Effects of Recreational Use on Forested Sites

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ABSTRACT / Impact of recreational activities on soil and vegetation was evaluated in eight forested camping and picnic areas in southern Rhode Island. Forest vegetation consists of mixed-oak and white pine stands. Soils are of granitic glacial till or outwash origin and textures range from loamy sand to find sandy loam. Recreational use resulted in significant compaction of soils as indexed by soil penetration resistance and bulk density. Evidence indicates that compaction influences bulk densities to a depth of about 12.7 cm. Rates of water infiltration are less on recreation areas. Soil water accretion and depletion during the growing season are less rapid on recreation sites than on control sites. Differences are attributed to reduced infiltration, percolation, and rooting activity. Much of the ground surface on recreation areas is devoid of vegetation. The surface consists primarily of bare mineral soil, rock, or litter. The plants most commonly present are grasses. Native ground cover vegetation including tree seedlings, ericaceous shrubs and herbs has been eliminated or greatly reduced by trampling. Damage to tree trunks is common in recreation areas. White pine radial growth and scarlet oak height growth were significantly less on recreation sites. Scarlet oak appears intolerant to heavy recreation use.

Recreational use of forest land in southern New England has increased greatly in recent years, placing strong demands upon both sites and facilities. The impact of this heavy use on biotic communities and the physical site itself is not clear.

Most outdoor recreation areas are located on sites occupied by forest or other plant communities made up of vegetation that is not suited to intensive human use. Forested areas receiving heavy recreational use often exhibit visible evidence of deterioration shortly after use begins. Studies have shown that changes in esthetic appeal are often related to changes in ground vegetation and a general reduction in types and numbers of trees (LaPage 1967, Beardsley and Wagar 1971). This change in vegetation is due to direct physical injury and to changes in soil characteristics associated with trampling.

In most early studies of recreational impact, changes in soil properties were given only cursory consideration. Recent research (Dotzenko et al. 1967, Settergren and Cole 1970), however, has examined soil characteristics including penetration resistance, infiltration rate, bulk density, pore space, and water holding capacity. Often such investigations note how the soil condition, as measured by these parameters, changes from good to poor with continuing heavy recreational use.

KEY WORDS: Recreational impact, Forests, Tree growth, Human traffic impact, Soil compaction, Washington County R.I.

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Basic studies of the interrelationships between soil condition and tree growth have rarely been attempted. Settergren and Cole (1970) compared moisture regimes on heavily used recreation sites with undisturbed sites and commented on the impact of observed differences on tree vigor, but they did not obtain quantitative measures of tree growth.

Because of the general lack of comprehensive studies on sites similar to those typically found in southern New England, this study was undertaken to evaluate impacts of heavy recreational use on physical site factors and on vegetation in forest recreation areas. Objectives include not only a survey of recreational impact on vegetation and soil characteristics, but also an examination of interrelationships between recreational use, soil moisture regimes, and growth of trees.

Study Area

The study was conducted in Washington County, Rhode Island, in forest stands typical of those occupying large areas in southern New England. Eight recreation areas were studied—four campgrounds and four picnic areas. Five of the areas are in mixed-oak stands, two in nearly pure white pine (*Pinus strobus* L.) stands and one in a stand comprised of a mixture of oak and pine.

Nomenclature is according to Fernald (1950). All stands studied are in the 30- to 50-year age classes. In most of the study areas there are a few trees that are considerably older than the stand aveage. These individuals are either survivors of past fires and logging, or they were early invaders of open areas following land abandonment.

The most important tree species in the mixed-oak stands are white oak (*Quercus alba* L.), scarlet oak (*Q. coccinea* Muench), and black oak (*Q. velutina* Lam.). Other species frequently present, but generally in small numbers, are red maple (*Acer rubrum* L.), red oak (*Q. rubra* L.), black gum (*Nyssa sylvatica* March.), birches (*Betula spp.*), white pine, and pitch pine (*Pinus rigida* Mill.).

