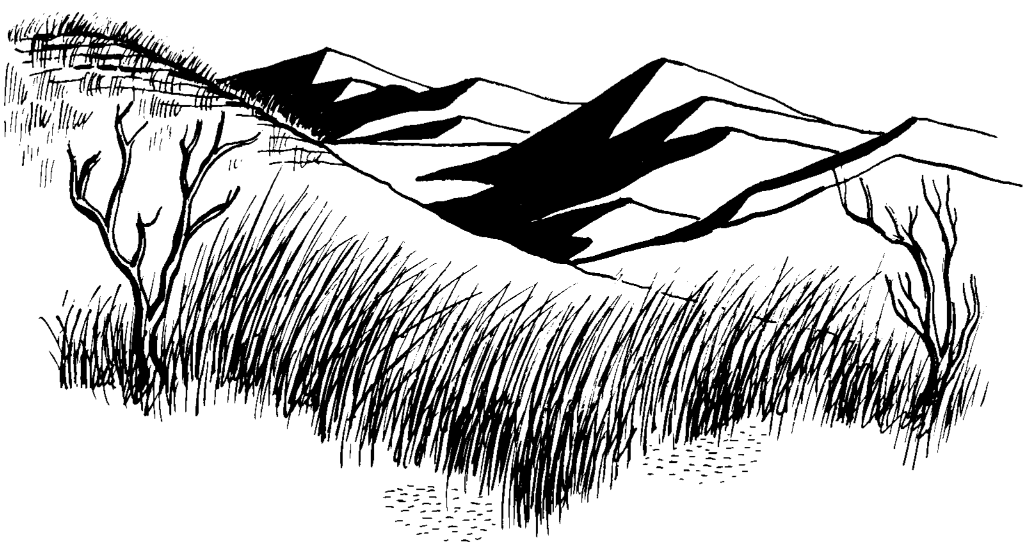
# Emergency Revegetation to Rehabilitate Burned Watersheds in Southern California

E. S. Corbett and L. R. Green



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# Contents

## *The Authors*

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A wildfire denuded most of the San Dimas Experimental Forest in 1960. Before the fire the watersheds grew a dense cover of chaparral, consisting mostly of chamise *(Adenostoma fasciculatum)* with lesser amounts of ceanothus *(Ceanothus* spp.*)*, white sage *(Salvia apiana),* black sage *(S. mellifera),* manzanita *(Arctostaphylos glauca* and *A. glandulosa),* California buckwheat *(Eriogonum fasciculatum),* and scrub oak *(Quercus dumosa).* The fire was extremely hot. It consumed all of the lighter vegetation and most of the heavy brush stems (fig. 1). And it left the soil in a loose powder-dry condition—unshielded from the wind and from heavy rains that usually occur in winter. Experience has shown that the removal of the vegetation cover by fire may greatly increase flood and erosion damage in the chaparal-covered mountains of southern California (Rowe *et al.* 1954).

To test "first-aid" treatments aimed at reducing the damage, an emergency research program was started at once.[1] The treatments included both vegetative and physical measures. This paper discusses the results of vegetative treatments in the first four years after the fire: the establishment and growth of artificially seeded species, the regrowth of native vegetation, and the effects of plant growth on watershed rehabilitation.

Physical measures have been described in detail elsewhere, along with some preliminary findings of the research program (Krammes and Hill 1963; Rice *et al.* 1965). These measures were of three types: contour trenches built by bulldozers to intercept storm runoff and enhance its infiltration; small check dams of soil cement to stabilize channel's; and rows of barley planted on closely spaced contours to stabilize side slopes. Because the barley planting was designed to create physical barriers to overland flow, this treatment was considered a physical measure in the experimental design. In the analysis of preliminary findings, such "side slope stabilization" appeared to be the most effective physical measure in reducing erosion. In this report, however, we consider the barley planting primarily as part of the plant cover.

## Erosion Control Treatments

### *Experimental Design*

In testing the vegetative treatments to control erosion, we used 25 watersheds, each 2 to 9 acres in size. From this group we randomly selected eight watersheds for testing annual grasses, eight for testing perennials, and four—left unseeded—for controls. Twelve of these 20 watersheds received one of the physical treatments. These 20 (table 1) are designated the "main treatment group watersheds" throughout this paper. The other five watersheds were given more than one physical treatment, and one of these was also seeded to annual grass.

In southern California, broadcast sowing of annual grasses is the most widely used method of rehabilitating burned watersheds. Four of the watersheds were broadcast sown by helicopter to a "low-density" mixture of 2 pounds of Wimmera 62 ryegrass *(Lolium rigidum)* and 1/2 pound of blando brome *(Bromus mollis)* per acre. Five (including one not in the main group) were sown to a "high-density" mixture of 16 pounds of Wimmera ryegrass and 4 pounds of blando brome per acre. Annual ryegrass is hardy, germinates well under local winter temperatures, and the seed is not ex-

[1] Since 1947 research at the San Dimas Experimental Forest has been conducted in cooperation with the California Division of Forestry. Other agencies that assisted in the emergency research program described in this paper were the California Department of Water Resources, Los Angeles County Fire Department, and Los Angeles Flood Control District.

