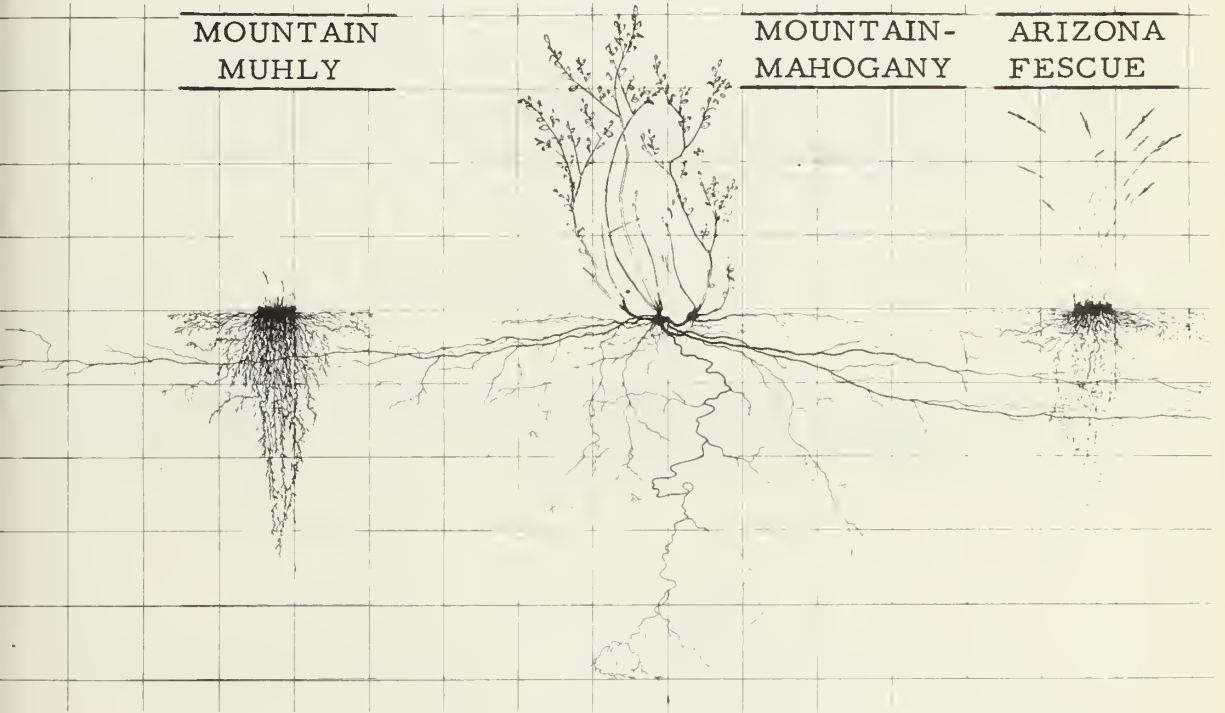


Figure 12. --The fibrous root system of mountain muhly consisted of 308 individual roots. The plant was 0.5 foot high and 6 inches in diameter. The maximum penetration of the roots was 3.4 feet and the maximum lateral spread was 1.3 feet. The mountainmahogany plant was 4 feet high. Its root system had a maximum penetration of 5 feet and a maximum lateral spread of 10 feet. The fibrous root system of Arizona fescue consisted of 780 individual roots. The plant was 2.7 feet high and 6 inches in diameter. Maximum penetration of its roots was 3.1 feet and maximum lateral spread was 1.7 feet. All three root systems were excavated from the same trench and the diagram shows the intertwining of the roots.



## SKELETAL SOIL FROM SANDSTONE

The site was located on a northwest exposure at 8,350 feet elevation. Slopes ranged from 7 to 14 percent. The surface soil was a loose, fine, gray sand resting directly on disintegrating sandstone. Topsoil depth varied from 4 to 6 inches. Parent rock was a hard, light gray sandstone in the Sawatch Formation, fractured into a massive block pattern.

