Desert soil compaction reduces annual plant cover

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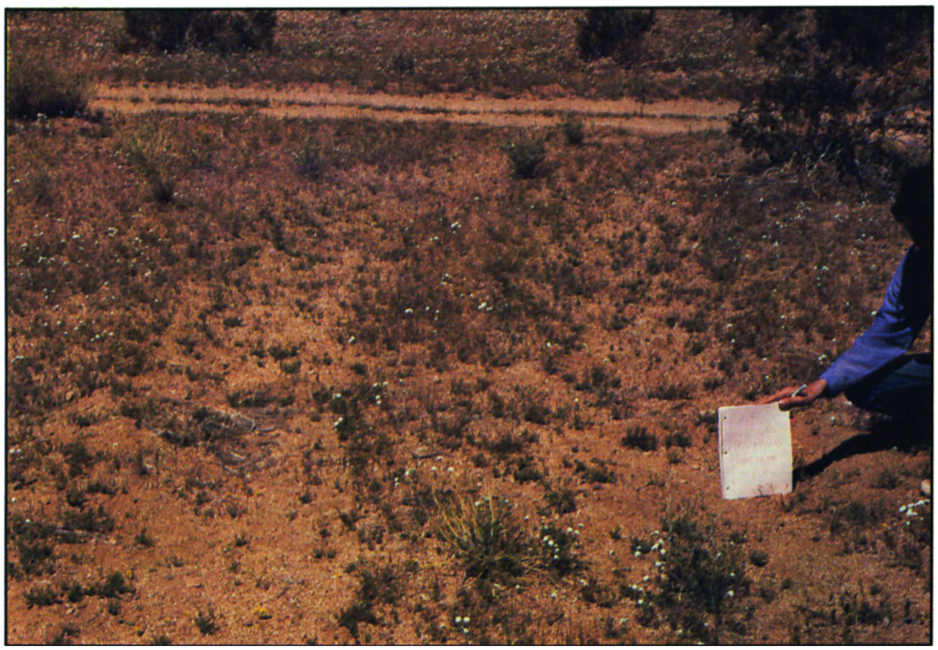
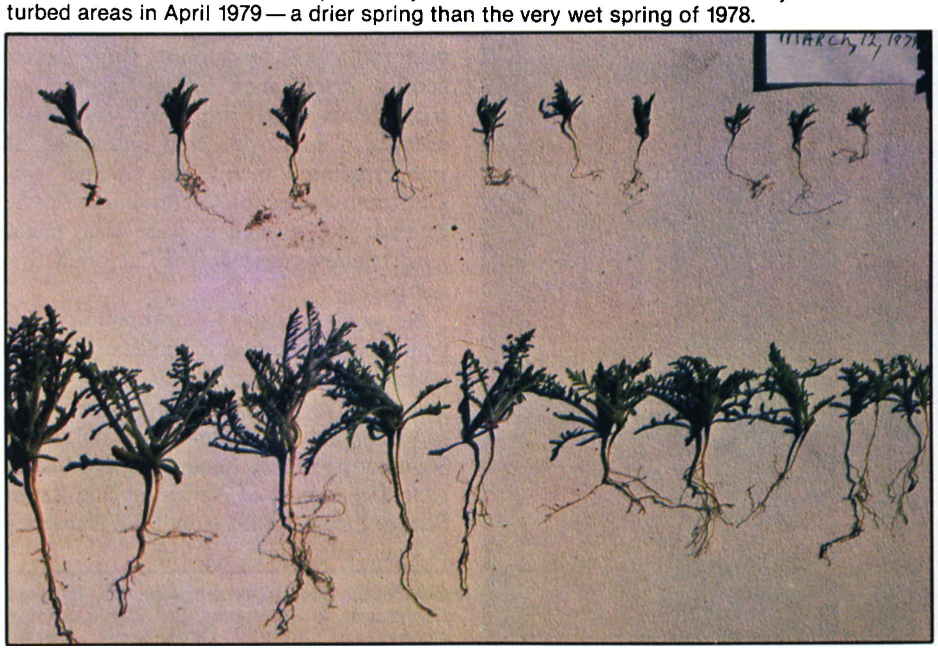
Dry conditions intensified harmful effects of compaction to sensitive desert annual plants.