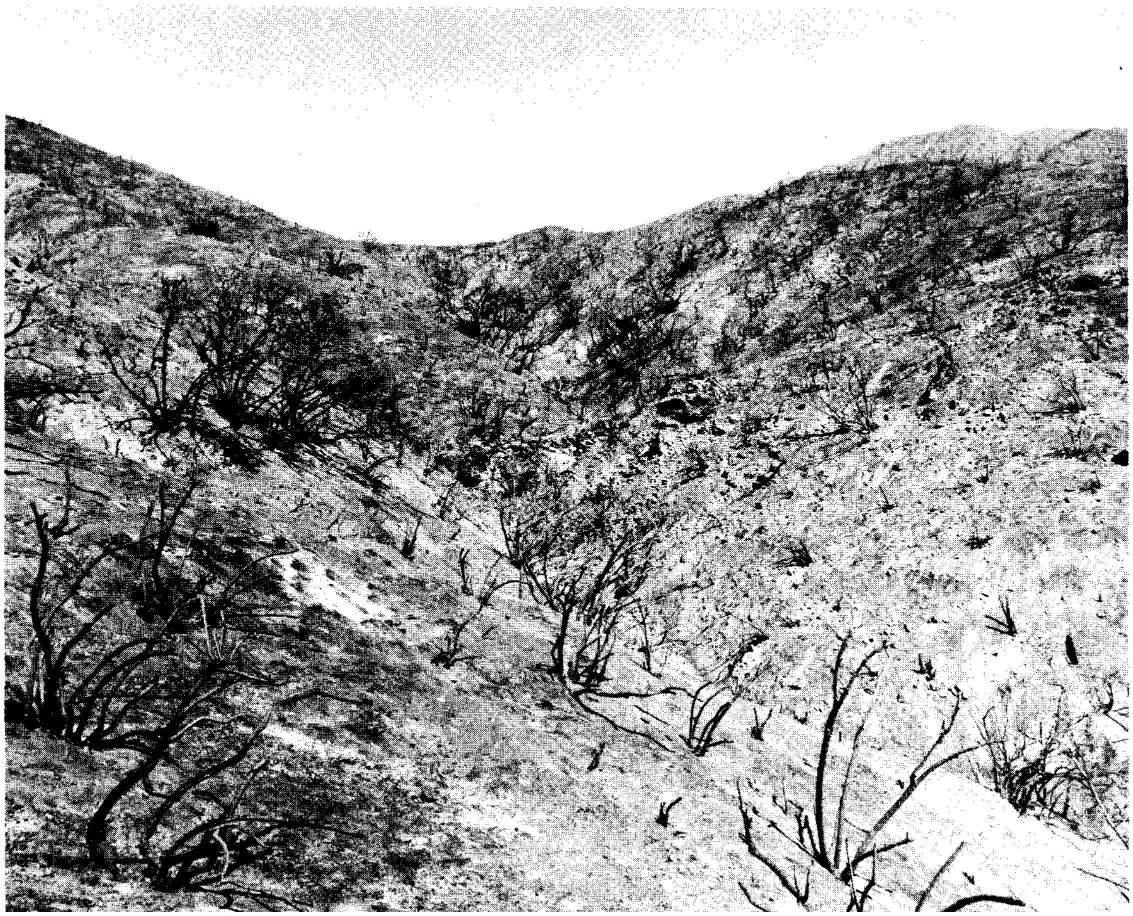

*Figure 1.—Typical watershed conditions after the fire of July 1960, at the San Dimas Experimental Forest.*

Table 1.--*Experimental design of erosion control treatments--main treatment group watersheds*

| Vegetative treatment | No physical treatment | Contour trenches | Channel checks | Side-slope stabilization |
|---|---|---|---|---|
| No seeding | XX | XX | XX | XX |
| Low density annuals | XX | XX | XX | XX |
| High density annuals | XX | XX | XX | XX |
| Low density perennials | XX | XX | XX | XX |
| High density perennials | XX | XX | XX | XX |

pensive (Hellmers 1957). On California's foothill ranges seeds of annual plants start to germinate after the first rains of 1/2 to 1 inch (Bentley and Talbot 1951) . Schultz *et al.* (1955) found that about 2 inches of rain were necessary to start germination in heavy ashes from a brush fire. Rainfall must occur at frequent intervals after germination to assure continuous growth.

Perennial grasses, slower growing than annuals, are recommended as permanent cover on areas where chemical spraying will be used to kill the brush. They are often used on fuel-breaks and for increasing the grazing capacity of brushlands. Four watersheds were broadcast seeded to a "low-density" mixture of perennial and annual grasses; it included 1 pound each of pubescent wheatgrass *(Agropyron trichophorum)* and Harding grass *(Phalaris tuberosa* var. *stenoptera);* 1/2 pound each of intermediate wheatgrass *(A. intermedium),* tall wheatgrass *(A. elongatum),* big bluegrass *(Poa ampla),* and smilo grass *(Oryzopsis miliacea);* and 1/4 pound of blando brome per acre. Four watersheds were seeded to a "high-density" mixture totaling 20 pounds per acre: Harding grass, 6 pounds; pubescent wheatgrass, 4 pounds; tall and intermediate wheatgrasses, smilo, and big bluegrass, 2 pounds each; and Wimmera 62 ryegrass and blando brome, 1 pound each. These mixtures are designated as the perennial grass treatments.

All the watersheds were sown on November 27, 1960. The watersheds sown with perennials were also sprayed with 2, 4-D and 2,4,5-T, during the springs of 1961, 1962, and 1964, to aid in perennial grass establishment by reducing competition from brush species. The two annuals—ryegrass and blando brome—were added to provide some additional ground cover until the slower developing perennials could take over.

The average cost of helicopter sowing on large areas was about $1.00 per acre plus cost of seed (Bentley *et al.* 1961). Cost of annual grass seed was moderate: 12 cents per pound for Wimmera 62 ryegrass and 60 cents for blando brome (table 2). The low density mixtures cost 54 cents per acre for annual grasses and $2.85 for the perennial grasses; the per acre cost of the high density mixes was $4.32 for annuals and $13.32 for perennials.

The side slope stabilization treatment was installed on nine watersheds, five of which were in the main treatment group. The contour rows of barley were hand planted in furrows 2 feet apart, cut into the soil with hoes, between December 1960 and mid-January 1961. Barley at 150 pounds per acre and 16-20 ammonium phosphate fertilizer at 140 pounds per acre were distributed in the furrows and covered with soil. The cost of this treatment was about $140 per acre.

### *Sampling Methods*

Vegetation cover was determined by ocular estimates on permanent 4-square foot-quadrats. The quadrats were subdivided into 1-foot squares to increase the accuracy of the estimates. They were distributed in a stratified (on aspect) random fashion in the watersheds. Vegetation estimates consisted of the percentage of soil within the quadrats covered by a vertical projection of actual foliar density. Areas sampled within the watersheds ranged from 96 to 240 square feet. The estimates for each strata were weighted by the areas of the aspects in the watershed.

Estimates of percent cover on each quadrat were made for the following categories: (a) sown annual grass, (b) sown perennial grass, (c) planted barley, (d) native grasses, (e) native broadleaves, (f) brush seedlings, (g) brush sprouts, (h) dead brush stems, and (i) litter. The vegetation surveys were made in April-May 1961, February and July 1962, May-June of 1963 and 1964. In the May-June 1964 survey we sampled only 13 of the 25 watersheds.

