Fire Ecology of the Valdivian Rain Forest*

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ALTHOUGH less widespread than formerly, there exists perhaps nowhere in Latin America a better example of a temperate-marine forest than in the Lake District of southern Chile and Argentina. This forest reaches its optimum growth on the slopes of the Chilean watershed between 39° and 42° S (Fig. 1). Here thrives the exuberant plant community known as the Valdivian rain forest. The extraordinary growth of trees and shrubs, the thick stands of bamboo, the imposing lianas artistically twisting round the trunks of the massive beeches, and the luxuriant upholstering of epiphytes recall impressions of the tropical rain forest (Fig. 2).

The sole purpose in presenting this paper is to emphasize how man, through the agency of fire, has drastically altered the Valdivian rain forest ecosystem, and to conclusively show that most ruthless forest destruction has occurred in the past 75 years.

BRIEF DESCRIPTION OF THE RAIN FOREST

With just reason, the rain forest has been designated by Dimitri

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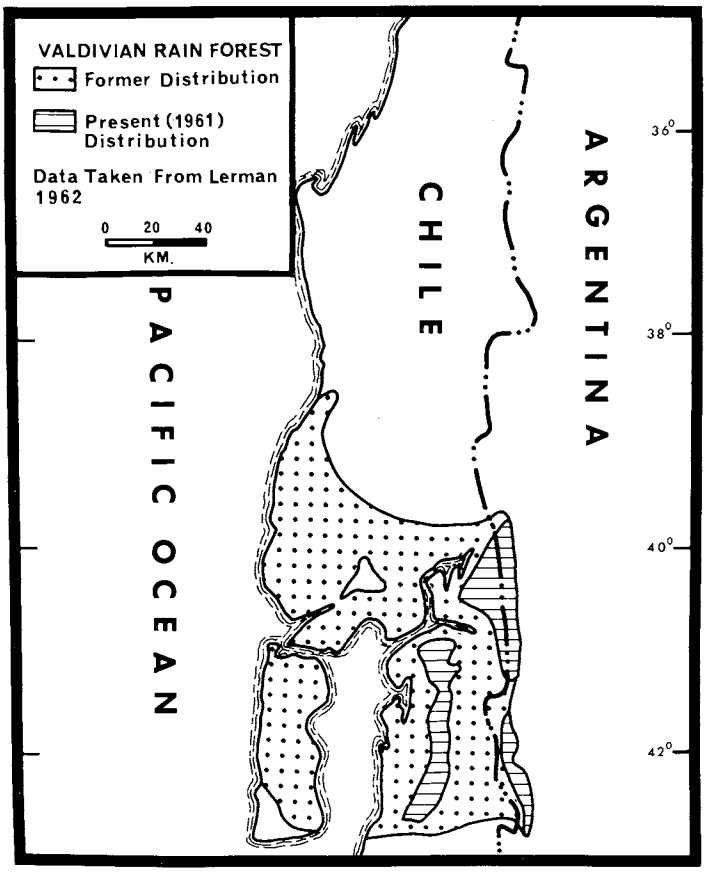

FIG. 1. Past and present (1961) distributions of the Valdivian rain forest.

(1962:29) and others as the Valdivian selva, in which numerous lianas, epiphytes, mosses, lichens, and other plants morphologically resemble a tropical rain forest. A special feature of the Valdivian rain forest is the leathery leaves, a characteristic resembling the physiognomy of dry region plants. In this manner the trees probably protect themselves from an excess of rain as well as short periods of aridity.

Although dominated by the southern beeches, like the *coihue* (*Nothofagus dombeyi*), a great variety of woody plants exists in the rain forest. Most are broad-leaved evergreen trees which resemble

FIG. 2. The Valdivian rain forest.

magnolias and laurels found in the United States. In the better drained spots throughout the forest the highest tier is made up of *coihue* (Fig. 3), generally 40–45 meters high. Beneath these stately trees at 25–30 meters lies the understory of *maniu hembra* (*Saxegothea conspicua*) *and hua-huan* (*Laurelia philippiana*). Poorly drained or swampy habitats permit the *alerce* (*Fitzroya cupressoides*) to grow in dense unmixed stands. In drier soil this giant sequoia-like conifer mixes with beeches like the *coihue*, and with the conifers *maniu hembra* and *cipres de las Guaytecas* (*Pilgerodedron uviferum*). The association of coniferous with broad-leaved evergreen species is another characteristic feature of the ecosystem.

