RESULTS OF RYEGRASS SEEDING AFTER THE 1970 WRIGHT FIRE

by

Klaus W. H. Radtke

A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Natural Resources

With an Emphasis in Forestry

January 1980

RESULTS OF RYEGRASS SEEDING
AFTER THE 1970 WRIGHT FIRE

by

Klaus W. H. Radtke

Approved by the Master's Thesis Committee

Dale A. Thornburgh, Chairman

Robert B. Turner

William R. Sise

Approved by the Graduate Dean

Alba M. Gillespie

ABSTRACT

Commercial annual ryegrass (Lolium multiflorum Lam.) has been used extensively since the early 1950s for emergency revegetation of California's burned watersheds. An analysis of photo sequences and temporary plots was utilized to evaluate ryegrass establishment during the first season following fire on the 28,000 acre Wright (Malibu) burn of 1970. The results provide insight into the dynamics of ryegrass, chaparral, and annual grass competition.

The success of ryegrass establishment, development of cover, and maturation varied throughout the burned area. On slopes in the Monte Nido area where shallow and low fertility soils were a limiting factor, annual ryegrass accounted for less than 10 percent of the cover. However, a 30 to 40 percent cover was successfully established on most areas of the coastal mountains where deeper, more fertile soils were present.

Approximately 20 percent of the cover was established within 14 weeks following the first heavy rains. During this period, 90 percent of the season's rainfall occurred. Resident grasslands reestablished themselves quickly from abundant seeds in the soil crowding out the annual ryegrass. Therefore, seeding with annual ryegrass was probably not necessary.

ACKNOWLEDGEMENTS

Teamwork has made this thesis possible. I appreciate the love, patience and tolerance that my wife, Yoshiko, has shown over the years towards both my job and my work.

The late Range Scientist for the Riverside Fire Laboratory, Eamor Nord, and Fire Ecologist Bob Sweeney of San Francisco State University have provided constant inspiration and warm friendship for which I am very thankful.

Much credit belongs to the foresters of the Los Angeles County Department of Forester and Fire Warden. Head Deputy Forester Arthur Arndt and Senior Deputy Forester John Haggenmiller are two great people who have made it possible for me to enjoy my job for so many years. They have encouraged me to undertake this study.

I also had advice and help during our chess games from Deputy Forester Russ Stallings who was my supervisor when this study was initiated. Assistant Head Deputy Forester Grant Brown kept me on the right track when my enthusiasm would carry me away. Much appreciated are the Malibu foresters, Dave Boyd and Mike Hudson, who along with Range Specialist Joe Agozino carried my load while I was back in school finishing this thesis.

Special thanks belong to my major advisor, Dale Thornburgh, who not only provided me with intellectual inspiration during my undergraduate work but also eight years later during my graduate studies. Besides being an inspiring teacher, he is a great person. My other advisors, Range Professor Dave Bryant and Fire Science Professor Brooks

Sibley, deserve credit because they assisted in organizing this unorthodox thesis.

A deep appreciation also goes to my friend, John Thomas, who postponed his world travels long enough to make it possible for me to return to school.

Last but not least, special thanks go to the assistance offered by MSU forestry secretary, Hannelore Edwards, and forestry student, Leslie Roessler.

This thesis is dedicated to my wife, Yoshiko, who made many sacrifices in supporting it and also to my late friend, Eamor Nord, who continuously inspired me with his inquisitiveness about life.

TABLE OF CONTENTS

INTRODUCTION

On September 25, 1970, hot, dry Santa Ana winds fanned fires throughout Los Angeles County that destroyed in excess of 100,000 acres of watershed cover within three days. The Wright (Malibu) Fire alone accounted for almost 28,000 acres (Fig. 1).

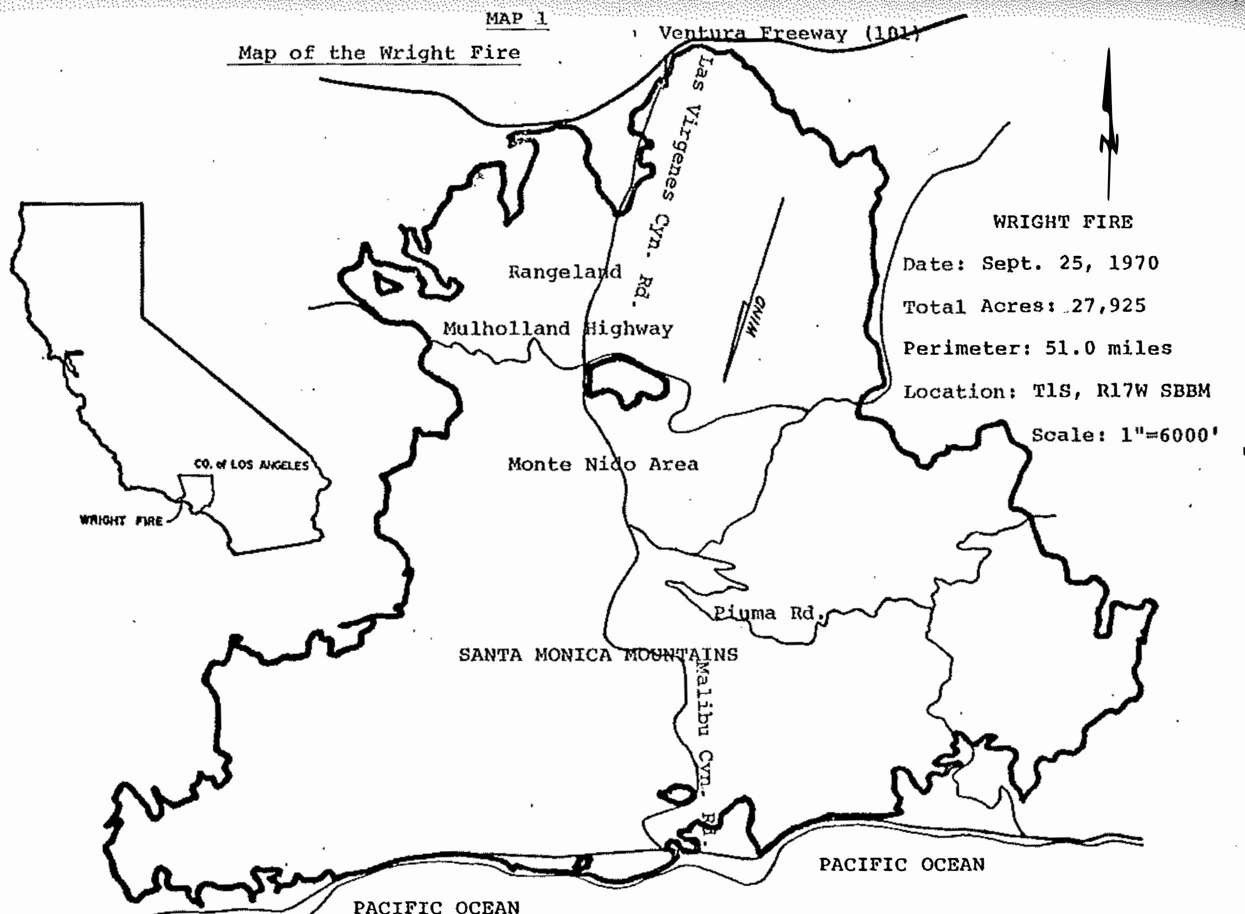
The fire left unstable soils exposed to winter rains, and a protective cover was needed to minimize expected erosion. From October 9 through 16, 1970, the Forestry Division of the Los Angeles County Fire Department supervised the emergency seeding of 79,000 acres of watershed with a high erosion potential, including all but a few hundred acres of the Wright Fire. Commercial annual ryegrass (Lolium multiflorum Lam.) was seeded by aircraft at the rate of 8 pounds per acre to achieve an average coverage of 32 seeds per square foot. Actual seed coverage was verified by ground checks. It was uniform and in most places averaged over 20 seeds per square foot.

The objective of this study was to evaluate annual ryegrass seeding following fire as an emergency revegetation measure to prevent excessive erosion. This was accomplished through ocular crown density estimates of annual ryegrass production on temporary plots during the first year following seeding. A complete photo study of the burned area was also used to show the ryegrass and other competing vegetation. The photo study was continued for one year. These observations were then used as an information base for future management decisions on the use of seeding annual ryegrass for emergency revegetation.

The Santa Monica Mountains were chosen for this study because they are the most extensive watershed area in the 1970 burn that is still covered with native chaparral. They offered variety in topography, vegetation, climate, and soils. This provided an opportunity for a complete evaluation of the seeding efforts.

MAP 1

Map of the Wright Fire



LITERATURE REVIEW

Annual Ryegrass

Commercial annual ryegrass (Lolium multiflorum Lam.) has been used extensively in California since the early 1950s for emergency revegetation of burned watersheds. Information concerning the usefulness of this species has been based on the seeding of watersheds burned by wildfires in southern California during the 1930s and 1940s, and on range improvement seedings of areas cleared by controlled fires. Prior to the extensive use of annual ryegrass, mustard (Brassica spp.) was seeded following wildfires to control erosion. However, the objections of agriculturalists and range specialists, who considered it a noxious weed, caused it to be discontinued (Bentley, et al, 1956).

Commercial annual ryegrass is considered to be well adapted for initial erosion control. It has the ability to grow in the winter and spring temperatures found in southern California, is easily established, has vigorous seedlings and extensive fibrous root systems, is cheap and abundant, is palatable forage for livestock and wildlife, and is also highly competitive with brush seedlings. Hafenrichter, et al (1968) state that annual ryegrass is also adapted to a wide range of soil and drainage conditions; however, it does not do well on excessively, or poorly, drained soils. Bentley, et al (1956) state that annual ryegrass usually requires productive soils with at least fair soil fertility.

Annual ryegrass germinates within 5 to 7 days after the first winter rains, provided temperatures reach 15 degrees C. and the soil surface does not dry out during germination. Leaf growth during the winter months may stop for several weeks if night temperatures dip below 0 degrees C. and the days are cold and cloudy; however, the roots continue to grow.

Top growth accelerates when warmer and drier weather begins. This corresponds with the time of maximum emergence of brush seedlings (Schultz, Launchbaugh, and Biswell, 1955). Thereafter, annual ryegrass density declines quickly. Nutrient deficiencies, especially nitrogen, appears to be the main contributing factor. Grazing by the meadow mouse (Microtus californicus) and other small rodents may also occasionally be of importance (Papanastis, 1973).

Blanford and Gunter (1971) state that chances for successful annual ryegrass establishment after direct seeding are better in a cool summer climate than in a hot summer climate. Their studies showed that first year crown densities of the species on revegetated watersheds averaged 46 percent in cool summer fog climates, 20 percent in cool summer climates, and 10 percent in warm summer climates. During the second season, crown density persisted in cool summer climates but declined in warm summer climates. By the end of the third season, crown density declined to about 23 percent in cool summer climates, and annual ryegrass was almost non-existent in the warm summer climates.

The California Division of Forestry (CDF) recognizes these limitations on annual ryegrass and does not consider the species a cure-all when used for erosion control; however, they feel it is a good "first aid treatment" for burned watersheds. The CDF has therefore cooperated with local agencies in seeding more than one million acres of burns between 1956 and 1970. The seeded ryegrass is expected to give cover for 3 years, by which time it is hoped that the native vegetation will be well on its way to recovery (Blanford and Gunter, 1971).

Since 1 pound of annual ryegrass contains approximately 217,000 seeds, a seeding rate of 1 pound per acre would give a theoretical coverage of 5 seeds per square foot. Field experience has shown a 20 percent drift loss from aerial seeding which reduces this to 4 seeds per square foot (Miller, 1956). To reach the desired density of 24 seeds per square foot, 6 pounds would be needed per acre. Half of these are expected to germinate, and 6 of the 12 germinated seeds will normally die. This is expected to leave 6 mature ryegrass plants to provide a crown density of nearly 30 percent per square foot (Bentley, et al, 1956). Eight pounds of annual ryegrass per acre is presently used for California's burned watersheds to provide a buffer. An increase in the seeding rate from 8 to 16 pounds failed to show an increase in cover density (Haggenmiller, 1970).

Ryegrass-Erosion Relationships

On steep mountain slopes, soils often slide as soon as vegetation is removed. This loose soil is then swept away by the first heavy rains clogging stream channels (Rice, et al, 1963). Therefore, ryegrass must form an instantaneous cover to be fully effective.

Blanford and Gunter (1971) point to studies made on established stands of annual ryegrass (those that were not part of a fire cycle) to arrive at some measure of the reduction in erosion obtained by seeding annual ryegrass. A 50 to 60 percent cover can significantly reduce soil losses, and a 30 to 40 percent cover could practically stop soil losses associated with light storms and also reduce soil losses from heavier storms to about 60 percent. The authors conceded that there is not enough information on erosion-ryegrass relationships and that sophisticated studies would be needed to arrive at more precise prediction models.

Rice, Crouse, and Corbett (1963) concluded that ryegrass is unsuited to southern California soils and climate. In their studies during the first year after seeding, the perennial ryegrass never formed a cover of more than 1.7 percent and annual ryegrass never more than 10 percent. In any case, ryegrass seeding had no effect on flood peaks but may have helped reduce the accumulation of debris. The authors concluded that ryegrass seeding is still a low cost alternative, but does not have great promise for the land manager.