Shrub cover on undisturbed portions of all study areas consists primarily of ericaceous shrubs including black huckleberry (*Gaylussacia baccata* Wang.), early sweet blueberry (*Vaccinium vacillans* Torr.), low sweet blueberry (*V. angustifolium* Ait.), mountain laurel (*Kalmia latifolia* L.), and sheep laurel (*K. angustifolia* L.). Non-woody ground cover common to undisturbed sites includes spotted wintergreen (*Chimaphila maculata* Pursh.), false lily-of-the-valley (*Maianthemum canadense* Weber), and sedges (*Carex spp.*). In general, shrubs and herbs that occur in undisturbed portions of pine stands are the same as those found in mixed-oak stands, but they are less abundant.

Woody and non-woody ground covers are sparse or absent in heavily used portions of stands. Cover is typically limited to red fescue (*Festuca rubra* L.), and mosses and lichens growing in protected locations.

Soils in all eight study areas have formed on upland sites, either from granitic glacial till or outwash. Soil textures are similar, ranging from loamy sands to fine sandy loams. All soils are well drained except for one area that is considered moderately well drained due to the presence of a fragipan at a depth of 78 cm. The presence of plow horizons in all eight areas indicates past clearing of forest and cultivation.

According to Thornthwaite (1948), the climate for southern Rhode Island is humid to the third degree with little water deficiency in any season. The temperature efficiency regime is first degree mesothermal. Average annual precipitation is approximately 114 cm and is normally uniformly distributed throughout the year (Brumbach 1965).

Materials and Methods

In each study area three 0.04 hectare circular plots were established on sites under recreational use, and three control plots were located on comparable sites in nearby undisturbed forest. Within each plot all trees having a diameter of 1.5 cm or greater at 137 cm above the ground were sampled. Characteristics of each stem including species, diameter, height, origin, and visible vigor were recorded. Age and radial growth for the years 1960 to 1970 were determined from all trees having diameters of 10.2 cm or greater. A DeRouen Dendrochronograph was used to make increment and age determinations. Ground cover was sampled from four one-meter square quadrats randomly located within each 0.04 hectare plot. Sampling consisted of photographing quadrats using a 35 mm camera with a 35 mm wide angle lens suspended from a tripod 2.44 m high. Quadrats were photographed in the fall of 1973 and spring of 1974. Color slides were used to estimate percent cover for the various ground cover types present.

Resistance to vertical penetration was determined with a Soil Test CL–700 hand-operated, calibrated-spring penetrometer. Twenty-five readings were taken from each study plot. The core method was used to obtain four soil samples from the surface 5.1 cm of each plot for bulk density determinations. In addition, on one study area core samples were taken to a depth of 15.2 cm to determine the depth to which trampling influences bulk densities. Infiltration rates were determined for all study areas using 10.2 cm diameter single ring infiltrometers driven 5.1 cm into the soil surface. Sampling points were not presoaked.

Soil moisture levels were monitored weekly from June 22 to October 10, 1973 by the neutron thermalization technique in the plots of one campground, one picnic ground and their respective control plots. In each plot one access tube was installed to a depth of 152 cm and two to 91 cm depths. Readings were taken at the 15.2 cm depth and at 30.5 cm intervals to effective tube depths. In addition, soil water holding capacities (⅓ bar) using the bulk density cores were obtained on these same soils with the aid of a pressure plate apparatus.

Results and Discussion

Impact on Soil Physical Properties and Water Relations

Soil Compaction. Recreational use resulted in significant compaction of soils as indexed by soil penetration resistance and bulk density of the surface 5.1 cm of soil (Table 1). Surface bulk densities ranged from a low of 0.32 g cm^{-3} on undisturbed areas to a high of 1.2 g

Table 1 Characteristics of the soil surface on recreation and control sites

	Recreation sites	Control sites
Penetration Resistance (kg cm^{-2})	3.05**	1.25
Bulk Density (g cm^{-3})	0.93**	0.54
Infiltration (cm hr^{-1})	12	378**