## Results and Discussion

### *Broadcast Seeding of Grasses*

The establishment of seeded species was extremely poor during the winter of 1960-1961. One reason was scanty rainfall (fig. 2). During the 2-month period immediately following the November 27 sowing, only 0.06 inch of rain fell. Throughout the remainder of the hydrologic year only 4.23 inches fell—bringing the total to 39 percent of the 35-year average. Furthermore, above-normal temperatures and high winds dried the soil and desiccated seedlings during late fall and early winter.

Since the aim of the study was to test the effect of grass cover and not seeding techniques, the ex-

Table 2. --*Cost of seed per acre, by species and treatment*

| Species | Estimated 1960 cost per lb. | Low density annuals (2 1/2 lbs. seed per acre) | High density annuals (20 lbs. seed per acre) | Low density perennials and annuals (4 1/4 lbs. seed per acre) | High density perennials and annuals (20 lbs. seed per acre) |
|---|---|---|---|---|---|
| | *Dollars* | | | | |
| Harding | 0.90 | 0 | 0 | 0.90 | 5.40 |
| Pubescent wheatgrass | .60 | 0 | 0 | .60 | 2.40 |
| Tall wheat-grass | .40 | 0 | 0 | .20 | .80 |
| Intermediate wheat grass | .60 | 0 | 0 | .30 | 1.20 |
| Smilo | .80 | 0 | 0 | .40 | 1.60 |
| Big blue | .60 | 0 | 0 | .30 | 1.20 |
| Blando | .60+ | .30 | 2.40 | .15 | .60 |
| Wimmera | .12 | .24 | 1.92 | 0 | .12 |

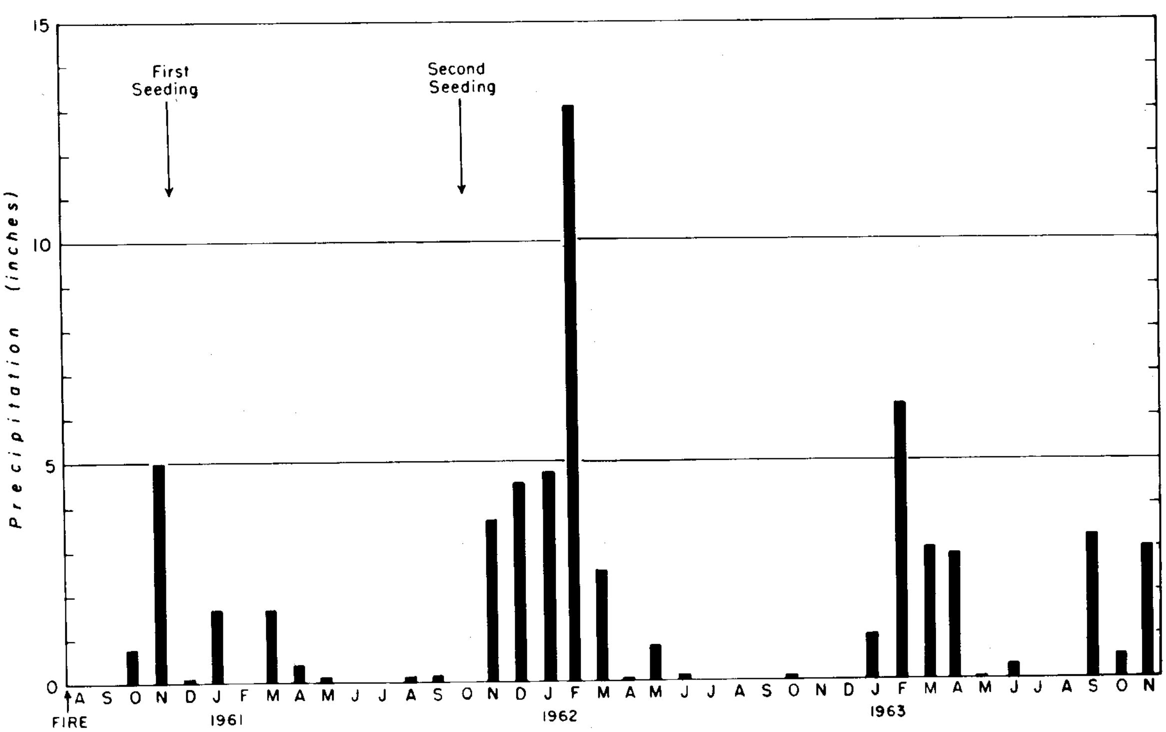


*Figure 2.—Precipitation regime after the fire of July 1960.*

perimental watersheds were broadcast seeded again less than a year later, in October 1961. The purpose of reseeding was to establish a sufficient cover of seeded species for experimental testing.

In the spring following the first sowing, watersheds seeded with "high-density" annuals had only a 2.2 percent cover of seeded grasses; the watersheds seeded with "low-density" annuals only 1.3 percent (fig. 3[2]). The watersheds sown with perennials had less than 1 percent cover in all samples. Because the second seeding was followed by substantial rainfall in late fall and winter, the cover of seeded grass was measurably improved. The grass covers in the watersheds with "high-density" and "low-density" annual grass seedings were 10.0 and 4.8 percent, respectively, in February 1962. The maximum cover in a single "high-density" annual watershed was 12.9 percent. Seeded cover in the perennial-sown watersheds was only 2.6 percent, most of which was accounted for by annual species. Later in the spring the seeded grass cover in the watersheds with the "high-density" perennial mixture was 6.2 percent, the bulk of which was still annual grass.

In the annual-sown watersheds the grass cover decreased gradually over the next 2 years, while in the perennial-sown watersheds, the cover increased as the perennial species began to take hold. In most cases annual species still contributed a substantial amount of cover in the perennial-sown watersheds (fig. 3), where sown grass did not have to compete with the native vegetation. The perennial grasses have done the best under low density rates of sowing where the amounts of annual grass seed included was low. The seeded grass cover (excluding barley) in the watersheds with the side slope stabilization treatment was about 50 percent lower than in those without it.

## Barley Plantings

Barley emerged within 10 days of planting, and quickly established rows. It provided 6.4 percent cover in the spring of 1961 and reached a maximum of 18.8 percent in the summer of 1962 (table 3). It also retained its row effect very well during this period (fig. 4). Rice *et al.* (1965) attributed a 65-percent reduction in debris yield during the hydrologic year 1961-1962 to the barley treatment.