In its 1970 annual revegetation report, the California Division of Forestry indicated that reseeding the 1966 Round Fire burn in Lake County, northern California (average rainfall above 35 inches), resulted in 56, 65, and 43 percent cover for the first three years respectively. Seeding was done at the rate of 8 pounds per acre.

Rice (1973) stated that sowing burned watersheds with annual grasses is probably a misdirected effort because the grasses only affect a small portion of the erosion on a watershed. He cited the example of a severe January 1969 storm with a recurrence interval of 35 years that occurred in Harrow Canyon near the San Dimas experimental forest (Table 1). The storm removed much soil and ryegrass seed from exposed areas and accumulated the debris in low spots and depressions. Thick stands of ryegrass developed there in early April after 90 percent of all storms had taken place.

Table 1 — Sources of Sediment in Harrow Canyon During the 1969 Flood

Mechanism	Percent
Wind	1
Dry Ravel	1
Landslides	2
Rills	22
Channel Scour	74
Total: 232 cubic yards per acre	

Of the erosion mechanisms shown in Table 1, annual ryegrass cannot affect wind and dry ravel but could reduce the rill and gully erosion by approximately one-third (interpolation of previous data by Rice). The sediment from channel scour could only have been reduced if the annual ryegrass improved infiltration, thereby reducing peak runoff. From Table 1, it is apparent that annual ryegrass at its best could only have affected about 8 percent of the sediment transport in Harrow Canyon. Rice concluded that evaluating the effect of sowing annual ryegrass for erosion control may never be resolved because of southern California's mediterranean climate, and the resultant washing away of seeds in wet years and seed failure in dry years.

Since much of California's chaparral is found on steep, unstable mountains, runoff and erosion rates are high during very large storms. However, for the most part, rainfall intensities are rarely so high that water cannot be absorbed on even thin soils. The up to 10 feet thick, hydrologically active mantle can absorb and transmit large volumes of water (Rice, 1973). Large storms that occur about every five years are responsible for moving approximately 40 to 60 percent of the sediment produced by a watershed. Rice states that about 70 percent of the long-term erosion occurs the first year after a fire. Annual ryegrass would therefore need to form a quick cover before the end of the winter rains to control at least part of this erosion.

Ryegrass and Chaparral

In studying the relationship between grass density and chaparral seedling survival, many researchers have found that annual ryegrass may be detrimental to chaparral reestablishment. A review of grass-chaparral relationships is therefore necessary.

During a fire, the growing points of grasses are protected from all but the most severe heat, but the living tissues of taller growing shrubs are exposed. In open country therefore fire favors grasslands and restricts chaparral (Cooper, 1963). Indians, through their habit of burning brush, may have spread California's perennial grasslands; however, some authors believe that Indian burnings were seldom extensive (Burchum, 1959). Prior to the arrival of the white settlers, perennial bunchgrass ranges consisted primarily of needlegrass, Stipa spp., (Stoddart, Smith, and Box, 1975).

It is believed that extensive burning and overgrazing, along with clearing for settlement and cultivation, favored the annual grasses which must have been introduced by the settlers (Heady, 1972). In combinations of seedings involving annual and perennial grasses, the annuals have the competitive advantage because they germinate earlier and grow faster. These conditions, along with the low rainfall found over much of the annual grasslands, may have produced a California annual rather than perennial grassland during the last 200 years.

Perennials do not offer good first year cover, and their root system is not as fibrous as that of annuals, especially annual ryegrass. Seeding perennial grasses has therefore often failed on southern California's burned watersheds. Therefore, annual grasses are recommended for the treatment of chaparral after fire, and for range improvement perennial grasses are best (Bentley, et al, 1956).

However, annual ryegrass may actually discourage chaparral re-establishment. For example, on a chamise burn annual ryegrass density of less than 5 percent resulted in the survival of more than 200 chamise (Adenostoma fasciculatum) seedlings. However, less than 30 seedlings per mil acre survived when grass density was 25 percent (Biswell, et al, 1952). The study also showed that no matter how dense the original population of seedlings in a burn, approximately 2 seedlings per square foot survived the first year when no grass competition was present. Additional mortality reducing the seedling density below 2 seedlings per square foot was almost entirely attributable to ryegrass competition. When annual ryegrass density reached 30 percent, all chaparral seedling mortality was the result of ryegrass competition.

Schultz, Launchbaugh, and Biswell (1955) noted that 70 percent foliar annual ryegrass density decreased both root and shoot length of three month old wedgeleaf ceanothus (Ceanothus cuneatus) by at least 300 percent and reduced lateral development to insignificance. Hedrick (1951) reported that herbaceous species suppress chaparral seedlings, thereby changing the succession of the brush cover. The 1971 California Division of Forestry report on ryegrass revegetation stated that annual ryegrass encourages brush conversion because of its early competitiveness. Since regrowth of native herbaceous cover is rapid in coastal areas, the question arose whether seeding these areas after fire with annual ryegrass is necessary for erosion control.

Chaparral Fire Ecology

California has close to eleven million acres of chaparral and nine million acres of woodland within the brushland zone below its commercial timber belt (Bentley, 1967). The chaparral, more than other plant communities, has adapted to the selective pressures of fire to the extent that its sclerophyll vegetation is rejuvenated by fire and increases in species diversity (Sweeney, 1969).

During a fire, surface temperatures in chaparral can vary between 200-300 degrees C. and reach 550-650 degress C. with little uniformity of distribution over a given burn (Sweeney and Biswell, 1961). When fire was not too hot, sprouting resulted in rapid recovery of the vegetation. Shrubs have been found to sprout within 10 days of a fire and grow as much as 25 cm within 30 days. The plants apparently utilize water reserves from the soil depth or rock crevices when the fires occur during the dry season (Plumb, 1961). On the driest sites, shrubs may delay sprouting for up to 2 years (Plumb, 1963).

Increased germination is apperently another major fire adaptation. Although only approximately half the major chaparral species sprout, all seed prolifically. The vast majority of the seedlings germinating after a burn were present as seeds before the fire. These seeds are tolerant of relatively high temperatures for short periods of time; some air dried seeds can withstand temperatures exceeding 160 degrees C. for about five minutes. Such temperatures are rarely exceeded one-half inch below the soil surface (Sweeney, 1956). The increase in light intensity appears to be directly responsible for the marked increase in flowering of plants and therefore seed production in burned areas.

Germination inhibitors present in the litter of unburned chaparral decrease seed germination in old stands (Sweeney, 1967). Fire apparently eliminates these inhibitory substances. For instance, after the 1947 Bryant Fire in Pasadena it was noted that there was practically no seed germination adjacent to the burn, while on the burn itself chaparral species germinated profusely (Went, Juhren and Juhren, 1952).

Fire succession proceeds from a profusion of annuals during the first year through a continuously changing dominance of herbaceous cover over the next three to four years. A more complete overstory of chaparral broadleaf sclerophyll species establishes itself thereafter, and the herbaceous cover fades out. In northern California, grass has a tendency to replace broadleaved herbs the fourth and fifth year (Sweeney, 1967).

Chaparral Soils

Annual ryegrass establishment is greatly enhanced by fertile soils. Since nitrogen is the most limiting factor on chaparral soils, natural fertility of a site can be estimated by the chaparral species growing on it. Chamise depletes the soil by almost 50 pounds of nitrogen per acre per year (Zinke, 1967), but scrub oak (*Quercus dumosa*) and hoaryleaf ceanothus (*Ceanothus crassifolius*) each add approximately this amount (DeBano, 1973). Some annual legumes present after fires, such as deerweed, also fix nitrogen.

Nitrogen, phosphorus, potassium, calcium, and magnesium are tied up in standing brush. These elements are released by fire and are made readily available in the form of ash for quick plant growth. However, nitrogen is an easily volatized element and it has been shown that up to 100 pounds per acre are lost during prescribed burns.

High erosion rates which usually occur after wildfires are aided by both a water-repellent soil layer formed during hot fires and the burning of organic matter which had provided aggregation, improved infiltration, and aeration.

During the years between fires, water-repellent brush leachate accumulates between A-O and A-1 horizons. Decomposition of plant parts and alteration by micro-organisms and intermixing with leachate results in severe water repellency in unburned soils. This is accumulative over time. The large temperature gradients existing during fires then cause these hydrophobic substances to move deeper into the soil profile. Hot fires acting on chamise leachates produce the greatest water repellency. Since this water repellency is produced by particle coating, the light textured soils with a smaller internal surface area are more severely affected. A beneficial aspect of this phenomenon is that the thin, moist layer of soil overlying the water-repellent layer dries out quickly and forms a dry mulch layer which reduces evaporation (DeBano, 1969).

Since water repellency also affects the germination and survival of ryegrass, DeBano and Conrad (1974) applied a wetting agent by sprinkler irrigation to nitrogen fertilized plots on a burned watershed. They found that the wetting agent in combination with the nitrogen enhanced the establishment of ryegrass but not of mustard.

Allelopathy

Allelopathy, the direct or indirect harmful effect of one plant on another through the production of exuded chemical compounds, may be responsible for the patterns of many vegetation types and the exclusive dominance of many species (Rice, 1974). Such allelopathic effects exist in chaparral communities during successional interactions and may influence the establishment and persistence of annual ryegrass.

Nitrification inhibition is one of these effects. Nitrification is the process by which complementary soil bacteria convert ammonia nitrogen to nitrate nitrogen more readily available for plant uptake. Low successional invaders on disturbed sites use this nitrate nitrogen while the late successional and climax species not only make greater use of ammonium nitrogen, but also suppress the growth of nitrifying soil bacteria (Rice, 1964: Rice and Pancholy, 1972). Perennial ryegrass (Lolium perenne), a close relative of annual ryegrass, causes up to an 84 percent reduction in the nitrification rate and therefore behaves much like a climax species in its ability to suppress the activities of nitro-bacteria (Moore and Waid, 1971). In a mature chaparral stand, sage (Salvia spp.) greatly inhibits the germination of chamise (Went, Juhren and Juhren, 1952). Muller, et al, (1964) discovered that both genera released water soluble and volatile chemical inhibitors. For example, chamise and manzanita (Arctostaphylos spp.) release water soluble substances into the soil which are leached from branches and leaves. These phytotoxins can completely inhibit other plant growth. Volatile terpines emitted from leaves of sage, especially on hot days, are either deposited on the soil surrounding the plant or on leaves of adjacent plants. These terpines can act as preemergent chemicals and are more readily absorbed and more persistent in dry soils than in wet soils.

Prior to the extensive use of annual ryegrass for erosion control, mustard was suspected of having allelopathic effects on other vegetation. Studies showed that the greater the number of mustard plants per square foot, the smaller the number of germinated chaparral seedlings. Went, Juhren and Juhren (1952) also noted that black mustard strongly inhibited the growth of laurel sumac (Rhus laurina), Spanish broom (Spartium junceum), and black sage (Salvia mellifera) but had no effect on deerweed and hoary-leaf ceanothus. Bell and Muller (1973) showed that rainwater leachate from dead stalks and leaves of the previous year's growth of black mustard is responsible for this phenomenon and results in almost pure stands of mustard.

Tinnin and Muller (1971) investigated wild oats (Avena fatua) of California's grasslands. They found that the dry straw of the previous year's growth contained water soluble toxins that leached into the soil and selectively inhibited the germination of seeds of other species.

Rice (1974) suggests that the longevity of seeds of herbaceous annuals found so profusely the season after a fire is caused by phytotoxins which are deposited in the seed coat. Ferenczy (1956) showed that these phytotoxins are instrumental in warding off fungal and microbial attacks. Many authors have reported that leaching seeds often enhances germination as it removes the phytotoxins, and that good results may also be obtained by germinating the seeds with slight amounts of heat. In all species investigated fire released soils from these allelopathic effects.

STUDY AREA DESCRIPTION

Topography

The Santa Monica Mountains are part of the Transverse Range which extends for about 50 miles from the Los Angeles River (118 degrees 16' W) to the Oxnard Plain (119 degrees 9' W). These mountains are from 5 to 8 miles in width with their main axis located near latitude 34 degrees 6' N. For the most part their southern edge is the Pacific Ocean (Waco, 1968).

The area of the Wright Fire was divided into three major study areas based upon the success of ryegrass establishment.

1. Las Virgenes Hills and Alluvial Lowlands

   This area is made up of shales with sandstone beds and lenses of the Middle Miocene Topographic Formation (Walton, 1971). Prior to the fire it had been covered by wild oats, some brome species and scattered oaks, and was used primarily for grazing. The alluvial lowlands are used primarily for alfalfa, oat production, and pasture. Settlement was still sparse prior to the Wright Fire.

2. Monte Nido Volcanic Area

   This area encompasses Cold Creek and its tributaries and is underlain by Miocene volcanic rocks, mainly pyroclastics. It has a weathered appearance of rounded hills with local knolls of more resistant material. Chamise chaparral is predominant throughout the area. The community of Monte Nido is in the center of this area.