The *alerce* perhaps best represents a tree species of the Valdivian rain forest more than any other type (Fig. 4). Its northern limit originally included the coastal mountains of Valdivia Province, Chile, at elevations above 300 meters. It then extended south to

FIG. 3. The *coihue* (*Nothofagus dombeyi*) dominates the Valdivian rain forest. It often attains a diameter of 3–4 meters at breast height.

Chiloe Province, Chile, and adjacent Chubut Province, Argentina. It was also found on moist sites in the central valley between Lake Llanquihue and Puerto Montt. Presently, however, *alerce* stands are restricted to a few inaccessible localities. The largest and best preserved tract in Chile occurs in a 50-kilometer-long area southeast of Puerto Montt on the Hornopiren Peninsula (Fig. 1).

In a general way the appearance of the *alerce* resembles that of the coastal redwood (*Sequoia sempervirens*) of California. Like the redwood, the sapwood is yellow and the heartwood is light red to cinnamon. The *alerce* prefers low, marshy, peat-like soils, but in some areas of Argentina and Chile it reaches an altitude of 900 meters above sea level. An evergreen which craves humid conditions, it has an unquenchable thirst for water. Some specimens thrive under

conditions of more than 5,000 millimeters of annual precipitation. The tree reaches diameters of 3 to 4 meters and heights in excess of 50 meters under the favorable criteria of damp, peaty soil and humid atmosphere.

THE HUMAN ELEMENT

Aboriginal man, prior to the coming of the European, apparently was not an integral part of the Valdivian rain forest ecosystem. Although archeological excavations are lacking for the rain forest zone, historical evidence at least points to the conclusion that Araucanian Indians lived generally outside of the primeval forest and utilized it only when absolutely necessary. Most of the southern Araucanians dwelled along the Pacific coast, adjacent bays, and the shores of nearby inland freshwater lakes where the primal needs of

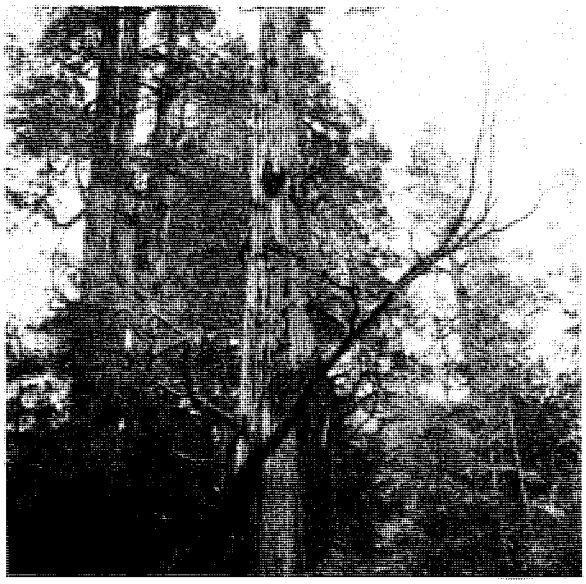

FIG. 4. The *alerce* (*Fitzroya cupressoides*) grows in poorly drained habitats in the Valdivian rain forest. In general appearance it resembles the coastal redwood (*Sequoia sempervirens*) of California.

life were satisfied. The adjoining rain forest harbored a ready source of building materials, fuel, and some wild game and plant-life. Thus it was advantageous for most Indians to build their settlements beside the water-bodies as close to the rain forest as possible.

The coastal southern Araucanians, however, were not typical slash-and-burn agriculturalists like their northern inland Indian neighbors. Faron (1961:18) believes that it is even misleading to think of the northern Araucanians, prior to 1600, as field farmers, since equipment for field cultivation did not appear until the colonial period. The coastal southern Araucanians remained small-scale garden cultivators at best during the pre-colonial period, and depended almost entirely upon the sea for their livelihood.

It is quite apparent that the southern Araucanians knew fire long before Spanish contact. Fire was used for cooking, heating, burning out dugout canoes, and to a lesser degree, for clearing portions of the rain forest. Bullock (1911:31) states that cultivation of potatoes occurred in open glades in the rain forest. These small openings were certainly formed by burning the rain forest and were located in close proximity to Indian settlements. Nevertheless, aboriginal burning was definitely restricted to a narrow segment of the Valdivian rain forest and thus had a minor influence on the ecology of the ecosystem.