Overstory was predominantly Douglas-fir, with scattered ponderosa pine and aspen. Dense stands of mountainmahogany occupied all openings. The sparse understory consisted of kinnikinnick, aspen root-suckers, low juniper, Arizona fescue, mountain muhly, and some low annuals.

These skeletal soils are little more than disintegrated parent rock and are of limited extent. Their fertility is extremely low.<sup>4/</sup>

Root distribution of plants studied on skeletal soils are shown in the figures that follow (figs. 13, 14, 15, 16, 17). All systems had roots that penetrated the shallow soil mass, trailed along the parent rock, and penetrated fissures. All root systems were contorted by the many barriers. Grid scale equals 1 foot.

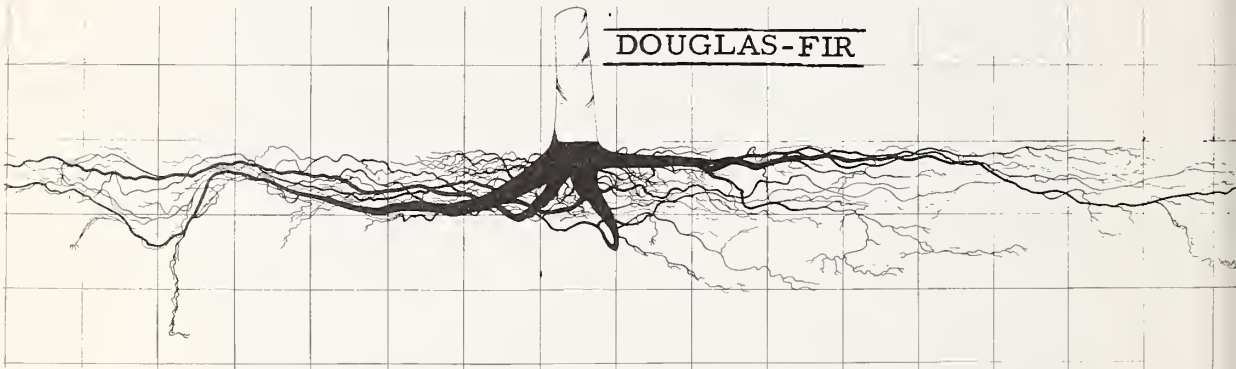


Figure 13. -- This tree was 60 years old, 22 feet high, and 4 inches d.b.h. Its root system had a maximum penetration of 2.7 feet and a maximum lateral spread of 10 feet.

<sup>4/</sup> Retzer, J. L. Soil and physical conditions of Manitou Experimental Forest. U. S. Forest Serv. Rocky Mountain Forest and Range Expt. Sta. 1949. [Processed.]



QUAKING ASPEN

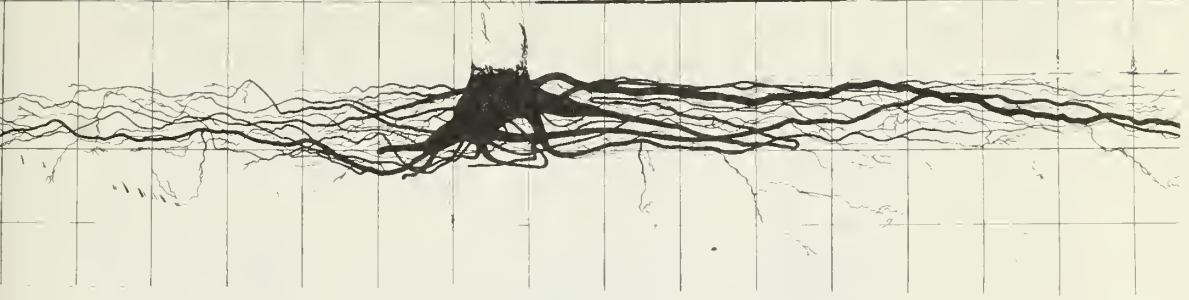


Figure 14. -- This root system was from a tree that was 110 years old, 22 feet high, and 7 inches d. b. h. Maximum penetration of the system was 2.4 feet and maximum lateral spread was 20 feet.

