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# The influence of subterranean termites on the hydrological characteristics of a Chihuahuan desert ecosystem

**Ned Z. Elkins*, George V. Sabol, Timothy J. Ward, and Walter G. Whitford**
Departments of Civil Engineering and Biology, New Mexico State University, Las Cruces, NM 88003, USA

**Summary.** Rainfall simulation at an average intensity of 124 mm·h$^{-1}$ was used to compare infiltration and run off on arid areas where subterranean termites had been eliminated four years prior to the initiation of the study (termite free) with adjacent areas populated by subterranean termites (termites present). Infiltration rates on termite free plots with less than 5% perennial plant cover were significantly lower $51.3 \pm 6.8$ mm·h$^{-1}$ than rates on comparable termites present plots $88.4 \pm 5.6$ mm·h$^{-1}$. On plots centered on *Larrea tridentata* shrubs, there were no differences in infiltration rates with or without termites. Plots with shrub cover had the highest infiltration rates $101 \pm 6$ mm·h$^{-1}$. Highest run-off volumes were recorded from termite free $<5\%$ grass cover plots and the lowest from plots with shrubs. There were no differences in suspended sediment concentrations from termites present and termite free plots. Average bed load concentration was more than three times greater from termite free, $<5\%$ cover plots than from termites present, $<5\%$ cover plots.

The reduction in infiltration, high run-off volumes and high bedloads from termite free areas without shrub cover is related to increased soil bulk density resulting from the collapse of subterranean galleries of the termites that provide avenues of bulk flow into the soil. Subterranean termites affect the hydrology of Chihuahuan desert systems by enhancing water infiltration and retention of top soil. The presence of a shrub canopy and litter layer cancels any effect of subterranean termites on hydrological parameters. Since approximately 2/3 of the area is not under shrub canopies, subterranean termites are considered to be essential for the maintenance of the soil water characteristics that support the present vegetation.

Wood and Sands (1978) in a review of the role of termites in ecosystems summarized the data on soil transport, nest construction, extent of foraging galleries and chemical and physical properties of termite mounds. They state that, in tropical areas, sub-surface termite galleries are commonly so numerous as to collapse under-foot. They cite several workers who have commented that this dense network of galleries must affect porosity and aeration, infiltration, storage and drainage of water, and growth of plant roots. Wood and Sands (1978) indicate that measurements of the effect of termites on these soil parameters have yet to be made and that such measurements are crucial to a proper understanding of the total influence of termites on soils.

On arid watersheds in the Southwest, subterranean termites are important detritivores, processing a large fraction of plant litter and organic debris in these systems (Haverty and Nutting 1975, Johnson and Whitford 1975, Whitford et al. 1982). Activities of subterranean termites could be important in the maintenance of hydrologic stability through subsurface tunneling and soil profile disturbance. Subsurface tunneling is extensive as evidenced by the high density of foraging groups recorded on a desert watershed by Johnson and Whitford (1975). The extensive subsurface tunnels and galleries may provide improved water infiltration capacity, soil-water storage capacity and subsequent increased primary productivity.

However, surface depositions by termites of translocated, subsurface soils as gallery carton is generally of finer texture than surrounding surface soil (Whitford et al. 1982). This deposited material may serve as a source of readily detachable sediments that can be transported over the surface with overland flow following rain events. This would lead to an appreciably higher loss of surface soils from termite inhabited areas.

Our rainfall simulation studies were designed to examine the effects of subterranean termites on infiltration and run-off on a desert watershed. We utilized plots on areas from which termites had been eliminated and plots with active termite colonies to examine hydrologic parameters.

## Methods and materials

The studies were conducted on the Long Term Ecological Research (LTER) watershed on the New Mexico State University Ranch 40 km NNE of Las Cruces, N.M. The dominant vegetation is creosotebush, *Larrea tridentata*. The long term average precipitation is 225 mm·yr$^{-1}$ with more than 70% of the yearly average from summer conventional storms, July–October. Measurements were made on large research plots (1200 m$^2$ each) which had been treated with chlordane (TM) at 10.3 kg·ha$^{-1}$ in 1977. By spring 1979, all common taxa of arthropods had recolonized the treated plots except for the subterranean termites. Untreated plots were compared to plots from which termites had been eliminated.

*Offprint requests to:* W.G. Whitford

* *Current address:* Sunbelt Mining Co., P.O. Box 2106, Albuquerque, NM 87103, USA

During late September and early October 1981, we estimated gallery carton production on the site in randomly selected 1-$m^2$ plots along 100-m transects traversing the selected study site. No carton material was found within the chlordane plot boundaries.

On a separate transect, gallery carton was collected at random together with a sample of bare soil immediately adjacent to the gathered material. These paired samples were analyzed for nitrogen content by a microkjeldahl digestion technique (Thomas et al. 1967). Two 500-g samples of carton were analyzed for particle-size distributions using a sieve-hydrometer combination procedure modified from Bowles (1978).