Spanish immigrants occasionally penetrated the southern forests between the 17th and 19th centuries, only to be met by hostile native resistance. It was apparent from the beginning of Spanish colonization that the central region of Chile was more conducive to settlement, thus the southern forested region was bypassed.

Chilean independence from Spain in 1818 awakened national interest in south Chile. The land tenure policy, introduced by the Spanish and largely retained after Chile's independence, combined with giving private initiatve a free hand in clearing forest lands. This plan had the result that much rain forest of south Chile came to be considered private property. Further, by clearing the rain forest with fire the settlers were destroying suitable habitat for offensive Indians. This was the beginning of the extensive forest burning in south Chile, although still somewhat restricted as to area. The southlands were opened fully to Europeans, and in the 1850's

German immigrants began to buy and clear land between Valdivia and Puerto Montt.

The German immigrant of the late 19th and early 20th centuries was the epitome of ruthless land clearing. According to Fergusson (1943:50), earliest efforts were almost entirely devoted to clearing the extensive forests for agricultural crops and grazing. From the beginning the forest was regarded as an impediment to be cleared away as rapidly as humanly possible. After making a clearing in the forest, the German settler constructed a temporary log house and prepared a field to plant his crops. Stumps, charred trunks, and surface roots prevented the Germans from using a plow, so they used a hoe or a dibble.

Fire was quickly and easily employed in the warmer months when least precipitation fell. The usual method of firing the land centered on selecting dead but standing trees. Branches, twigs, and other organic debris were piled up around the base of the tree, then set afire. By firing several "match" trees in any given stand, the fire quickly spread to adjoining live trees. Only a very few highly selective trees were cut beforehand and utilized for domestic purposes.

These fires were very destructive, not only killing and injuring the trees left in the stand (often up to 80% of the original volume), but also spreading far outside the original stand to adjacent unburned and uncut areas.

ECOLOGICAL CHANGES TO THE ECOSYSTEM

In spite of controversies as to its true impact, fire has greatly modified the composition of vegetation in the rain forest. This was vividly displayed in an area between Lakes Llanquihue and Todos los Santos (Fig. 5). Prior to 1900, part of this area (15 kms. long by 5 kms. wide) was covered by an *alerce* forest. Tree specimens reached, according to nearby inhabitants, heights of 40 meters and diameters at breast height of 3 meters (Fig. 6). The land was acquired by several German families around 1900, and they immediately began firing the land in order to create agricultural fields. The settlers consistently burned section after section of the *alerce*

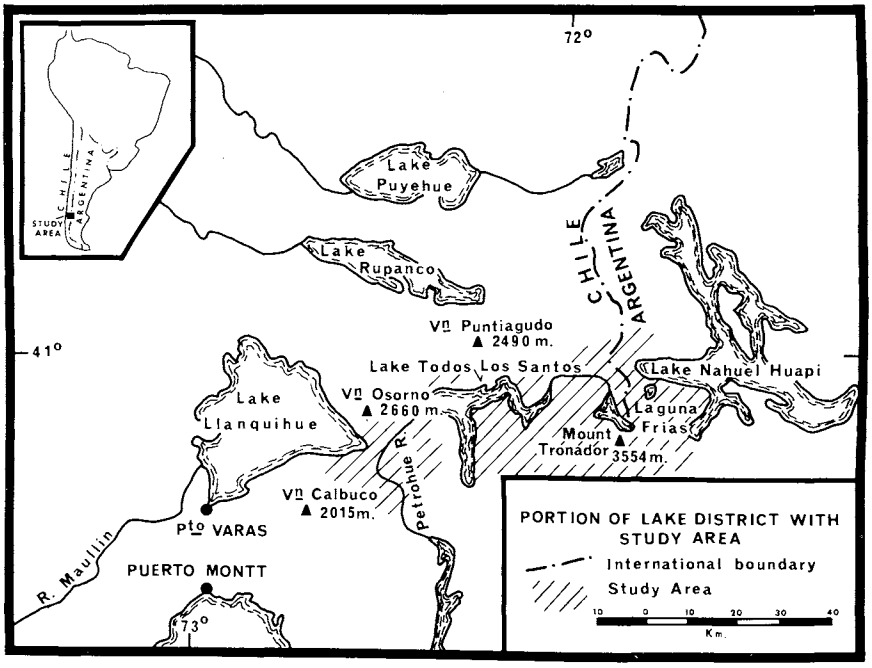

FIG. 5. Portion of lake district with study area.

stand, concentrating their energies in the drier warmer months of the year. These fires continued to burn unchecked for days and weeks at a time, slowly but meticulously destroying the giant conifers. Again inhabitants stated that it took residents nearly a decade to exterminate the tract of truly prime rain forest.