**Denotes significance at the 0.01 level.

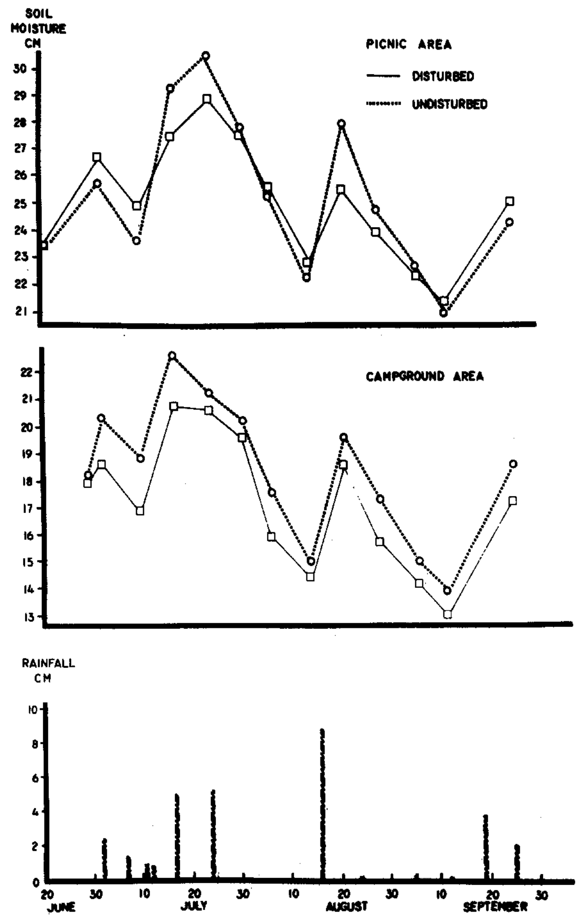

Figure 1. Moisture in the surface 1.52 m of soil at the picnic area and campground, and precipitation record for the study period.

cm^{-3} on sites used for recreation. Evidence indicates that compaction on recreation areas increased bulk densities to a depth of approximately 12.7 cm. Average bulk densities on recreation sites are greater than those on undisturbed sites for the 5.1 to 12.7 cm depths, but not significantly greater. Findings agree with those reported in earlier investigations of soil compaction associated with recreational use (Lutz 1945, LaPage 1962, Dotzenko et al. 1967, and Settergren and Cole 1970).

Rates of infiltration of water into soil were greatly reduced by recreational use (Table 1). Low infiltration rates could deprive plants of badly needed water during the growing season and could result in increased surface runoff. Excessive runoff could cause erosion of litter and surface soil, both of which are important in nutrient and water budgets.

Soil Moisture Regimes. The seasonal pattern of average moisture contents for the surface 152 cm of soil in the picnic area differed from the pattern in the adjacent control location (Fig. 1). Surface soil at the control site recharged and lost moisture at a faster rate than did soil in the recreation area. It also contained more moisture than the soil in the recreation area following storms and less after extended periods of depletion. Differences in patterns are apparent at most monitored depths within the 152 cm profile (Fig. 2). More water percolates to greater depths on the control site. This is especially noticeable following the large storm in mid-August at which time some recharge occurred to a depth of 137 cm. With less water entering the soil on the recreation site due to surface compaction, there is less water available to percolate to greater depths.

Moisture regimes at the campground did not exhibit sharp differences between disturbed and undisturbed sites. Seasonal rates of moisture gain and loss for the surface 152 cm of soil under recreation and control sites were similar (Fig. 1). Patterns were also similar for the different depths monitored (Fig. 3). One would expect that compaction and reduced infiltration on the recreation site would result in less water occurring in the profile following storms. This, generally, was not evident from examination of moisture regimes. This anomaly may be related to soil characteristics. The campground soils are coarser textured and have a lower water holding capacity than soils in the picnic area. Mean water holding capacities (⅓ bar) for the surface 152 cm of soil on the picnic area and paired control site were 26.9 cm and 28.2 cm, respectively. Soils at the camp-