Annual cover in tracks after 20 passes by a vehicle was much less than in adjacent undisturbed areas in April 1979—a drier spring than the very wet spring of 1978.



Annual plants, *Chaenactis fremontii*, in top row were from vehicle tracks shown above. Larger *Chaenactis* plants in bottom row were from adjacent undisturbed soil.

Controversy about environmental effects of soil compaction by recreational off-road vehicles and by livestock prompted this study in the California deserts. Field measurements of compaction with a recording penetrometer (which measures the force of penetration of a metal point into the soil, as a function of depth) showed intense compaction produced by off-road vehicles (ORVs) in campsites, pit areas, and heavily used trails. We also measured intense compaction in livestock watering locations, holding areas, and adjacent well-used trails.

Aerial photographs were used to estimate land areas disturbed by off-road vehicles and livestock grazing. Campsites and pit areas produced by ORVs in the California deserts cover approximately 500 hectares (1,236 acres), about 0.005 percent of the desert area. Hill climb areas, which are very susceptible to accelerated water erosion, occur on approximately 2,400 hectares, or about 0.024 percent of the desert. Land areas with a relatively large number of severely compacted ORV trails, generally covering less than 5 percent of the surface, however, occur on about 16,500 hectares (0.16 percent of the California desert).

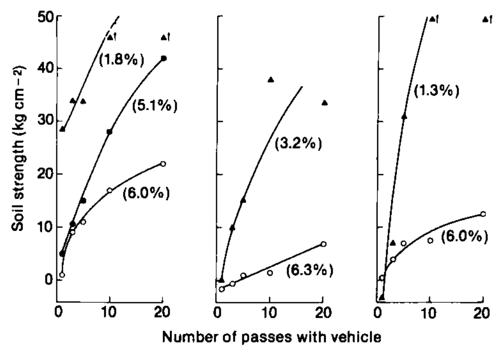
The aerial photographs showed an estimated 290 hectares of intense soil disturbance in livestock watering sites and holding areas out of a total of about 1,083,000 hectares examined in 13 cattle-grazing allotments in the desert. The disturbance in watering and holding locations represents 0.027 percent of the surface within the allotments. Intense compaction also occurs in well-used livestock trails: the estimated area averaged about 10 percent of the total heavily impacted area of the watering or holding locations.

Areas of lesser compaction, created by one to several passages of an off-road vehicle over the same path, cannot be fully assessed from aerial photographs. We attempted to learn whether these areas may be damaging plants by studying the minimum amounts of

Soil strength of two undisturbed soils (controls) at various water contents, Mojave Desert, California

Soil water (by weight)	Average soil strength* Loamy sand (Stoddard Valley)	Sand (Johnson Valley)
%	kg cm - 2	
6.3	5.3	...
6.0	9.2	5.1
5.1	11.3	...
3.2	14.5	...
1.8	21.1	...
1.3	...	17.6

*kg cm − 2 = kilograms per square centimeter, a measurement of soil resistance to a penetrometer; 1 kg cm − 2 is equal to 14.22 pounds per square inch. Root growth is stopped at about 20 kg cm − 2.



Soil strengths at 10-cm depth in tracks made by 1975 Ford Bronco compared with undisturbed soil, at various percentages (in parentheses) of soil water by weight. Soil strength of control area was subtracted from each adjacent soil strength in track.

soil compaction that could significantly reduce growth of desert annuals in subsequent years.

Compaction was produced by driving off-road vehicles, such as a Ford Bronco and a Yamaha motorcycle, to produce sets of tracks consisting of 1, 3, 5, 10, and 20 passes. Tracks were made in both Stoddard Valley and Johnson Valley in the Mojave Desert, on soils with surface textures ranging from sand to loamy sand. We determined responses of annual plants in tracks and in adjacent undisturbed locations by measuring both plant density and percentage of ground covered by annuals.