The *alerce* is adapted to seeding-in following a fire, but has no mechanism for sprouting from a burned stump. The first fires apparently produce a new crop of seedlings, but recurrent fires each year gradually eradicate the entire population. Within a few years this tract of land was covered with brambles and weedy undergrowth, all of which could resprout following fire and thus remain in control of the ground itself. In reality, excessive, repeated burning produced a "barren" desolate tract of land, devoid of large woody plants. In 1961–62 this tract consisted of brambles (70 percent of

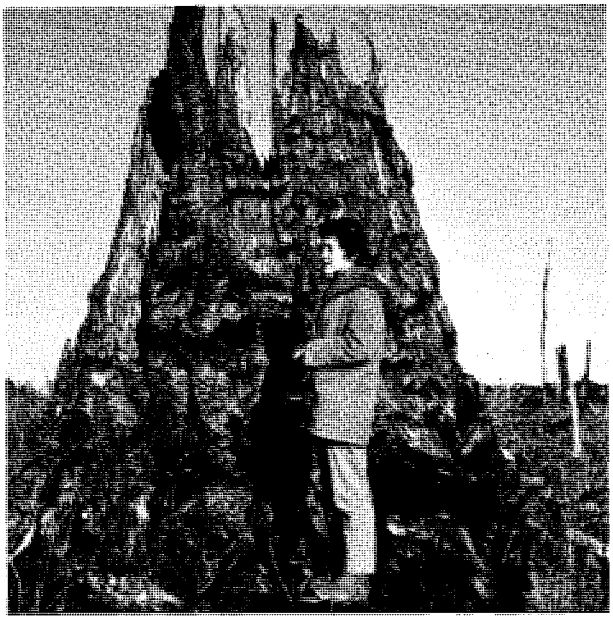

FIG. 6. This charred remains of an *alerce* was photographed near Lake Llanquihue, Chile. Until 60 years ago hundreds of specimens like this example grew in the zone.

vegetation), ferns (15 percent), lichens and mosses (10 percent), and other herbs like grasses and sedges making up the rest of the vegetation cover. Only an occasional charred black-gray stump, or a decaying prostrated log attest to a once vigorous, prosperous *alerce* stand.

In this particular *alerce* stand the people burning the land had insufficient time to change the end results or did not heed the intrusion of undergrowth vegetation. It is not customary in this zone to cultivate the soil until charred logs and debris can be pulled to the sides of the fields, there again to be burned. Or, if the land is to be used for grazing, sufficient herbage does not appear until 2 years after repetitious fires. In this particular tract brambles and ferns came in with the grasses and sedges, but quickly dominated the ground, choking out the sedges and grasses.

Accompanying the changes in species composition within the

tract have been changes in the micro-environment. Recurrent fires in the zone resulted first in an opening of the forest canopy, then an eventual destruction of it altogether. These vast openings created a very different microclimate from the typical Valdivian rain forest described above. The most significant change is an increase in the rate of evaporation, which increased proportionally until it reached its maximum value in the completely burned situation. Although the tract was located in a humid zone, the net result of the burning was that all the environmental changes were in the direction of a more xeric habitat: greater amount of light, more variable temperatures, more variable moisture, and much greater transpiration stress. Such conditions are most suitable for the ecologically hardy pioneer plants of the region. These species, like lichens, mosses, ferns, brambles, and the like, grow vigorously under the unstable climatic conditions and possess adaptations to make use of the high light intensities. Ordinarily such species possess highly effective means of reproduction and dispersal, and, in addition, are likely to survive under severe disturbance, as by recurrent fires, through the ability to sprout from thousands of roots or spores.