PONDEROSA PINE

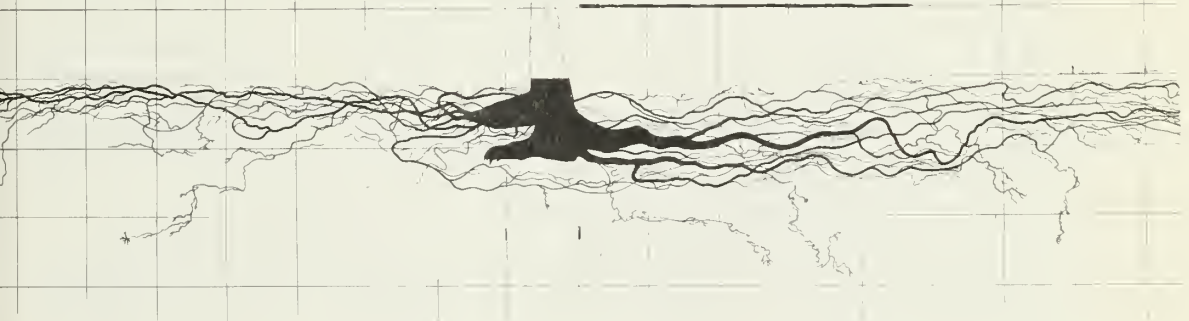


Figure 15. -- The pine tree was 75 years old, 19 feet high, and 5 inches d. b. h. Its root system had a maximum penetration of 2.8 feet and a maximum lateral spread of 19 feet. The tree was anchored by a tap root, penetrating a crevice to an undetermined depth (see cover photo).

KINNIKINNICK

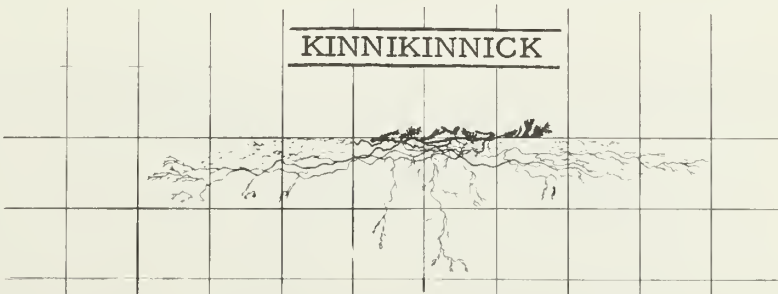


Figure 16. -- This plant had a very shallow root system with maximum penetration of 2 feet. Most of the roots were in the top 6 inches of soil, and many could be exposed by simply turning back the thin humus layer.