After reaching its peak, the barley cover declined rapidly. This decrease was probably due to loss of fertilizer effectiveness, failure of soil to cover seed, and rodents destroying seeds. Competition from native herbaceous and brush species also took its toll—especially on the drier sites. Even in these areas, however, cows of dead barley stubble remained (fig. 5).

The close spacing of the barley rows helped prevent detached soil particles from moving down slope any great distance. The soil particles became trapped among the barley plants and gradually built up a series of small terraces, giving the watershed side slopes a miniature step-like effect. This helped to reduce serious rill and gully erosion from runoff-producing storms. The barley treatment also aided in protecting the soil from rain drop impact—thus lowering the probability of soil detachment—and helped to increase the infiltration capacity. On such critical erosion source areas as dry erosion chutes and unstable soil banks, however, this treatment, as well as any other type of vegetative measure, is difficult to install successfully without some type of mechanical aid.

## Growth of Native Species

Within 10 days after the fire, sprouts of native species started emerging from the crowns of many burned shrubs (Plumb 1961). By December, herbaceous species, where present, were still in the cotyledon stage or not much beyond it. The charred brush stems probably provided about as much cover then as the new sprout foliage. Sprouting was more prevalent on areas of deep soils where moisture conditions were the most favorable.

By the spring of 1961, the native vegetation provided about 10 percent cover on all watersheds without the side slope stabilization treatment (fig. 6), and 5 percent on watersheds that had this treatment. The plant species occurring most often on the plots were short-lobed phacelia *(Phacelia brachyloba),* whispering bells *(Emmenathe penduliflora),* broom deervetch *(Lotus scoparius),* hoaryleaf ceanothus seedlings, and morning glory *(Convolvulus occidentalis).* Herbicidal spraying kept the native vegetation in the perennial-sown watersheds in check from 1961 through 1964 (that is, the natives never exceeded 10.5 percent cover).

[2] Graphs in this paper indicate the trends from one sampling period to the next and do not represent the actual vegetative cover for each month throughout the year.

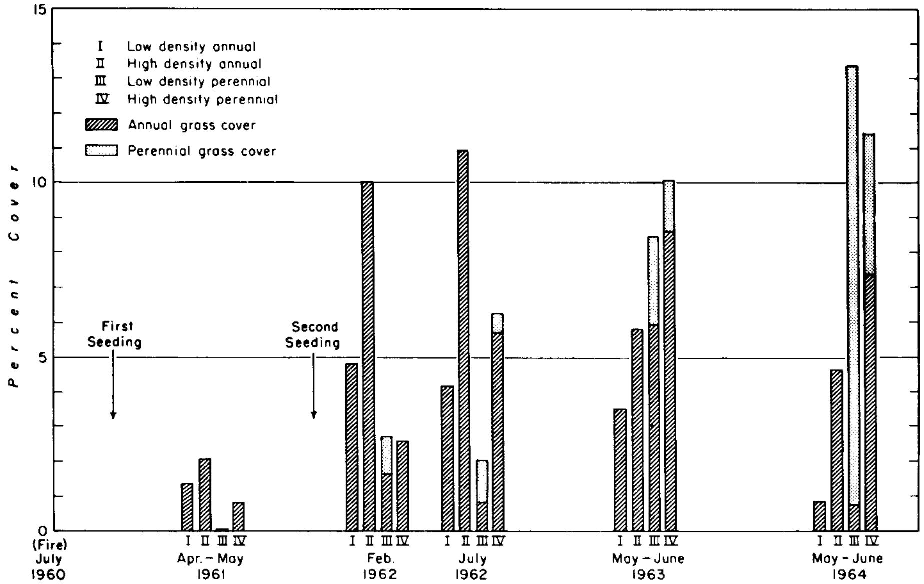


*Figure 3.—Percent of soil covered by sown grasses in the seeded watersheds without the side slope stabilization treatment.*

*Figure 4.—A new and second crop of barley had developed in the original rows on the experimental watersheds when this photo was taken in January 1962.*

Table 3.--*Development of barley in eight experimental watersheds seeded in December 1960-mid-January 1961*

| Date of survey | Row length[1] | Density [2] | Cover |
|---|---|---|---|
| | *Ft./acre* | *Stems/in.* | *Percent* |
| April-May 1961 | 15,060 | 4.1 | 6.4 |
| February 1962 | 13,550 | 6.1 | 12.6 |
| July 1962 | 14,930 | 6.0 | 18.8 |
| August 1963 | 2,780 | 7.7 | 3.8 |

[1]Actual length of barrier created by barley plants in the watersheds.
[2]Density of existing barley rows.

*Figure 5.—Vegetation recovery three years after the fire in a watershed that received both the side slope stabilization treatment and a high density, rye-grass seeding. Lack of native vegetation is evident in the spaces between the brush sprouts.*