Soil strength, which is affected by compaction and other factors, such as moisture content, texture, and bulk density, was measured with a penetrometer inside and outside tracks. The undisturbed soil was considered a control. We measured tracks and controls at various times with different water contents to a depth of 30 centimeters (11.8 inches). Average soil strengths in the undisturbed areas ranged from values of 5.1 in sand at 6 percent water content to 21.1 in loamy sand at 1.8 percent soil water (see table). Root growth is stopped at a soil strength value of about 20.

Soil strengths during drying were much higher in tracks than in adjacent control areas. For example, at 6 percent water content, wet loamy sand in Stoddard Valley showed little difference in soil strength between tracks created by one pass of the Bronco and adjacent undisturbed soil (graph A). Average soil strength in the single-pass track was 5.3 units greater than in the control when the soil had dried to 5.1 percent moisture, and 28.4 units greater at 1.8 percent soil water. Drying caused the soil in the slightly compacted track to become much harder (increased soil strength) than the undisturbed soil. Tracks created by more vehicle passes showed even greater increases in soil strength when compared with controls. For 10 and 20 passes at 1.8 percent soil-water content, soil strengths were too high to measure with the penetrometer (see vertical arrows).

Bronco tracks on dry loamy sand in Stoddard Valley (graph B) or on wet sand in Johnson Valley (graph C) also showed large increases in soil strength after drying, although not for a single pass. Ten vehicle passes on dry loamy sand increased soil strength only slightly over the control at 6.3 percent soil-water content, but after soil had dried to 3.2 percent, the 10-pass track had a much higher soil strength than did undisturbed soil. A similar pattern was observed on wet sand at 6 and 1.3 percent moisture.

The amount of soil water significantly affected response of plants to soil compaction. The spring of 1978 was very wet in the Mojave Desert, with frequent rains. Total rainfall was 19.63 cm (7.5 inches) at Stoddard Valley between December 18, 1977, and May 1, 1978. There was little noticeable difference in plant density and cover in and out of the tracks.

The spring of 1979 was drier: rainfall was 9.7 cm in Stoddard Valley between December 1, 1978, and May 25, 1979, and soil strength was higher. During 1979 greater reduction in plant growth occurred in tracks when compared with control areas, although numbers of annuals per unit area of tracks were generally not reduced. Annual cover, when compared with controls, was significantly reduced during the spring of 1979 in tracks made the previous year, before those annuals had germinated. The reductions occurred in tracks created by as few as one Bronco pass or five motorcycle passes on wet loamy sand, or 20 Bronco passes on dry loamy sand, not because numbers of plants decreased, but because plants were smaller. The great sensitivity of desert annuals to the compaction probably was caused by periods of drying, which intensified soil strength in tracks when compared with control areas.

Desert annual response also varied with species. In 1979, cover of large taprooted annuals such as *Chaenactis fremontii* decreased in all tracks referred to in graph A. However, in the same area, *Schismus barbatus* (L.) Thell, a grass with a fibrous root system, had significantly greater cover in tracks made by 1, 3, 10, and 20 passes than in undisturbed soil. The single cotyledon leaf and fibrous root system allows greater ease of germination and root growth than is possible with taprooted dicotyledons. Also, more water may have been available for the grass in the track, because growth of nongrass species was reduced.

The reduction in annual growth with relatively small numbers of ORV passes suggests that areas with slight compaction from grazing may also be affected. Slight to moderate soil compaction caused by grazing or ORVs cannot be detected from aerial photographs. Effects of such compaction on total productivity could not be estimated, because plant responses vary with rainfall characteristics and species.

The effects of soil water on plant response to compaction have implications for agriculture. Research is needed to study the cause of greatly increased hardening of slightly compacted desert soil when compared with undisturbed soil. Is this hardening caused by chemical cementation or by a greater number of interstitial water bonds remaining between soil particles after drying?

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