3. Coastal Mountains

   Malibu Creek is the major drainage in the burn and the only inland drainage in the Santa Monica Mountains. The steep mountain slopes rise to 2,800 feet within just a few miles of the ocean (the highest point in the Santa Monica Mountains is 3,000 feet) and are underlain by strongly tilted, folded, and faulted sedimentary rocks. These are locally invaded by basalt, nonmarine Ologocene sandstones and conglomerates, and lower to middle Miocene marine sandstone beds. Prevailing northernly dips range from about 30 percent to more than 60 percent. Natural vegetation consists of chamise chaparral, chamise, sagebrush, and woodland.

Soils

Soils in the fire area are derived from sandstone, shale, and basalt, and for the most part are shallow, highly erodible and have a low infiltration rate and low inherent fertility.

The Monte Nido area is comprised of shallow, low-fertility, basaltic soils. The canyon and rolling upland mountain soils vary in depth from 15 to 40 inches, have a medium to occasionally high soil fertility, and slight to moderate erosion hazard (Anon, 1967).

Vegetation

The vegetation prior to the fire consisted of approximately a) 20 percent grass (primarily wild oats) and cultivated land; b) 40 percent chamise chaparral composed of primarily chamise, sage, buckwheat, ceanothus, scrub oak (*Quercus dumosa*), manzanita and mountain mahogany (*Cercocarpus betuloides*); c) 20 percent chaparral (primarily ceanothus, toyon, sumac, mountain mahogany and manzanita); d) 10 percent sagebrush; and e) 10 percent woodland. The woodland vegetation was found on northern exposures and in canyons and draws and consisted mostly of live oaks (*Quercus* spp.), sycamore (*Platanus racemosa*), California Bay (*Umbellularia californica*), white alder (Alnus rhombifolia), cottonwood (Populus spp.), willow (Salix spp.), and elderberry (Sambucus spp.).

Climate

The climate is classified as mediterranean, with over 90 percent of the rain falling during the six months from November to April.

Weather is greatly influenced by the coastal mountain ranges. Along the coast, rainfall averages 15-16 inches, reaching a peak of about 23-24 inches around the highest mountain tops and dropping again to 16 inches along the Ventura Freeway to the north. Temperatures vary from an average July high of 66 degrees F. and January low of 50 degrees F. in the coastal mountains to a July high of 75 degrees F. and January low of 53 degrees F. in the hills around the Las Virgenes Valley. Isolated frost pockets exist in the Cold Canyon area and its tributaries.

For the first two weeks after the aerial seeding of October 9 through 16, heavy fog covered the coastal mountains. The humidity was high and daytime temperatures range from 60 to 75 degrees F. By late October, temperatures increased to the mid eighties and humidity dropped at times to as low as 10 percent. Santa Ana winds made a dust bowl of the upper Malibu Canyon and seed displacement occurred.

On November 5, light drizzles brought 0.25 inches of rain to the mountains and the cycle mentioned above was then repeated. Finally, between November 25 and December 1, major storms dumped 8 inches of rain with over 6 inches falling on November 29. Finger and gully erosion were evident in most places, but no major flood damage occurred. Germinating seedlings were nourished by 0.3 inches of rain on December 6 and by another 5.5 inches between December 16 and 21.

Precipitation of consequence in the new year started on January 12 and 13, 1971, with a 1.8 inch rainstorm. It then continued once a month through April with an additional 0.8 inches on February 18, 1.7 inches on March 13, and 0.7 inches on April 14.

METHODS

The Wright Fire burn in the Santa Monica Mountains was chosen for this study because it was the most extensive watershed area of the total 1970 burn still covered with native chaparral. The burn also offered variety in topography, vegetation, climate, and soils which lent itself to an evaluation of the seeding efforts.

During the aerial seeding operations ground checks for even ryegrass seed distribution were made by using a metal frame to randomly establish more than 2,000 temporary one square foot plots. These plots were located within 1,000 feet on either side of Mulholland Highway, Piuma, Las Virgenes Canyon, and Saddle Peak Roads and on the west side of Malibu Canyon Road. Annual ryegrass seed distribution was found to be uniform and averaged 20 seeds per square foot.

In order to obtain estimates of annual ryegrass crown density for the first year after seeding through most of the 28,000 acre watershed burned by the Wright Fire a comprehensive ground and aerial photo survey was undertaken. The Brown-Blanquet cover abundance value method (Mueller-Dombois and Ellenberg, 1974), modified so that it states particular cover percentages, was used to arrive at vegetation cover estimates as shown on the photos.

An advantage of the photo method was that less accessible areas that otherwise could not be readily evaluated could be incorporated into the study. It was also hoped that periodic photos of selected areas would reveal the vegetation pattern more clearly and would indicate the competitive ability of both the seeded species and resident vegetation. All photos were taken with a 35mm Asahi Pentax camera using both 55mm (f 1.4) and 135mm (f 2.5) Takumar lenses. ASA 25 Kodachrome film was used. The slow speed film was chosen because it produces a finer grain pattern per unit area and thus a sharper photo image.

Photo Points

Photo points were chosen along Piuma and Saddle Peak Roads (700 to 2,600 feet elevation) and along Las Virgenes Canyon Road, Malibu Canyon Road, and Mulholland Highway (600 to 1,100 feet elevation). These roads had been previously selected for aerial seeding distribution counts and traversed the center of the burn. They offered an excellent view of the affected watershed areas, including many of the steep slopes where maximum erosion was expected. The photo sequence was started on December 31, 1970 at about the same time the ryegrass emerged along the slopes adjacent to the roads. The mountains along Piuma Road began showing a light annual ryegrass cover by late February; hence, a photo sequence was started there on March 2, 1971. Within a month, striking contrasts in plant establishment developed on certain slopes close to the road. These slopes were then incorporated into the study sequence since they provided closer view points for appraising the emergency revegetation program.

An initial aerial survey by helicopter was made on March 18, 1971 by the Los Angeles County Forestry Division and thereafter the author flew over the burn on the average of once a month by fixed-wing airplane. This enabled an evaluation of the less readily accessible areas. On May 18, when the coastal mountains displayed a lush ryegrass cover and the Santa Ana winds dispersed the seemingly ever present haze, 200 feet of 8mm movie film were taken of the entire burn in order to have a permanent record of the seeding results. The above film and the more than 500 slides taken for this study are on record with the Los Angeles

County Fire Department, Forestry Division.

On-Site Inspection

In order to clearly identify the emerging vegetation shown in the photos, 950 one square foot temporary plots were randomly established using the same sampling frame as for the aerial seeding distribution plots. Uninhabitable areas, such as rock outcroppings, were excluded from the sampling. The plots were located within 1,000 feet of Mulholland Highway, Las Virgenes Canyon, Malibu Canyon, Piuma, and Saddle Peak Roads and were established whenever ground photos were taken. These were the areas initially sampled for seed distribution after the aerial seeding. Because of inaccessibility, no plots were established east of Malibu Canyon Road (Photo Sequence 8) and along the upper mountain range above Dark Canyon (Photo Sequence 12). Crown density and the number of ryegrass seedlings encountered were recorded. Competing vegetation consisting of chaparral species and their herbaceous associates and also introduced annual grasses and forbs which had established themselves prior to the fire were also analyzed. This introduced herbaceous cover will be referred to in this report as resident vegetation.

RESULTS

Temporary Plots

The data below is a summary of the 950 temporary plots which were established along with the ground photos. Because of the establishment pattern of the seeded ryegrass, only 50 of the plots were located in the Las Virgenes Hills, 550 in the Monte Nido area, and the remainder in the coastal mountains. The photo report in Appendix B is comprised of 58 photos and individually or in photo sequences shows the results of that particular area of the burn as summarized here for the temporary plots.

1. Las Virgenes Hills

   The rangeland found throughout the Las Virgenes Hills and adjacent areas consisted primarily of wild oats which furnished an abundant seed source. These seeds germinated quickly with the first heavy winter rains of November 25-29, 1970, and formed a complete grass cover within 10 to 12 weeks. Exceptions were steep, overgrazed slopes with thin soils. Seeded ryegrass was not able to compete successfully with these resident grasses and accounted for less than 5 percent of the total grass cover.

2. Monte Nido Area

   During early April when annual ryegrass had reached maturity in the Monte Nido area, temporary plots consistently showed a ryegrass cover of less than 10 percent on most slopes with some harsh southern exposure slopes completely devoid of ryegrass except for drift areas. Such drift areas were found on animal trails and other such micro-sites. Ryegrass crown density here reached 60 percent with other herbaceous vegetation often making up the remaining cover. During February the drainages and level areas showed a 20 percent crown density which by early April increased to 50 percent in areas where soil fertility and moisture were favorable. Occasionally, nearly solid stands of annual ryegrass were encountered here about one month after resident grasses had completely covered the Las Virgenes rangelands. Seedling counts taken at the temporary plots showed that the number of ryegrass seedlings per square foot was greater than the chaparral seedlings at the beginning of the season but consistently less than chaparral seedlings after early March. By mid-April crown density of fire-type annuals on almost all temporary plots was greater than the crown density of ryegrass. This also was true for the coastal mountains where chaparral seedlings outnumbered ryegrass seedlings by a ratio of 3:1.

3. Coastal Mountains

The coastal mountains and Malibu Canyon, for the most part, offered deeper and more fertile soils than the Monte Nido area. Ashes, several inches thick, covered many of the previously wooded north and east slopes. The cool coastal influence was also more pronounced. Annual ryegrass did not germinate as quickly and stooled out later when compared to the Monte Nido area.

Ryegrass crown density on temporary plots was less than 10 percent by the end of December, 1970. By this time 75 percent of the season's rain had fallen. By March, when almost 90 percent of the rain had fallen, ryegrass crown density had reached 20 percent. By early May when ryegrass had reached full maturity in the coastal mountains (about one month later than in the Monte Nido area a few miles inland), crown densities averaged 30 to 40 percent on most slopes. On some north and east slopes, rich, deep soils favored ryegrass stands reaching 80 percent cover. However, on steep slopes with thin soil, herbaceous vegetation became established more readily than ryegrass and competed strongly with it. This was also true of harsher sites on disturbed areas such as roadsides where wild mustard, bromes, and wild oats predominated. However, in disturbed areas on fertile, moist soils, ryegrass became the dominant species and often accounted for almost 100 percent cover.

Fig. 1 on the following page summarizes the above data and shows the cummulative rainfall for the season. Ryegrass germination started during the November 25-29 rains which were followed by drizzles until December 1. This one week period of optimum surface soil moisture conditions initiated germination and enhanced establishment.

Fig 2 compares growth responses of annual ryegrass to that of postfire vegetation on the few good sites (mostly level) where a 100 percent cover of the ryegrass and fire-type annuals was observed. Resident grasses covered the fastest and herbaceous the slowest. Crown cover density of annual ryegrass varied with each postfire season and is primarily dependent on an optimum soil moisture regime during germination and continued rain for growth and establishment. Drought and cold weather, conditions to which the resident cover is better adapted, will inhibit top of growth of annual ryegrass and therefore affect crown density.

In all three areas discussed above, resident grasses matured and cured about a month earlier than the seeded ryegrass. By 1972, the second season after the fire, ryegrass, except for disturbed areas and drainages, had disappeared from the Las Virgenes and Monte Nido areas. In the coastal mountains strong competition from herbaceous vegetation reduced ryegrass cover to about one-half its previous year's cover. By the end of the third season, ryegrass had practically faded out throughout the former fire area.

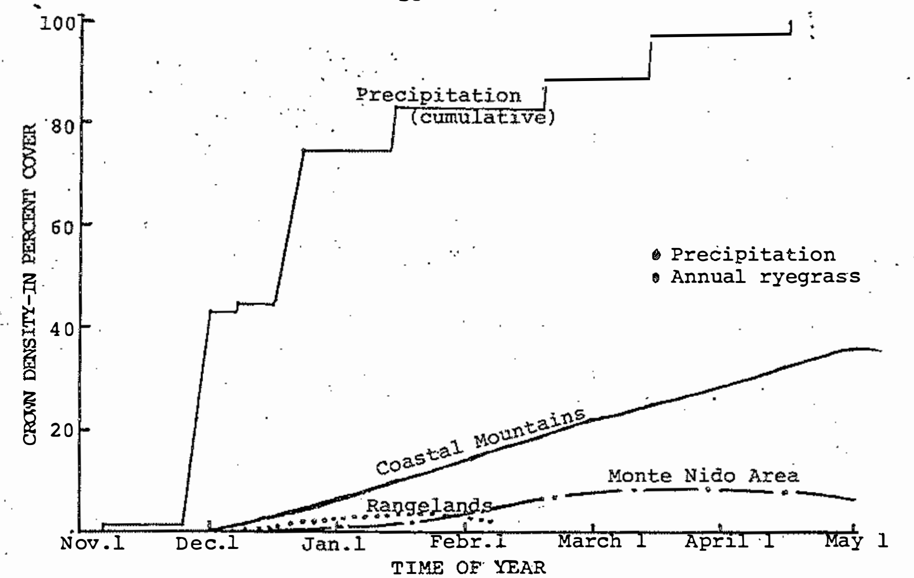


Fig. 1: Crown density of seeded ryegrass during the first growing season.