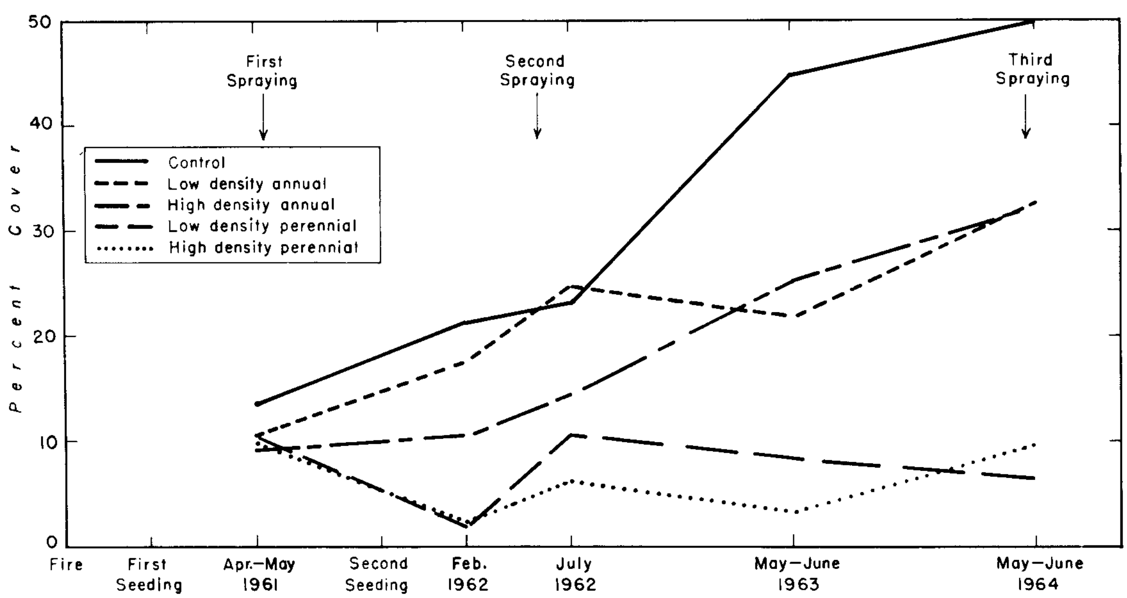


*Figure 6.—Percent of soil covered by native species (native grasses, broadleaves, seedlings, and sprouts) in the main treatment group watersheds without the side slope stabilization treatment.*

In the control watersheds, cover from native species increased from 12.3 percent in the spring of 1961 to 49.8 percent in 1964 (fig. 7). The watersheds sown with low density annuals had a native cover similar to that in the controls until 1962, when the rate of increase leveled off. Competition from the seeded grass in the watersheds sown with high density annuals slowed the establishment of native vegetation until 1963, when the annual grasses began to decline. The seeded grass cover in the watersheds sown with low density annuals was not great enough to affect establishment of native vegetation substantially in the first two years.

Recovery of native vegetation was significantly suppressed by the barley plantings. Control watersheds without barley had from 7.3 percent (spring 1961) to 23.7 percent (spring 1963) more native cover than watersheds with this treatment (fig. 8). When the barley began to fade out in 1963, the native species in the barley-sown watersheds began to respond more vigorously. In all barley-treated watersheds, the native cover was held back by about 40 percent during the first 2 years. This development was readily apparent by comparing two adjacent watersheds—one with and one without the barley treatment (figs. 5, 7).

The first two years after the fire, cover provided by the barley more than made up for its effect in holding back the native vegetation in the control watersheds (fig. 9). When the barley deteriorated, however, the live vegetation was greatest in the watersheds without the barley treatment. The amount of live vegetative cover could be important in areas where mass slumping of soil is likely because plants with live, deep vigorous root systems would be needed to maintain soil stability.

### Litter and Dead Stems

Since the first vegetation sample was taken in 1961, the dead vegetative cover (primarily litter) has been gradually increasing. This cover averaged 1.3 percent in 1961 and 9.5 percent in 1964 in the main treatment group watersheds. A large amount of litter was added in 1963 and 1964 in the side-slope stabilized watersheds—primarily from barley.

### Total Vegetative Cover

Vegetative cover was uniformly low after the first rainy season, which was 61 percent below normal. Including seeded grasses, native species, and litter and dead stems, total cover averaged only 12.5 percent in the spring of 1961, and differences between treatments were small—within 2 percent cover (fig. 10).

The following year, after another seeding and appreciable rainfall, cover in the unsprayed watersheds increased to about 30 percent. The perennial-sown watersheds still had a low cover of vegetation in February 1962—about 9 percent, but increased to 16 percent by the summer.

The annual-seeded watersheds never had a significantly greater vegetative cover than the controls. In the third and fourth years after the fire, the total vegetative cover was highest in the control watersheds. There was no significant difference in total vegetative cover between the high and low density annual watersheds and between the high and low density perennial watersheds. Table 4 lists the significance of differences among the various seeding treatments.

The importance of each type of vegetation in the makeup of total cover varied among the watershed groups. In the control watersheds without side slope stabilization, vegetative cover is provided mainly by the native species (fig. 11C). In the annual-sown watersheds the native species were a little slower in responding, seemingly because of competition from the seeded grass (fig. 11 A). When the annual grasses began to decline after 2 years, the native species increased their cover more rapidly. Litter and dead stems provided gradually increasing cover in all watersheds. In the sprayed perennial-sown watersheds (fig. 11 B), the seeded grass cover was slow in becoming established; not until the third and fourth years after the fire did the cover show signs of increasing appreciably. In the four control watersheds with the side slope stabilization treatment, barley held back the recovery of the native vegetation and added appreciably to the litter cover (fig. 11D).

## Effects on Watershed Rehabilitation

There have been only six analyzable storms to evaluate the treatments since the fire on the Experimental Forest. Five of them have been reported by Krammes and Hill (1963) and Rice *et al.* (1965). The sixth storm, on January 20-22, 1964, produced 3.76 inches of rain. Rainfall intensities

*Figure 7.—Recovery of native vegetation in one of the control watersheds three years after the fire.*

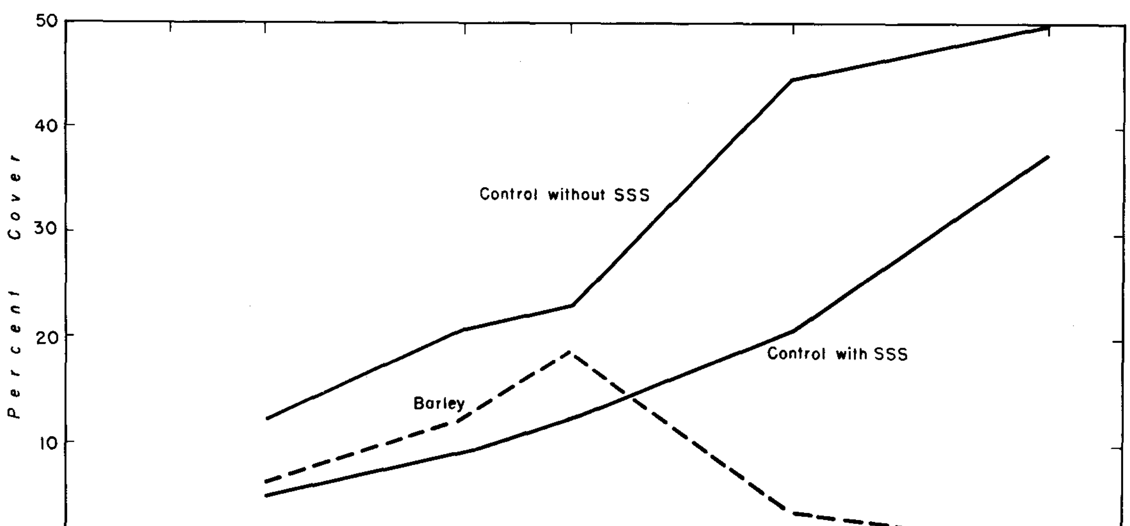


*Figure 8.—Percent of soil covered by native species (native grasses, broadleaves, seedlings, and sprouts) on all the unseeded watersheds, with and without the side slope stabilization treatment; and barley cover in the watersheds with side slope stabilization treatment.*

