The Pattern of Influence of Individual Forest Trees on Soil Properties
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cache of seeds which were later identified as *C. album* (Fig. 1). The seeds were in a circular, straight-sided hole about 15-17 cm wide and 20-22 cm deep that was “just like a jar,” according to the finders. The top of the cache was roughly level with the lower portion of the 10- to 12-cm-deep occupation layer. The finders stated that the soil layer over the cache was intact with no evidence of former burrows or other disturbance. The 4-5 liters of seeds were all as clean as that in Figure 1. Unfortunately, the finders did not recognize the possible significance of the find and it was only as an afterthought that they retained about one cupful of the material. There was no evidence of a container and no photographs were obtained *in situ*. The seed sample consisted of empty hulls but with vestiges of a primary root adhering to many. The seed coats, a glossy black color in fresh material, were dull and lusterless. Indications were that the seeds had germinated and the primary roots and cotyledons had later disintegrated, while the hulls were preserved intact.

In view of the widespread use of *C. album* as a food plant by primitive peoples, the apparent man-made characteristics of the storage hole, and the location of the cache in relation to a former occupation site, it is suggested that this find provides further evidence of the gathering and use of *C. album* by the Blackfoot Indians in the prehistoric period.

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**THE PATTERN OF INFLUENCE OF INDIVIDUAL FOREST TREES ON SOIL PROPERTIES**

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**INTRODUCTION**

The soil under the influence of a forest develops properties that vary spatially with relation to the location of the trees. This variation in soil properties is frequently reflected in the distribution of the various species of the ground flora. The amelioration or degradation of the forest soil takes place with each tree as a center of influence. This paper reports the patterns of soil properties which develop under individual trees with examples drawn from work in the forested areas of California.

The literature of forestry and soil science has frequent reference to the effect of different species on soil properties but there are relatively few papers dealing with the spatial variation in these soil properties relative to individual forest trees. Among these papers a classic is P. E. Muller's (1887) description of the occurrence of distinctive mull humus soils under each clump of oak trees on otherwise podzolized soils of heath lands in Denmark. Jamison (1942) noted that certain soil properties varied systematically with distance from individual orange trees in orchards in Florida. Harradine (1954) observed that in California forests where *Pinus ponderosa* Laws. and *Quercus kelloggii* Newb. were mixed there was less soil nitrogen in the open than under the influence of the pines or oaks. Fireman and Hayward (1952) found a distinctive pattern of occurrence of exchangeable sodium under various shrub species in the

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ESCALANTE DESERT IN UTAH. Sodium was high under Sarcobatus vermiculatus (Hook.) Torr. and low under Artemisia tridentata Nutt. Muller and Muller (1956) noted that in desert areas the occurrence of herbaceous ground vegetation was associated with the influence of individual shrubs on the soil. The general pattern apparent from these studies is that the individual plant is a center from which soil properties may vary in a predictable manner. This paper reports an evaluation of these effects by sampling soils systematically with relation to individual forest trees in California and determining the properties of these soils.

SOIL VARIATION UNDER A SINGLE PINUS CONTOR TA

The effect of a single tree on patterns of soil properties was evaluated by sampling under a 45 yr old shore pine (Pinus contorta Dougl. ex Loud) growing on a sand dune area one mile inland from the Pacific Ocean near Crescent City in northwestern California. The mineral soil was sampled to a depth of 2 1/2 in. at distances of 1, 4, 8, 12 and 16 ft from the tree on 4 transects at right angles to each other. The tree had a crown projection radius of approximately 12 ft. Two of the sampling transects outward from the tree were parallel to the prevailing winds in the area which during clear weather come from the northwest, and during storms and moist weather come from the southeast. The other transects were at right angles to these directions. Soils were sampled for volume weight and a bulk sample. The bulk samples were analyzed for pH, total nitrogen content on all transects, and exchangeable bases on one transect.

The volume weight of soil on all 4 transects increased with distance from the tree. It varied from 1.17-1.32 g/cm² near the tree to 1.65 g/cm² in the open sand dune. The soil volume weights on the northwest transect were 1.20, 1.27, 1.44 and 1.58 at distances of 1, 4, 8, and 12 ft from the tree trunk.

The pH as determined from saturated soil pastes with a glass electrode is in Figure 1. The pH was lowest (5.7) adjacent to the trunk and rose progressively with distance from the tree to 7.2 on the open sand dune. The high pH on the open dune is due to weathering shell particles in the sand. There was a change in ground flora from a single Pyrola dentata (Sm.) Piper immediately adjacent to the trunk to scattered Franseria Chamissonis Less. on the open sand dune. These species are associated with acid and alkaline soils, respectively. The pattern of soil pH as expressed by the isolines of pH (Fig. 1) indicates an effect of the soil surface. The tree has a maximum influence under the crown canopy and the influence decreases outward from the tree. To test the generality of this conclusion transects extending radially outward from mature forest trees in various areas in California were sampled.