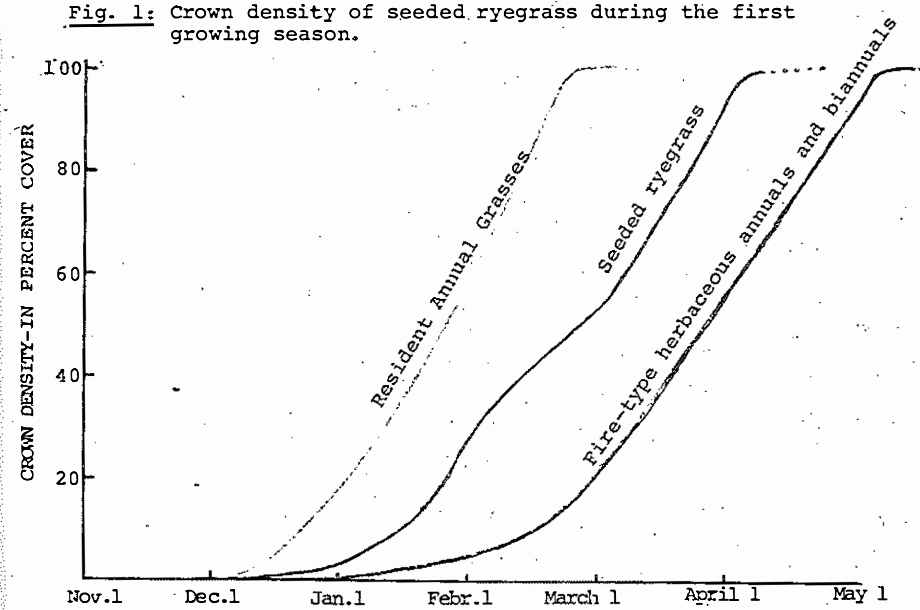


Fig. 2: Crown density of post-fire vegetation under optimum site conditions.

DISCUSSION

The controversy over the effectiveness of commercial annual ryegrass for emergency revegetation to minimize erosion after wildfires will not be resolved by this report just as it has also not been resolved by the many ryegrass reseeding studies done in the last two decades. However, from observations made in this study, predictions can be formed concerning annual ryegrass establishment in southern California. The observations discussed below should be of value to the land manager as they have proven to be consistent with the results of numerous other emergency reseeding operations since the 1970 Wright Fire.

Photo sequences in this thesis documented that annual ryegrass establishment was rather slow. Temporary plots then showed that ryegrass crown density did not account for more than 20 percent throughout the Wright Fire burn after 90 percent of the season's rain had fallen.

Rice (1973) pointed out that about 70 percent of the long-term sedimentation from a watershed occurs the first year after a fire. Of this amount, one-third at the most (probably much less) is due to rill and gully erosion. These two erosion mechanisms are the only ones that are readily affected by ryegrass. So, even if ryegrass should form an instantaneous cover with the first rains, it could only affect about one-third of the post-fire erosion. However, since most heavy storms occur when ryegrass cover has not emerged yet or is only minimal due to slow growth caused by low winter temperatures, even this one-third figure is reduced. Rice further estimates that even if the claim is considered that annual ryegrass is effective for soil erosion the second through the fifth season after a fire, it can only affect up to 10 percent of the long-term erosion on a watershed. This estimate is based on extensive literature reviews and Rice's studies. However, Blanford and Gunter (1971) state that a 30 to 40 percent ryegrass cover can practically stop soil erosion associated with light storms and also reduce soil losses associated with heavier storms by about 60 percent. The authors admit that their estimates are based on annual ryegrass studies that are not a part of a fire cycle. In this case a 30 to 40 percent ryegrass cover was established on the Wright Fire watershed only after the season's rainfall was practically over.

Personal communications with Los Angeles County Head Deputy Forester Arthur Arndt, Research Hydrologist Dr. Ray Rice of the P.S.W. Forest & Range Experimental Station in Arcata, Research Botanist Gene Conrad of the P.S.W. Station in Glendora, and other experts familiar with annual ryegrass seeding in southern California revealed that one of the most successful annual ryegrass emergency revegetation projects in southern California was achieved after the 1961 Bel Air Fire. Light rains throughout most of the first season after seeding favored the establishment of an excellent annual ryegrass cover. The justification for many subsequent emergency reseeding operations in southern California was based largely on these results; however, most later seeding efforts either were inconclusive or failed.

The three regional variations in ryegrass establishment (Las Virgenes grasslands, Monte Nido area, and coastal mountains) recorded throughout the Wright Fire burn on the photo sequences can be attributed primarily to such site differences as soil fertility and depth, and to the pre-fire vegetation which is often an indicator on these sites. Climate, such as the cooler climate found in the coastal mountains, probably helped to accentuate these differences.

The near exclusion of the seeded species from the grasslands of the

Las Virgenes area and other patches of grassland found throughout the burn can be attributed to strong competition from these grasses which are adapted to local conditions. Resident grasses offer a ready seed source which often escapes injury during a fire (Schultz, Launchbaugh, and Biswell, 1955), and the same apparently holds true for naturalized annual grasses. This prediction was demonstrated to local residents after the 1973 Rolling Hills Fire which burned principally stands of annual grasses and black mustard.

The shallow, low fertility soils of the Monte Nido area, where soil pH reached as high as 8.5, displayed an extremely poor ryegrass cover on slopes. Chamise chaparral, with chamise the predominant species, was an indicator of these poor sites. Contrary to the statement in the Malibu Soils Report (Anon, 1967) which listed this area as highly erosive, visual erosion on these shallow, low fertility soils was very low when compared to the rill and gully erosion encountered in the coastal mountains on slopes with deeper soils. Annual ryegrass furnished to hillside homeowners and seeded and sprinkler-irrigated prior to natural rainfall showed poor establishment even after the soil surface was lightly raked to prepare a seedbed. Fire ecology studies (Radtke, 1971) indicated a water repellent soil layer which was more pronounced where chamise had burned very hot. These findings agree with DeBano (1969) who stated that hot fires coupled with chamise leachate produce the greatest water repellency. Thus in the Monte Nido area, limited soil fertility, high pH, and water repellent soils were probably responsible for the poor ryegrass establishment.

The coastal mountains, where ryegrass establishment was most successful, have more fertile and deeper soils and a milder climate. However, even in the Monte Nido area, annual ryegrass cover in excess of 30 percent was found on the deeper, more fertile soils whenever sufficient moisture was present. This was evident along roads, along animal trails on slopes, in drainages, near ridge tops, and on some north facing slopes as compared to south facing slopes. Thus the prediction was made that greater ryegrass densities would be found on the better sites throughout a burn area. This agrees with Bentley, et al (1956) who stated that annual ryegrass requires at least fair soil fertility, but somewhat conflicts with Hafenrichter, et al (1968) who stated that the seeded species is adapted to a wide variety of soils except those excessively or poorly drained.

In more recent ryegrass studies undertaken in Los Angeles County, Agozino (1976) noted that a good cover of annual ryegrass during the unusually dry 1976 season following the 1975 Big Tujunga Fire was only established on northeast exposures on slightly acid soils. A good ryegrass cover was also observed by Radtke (1976) the season after the 1973 Trippett Fire (Topanga Fire) on north and east slopes with slightly acid soils. These particular slopes were cleared during the second season after seeding for fuelbreak plantings, and a solid ryegrass cover was reestablished from seeds furnished by the first season's crop. However, ryegrass cover declined on the non-disturbed slopes. This may indicate that, besides nitrogen deficiency recorded by Papanastis (1973), there must be other site-related reasons for the decline of the original ryegrass cover established the first season after a fire. On the other hand, weeding of cured ryegrass from among the planted low-fuel plants greatly increased the size of these plants during the summer. This indicated that not only moisture deficiency but perhaps also some allelopathic effects on other species by ryegrass may have accounted for the stunted growth of the low-fuel plants in non-weeded areas. During the dry spring of 1976, the second season after the ryegrass was established on the disturbed slopes mentioned above, solid stands of black mustard replaced ryegrass on the driest sites. Moisture deficiency in subsequent seasons could therefore have been an additional factor in ryegrass decline.

The temporary plots of the Wright Fire burn, along with studies by Fisher (1971) in the same burn, point to the abundant establishment of chaparral seedlings the season after the fire and to the heavy competition of herbaceous species, especially fire-type annuals which account for the greater part of the cover during spring. This abundance of chaparral seedlings and subsequent quick resprouting of chaparral plants was documented by Sweeney (1969). Earlier studies by Cooper (1963), Bentley, et al (1956), Biswell, et al (1952), and others had already shown that annual ryegrass may be detrimental to the establishment of chaparral seedlings. All these findings led many researchers to question the need for the emergency seeding of annual ryegrass after fires. However, the alternatives to commercial ryegrass, which are discussed below, are presently impractical on a large scale due to the high cost of seeds or the lack of seed availability.

Blando brome, an improved strain of soft chess (Bromus mollis), compares favorably to the commercial annual ryegrass used in seeding the Wright burn and other burns throughout California. Blando brome persists longer during the second and third year in southern California but does not have the extensive root system of the seeded species and is relatively expensive. Wimmeria annual ryegrass (Lolium multiflorum) has been tested and was recommended by the Soil Conservation Service for low elevation dry sites. This grass could be used for seeding of burned watersheds if seeds were not too expensive (Bentley, et al (1956).

Edmunson and Cornelius (1961) did not recommend commercial annual ryegrass for southern California fuelbreaks but suggested early maturing strains of Wimmeria annual ryegrass. Bentley (1967) recommended a mixture of blando brome and Wimmeria 62 ryegrass to replace the commercial annual ryegrass strain. Phillips, et al (1972) suggested Creeping sage (Salvia sonomensis) as an alternative to the "flashfuel" annual grasses.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, it can be said that the seeding of annual ryegrass is an emotional issue. Action is demanded by the public after disasters such as wildfires, and annual ryegrass seeding is the cheapest way to show action and reap the benefits of any cover, ryegrass or not, that is established. Ryegrass is also aesthetically very pleasing as it turns the hillsides green and is visible from far away. Not much is lost if a cover is not established since resprouting and germinating chaparral species will soon heal the fire scars on their own. If the true objective is to establish a quick cover to stop soil erosion from winter rains, one must realize that annual ryegrass may not become established until after most of the season's rains are over. However, if well established, it could be beneficial in reducing soil erosion during late season rainstorms. Furthermore, annual ryegrass only forms a good cover on the better sites where it strongly competes with an abundance of herbaceous seedlings.

Recommendations for seeding of annual ryegrass on future burns in Los Angeles County are therefore as follows:

1. It is not necessary to seed the grasslands because of the abundant seed supply of quickly covering resident grasses found there.
2. It is not recommended to seed shallow and low fertility soils and other harsh sites because annual ryegrass will not become established there as it needs fertile sites in order to provide a good cover (chamise is an indicator of poor soils and harsher sites).
3. It may not be necessary to seed the coastal mountains because of an abundance of herbaceous fire-type seedlings which will quickly cover the ground.

APPENDIX 1
(Map 2)

The numbers shown on Map 2 give the locations of the photo sequences shown in Appendix 2.

Las Virgenes Hills

Fig. 3. January 8, 1971

This view shows a southwest aspect. Wild oats, five weeks after germinating, are again covering parts of the overgrazed hills.

Highway 101, just past the telephone posts, was the line where the Newhall Pass Fire, coming from the north, and the Wright (Malibu) Fire met. The Wright Fire started at Brent's Junction, which is to the right of the area covered in this photo.

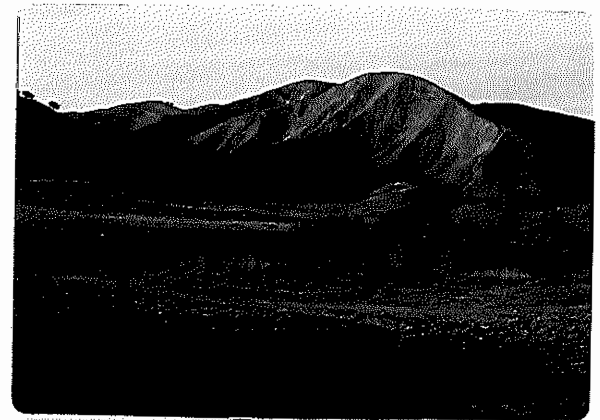
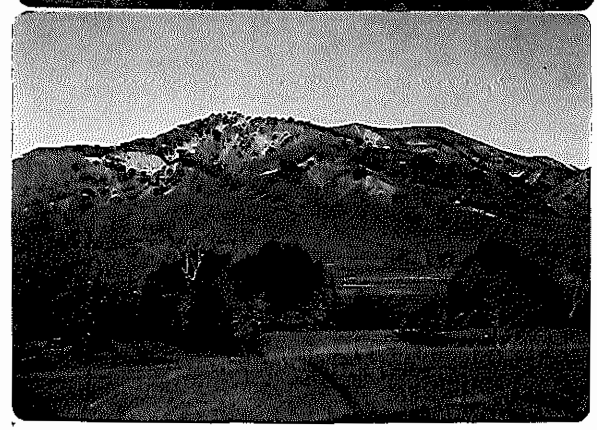


Fig. 4 January 8, 1976

This close-up view of the wild oats rangelands along Las Virgenes Canyon Road shows the still thin but already even cover of wild oats. The speed of the Wright Fire through the grassland area is indicated by the weed stubble (X) which was not consumed by fire.