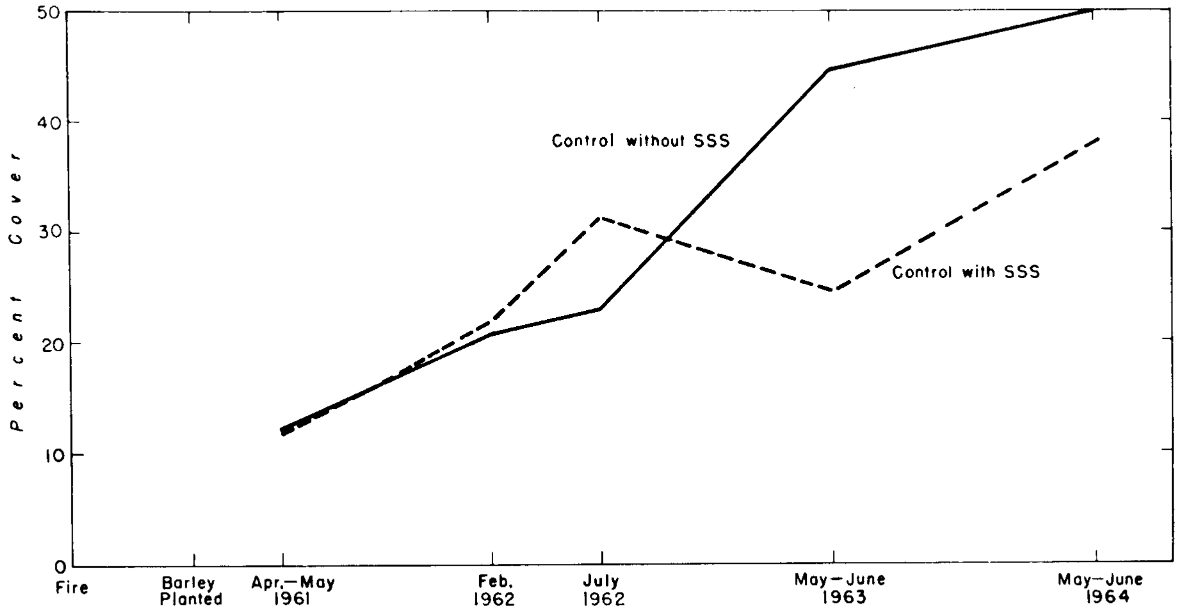


*Figure 9.—Percent of soil covered by live vegetation (planted barley and native species) on all the unseeded watersheds with and without the side slope stabilization treatment.*

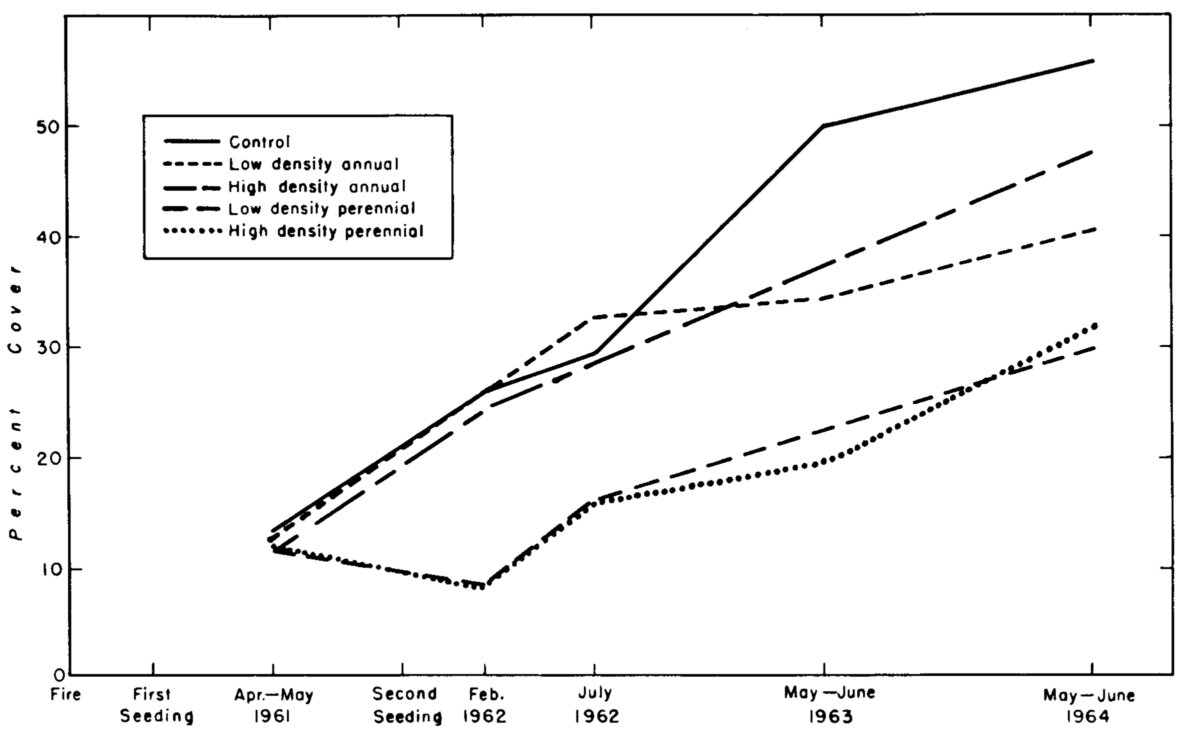


*Figure 10.—Percent of soil covered by all vegetation (dead and alive) in the main treatment group watersheds without the side slope stabilization treatment.*

