

Percent 2,4-D and 2,4,5-T Remaining Following Application to Two Chaparral Sites\*

	% 2,4-D							% 2,4,5-T						
	0.05	30	60	90	180	360	LSD <sub>.05</sub>	0.05	30	60	90	180	360	LSD <sub>.05</sub>
	(days after application)							(days after application)						
chamise	20.7	5.6	3.3	2.1	1.1	0.01	5.8	18.0	1.3	0.8	1.0	0.8	0.02	3.8
grass and forbs	25.2	2.0	—	—	—	—	6.6	31.2	3.0	—	—	—	—	23.0
litter	54.0	6.0	2.9	2.2	0.7	0.03	8.1	50.7	6.6	3.7	3.3	0.5	0.01	6.2
soil (0-5 cm)	0.1	0.07	0.2	0.17	0.01	0.01	0.15	0.07	0.09	0.11	0.11	0.06	0.01	0.1
TOTAL	100.0	13.7	6.4	4.5	1.8	0.05	7.4	100.0	11.0	4.9	4.4	1.4	0.04	4.4
LSD <sub>.1</sub>	10.1	4.1	2.4	1.0	0.3	0.04		8.3	1.6	0.7	2.2	0.46	0.01	

\* Means of four samples taken from two locations: San Diego and Monterey counties. Values are % of the total 2,4-D (1068 µg/gdw) or 2,4,5-T (1023 µg/gdw) recovered immediately after application.

Identical experiments at two sites (near Alpine, San Diego County and Salinas, Monterey County) were established in the spring of 1974. Both experiments were situated at approximately 915 m elevation where the principal vegetation was 3- to 5-year-old crown shoots of chamise (1.9 plants per square meter), grown on areas that had been burned three to five years earlier. Chamise shoots were 0.5 to 1 m high. Plots (186 square meters) were treated with 4.5 kg per ha. of either 2,4-D (butoxypropyl ester) or 2,4,5-T (propylene glycol butyl esters). The herbicides were applied using a constant pressure sprayer in a water emulsion at 234 L per ha. Each experiment contained four replications.

Samples of the terminal 10 to 15 cm of chamise foliage, understory grass and forbs, soil surface litter, and soil (0 to 5 cm deep) were obtained before, immediately following, and at 30, 60, 90, 180, and 360 days after application of the herbicides. Soil samples were also taken at 10 to 15, 25 to 30, and 55 to 60 cm depths at every sampling time except the day of application. Samples were analyzed by gas liquid chromatography.

## Results

A vertical pattern of herbicide distribution was observed with soil surface litter being the major receptor of both herbicides (see table). Surface litter contained over 50 percent of the 2,4-D or 2,4,5-T initially recovered after application. The relatively upright and rigid structure of chamise shrubs and the vertical growth habit of the grass and forbs may account for the distribution of herbicide. Similar results have been reported in which forest floors were observed as major receptors of aerially applied 2,4,5-T. Less herbicide was also found in the top-story dominated by brush or weed-trees.

Herbicide residues on foliage and litter decreased rapidly (up to 93 percent) within 30 days after application. Following the initial loss, residues of both herbicides decreased at a slower rate until, after 360 days, residues were 0.01 to 0.03 percent of that applied (see table).

Residues of 2,4-D and 2,4,5-T in the soil immediately after application (0.1 and 0.07 percent respectively) were markedly less than those in surface litter or vegetation. No detectable (0.001 percent) residue was found below 5 cm in the soil profile. These data indicate minimum transport of the herbicides by vertical water movement. The soil residues of both herbicides remained constant (0.07 to 0.2 percent) for 90 days after application. By 180 days for 2,4-D and 360 days for 2,4,5-T, herbicide residues in the soil were 0.01 percent of the amount initially applied (see table). Although some herbicide can be removed by surface-water runoff, these and other data—where 2,4,5-T moved less than 0.3 m downslope with surface water—indicate that contamination of water supplies from residual 2,4-D or 2,4,5-T in soil is unlikely.