Fig. 5. February 12, 1976

Less than ten weeks after germinating, the resident grasslands along Las Virgenes Canyon Road had formed a lush, even cover.



- - -

Resident grasses germinated quickly in the rangelands and competed heavily with the slower developing annual ryegrass, which accounted for less than 5 percent of the total grass cover.

Fig. 6. February 12, 1971

A close-up view of lightly grazed rangelands along Las Virgenes Canyon Road shows quick-covering resident oats. No annual ryegrass was found on these rangelands.

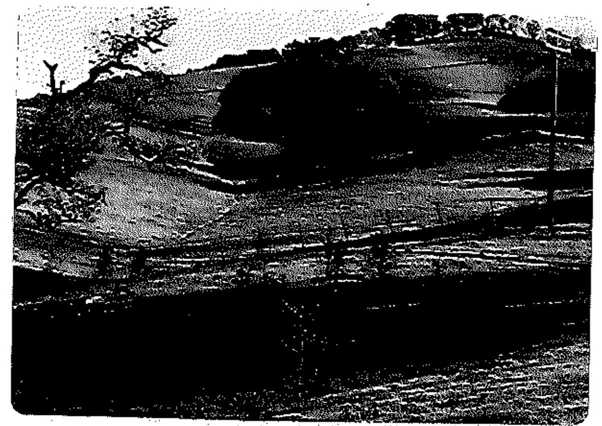


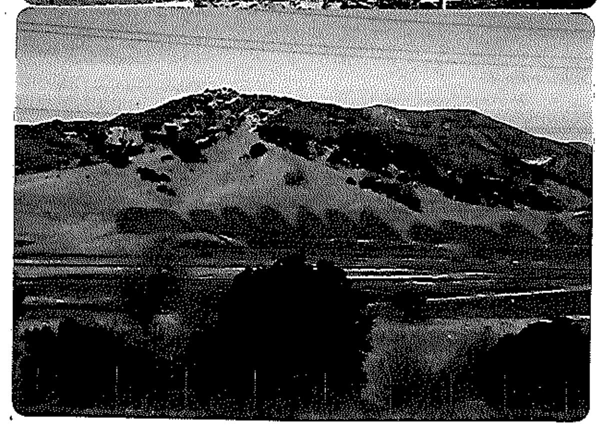
Fig. 7. February 19, 1971

Junction of Mulholland Highway and Las Virgenes Canyon Road. The alluvial valley lowlands in the foreground and Las Virgenes Hills towards the left are already thickly covered with native grasses. The Monte Nido area (center range X) shows a very sparse cover of seeded annual ryegrass. The coastal mountains in the background, except for rock outcroppings, already show a light ryegrass cover.

The view is towards the southeast.

Fig. 8. January 6, 1976

This east aspect shows the alluvial lowlands and Las Virgenes Hills sprinkler-irrigated with sewage effluent during a particularly dry year. During normal rainfall years these lowlands would exhibit the green cover of native grasses shown in Fig. 3.



\- - -

Twelve weeks after the first heavy rains that started on November 25, 1970, the resident rangelands showed a complete cover of native grasses. In the coastal mountains, crown density of seeded ryegrass was less than 20 percent.

Photo Sequence 1

Fig. 9. January 8, 1971

For comparison with the previous figures a less intensively grazed wild oats range is shown here in the Newhall Pass burn. Notice the burned oaks which suggest that the area must have been ungrazed prior to the fire. Little rill and gully erosion occurred during the intensive December rains.

Fig. 10. April 26, 1971

An abundant seed source, quick germination, and strong competition from the resident annual grassland (wild oats) preclude the establishment of annual ryegrass.

Fig. 11. June 23, 1971

If not grazed, these cured oats may furnish the flash-fuel for another fire. The same is true for the seeded annual ryegrass. As soon as it has done its job of soil protection it becomes a liability to the fire fighter.

- - -

The quick recovery of resident wild oats from an abundant seed source that survived the fire precluded the establishment of the seeded ryegrass.

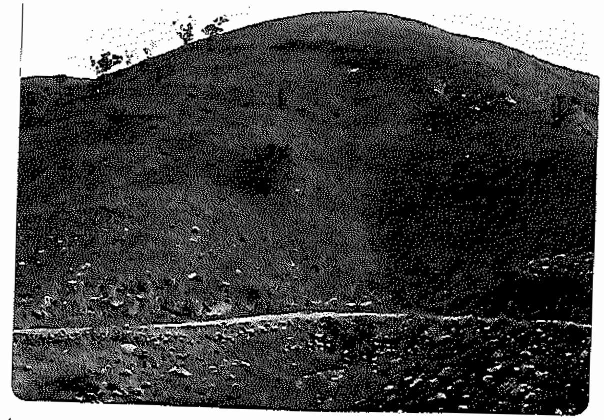


Fig. 12. May 18, 1971

This aerial photo, taken during a survey of the seeding results, shows the overgrazed hills of Brents Junction. (X) marks the point of origin of the Wright Fire.

On September 25, 1970, hardly enough wild oats stubble was present on this greatly abused range to carry a fire. However, within seconds after a careless passerby had furnished the initial sparks, winds in excess of 50 miles per hour had taken the flames over and around these mountains. Notice that most of the oaks scattered on the hillside did not burn.

Fig. 13. May 18, 1971

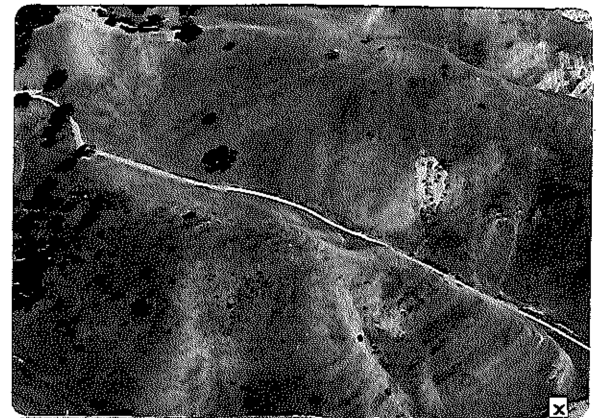
These southwest facing slopes of Brents Junction reach an elevation of 1202 feet and show the isolated pockets of black mustard (X), and the thin cover of wild oats (Y).

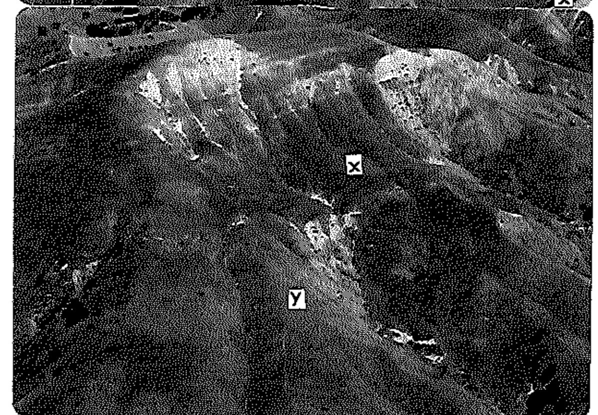
Fig. 14. May 18, 1971

This curing wild oats rangeland is in poor condition because of overgrazing accentuated by shallow soils. Nearby canyons showed wild oats intermixed with annual ryegrass and bromes.

- - -

On the heavily grazed slopes, where resident grass competition was not excessive, ryegrass did not readily become established because of the harsh conditions found there.





Monte Nido Area

Fig. 15. May 18, 1971

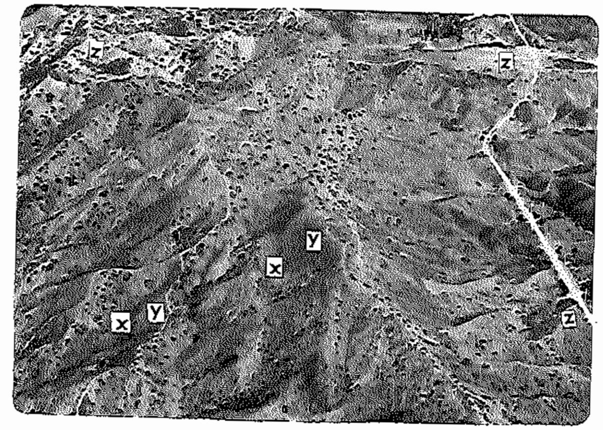
This aerial view shows Mulholland Highway as it crosses Cold Canyon at the upper right side of the photo. Annual ryegrass had congregated in the drainages (X) and is more evident on the north facing slopes (Y) than on the south facing slopes. The yellow patches (Z) are early maturing native grasses.

Fig. 16. October, 1971

This aerial view is looking north towards Mulholland Highway (telephone posts) and shows part of the Monte Nido community in the foreground. The success of the ryegrass establishment is visible as yellow patches (X) that have accumulated heavily in draws and lightly on ridge tops. Ryegrass temporarily replaced red bromegrass (Bromus rubens), soft chess (Bromus mollis) and scattered other grasses normally found there.

– – –

In the Monte Nido area, ryegrass germinated readily along ridgetops, in drainages, and on roadsides, but accounted for only 0-10 percent cover on most slopes.



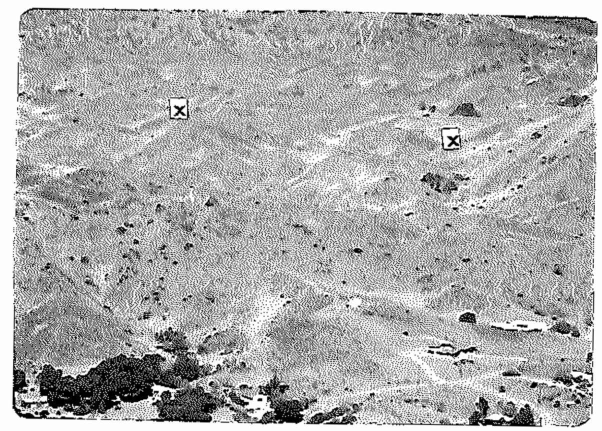


Photo Sequence 2

Fig. 17. December 31, 1970

The bare hills of the Monte Nido area (foreground to center of photo - X) contrast with the Las Virgenes Hills and lowlands (Y) in the upper part of the photo where the wild oats and scattered bromes are already turning the hillsides green. Both areas, along with the entire Wright Burn Watershed, were seeded with annual ryegrass in October 1970.

Fig. 18. March 2, 1971

Shallow, low fertility soils characterize the Monte Nido area. A barren appearance was evident here at a time when the coastal mountains displayed a thin but even ryegrass cover (Figs. 32-55). Spot checks in the Monte Nido area averaged seven ryegrass seedlings per square foot on ridge tops, less than one on steeper slopes, and occasionally more than 30 seedlings per square foot near drainages.

Fig. 19. June 1973

This photo shows an overall vegetative cover of above 80 percent on east slopes and 60 percent on south slopes. Site inspections indicated that about half this cover was made up of chamise chaparral, and the other half of herbaceous plants. Annual ryegrass was found the third season after aerial seeding in only a few recently disturbed areas.

- - -

Fourteen weeks after the first heavy rains, the Monte Nido area still had a barren appearance. (Fig. 18.) Even twenty-one months after the fire, the slowly resprouting chamise chaparral still emphasized the harshness of the area.

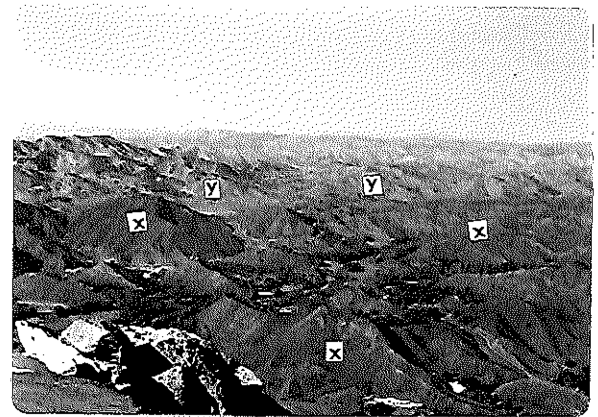


Photo Sequence 3

Fig. 20. December 31, 1970

This photo sequence depicts a 45° south facing slope behind Fire Station 67 in the community of Monte Nido. The hot fire eliminated all vegetation. Notice the thin band of ryegrass on the rodent trails (X) on steeper parts of the slope, and the heavier accumulation of the sown species in the drainages (Y) and the gentle slope in the foreground (Z).

Rill and gully erosion resulted from the November and December 1970 storms which dumped 14.5 inches of rain on this watershed. Total rainfall for the season was 19 inches.

Fig. 21. February 12, 1971

Ryegrass (X) is still sparse except in drainages and the level area in the foreground. However, it germinated more quickly than the forbs (Y) and created strong competition for them.

Fig. 22. May 21, 1971

Notice the thick field of annual ryegrass in the foreground. Flowering annuals are dotting the hillsides and are found in areas where ryegrass did not become readily established (X). Resprouting chamise (Y) already accounts for about 15 percent cover.