Table 4.--*Statistical significance of differences in total vegetative cover among watershed groups*[1]

| Watersheds compared | Date surveyed | | | | |
|---|---|---|---|---|---|
| | April-May 1961 | Feb. 1962 | July 1962 | May-June 1963 | May-June[2] 1964 |
| Control-high density annual | (3/) | (3/) | (3/) | 0.05 | (3/) |
| Control-low density annual | (3/) | (3/) | (3/) | .05 | .05 |
| Control-high density perennial | (3/) | 0.01 | 0.05 | .01 | .05 |
| Control-low density perennial | (3/) | .01 | .05 | .01 | .01 |
| High density annual-low density annual | (3/) | (3/) | (3/) | (3/) | (3/) |
| High density annual-high density perennial | (3/) | .01 | .05 | .01 | (3/) |
| High density annual low density perennial | (3/) | .01 | .05 | .05 | (3/) |
| Low density annual high density perennial | (3/) | .01 | .05 | .01 | (3/) |
| Low density annual-low density perennial | (3/) | .01 | .05 | .05 | (3/) |
| High density perennial-low density perennial | (3/) | (3/) | (3/) | (3/) | (3/) |

[1]On the basis of Duncan's new multiple-range test.

[2]This analysis was less sensitive than the previous ones owing to the reduction in the number of watersheds-sampled.

[3]Not significant.

were as follows:

| *Duration (minutes)* | *Inches per hour* |
|---|---|
| 5 | 1.51 |
| 10 | 1.24 |
| 15 | 1.09 |
| 20 | .92 |
| 30 | .82 |
| 60 | .66 |

Although this storm was similar in amount and intensity to some of those occurring during the winter of 1961-62, the peak flows (mean average response) were only 18 percent as great. Seven of the 20 main treatment group watersheds had no flows during this storm; 2 years before all watersheds had measurable peak flows. During this period the total vegetative cover doubled. The trends in flood peaks corresponded well with the total vegetative amounts (fig. 10).

Analysis of the four largest storms in the winter of 1961-62 (Rice *et al.* 1965) suggests that a substantial grass cover established the first year after a fire can help reduce erosion measurably. In watersheds with the "high-density" annual sowing, the seeded grass (10 percent cover) was associated with a 16-percent reduction in debris even though it had no apparent effect on flood peaks. "Low-density" annuals had little or no effect.

In watersheds seeded with perennial mixtures, the seeded species apparently could not compensate for the reduction in native species caused by herbicidal sprays. The total vegetative cover in perennial-seeded watersheds was 13 to 30 percent lower than in the unseeded control watersheds for 3 years after the first spraying. Rice *et al.* (1965) found that watersheds seeded to "low-density" perennials tended to have higher flood peaks and greater debris yields than the other watersheds the first two years after the fire. "High-density" perennial watersheds showed little difference from unseeded watersheds in those years. Since then, however, flood peaks from all the perennial watersheds

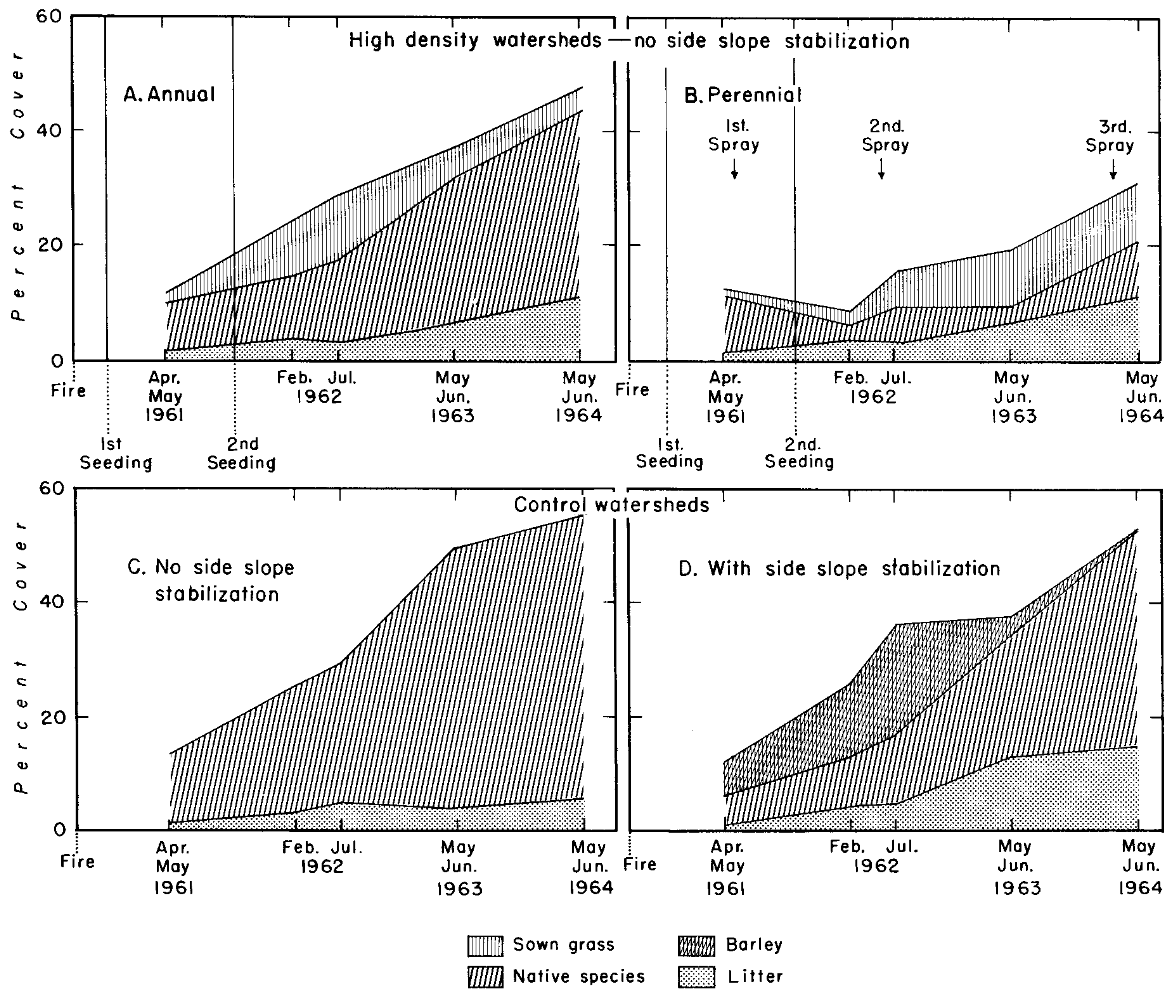


*Figure 11.—Relative contribution of the various vegetative components in the various watershed groups.*

have been greater than peaks from unseeded watersheds.