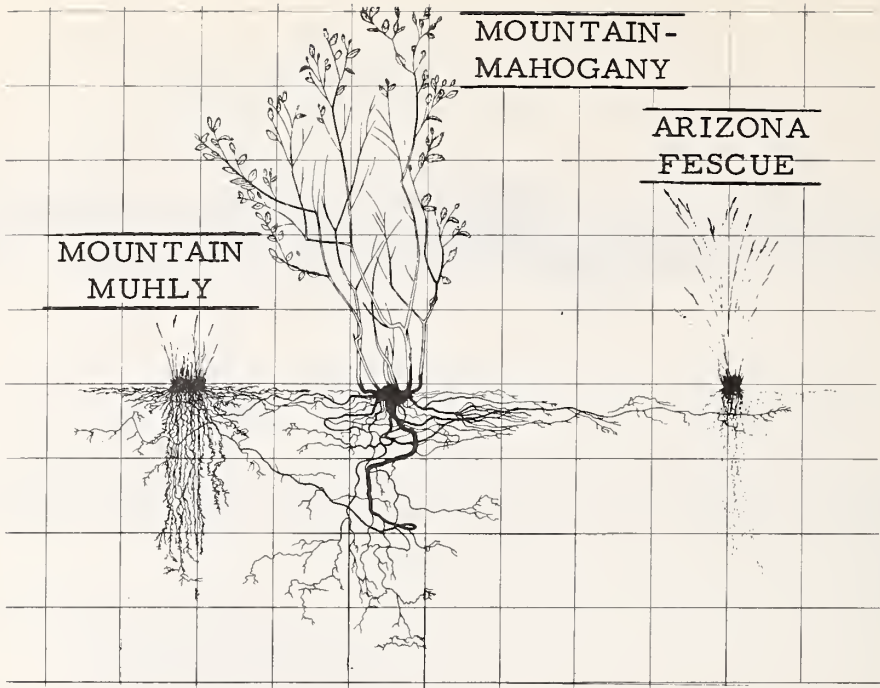


Figure 17. --The root systems of these three plants were excavated from the same trench and the diagram shows the intertwining of the roots. The mountain muhly plant was 0.9 foot high and 6 inches in diameter. Its roots penetrated to a maximum depth of 2.7 feet and had a maximum lateral spread of 1.3 feet. The fibrous root system consisted of 324 individual roots. The mountainmahogany plant was 5 feet high. Maximum penetration of the roots was 3.5 feet and the maximum lateral spread was 5 feet. The fibrous root system of Arizona fescue consisted of 308 individual roots. The plant was 2.6 feet high and 2.5 inches in diameter. Maximum penetration of its roots was 2.6 feet, and maximum lateral spread was 1.2 feet.

The three residual soils studied exhibited different characteristics and provided different sites for plant growth. In table 1, comparisons are made of the plants studied on the three soils. For the trees and shrubs, root penetration and lateral spread was least for the skeletal soil and about equal in depth for the Edloe and Chubbs soils, but of greater lateral spread in the Chubbs soil. Root penetration of the grass roots was about equal in the Edloe and skeletal soils, but of greater depth in the Chubbs soil. Lateral spread was greatest in the Edloe soil, somewhat less in the Chubbs soil, and least in the skeletal soil.

Table 1. --Comparisons of native plants studied on three soils of the Colorado Front Range

Species	: Age	: Height	: Diameter	: Maximum	: Maximum
	: Years	: Feet	: Inches	: root depth	: spread
				Feet	Feet
<u>E D L O E S O I L</u>					
Lodgepole pine	90	23	5	4	16
Douglas-fir	80	21	5.5	5	13
Aspen	70	26	4.5	5	31
Ponderosa pine	85	19	4.5	5	10
Mountainmahogany	--	4.5	--	5	8
Kinnikinnick	--	--	--	3	--
Mountain muhly	--	1	10	2.8	1.7
Arizona fescue	--	2.3	4	2.8	1.5
<u>C H U B B S S O I L</u>					
Lodgepole pine	--	--	--	--	--
Douglas-fir	72	24	5	4.8	21
Aspen	97	38	8.5	4.2	48
Ponderosa pine	63	25	5	5.6	20
Mountainmahogany	--	4	--	5	10
Kinnikinnick	--	--	--	2	--
Mountain muhly	--	0.5	6	3.4	1.3
Arizona fescue	--	2.7	6	3.1	1.7
<u>S K E L E T A L S O I L</u>					
Lodgepole pine	--	--	--	--	--
Douglas-fir	60	22	4	2.7	10
Aspen	110	22	7	2.4	20
Ponderosa pine	75	19	5	2.8	19
Mountainmahogany	--	5	--	3.5	5
Kinnikinnick	--	--	--	2	--
Mountain muhly	--	0.9	6	2.7	1.3
Arizona fescue	--	2.6	2.5	2.6	1.2

### S U M M A R Y

Lateral extent and depth of root systems for 8 plant species on 3 different soils of the Colorado Front Range were examined on the Manitou Experimental Forest near Colorado Springs, Colorado. The trees studied were between 60 and 110 years in age, 19 and 38 feet in height, and 4 to 8.5 inches in d. b. h.

Ponderosa pine, Douglas-fir, lodgepole pine, and mountain-mahogany roots reached maximum depths between 4 and 5.6 feet, except where downward penetration was limited by bedrock. Mountain muhly, Arizona fescue, and kinnikinnick roots grew to depths of between 2 and 3.4 feet.

Quaking aspen roots had the greatest lateral extent, with some laterals growing 48 feet from the parent stump. Other tree species had laterals less than one-half this length.

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