- - -

By the end of 1970 when annual ryegrass furnished virtually no erosion protection for this hill, 75 percent of the season's rain had fallen. Six weeks later, after 85 percent of the rain had fallen, a combination of herbaceous vegetation and ryegrass covered about 20 percent of the slopes.

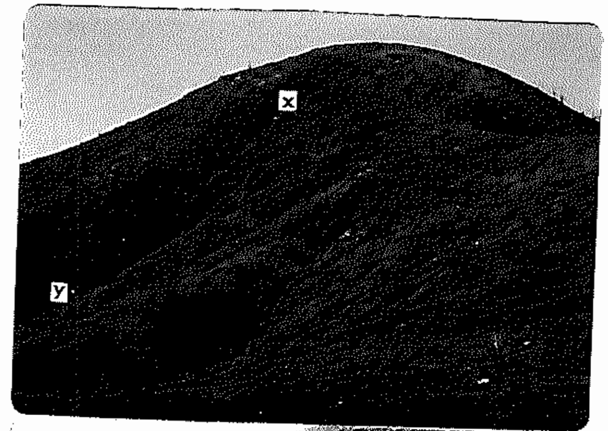


Fig. 23. July 2, 1971

It can now readily be seen that the first season's ryegrass cover was almost exclusively confined to drainages (X), trails (Y), ridge tops (Z), and level areas with deeper soil (foreground). At this stage the cured, three feet tall ryegrass is a fire hazard. Sprouting chamise is dotting the slope.

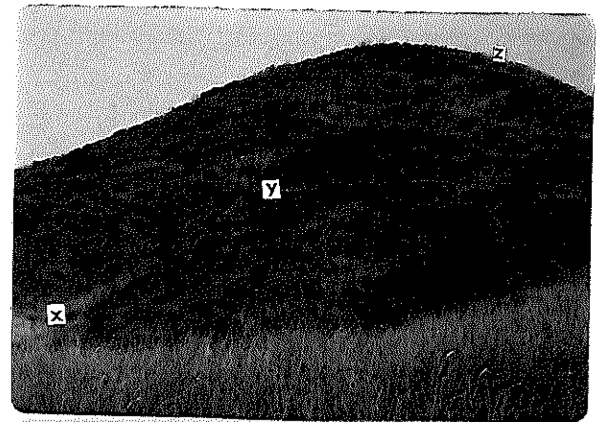
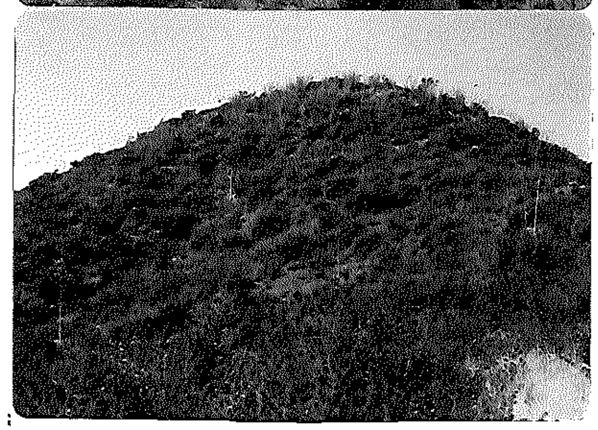


Fig. 24. June 1973

By the third season ryegrass had been replaced by forbs and had faded out on the trails. Bushpoppy (Dendromecon rigida) is scattered around the top of the knoll. Clumps of chamise chaparral are covering about 30 percent of the area.

Fig. 25. February 1976

The sixth season after the fire approximately 15 percent of the area was still bare ground, indicating the harshness of the site. Less than 1 percent was covered by grasses, with red bromegrass, soft chess and rescuegrass (Bromus catharticus) (scattered in drainages) the dominants. The rest of the area was covered by chamise (30%), black sage (20%), ceanothus species (20%), buckwheat (Eriogonum fasciculatum) (10%), and a residual of deerweed and bushpoppy.



\- - -

By the end of the first season, cured ryegrass accounted for about 50 percent of the cover on ridgetops, animal trails, drainages and level areas, and occasionally formed solid stands. By the third season following the seeding, it had disappeared.

Photo Sequence 4

Fig. 26. December 31, 1970

This steep (45-60°) southwest slope again shows the ryegrass pattern so prevalent in the Monte Nido area. This area consisted of thin, volcanic soils with low inherent fertility. Germinated ryegrass is barely visible as green bands (X) along rodent trails and drift areas.

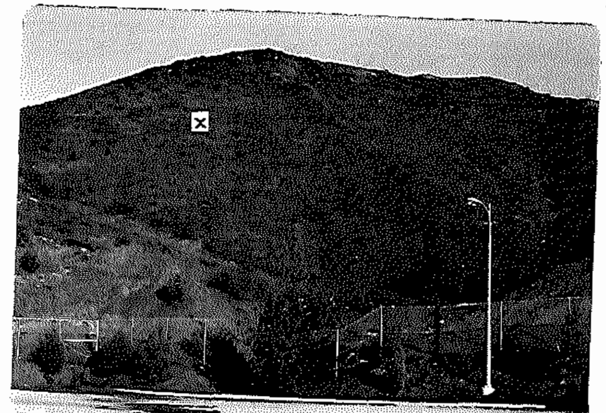


Fig. 27. February 12, 1971

The thin bands of ryegrass (X) mentioned above are more prevalent now. Animal activities had terraced the hillsides and provided drift areas for seed accumulation similar to man-made terracing of fill slopes for roadside stabilization. Selective post-fire terracing of highly erodible slopes will therefore aid seedling establishment.

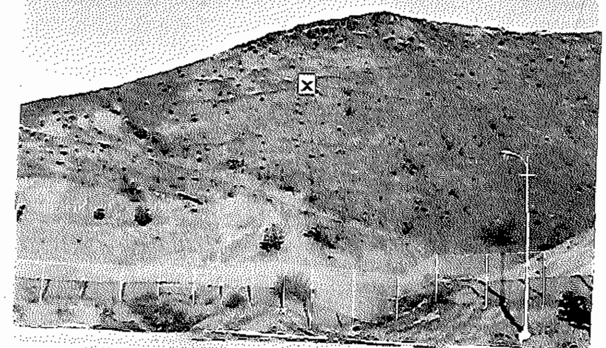


Fig. 28. July 2, 1971

It is evident that very little grass became established on this harsh site. Next to the fence, juvenile crews have already cleared the fire hazard created by the mixture of cured grasses (resident bromes, fescues and ryegrass).

- - -

Some harsh slopes, except for animal trails, were completely devoid of seeded ryegrass. However, even native vegetation did not account for more than 30 percent crown density by the end of the first season.

Photo Sequence 5

Fig. 29. July 2, 1971

The photos on this page show that resident grasses, in certain places, accounted for a large part of the total grass cover. In this case, red brome grass, foxtail fescue (Festuca megalura), and rizomerous big wild-rye (Elymus condensatus) account for about eighty percent of the grass cover shown, with rye-grass making up the remainder. Ryegrass was found mostly in drainages. The second crop of black mustard this season is shown in the foreground (X).

Fig. 30. January 6, 1976

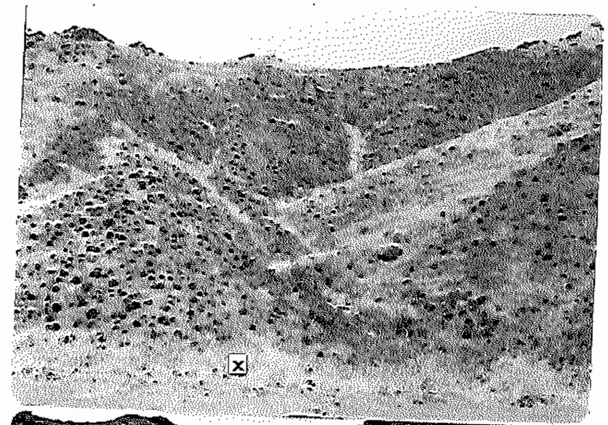
The above named native grasses are still a part of this plant community the sixth season after the fire. It can therefore be assumed that they provided the seed source or rizomes six years ago. The rest of the cover is made up of deerweed (20 percent), shown as red clumps (X), chamise (50 percent), black sage (20 percent), bushpoppy, deerbrush (Ceanothus integerimus) (Y), and toyon (Heteromeles arbutifolia) (Z).

Fig. 31. January 6, 1976

This photo is a close-up of the southeast slope shown in the above figure. It shows that big wild-rye (X), red bromegrass (Y), foxtail fescue (Z), and a scattering of bunchgrasses have persisted. Big wild-rye is a member of the Santa Monica Mountain chaparral community and is found throughout the area.

- - -

In some chaparral areas, resident grasses accounted for the greater part of the total grass cover found the first season after the fire and still persist five years later.



Coastal Mountains

a. Malibu Canyon

Photo Sequence 6

Fig. 32. April 7, 1971

This view looks down into Malibu Canyon and towards the ocean. Ryegrass establishment, probably due to the cooler climate, was slower than in the inland areas. However, the upland soils were deeper and more fertile than the Monte Nido area previously discussed. At the end of December, ryegrass germination averaged three plants per square foot. By this time 75 percent of the season's rain had fallen. The denuded line in the foreground (X) indicates overcast soil.

Fig. 33. March 2, 1971

The green tint on this east exposure is annual ryegrass, which germinated and became established before fire type annuals germinated in abundance. Notice the bands of ryegrass in the upper left hand corner (X) indicating the swath of aerial seeding.

Fig. 34. May 21, 1971

Ryegrass is maturing on some harsher sites. Spot checks (excluding rocky exposures) averaged four mature ryegrass seedlings per square foot, which gave a crown density above 30 percent.

- - -

In the coastal mountains, ryegrass showed a more even cover than in the Monte Nido area. By the end of December 1970, at which time already 75 percent of the season's rain had fallen, crown density averaged less than 10 percent but increased to more than 30 percent.

Photo Sequence 7

Fig. 35. September 2, 1971

This steep (40-60°) southeast slope provided a striking contrast after the grasses had cured. Suddenly vigorously resprouting laurel sumac (green clumps) were obvious. Ocular estimates disclosed that the grasses consisted of about 20 percent annual ryegrass, and the remainder a mixture of red bromegrass, downy chess (Bromus tectorum), wild oats, leafy redtop (Agrostis diegoensis), and big wild-rye (along the ridge).

Fig. 36. January, 1973

Forbs replaced most of the grasses during the second growing season, with deerweed (X) gaining dominance. Ryegrass was completely displaced by the forbs.

Fig. 37. January 6, 1976

Four feet tall dead deerweed (X) covers more than half of the site and is eliminating potential competition for the laurel sumac (Y). Deerweed in this stage is a much underestimated flash-fuel which can set off the fire cycle earlier than expected.

\- - -

On most slopes, forbs gained dominance toward the end of the first season and had replaced annual grasses by the third season. On south and west exposures the flash-fuel deerweed often gained dominance among the forbs.

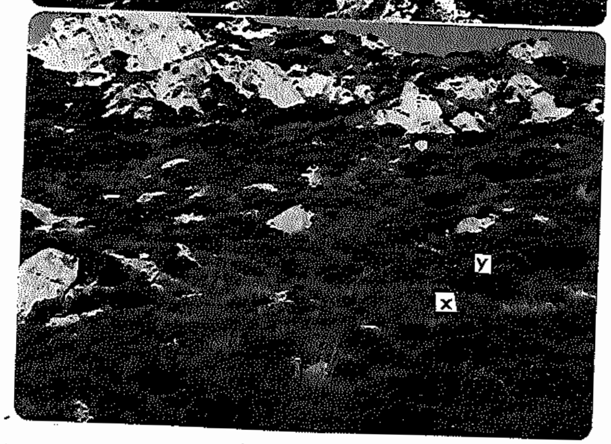


Photo Sequence 8

The steep Malibu Canyon separates the observer from this site.

Fig. 38. February 19, 1971

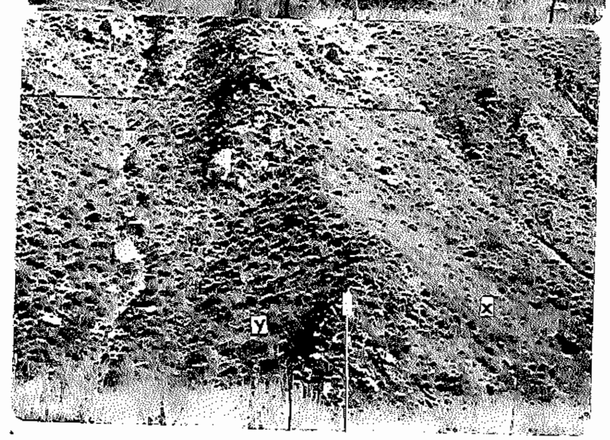
This steep, unstable, southwest exposure indicates the upper slope limits of ryegrass establishment. Many of the seedlings that managed to gain a foot-hold here were soon crowded out by the abundant germination of forbs (see photos below).

Fig. 39. May 21, 1971

Wild oats, soft chess, and ripgut brome line the roadside. The hillside in the background shows few maturing annual ryegrass plants, but a thick mixture of herbaceous vegetation (brown and yellow colors - X) mixed with the resprouting chamise.