Unfavorable weather the first year after the fire unquestionably reduced the effectiveness of seeded grasses in the experimental watersheds. The best seedbed conditions for establishing a grass cover existed that year. In Monroe Canyon at slightly lower elevations than the experimental watersheds, annual grasses were sown *before* the November rains in 1960. By the end of the first growing season, deep soils in this area had a 16.6 percent grass cover on north-facing slopes, and 2.6 percent on the drier south slopes. One year later the grass had increased to 53.1 percent on north slopes and to 24.3 percent on south slopes. The experimental watersheds were first sown *after* the November 1960 rains. And rainfall remained scanty the rest of that season. "High-density" seeding with annuals—the most successful broadcast seeding—produced only 2.2 percent cover the first year; even after a second seeding, it provided only 10 percent cover the next year. Thus, timing of the seeding may be a critical factor in the rehabilitation of burned watersheds.

Even if moisture is adequate for germination, several factors can inhibit grass establishment when no rain follows seeding. Growth of grass may be limited by deficient precipitation or low temperatures, or both, after germination. Strong winds can blow large amounts of seed from the hillside; harvester ants, rodents, birds, and other wildlife can destroy much seed. But rainfall tends to cover the seed with ash and soil, protecting it from such losses. The longer the interval between the time of seeding and the first good rain, the greater the loss is likely to be.

Despite these hazards, an effort to establish grasses seems worthwhile. For some erosion control problems, grasses may be more advantageous than many native plants—even though the aerial parts of natives are much larger. The grasses have fine, fibrous root systems that occupy the upper layers of soil. And the numerous grass plants are more uniformly distributed than native species in the watersheds. These are advantages when the problem is to bind down surface soil. Where mass slumping of soil is a problem, plants that put down deep roots have the advantage, for they can help bind the soil mantle to the underlying parent material. Such species as Eastwood manzanita *(Arctostaphylos glandulosa),* the oaks *(Quercus* spp.*),* and christmasberry *(Photinia arbutifolia)* would be desirable native plants in this situation (Hellmers *et al.* 1955). Where both surface erosion and mass movement of soil may occur, as on road fills, a mixture of deep-rooted woody shrubs and fibrous-rooted plants would be recommended. Besides the grasses, some native plants with shallow branching roots would help in this situation; for example, such species as bush monkeyflower *(Mimulus longiflorus),* California buckwheat, white sage, and thickleaf yerbasanta *(Eriodictydon crassifolium* var. *nigrescens).*

A grass cover may be helpful in reducing another problem: the hydrophobic characteristic of some chaparral soils. A water-repellent property of soil is commonly associated with both burned and unburned chaparral watersheds and is generally thought to result from an organic coating on soil particles. This property may be responsible for increasing surface runoff and erosion potential in southern California mountains. Van't Woudt (1959), in describing Zunker's (1930) work, showed that water-repellent soils were commonly associated with native heath vegetation, but were not found on adjacent areas which had been in a grass cover for 20 years or more. In examining burned chaparral watersheds in southern California, Krammes and DeBano (1965) found large areas of non-wettable soils. Sample sites where the soils did not demonstrate this hydrophobic characteristic were usually occupied by a grass cover.

## Summary and Conclusions

The testing of emergency erosion control measures after a wildfire burned the San Dimas Experimental Forest has been in progress since late 1960. Twenty-five small watersheds were treated with various "first aid" measures including grass seeding to reduce debris production and flood peak flows. Precipitation through 1964 was 66 percent of the 35-year average.

The total vegetative cover in the seeded watersheds was never significantly higher than in the unseeded controls. The seeded vegetation (sown grasses and planted barley) had a substantial effect, which varied directly with percent cover, on holding back the recovery of native species. But the grass cover established in the watersheds so treated might have provided better protection from surface soil erosion than a like area of some native species because of the rooting habits and uniform distribution of the grass plants and their possible effects on the existing areas of hydrophobic soils.

The benefit of grass cover was illustrated the second winter after the fire when, in four large storms, the "high-density" annual grass seedings were associated with a 16 percent reduction in debris. Owing to the low cost of the annual grass seedings and the speed with which it can be applied, land managers appear justified in trying to establish a grass crop. But this treatment should not be taken as a cure-all. In many instances a combination of vegetative and physical measures may be most appropriate—especially in critical erosion areas of a watershed.

The total vegetative cover in the watersheds sown with perennials which were sprayed with herbicides to aid in grass establishment, was far below the total in other treatments. The perennial grasses did not compensate for the reduction in native species during the first four years.

Barley planted in closely spaced rows on contour proved to be the most successful emergency treatment. Barley row length and density, and the resulting percent cover, stayed high for two years. But the barley stand began to deteriorate in the third and fourth years and storms were too few to test the treatment during this period.

The mean average peak flow from 20 treated watersheds in one 1964 storm was only 18 percent as great as the average peak produced from three storms of similar size in 1961-62. The total vegetative cover had doubled in the intervening 2 years, from 21.2 to 42.6 percent. "Healing" of the watersheds during this period has thus had a considerable effect on reducing the flood potential.

In selecting a vegetative treatment for use to control erosion on burned watersheds, several factors must be kept in mind. A good grass cover established a year or two after a fire can help reduce the amount of erosion. There is a risk (high in southern California), however, that establishment of a grass crop will be poor owing to critical and variable climatic conditions. Row plantings of barley have proved effective in controlling erosion, but are more expensive than broadcast seedings. Use of this treatment on critical erosion areas in a watershed and broadcast seedings on the other portions will help to minimize cost yet establish a sound erosion control program. If down-stream values are high, a combination of vegetative treatments and physical structures may be required to provide the needed protection. The most successful erosion control program is one that can prevent soil movement on the slopes from starting and concentrating in stream channels.

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