At neither experimental site did rainfall occur soon after the 2,4-D and 2,4,5-T were applied. Most of the rain occurred between October 1974 and April 1975. Although unseasonably early rains were recorded in June (Salinas) and July (Alpine), this precipitation occurred 30 days (Salinas) and 75 days (Alpine) after the herbicides

were applied. Rapid loss of both herbicides from surface litter and foliage occurred during the initial 30 days of treatment (see table). These results indicate that precipitation was not a factor in initial herbicide decline. Herbicide loss by either volatilization or photochemical degradation might account for the observed herbicide loss.

Sixty to 90 days after application, herbicide residues in chamise and grass and forb vegetation may be accounted for by 2,4-D and 2,4,5-T absorption into the plants since herbicide symptoms were evident. Adsorption to foliage, litter, and soil could also explain the observed residues. Following the initial (30-day) herbicide loss, residues of 2,4-D and 2,4,5-T remained constant (3.7 to 2.2 percent) until the winter rains began in late September and October 1974 (see table). No accumulation of herbicide residues on the soil surface due to litter fall was evident.

During the usual summer drought, annual plants are dead and chamise shrubs are inactive. Soil moisture, especially near the surface (0 to 10 cm), is low. During the winter, when moisture is adequate, chamise becomes physiologically active; thus, herbicide metabolism near the treated shrubs could cause the residue decline in foliage during this period. Washing of the herbicides from treated foliage and litter into the soil coupled with microbial degradation is also possible.

*Steven R. Radosevich is Assistant Professor, Department of Botany, and Wray L. Winterlin is Specialist and Lecturer, Department of Environmental Toxicology, University of California, Davis.*

# Measuring chaparral fuels

Ronald H. Wakimoto □ John W. Menke

In future years brushland fuel may prove to be a valuable source of energy. As this resource becomes more useful, the need for accurately measuring the biomass of standing vegetation—or the total weight of living plants including attached dead parts—becomes greater. Brushland fuels can no longer be adequately quantified using visual estimates of tons per acre. Brushland productivity must be measured in the same way as have most of our forest lands.

A project funded by the University of California Water Resources Center was begun in San Diego County to study brushland dynamics and to provide techniques for biomass measurement and productivity estimation. The study site encompassed approximately

51,400 hectares of chaparral vegetation, primarily chamise (*Adenostoma fasciculatum* H. & A.), red shanks (*Adenostoma sparsifolium* Torr.), Eastwood manzanita (*Arctostaphylos glandulosa* Eastw.), cupleaf ceanothus (*Ceanothus greggii* var. *perplexans* [Trel.] Jeps.), western mountain mahogany (*Cercocarpus betuloides* Nutt. ex. T. G.), California buckwheat (*Eriogonum fasciculatum* Benth.), and scrub oak (*Quercus dumosa* Nutt.). The elevation of the area ranges from 900 meters to over 1,800 meters at the top of Laguna Mountain.

To avoid the tedium of clipping, sorting, drying, and weighing, a linear regression approach was chosen to estimate plant biomass. Individual plant crown dimensions, basal stem numbers by diameter, plant age, and crown volumes were measured.

## Methods

Representative plants of each species were selected. Plants on or near fuel breaks subjected to excessive browsing or mechanical damage were rejected. All plants up to 10 years old were open-grown plants found on fuel breaks or recently burned areas. Older plants were collected from unaltered stands which had germinated or resprouted following past fires. Such plants had grown after crown closure and competed for light and water.

Before plants were cut, crown dimensions were measured and basal stems were categorized by diameter. Three measurements were taken: HEIGHT (the over-all plant height); DIAMETER (the average of the maximum crown diameter and the crown diameter taken at a right angle to it); and the variable HTMAXD (the height above the ground at which maximum crown diameter occurs).

Harvesting consisted in cutting plants off at the ground level or immediately above the root crown. The plants were placed in labeled plastic bags and transported to the laboratory. Representative portions of exceptionally large plants were cut and immediately weighed in the field—as was the remainder of the plant—and bagged. In this way the percentage of the total plant weight actually sampled and processed was determined. For all plants, age was determined by growth-ring counts and fire or fuel manipulation history.