Fig. 40. November, 1971

Ryegrass (X) is only visible in drift areas but was also found in Malibu Canyon (not visible in this photo). The green clumps of vegetation are chamise (Y), whose strong root system prevented major erosion damage during the first season after the fire.



- - -

The extensive root system of resprouting chaparral plants kept soil erosion to a minimum the first season after the fire. In coastal mountains re-sprouting chaparral already accounted for a 20-30 percent ground cover one year after the fire.

Photo Sequence 9

Fig. 41. March 2, 1971

The southwest facing coastal mountains in the background show a concentration of annual ryegrass in bands along more gentle slopes and drainages. The disturbed slope in the foreground is covered with slender wild oats (Avena barbata) (X), black mustard (Y), lupines (Lupinus spp.) (Z) and miscellaneous bromes.

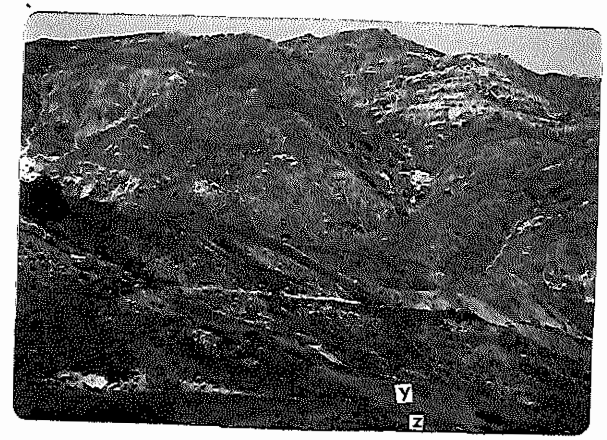
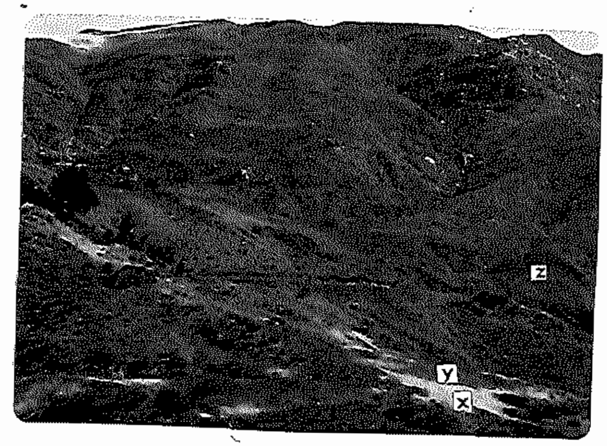


Fig. 42. May 21, 1971

The resident annual grasses matured about one month earlier than the seeded ryegrass and can therefore be readily distinguished (X). The five to seven feet tall mustard stalks (Y) show up as dense, light brown masses. The light brown areas in the background are matured forbs (Z). Compare the native grass stand in the upper left corner of this photo with Fig. 45.



- - -

Disturbed sites showed an abundance of resident and introduced herbaceous vegetation. Even from a distance this vegetation could be easily distinguished from the seeded ryegrass by its flowering and earlier maturity.

b. Coastal Mountains Proper

Photo Sequence 10

Fig. 43. December 31, 1970

Resident annual grasses covered more quickly than the seeded annual ryegrass, as shown by the wild oats grassland in the background (X) and the slope in the foreground (Y).

Resident annual grasses, where present, therefore provide the fastest soil surface protection after a fire. The root system of the burned chaparral ensures slope stability.

Fig. 44. February 16, 1971

By this date resident grasses, without closer inspection, can not be distinguished from the seeded ryegrass (X) becoming established underneath the north facing oak woodland.

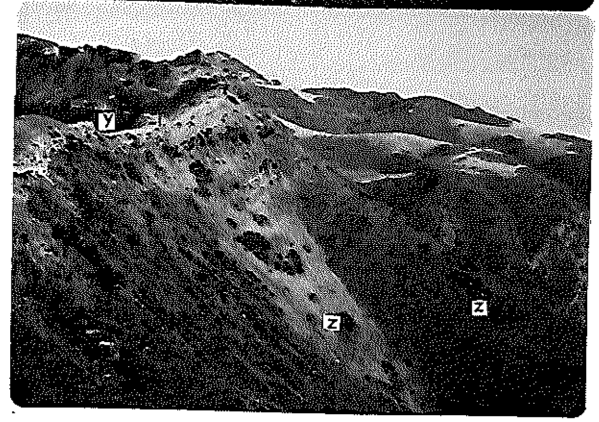
Piuma Road (Y) is shown along the ridgetop.

Fig. 45. May 21, 1971

By May the earlier curing resident grasses (X) can again be distinguished from the ryegrass (Y). Resprouting laurel sumac (Z) is now evident throughout the slope in the foreground.

- - -

Resident grasses, even when they germinated at the same time as annual ryegrass, grew much faster and matured about one month earlier. They therefore provided a better soil surface protection than the ryegrass.



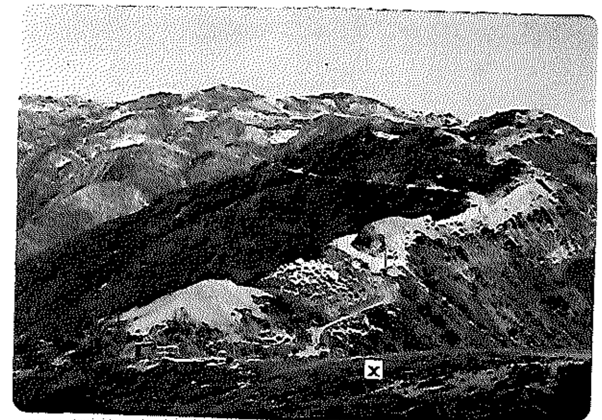


Fig. 46. April 7, 1971

Lupines are covering the firebreak in the foreground (X). The northfacing slope shown in the center of the photo is covered with oak woodland. Ryegrass crown density here reached 80 percent at maturity (see Photo Sequence 11).

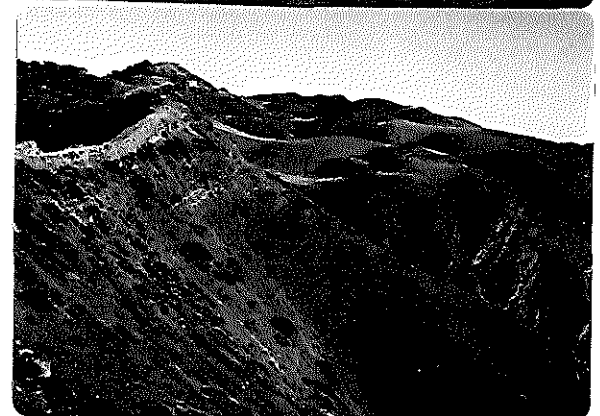


Fig. 47. January, 1973

At the beginning of the third growing season there is little evidence of ryegrass. Field checks during a fire ecology study in April 1972 showed a great decline in ryegrass cover over the first season, especially on harsher sites. Exceptions were disturbed areas such as firebreaks.

Fig. 48. January, 1976

The oat grassland in the background has already persisted for five years. Field checks showed that because of the lack of grazing, chaparral was re-invading this site.

- - -

During the second season after the seeding, annual ryegrass declined to less than half its original cover and strongly competing herbaceous cover eliminated it during the third season. However the original patches of wild oats were still found five years after the fire.

Photo Sequence 11

Fig. 49. March 2, 1971

This figure provides a panoramic view of west-to-northeast facing slopes along Piuma Road (Upper road-X). The more heavily vegetated north slopes (in this case oak woodland) did not burn as hot as the drier vegetation on the south slopes. Fig. 46 gave a distant view of the oak woodland slope (Y) shown in this photo. Notice the bands of ryegrass (Z) in the left part of the photo.

The road in the foreground leads to an abandoned homestead where wild oats (Z') had taken a foothold prior to the Wright Fire.

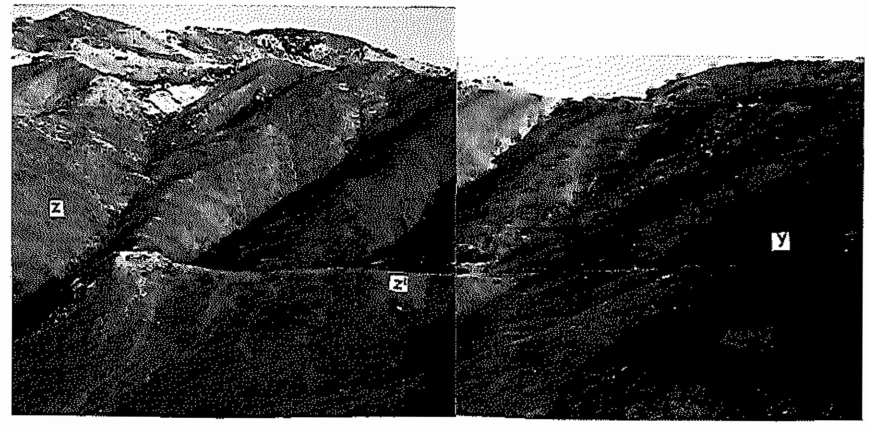
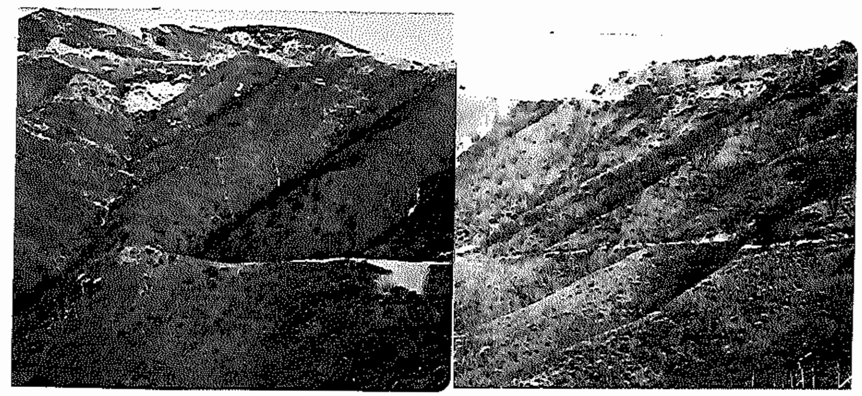


Fig. 50. May 21, 1971

The bands of ryegrass, intermixed with herbaceous cover, are still evident. Field checks on March 2 of the oak woodland at the right of the photo showed an average of 15 ryegrass seedlings per square foot and 42 miscellaneous seedlings. By May 21 mortality had reduced this number to 9 and 16 seedlings respectively. This slope was covered ankle deep in ashes after the fire, as verified by the author, who walked it for seed distribution checks. The rains did not wash the seeds away with the ashes but created gullies and rill erosion through the ashes and helped the seeds penetrate deeper into this rich, fertile seedbed.



- - -

Seeded ryegrass and native vegetative cover was more dense on north slopes than south slopes. Deep, fertile soils and a more equitable moisture regime made the difference.

Photo Sequence 12

Fig. 51. December 31, 1970

The greatly tilted, denuded mountain range above Dark Canyon indicates the clean, hot burn of the Wright Fire. The barely visible green tint (X) indicates germinating ryegrass.

Fig. 52. March 2, 1971

Annual ryegrass is now evident throughout the mountains except on rock outcroppings (X) and steeper slopes (Y). Field checks indicated that most of the living ryegrass seedlings present in these mountain ranges had germinated by the end of January. Thereafter, seedling abundance decreased due to mortality, but total crown cover increased because of rapid growth coinciding with warmer weather. In this, as in other areas of the coastal mountains, seeded ryegrass formed a cover after most of the season's rain was over.

Fig. 53. May 21, 1971

The lower part of the photo and the roads at the top of the mountain show cured resident annual grasses (X). Patches of mature ryegrass are scattered throughout the mountain, but are more readily visible on north exposures (X'). Forbs are showing up as brown patches (Y) on the harshest sites.

- - -

On south and west exposures ryegrass germinated and matured more quickly than on north exposures; however, it was also more readily replaced by forbs which are adapted to harsher sites.

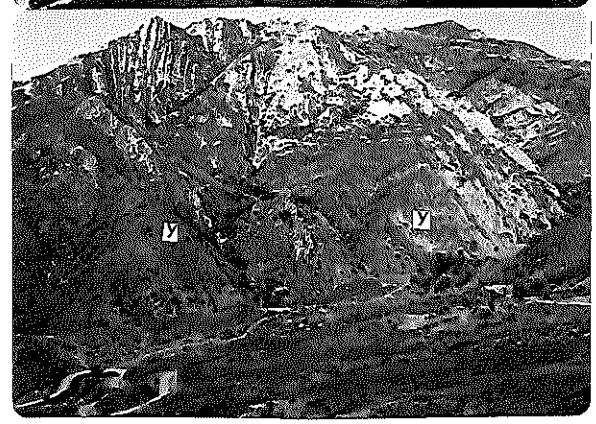


Photo Sequence 13

Fig. 54. March 2, 1971

These rugged southeast facing peaks above Malibu Canyon show a thin but even ryegrass cover on the slopes in the foreground (X). A heavier stand of ryegrass mixed with resident annual grasses is shown along a ridgetop (Y) and edge of the firebreak (Z). The resident annual grasses are a result of the seeds furnished by the firebreak. These firebreak systems and other such disturbances of the chaparral are easily invaded by annual grasses and thereafter furnish a yearly supply of resident annual grass seeds.