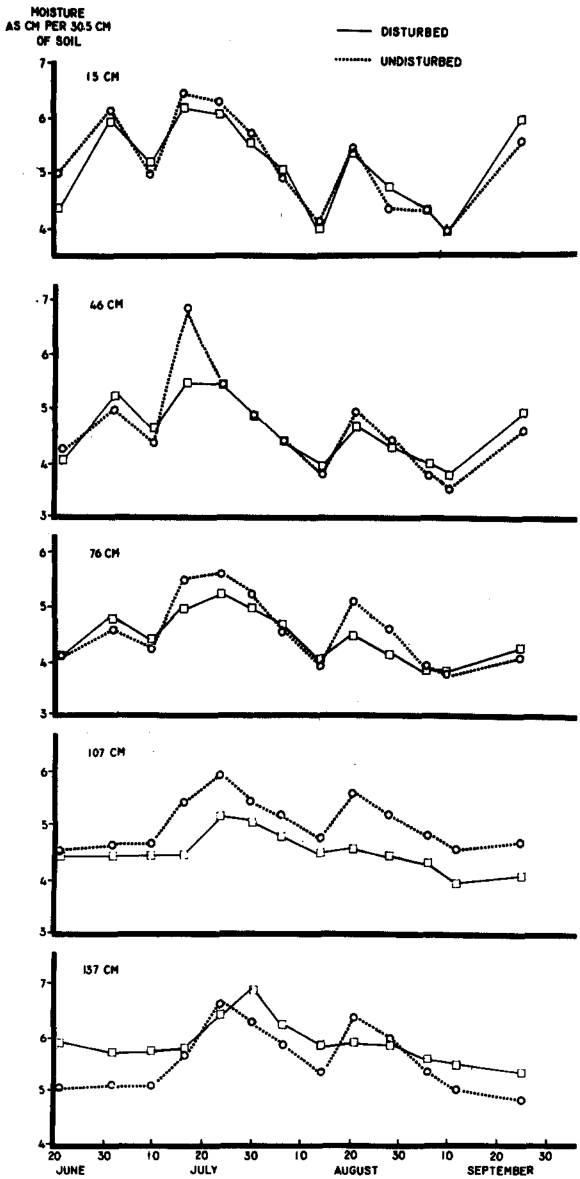

Figure 2. Soil moisture regimes by depth under disturbed and undisturbed sites in the picnic area.