Radial variation of soil properties about mature forest trees

The general pattern of soil properties under several mature individuals of Pseudotsuga menziesii (Mirb.)
Franco, *Pinus ponderosa* Laws., and *Libocedrus decurrens* Torr. were determined at locations throughout Calif. The trees were all mature (approximately 200 yrs old). Sampling of soils was carried out in surface mineral soils to a depth of 2½ in., usually at distances of 1, 4, 8, and 16 ft from the south side of the tree trunk. The outer sampling point was always beyond the influence of the crown canopy, its edge being between 8 and 16 ft.

A series of relationships between soil properties and distance from the tree were developed (Fig. 4). The pH associated with an individual tree was almost always lowest near the tree trunk, increasing with distance outward from the tree. The nitrogen content of the soil under a tree was generally lowest near the tree trunk, increasing to a maximum at 4-6 ft out, and declining or increasing with further distance outward depending upon the nature of the adjacent vegetation. The high nitrogen associated with tree no. 1 was occasioned by sampling under an adjacent *Ceanothus integerrimus* H. & A. bush which is a nitrogen-fixing plant. Generally the amount of exchangeable bases was low near the tree trunk, increasing with distance to a maximum, declining with distance beyond the influence of the crown canopy. The soil exchange capacity followed a similar trend.

**Reasons for the characteristic pattern of soil properties under individual trees**

The major reason for these patterns is the difference between the relative influence on soil properties of bark...
litter, leaf litter, and no litter in the opening between trees. Compared to leaf litter, bark litter is usually very acid, low in bases and results in a mineral soil that is acid, low in bases, nitrogen and carbon. Leaf litter is generally higher in base content and nitrogen and results in a soil that is higher in pH, base content, and nitrogen content. In the adjacent opening without leaf litter the soil becomes lower in exchangeable bases and nitrogen. A nearby tree or bush may alter this effect by eliminating or affecting the open area. In addition to the variation in litter properties the quality of the rain water entering the soil may differ due to source as stemflow from the tree trunk, drip from the foliage or unimpeded throughfall and this would be reflected in soil property differences. Thus a general, predictable soil pattern about individual mature trees develops. The tree is surrounded by an inner ring of bark litter, an outer ring of leaf and twig litter, and the adjacent marginal effects of an opening or the corresponding influence ring of a nearby tree. A characteristic distribution of soil properties in the forest develops from this pattern (Fig. 5).

**FIG. 5.** The hypothetical pattern of influence circles on soil that would develop under an open mixed conifer forest of *Pinus ponderosa* (Y), *Pseudotsuga menziesii* (D), and *Libocedrus decurrens* (1). Blank indicates bark litter effect, cross hatched indicates leaf litter effect, with properties depending upon species, and stippled indicates open rainfall leaching effect.

**DISCUSSION**

The presence of distinct patterns of soil properties in the forest centered in radial symmetry about each tree means that sampling of soils to correlate soil properties associated with individuals of various species must be carried out with regard to these variation patterns. These patterns may be as distinctive as the depth functions or profiles of soils. Thus to demonstrate the difference in influence of various species it is wise to sample comparable distances from the tree trunk.

The overall effect of a unit area of the forest on soil properties would best be determined as a summation of the individual influence patterns which occur in the area and the openings outside these areas. The denser the forest becomes the more these influence patterns merge. The older the trees the more definite the patterns will probably be. A pattern should subist for a period following the death of a tree. The shape of these patterns will tend to be circular, but this will vary with steepness of slope, direction and intensity of prevailing winds, and shape of the tree crown. The magnitudes of the soil properties within the patterns should be functions of the soil forming factors—climate, organisms, topography, parent material and time as defined by Jenny (1941). The development of knowledge of such patterns as they occur in a forest as a function of the species present when combined with percentage cover by species in the forest should aid in determining the role of various species mixtures in soil formation, as well as in the formation of the soil-vegetation system.

**SUMMARY**

The pattern of soil properties under single forest trees is generally developed with radial symmetry to the tree, varying with distance from the tree trunk so that there is a systematic change in pH, nitrogen content, exchangeable bases, and exchange capacity and volume weights. The general pattern of this variability is due to the difference between the effect of bark litter, leaf litter, and the adjacent opening or neighboring tree. The patterns obtained are predictable in a given forest region.

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