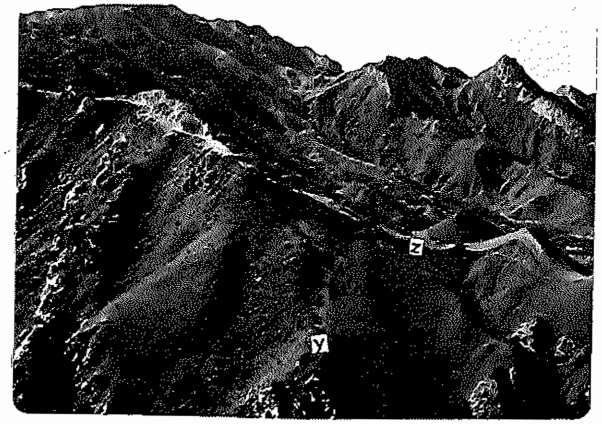


Fig. 55. January 15, 1976

Just slightly more than five years after the Wright Fire, chaparral has again reclaimed this slope and will continue to heal the fire scars as time goes by. Because of the extremely dry season, herbaceous plant growth has not yet started. Resident annual grasses are therefore still absent from this area.

Annual Ryegrass Phenology During the First Growing Season

Fig. 56. February 12, 1971

This site is part of the area shown in Photo Sequence 3. The resprouting mountain mahogany (X) is surrounded by ryegrass (Y) in the stooling out stage, ceanothus seedlings (Z'), and miscellaneous forb seedlings (Z). Spot checks showed that ryegrass seedlings, which had germinated by December 12, 1970, were in the two to eight leaf stage by December 31, 1970 (Fig. 20), and in the stooling out stage six weeks later (this photo).

Fig. 57. April 7, 1971

This photo covers approximately a 3 x 5 feet area and is part of Photo Sequence 3. About 20 ryegrass seedlings (X) are intermingled with more than 140 chamise seedlings (Y) and 10 ceanothus seedlings (Z). This spot was therefore covered with about 10 chaparral seedlings and less than two ryegrass seedlings per square foot.

Of the 19 inches of rain received during the season, only 0.7 inches fell after April 7, 1971.

Fig. 58. April 7, 1971

This photo was taken near the above site and again shows an abundance of brush seedlings /such as chamise (X) and ceanothus (Y)/ and fire type annuals (Z) sharing the site with scattered seeded ryegrass plants.

The red pen in the center measures 6¼ inches.

\- - -

During spring (April and May), fire type annuals and biannuals accelerated their growth and often became the dominant cover on sites where ryegrass had been the dominant cover during the late winter months.

Fig. 59. May 10, 1971

This almost pure stand of annual ryegrass was found nestled in a depression along Piuma Road at 900 feet elevation. Accumulated silt and plenty of moisture from run-off made this a fertile site for annual ryegrass.

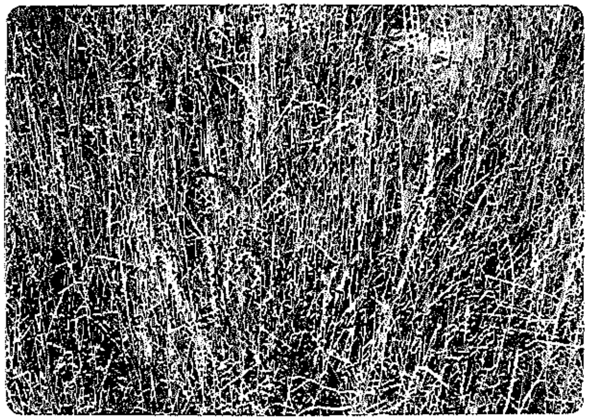
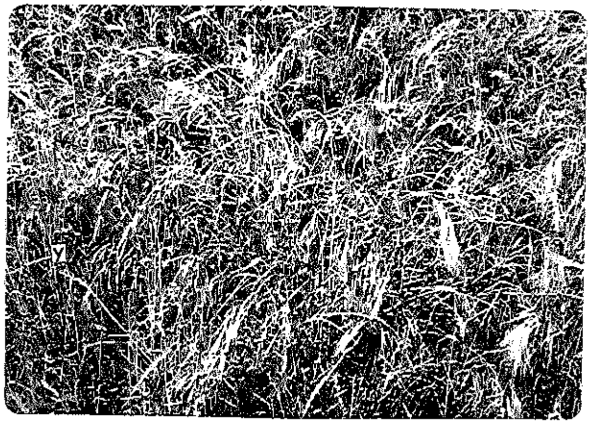


Fig. 60. May 10, 1971

This photo was taken along the shoulder of the road within a few feet of the above photo. This more rocky and drier site resulted in early moisture stress and hastened maturity. Ripgut brome (<u>Bromus rigidus</u>) (X) is intermingled with ryegrass (Y) on this poorer site.



- - -

In the more moist and fertile sites along roadsides annual ryegrass was often found in nearly solid stands. On harsher sites it occurred in mixtures of annual grasses, primarily bromes and wild oats.

LITERATURE CITED

Agozino, J. R. 1976. Results of Ryegrass Seeding After the 1975 Big Tujunga Burn. Los Angeles County Forester and Fire Warden.

Anonymous. 1967. Soils of the Malibu Area, California. U.S.D.A. Soils Cons. Serv., Top.-Las Virg. Soil Cons. District, and Los Angeles County Dept. of Eng. 117 p.

Bell, D.T., and Muller, C.H. 1973. Dominance of California Annual Grasslands by Brassica nigra. Amer. Mid. Natur. 90:277-299.

Bentley, J.R. et al. 1956. Range Species Recommended for Sowing on cleared Brushland in California. U.S. Forest Serv. Pacif. S.W. For. and Range Exp. Sta. Res. Note No. 111. 10 p.

__________ 1967. Conversion of Chaparral Areas to Grassland. Techniques Used in California. U.S.D.A. Handbk. 328. 35 p.

Biswell et al. 1952. Management of Chamise Brushlands for Game in the Northcoast Region of California. California Fish and Game 38:453-484.

Blanford, R.H. and L.E. Gunter. 1971. Emergency Revegetation 1956-1970. State of California, Division of Forestry. 21 p.

Cooper, C.F. 1961. The Ecology of Fire. Sci. America 204, 150-160.

DeBano, L.F. 1969. Water Repellent Soils. Agric. Science Rev. 7 (2):12-18.

__________ 1973. Chaparral Soils. Proc. Symp. on Living With the Chaparral (1973):19-26.

__________, and C.E. Conrad. 1974. The Effect of a Wetting Agent and Nitrogen Fertilizer on the Establishment of Ryegrass and Mustard on a Burned Watershed. Jour. Range Mgmt. 27(7): 57-60.

Edmunson, G.C., and D.R. Cornelius. 1961. Ryegrass for Southern California Fuelbreaks. U.S. Forest Service. Pacific S.W. Forest & Range Exp. Sta. Res. Note #186. 6 p.

Ferenczy, L. 1956. Occurrence of Antibacterial Compounds in Seeds and Fruits. Acta Biol. (Budapest) 6:317-323. Original not seen.

Fisher, C. 1971. Malibu Ryegrass Test Plots, 1970 Wright Burn. Los Angeles County Forester and Fire Warden. 16 p.

Hafenrichter, A.L. et al. 1968. Grasses and Legumes for Soil Conservation in the Pacific Northwest and Great Basin States. U.S.D.A. Soil Cons. Handbook No. 339. 69 p.

Haggenmiller, J.T. (1970) Rates of Ryegrass Seeding. Los Angeles County Forester and Fire Warden. 2 p.

Heady, H.F. 1972. Burning and the Grasslands in California. Proc., Annual (1972) Tall Timbers Fire Ecology Conference: 97-107.

Hedrick, D.W. 1951. Studies on the Succession and Manipulation of Chamise Brushlands in California. Texas A & M College, College Station. Unpubl. Ph.D. thesis.

Hopkins, W., J.R. Bentley, and R.M. Rice. 1961. Research and a Land Management Model for Southern California Watersheds. U.S. Forest Serv. Pacif. S.W. Forest and Range Exp. Sta. Misc. Pap. No. 56. 12 p.

Miller, H.W. 1956. Standard Seeding Rates. U.S.D.A. Soil Cons. Serv. Techn. Note No. 11.

Moore, D.R. and J.S. Waid. 1971. The Influence of Washings of Living Roots on Nitrification. Soil Biol. and Biochem. 3:69-83.

Muller, C.H., W.H. Muller, and B.L. Haines. 1964. Volatile Growth Inhibitors Produced by Shrubs. Science 143: 471-473.

Phillips, C.B. et al. 1972. Calif. Div. For., Sacramento Fire Contr. Note No. 26.

Plumb, T.R. 1961. Sprouting of Chaparral by December After a Wildfire in July. U.S. Forest Serv. Pacif. S.W. Forest & Range Exp. Sta. Tech. Pap. 57. 12 p.

__________ 1963. Delayed Sprouting of Scrub Oak After a Fire. U.S. Forest Serv. Res. Note PSW-1. 4 p.

Papanastis, Vasilos. 1973. Decline of Annual Ryegrass (Lolium multiflorum Lam.) Seeded on Burned Brushlands. Univ. Calif., Berkeley. Unpubl. Ph.D. thesis. 220 p.

Radtke, K.W. 1971. Fire Ecology Studies-Photo Report. Los Angeles County Forester and Fire Warden. 16 p.

Radtke, K.W. 1974. Cooperative Low-Fuel Plant Research Agreement-Annual Progress Report. Los Angeles County Forester and Fire Warden. 31p.

Radtke, K.W. 1976. Cooperative Low-Fuel Plant Research Agreement-Final Progress Report. Los Angeles County Forester and Fire Warden.

Rice, E.L. 1964. Inhibition of Nitrogen Fixing and Nitrifying Bacteria by Seed Plants. Ecology 45(5):824-837.

___________ 1974. Allelopathy. Academic Press, Inc., New York, N.Y. 353 p.

Rice, E.L. and S.K. Pancholy. 1972. Inhibition of Nitrification by Climax Vegetation. Amer. J. Bot. 59:1033-1040.

Rice, R.M. 1967. Cooperative Studies of Applied Watershed Management. U.S. Forest Serv., Pac. S.W. Forest and Range Exp. Sta. Ann. Progr. Rept. 1967. 9 p.

___________ 1973. The Hydrology of Chaparral Watersheds. Proc., Symp. on Living with Chaparral (1973):27-34.

___________ 1973. Sowing Ryegrass on Burned Watersheds is a Mistake. Unpubl. Rept. 20 p.

___________, R.P. Crouse and E.S. Corbett. 1963. Emergency Measures to Control Erosion After a Fire on the San Dimas Experimental Forest. U.S.D.A. Misc. Publ. No. 970. 8 p.

Schultz, A.M. and H.H. Biswell. 1952. Competition Between Grasses Reseeded on Burned Brushlands in California. Jour. Range Mgmt. 5(5):338-345.

___________, J.L. Launchbaugh, and H.H. Biswell. 1955. Relationship Between Grass Density and Brush Seedling Survival. Ecology 35(2): 226-238.

Stallings, J.R. and Radtke, W.H. 1974. Seeding the 1973 Rolling Hills Burn. Los Angeles County Forester and Fire Warden. 3 p.

Stocking, S.K. 1966. Influences of Fire and Sodium-Calcium Borate on Chaparral Vegetation. Madrona 18:192-203.

Stoddart, L.W., A.Smith and T.W.Box. 1975. Range Management. McGraw-hill, Inc., New York, N.Y. 532 p.

Sweeney, J. R. 1956. Responses of Vegetation to Fire. Bot. 28:143-250

___________ 1967. Ecology of Some "Fire-Type" Vegetation in Northern California. Proc. 7th Annual Tall Timbers Fire Ecol. Conf. p. 111-126

___________ 1969. The Effects of Wildfire on Plant Distribution in the Southwest. Pro., U. Arizona Acad. of Science 1969 Symp. on Fire Ecology: 23-28.

___________, and H. H. Biswell. 1961. Quantitative Studies on the Removal of Litter and Duff by Fire Under Controlled Conditions. Ecology 42:572-575.

Tinnin, R., and C.H. Muller. 1971. The Allelopathic Potential of Avena fatua: Influence on Herb Distribution. Bull. Torrey. Bot. Club 98:243-250.

Waco, D.E. 1968. Frost Pockets in the Santa Monica Mountains. Weather 23:456-461.

Walton, M. 1971. Description of the Malibou Creek Watershed. Unpubl. Rept. 25p.

Went, F. W., G. Juhren, and M. C. Juhren. 1952. Fire and Biotic Factors Affecting Germ nation. Ecology 33:351-364.

Zinke, P. J. 1967. Soil and Water Aspects of Brush Conversion. Proc., Calif. State Adv. Board, Sacramento, CA.