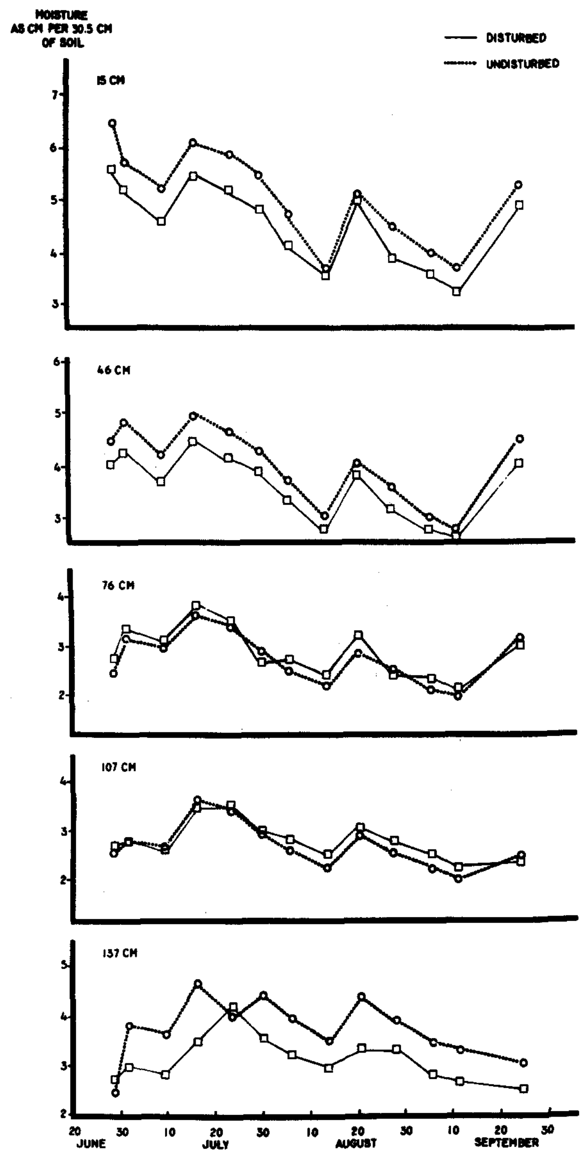

Figure 3. Soil moisture regimes by depth under disturbed and undisturbed sites in the campground.

ground had values of 20.1 cm for the camping site and 22.6 cm for the control. On the campground area loamy sand gives way to sand at about 60 cm, followed by gravelly sand at 66 cm. Apparently, the low water holding capacity and rapid permeability of soils on the campground area combine to overshadow any differences that recreation might produce between disturbed and undisturbed sites.

Impact on Vegetation

Ground Cover Vegetation. The impact of trampling on ground cover vegetation on forested recreation areas is dramatic. Ground cover consists primarily of leaf litter, bare mineral soil and rock, and grasses (Table 2). Exposed soil and rock average roughly 30% of the ground surface of recreation areas and only 1.4% at undisturbed locations. Ground cover vegetation on recreation areas is less abundant and differs in species composition from that of undisturbed areas. While ericaceous shrubs and herbs are normally abundant on undisturbed areas, they are noticeably scarce or absent from recreation sites. Vegetation occurring on recreation areas consists mainly of grasses, mosses, and lichens. Apparently, sensitive species are replaced in part by those that are more trample-resistant and better able to survive in the more hostile environment of recreation areas. Similar findings were reported by Beardsley and Wagar (1971) in Utah, and Magill (1970) in California.

No major seasonal shifts in ground cover vegetation were observed. On a few areas coverage by grasses and mosses increased slightly in the spring but increases did not persist through the summer season.

Expansion of disturbed area boundaries was apparent on sites experiencing heavy use. The expansion of disturbed areas is important because as sensitive plants are eliminated from bordering areas so is organic material that is critical in the maintenance of favorable moisture relations for remaining plants.

Perhaps the most significant long term impact of trampling is the near elimination of tree seedlings. Tree seedlings were almost nonexistent on recreation areas. It is significant that without seedlings, trees will have to be replaced by planting if recreation areas are to remain forested.

Overstory Vegetation. Stocking of trees in portions of stands intensively used for recreation tends to be less than that on undisturbed portions of the same stands, but differences generally are not great. For instance, basal areas for used and unused portions of stands are similar on four out of the eight recreation areas studied, and percentages of crown closure are similar on all but one area. However, trees in disturbed portions of stands are fewer in number but larger than trees occuring in undisturbed portions of stands. Tree diameters average 18.0 cm on recreation sites and 12.2 cm on undisturbed sites.

All overstory stems were examined for evidence of scars, foreign materials such as nails, and rot. Thirty percent of all trees occurring on disturbed areas were found to have scars or nails, while on undisturbed areas only six damaged trees (0.4%) were found. Magill and Nord (1963) in California reported that nails, screws, and wire for tents and tarps badly damaged trees, favored disease and insect attacks, and introduced toxic substances to trees. Further, they found that extensive carving and chopping killed small trees and badly damaged old trees.

From visual observations and increment cores, it was found that 21 trees on disturbed areas and 46 on undisturbed areas exhibited heart rot. Since the ratio of number of stems on undisturbed areas to the number on disturbed areas was also two to one, it may be concluded that rot was not caused by recreation pressures. Rot was probably associated with the coppice origin of most of the hardwood stems on the study areas.