The number and diameter of basal stems may give some indication of plant vigor before the last disturbance and constitute a high percentage of plant biomass. All basal diameters were taken at ground level or immediately above the root crown. The basal stem diameters were grouped in the following classes: 0.0 to 0.5 cm; 0.6 to 1.0 cm; 1.1 to 2.5 cm; and greater than 2.5 cm.

The plant measurements HEIGHT, DIAMETER, and HTMAXD are used in estimating individual plant biomass, along with crown volumes that are determined by the crown shape of the species studied. Five additional independent variables (crown volumes) were created using the plant measurements of HEIGHT, DIAMETER, and HTMAXD.

## Results

The linear crown measurements, HEIGHT, DIAMETER, and HTMAXD, were appropriate estimators for biomass of young, rapidly growing shrubs. They did not reflect the change in shrub weight due to stem increment growth in large mature plants. Basal stem diameter tallies, while accounting for stem increment growth in large plants, could not predict biomass for young upright plants. These estimators gave even poorer results when measuring species with extensive secondary branching. Crown volumes indicated more variation in biomass over a greater range of plant sizes for all species than either linear crown measurements or basal stem tallies. But volumes, like the crown measurements, often failed to account for biomass variation due to stem increment growth in the largest plants.

Crown volumes and basal stem tallies were combined in a multiple regression, giving excellent predictive results. For five of the seven species studied greater precision was obtained using the multiple linear regression than a simple linear regression. The combination of calculated crown volume and basal stem tallies accounted for crown expansion in various plant densities and increment growth in basal stems.

Forest managers often use yield tables for estimating timber volume in forests of particular ages and stocking densities. Chaparral managers could likewise use tables of fuel loading (weight per hectare) after an inventory of plant density and stand age (see table). Given that such tables existed for various site productivity classes, a manager could rapidly estimate fire intensity for a range of weather and fuel conditions. Such information could be used for making prescriptions for controlled burns or determining fire hazard.

## Needs for further research

The research results reported here are merely the beginning of a long list of research findings needed to manage California's chaparral land. Two primary needs are: (1) a chaparral site classification system based on fuel biomass productivity potential; and (2) a determination of the impact of fire frequency alteration on the maintenance of natural chaparral communities.

Refinement of fuel biomass predictive models of the kind presented here, for numerous sites in California, should provide the data base necessary for developing a chaparral site classification system. Such a system would provide managers with information needed for the establishment of fuel break systems, greenbelts, rotational prescribed burning schedules, and general fire hazard reduction programs.

Chaparral land managers have discovered that they cannot prevent fires in chaparral, but they can alter their frequency. Because the effect of fire on the biotic community is most directly related to fuel loading at the time of ignition, we must understand more fully the interrelationships between fuel loading, energy release, and nutrient cycles to maintain the protective cover of some of California's most fragile watersheds.

Ronald H. Wakimoto is Assistant Professor of Forestry and John W. Menke is Assistant Professor of Forestry and Range Management, Department of Forestry and Resource Management, UC, Berkeley.

Financial support under Water Resources Center Project W-490 and AES-2936MS.

Initial stocking (lb/ha.)	Plant spacing‡ (m)	Total standing biomass (kg/ha.)				
		2nd year	4th year	6th year	8th year	10th year
14000	0.9	3159	5924	10073	15024	19543
12000	1.0	2708	5078	8634	12878	16751
10000	1.1	2256	4232	7195	10732	13959
8000	1.2	1805	3385	5756	8585	11168
6000	1.4	1354	2539	4317	6439	8376
4000	1.7	903	1693	2878	4293	5584
2000	2.4	451	846	1439	2146	2792
1000	3.4	226	423	720	1073	1396
800	3.8	181	339	576	859	1117
600	4.4	135	254	432	644	838
400	5.4	90	169	288	429	558
200	7.6	45	85	144	215	279

\* $Y = 1.9052 / (1 + (15.8193)e^{-0.377X})$ , where Y = total plant biomass in kilo-grams and X = age of the plant in years since last burned or manipulated.  
†Plant growth assumes no interplant competition.  
‡Equilateral spacing.