Before initiating rainfall simulations, we randomly selected 5 open soil surfaces and 5 areas at 0.5 canopy radius under creosotebush canopies on both the treated and untreated study areas. Soil samples, each approximately 12 cm diameter $\times$ 10 cm deep, were excavated and excavation volumes determined using a sand-funnel apparatus. These samples were used to estimate treated and untreated soil bulk densities (Blake 1965) and total porosities (Vomocil 1965). Lastly, the characteristic particle-size distributions of treated and untreated soils were obtained from these samples using a combination wet sieve-hydrometer analysis (Bowles 1978).

We selected 3 vegetational cover regimes common to both areas – 1) low cover (less than 5% cover of fluff-grass, *Erioneuron pulchellum,* clumps), 2) medium cover (more than 10% but less than 15% grass cover), and 3) creosote cover (directly under the center of a creosotebush having a mean canopy diameter of greater than 1-m).

Five plots in each of the 3 cover regimes were selected and staked, with the exception of the medium cover, chlordane-treated plots, which we were forced to omit because of the lack of accessible grass densities sufficient to meet the minimum cover requirement (Whitford et al. 1982). Two soil samples were taken from immediately outside the plot frame with 7 cm $\times$ 5 cm deep sample tins at 0–5 cm and 5–10 cm soil depths and were used to determine the gravimetric moisture and organic matter content of the soils associated with each plot.

Simulation rainfall was produced using a calibrated nozzle and constant pressure pump system adjusted to produce equal rainfall, drop size, and velocity to the plots. The nozzle was mounted on a boom that was swung over and centered on the plot. A near constant-intensity, simulated rainfall averaging 124 mm $\cdot$ $h^{-1}$ across a plot was used.

The standard plot was a 1-$m^2$ steel frame fabricated from 12.7 cm wide strips of 0.31 cm steel plate. This frame was driven into the ground to isolate the plot from the effects of run-on and interflow. The downslope side of the frame consisted of a lipped galvanized flashing tray which, when installed, was flush with the soil surface across the width of the plot normal to the direction of maximum slope. Runoff from the plot emptied into a 8.2 cm I.D. PVC pipe and was pumped into a collecting tank fitted with a Stephens depth recorder. Each plot received two simulated rains of 45 min duration. The period of time between simulated rain events was at least 24 h and never more than 48 h.

During simulated rainfalls, we recorded times of initial water ponding on the surface and runoff (drip initiation off the tray). After runoff had begun, a secondary pump was engaged for 15 to 45 sec at 5 min intervals in order to transfer the accumulated water and sediment from the PVC channel to the collection tank. After each simulation the hydrograph recorder was stopped and final rainfall depths were recorded.

After the final depth of runoff in the collection tank was recorded, the total volume was vigorously agitated and 5 water samples, each approximately 130–150 ml, were immediately taken. Three of these, used to estimate suspended sediment concentration, were sealed and stored. Approximately 2-ml of chlorine were added to the two remaining samples as a biostatic agent and these samples were put on ice. In the lab these samples were frozen until nitrogen and phosphorus assays could be made. The remaining runoff volume in the tank was removed except for the bottom 7–10 cm (approximately $10 \pm 1$). This water and the large particulate sediment it contained were saved in order to estimate bedload sediment.

Immediately following the end of each dry (first) simulation, a large sheet of plastic was laid over the plot frame to eliminate interim evaporative losses.

Three water samples from each run were taken for measurement of suspended (fine) sediment loads. Sediment loads were analyzed using a filtering process. Each sample was run through a vacuum Buchner filter. This filter trapped all material larger than very fine silts. If the filtrate remained cloudy, a second filtration was performed using a standard millipore vacuum procedure employing a Gelman stainless steel apparatus with 0.2 micron Metricel membranes (47 mm diameter). Oven-dry weights (60° C for 48 h) of these filters gave total suspended sediment weights per sample.

Each bedload sample was measured for total volume and allowed to air dry, transferred to aluminum plates and oven-dried at 60° C for 72 h to obtain final dry weights of each sample.

Two water samples from each simulator run were analyzed for nitrogen and phosphorus content. Immediately upon thawing, each sample was processed by a modified microkjeldahl digestion (Thomas et al. 1967) and aliquots were subsequently independently analyzed for nitrogen and phosphorus content using colorimetric procedures (Thomas et al. 1967, Watanabe and Olsen 1965).

The difference between rainfall intensity and runoff rate provided an infiltration rate estimate for each time period. These infiltration rate estimates were fitted using an inverse exponential model (Horton 1939) to obtain a best-fit decay plot for each run. The selected model was of the form

$$\ln \text{infiltration rate} = mt + b, \text{ or infiltration rate} = e^b e^{mt},$$

where $m$ = slope of the decay, $b$ = infiltration-rate intercept (i.e., calculated initial infiltration rate extrapolated from rate decay), and $t$ = an incremental time variable. This manipulation supplied intercept and slope values for each simulation along with infiltration rate estimates at each minute. An estimate of the final measured infiltration rate was obtained by averaging the final two 5-min values from the hydrograph.

The bulk density data of chlordane-treated and untreated, open (low cover) and creosotebush-covered soils were analyzed using a single classification one-way analysis of variance (Sokal and Rohlf 1969). Particle-size distributions for these soils were compared by taking geometric means of percent finer material at selected points and apply-