Tree mortality associated with recreation pressures is difficult to document. Most studies of tree mortality on recreation areas fail to report number of trees actually removed from sites. This is a result of poor records as well as the difficulty in reconstructing tree losses from

Table 2 Percent cover by ground cover types

	Bare ground or Rock	Litter	Lichens and Mosses	Grasses and Sedges	Herbaceous Plants	Ericaceous Shrubs
Disturbed	29.8	55.1	3.0	9.8	1.6	0.7
Undisturbed	1.4	63.6	0.5	0.2	6.4	27.2

evidence on the site. However, an indication of the number of trees that have been removed because of recreation pressure can be obtained by comparing stem densities on comparable disturbed and undisturbed areas. Assuming that in site construction roughly 30 to 50 percent of the original stand remains, a smaller percentage remaining would indicate mortality because of recreation impact. Stems present on recreation sites, expressed as a percentage of those found on control sites, were 77, 46, 32, and 17 percent for black oak, white pine, white oak, and scarlet oak, respectively. Scarlet oaks on disturbed areas with only 17% of the stems occurring on undisturbed areas are apparently severely affected by heavy recreation use.

Radial and Height Growth of Trees. Comparisons of radial and mean annual height growth for dominant and codominant trees were made for all species having sample sizes sufficient to warrant analysis. Species analyzed using analysis of variance techniques included scarlet oak, white oak, black oak, and white pine. The radial growth of white pine and the mean annual height growth of scarlet oak were significantly less on recreation sites (Table 3). Most previous studies of tree growth on recreation areas have reported little or no effect attributable to recreation use (Beardsley and Wagar 1971, Echelberger 1971, Magill 1970). However, LaPage (1962) working in New Hampshire found that white pine diameter growth in recreation areas was slower than growth in undisturbed areas. He detected no differences in height growth and suggested that height growth may be unaffected by recreation pressure.

To some extent, differences in tree growth observed in our study may be related to the time and length of growing seasons. In southern New England, most height growth in white pine takes place in the late spring months while diameter growth occurs throughout the summer (Kienholz 1934). Thus, the shallow root system of this species would not normally be under mositure stress during the period of maximum height growth but, depending on precipitation levels, it could be under stress during the period of maximum radial growth. Compaction resulting from recreation could aggravate this stress and reduce radial growth. The differences in height growth in scarlet oak do not yield to a simple explanation. Neither growth nor root distribution patterns in this species have been noted to be vastly different from those of other oaks. However, Kalisz and Brown (1976) in a related study found that root starch contents of scarlet oak, unlike other oaks, were significantly lower on a heavily used campground than on a control area. This indicates that scarlet oak may be very susceptible to soil water stress caused by soil compaction. In fact, scarlet oak's susceptibility to drought-related damage and mortality as opposed to other oaks has been reported by Tyron and True (1958) in West Virginia and by Fletcher and Lull (1963) in Missouri. Apparently, scarlet oak is less able to cope with soil water stress than either black or white oak and this is reflected in reduced height growth on compacted recreation areas. Indirect evidence already presented, indicating that more scarlet oak stems have been removed from recreation sites due to decline and death than stems of other species, further support our conclusion that scarlet oak is very intolerant of heavy recreation use.

Merriam and Smith (1974), studying recreation impact on soils similar to those examined in this study, found that soil compaction stabilizes after the first two years of use. Although soils in the recreation areas studied may not compact further, continued loss of organic matter and soil resulting from the lack of vegetative cover will contribute to further degradation of recreation sites. Changes already observed in soil physical

Table 3 Radial increment for period 1960 to 1970 and mean annual height increment.

	Radial Increment				Height Increment			
	Recreation		Control		Recreation		Control	
Species	N	Mean (mm)	N	Mean (mm)	N	Mean (m)	N	Mean (m)
White Oak	27	14.974	53	14.002	27	0.37	56	0.30
Scarlet Oak	17	15.582	127	14.413	17	0.33	132	0.43**
Black Oak	104	14.764	81	15.000	107	0.40	84	0.47
White Pine	32	31.103	34	42.185**	46	0.52	56	0.55

**Indicates means for recreation and control sites are significantly different at the 0.01 level.

properties and direct physical abuse of ground cover and trees are great enough to limit regeneration of trees and to slow down growth rates in scarlet oak and white pine.

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