Four kilometers southwest of this former *alerce* tract burning was continuing at a rapid pace. Several species of southern beeches exist here, while the remaining parts of the region consist of grasslands, brushlands, and marshes. Vegetation composition and distribution are strongly governed by a long history of periodic fires over the past several decades. Since the earliest known records in the mid-1880's, there have been several major conflagrations in the locality, notably in 1885, 1890, and 1915. The 1915 fire burned an estimated 10,000 hectares, including a major segment of several farms, before being extinguished. Since 1915, a total of 80 percent of the zone has burned due to intentional fires. According to the present owners, only three of whom are not German, they have been burning portions of the rain forest every year since 1940. In 1956 an extremely devastating fire got out of control due to unusual high winds and dry conditions. Even today brush and forest fires occur annually in the ever decreasing rain forest zone. In dry years fires create a severe hazard to natural vegetation, animal life, and human property. In March and April, 1962 ten fires raged out of control near Lake

Todos los Santos. The fires destroyed hundreds of hectares of rain forest land and burned for days due to their inaccessibility. One serious fire in April, 1962, threatened the community of Cayute, spreading to the community limits before it was controlled.

Fires started by natural agencies east of the line of Chilean volcanoes are rare. No record of lightning strikes causing forest fires have ever been reported in the literature. Forty major blazes were reported on the Chilean side of the frontier during the 1961–62 fire season. All were started because of human intention or carelessness. The most serious blazes stem from unextinguished campfires. Both local inhabitants and visitors drink yerba mate several times a day. If the people are outdoors, a fire is quickly made to heat water for the tea. In the end many of these tea drinkers fail to extinguish their fires. In summary, the most devastating forest fires in south Chile have taken place within the last 75 years by German settlers. These people for the most part are interested only in immediate maximum returns from the land, and are anxious to clear the rain forest as soon as possible without heed to the future. The difficulties of exploitation, poor communication-transportation, and distance from markets have encouraged the frontier settlers to destroy the rain forest.

The normal undisturbed succession of arboreal species is a gradual march toward the climax forest of southern beeches and *alerce*. Most of the disturbed zone would be dominated by beech forests were there no fires to arrest and set back the progress of succession.

The severity of a forest fire is dependent on several factors: forest type, quantity and composition of combustible material, and the strength of the wind. The moisture content of the soil, particularly in the humus layer, is not the least important factor.

The survival of vegetation and micro-organisms after a fire depends on the temperature reached in the humus cover. The humus cover is an excellent thermal insulator, a fact pointed out by Uggla (1959:6). This is partly explained by the condensation of water vapor formed in the burning of organic matter near the top of the soil stratum. As the fire advances, the damp humus cover acts as a cold barrier, where moisture is condensed. Immediately below the fire zone lies a "sweating zone," which effectively prevents a fire

from penetrating deeper into the humus cover. During a warm, but not hot, fire, the high temperature does not as a rule last long enough for the moisture to evaporate. On moist sites, like depressions, the vegetation may be totally undamaged. From such islands regeneration of the burnt areas often starts anew.

FOREST SUCCESSION

The first year's succession following fire in the rain forest is a growth of herbaceous vegetation consisting of grasses, sedges, and other flowering plants. This lush, rapid growth may be related to the fertilizing action of mineral nutrients released by the ash. In the drier areas of the rain forest, the total yield of grasses and sedges increases three times after fire, possibly due to more light, more nitrogen in the soil, and removal of the competing shrubs. Burning seems to be a stimulant to flower and seed production of herbaceous plants. Fire removes the old insulation permitting earlier growth; simultaneously it builds up the food reserves before the next flowering period.

On former rain forest land, a dense growth of ferns appears in the 2nd and 3rd year after fire. At the same time grasses and sedges decline, primarily due to increase of shade. Sagebrush-like shrubs increase prolifically during this same period. I concluded that recurrent fires in this part of the Lake District every year prohibit surrounding trees from invading the burnt ground. Because of their low stature and small stems, shrubs are very liable to destruction by fire, but they resprout vigorously. Increase in shrubs may be due, in part, to the fact that heat stimulates the germination of seeds in some species, especially with increase of available minerals. On the other hand, shrubs decline or even disappear with annual recurrent fires. Grasses and sedges thrive in their place. Shrubs of the area grew sufficiently dense to retard both regeneration of the nearby forests and grasses.

In the 4th to 6th year following fire, vegetation succession changes from a dominance of ferns to a dense shrubby growth including *chilco* (*Fuchsia magellanica*) (Fig. 7), *maqui* (*Aristotelia maqui*), *michay* (*Berberis darwinii*) (Fig. 8), and other xeric-like plants. In about 8 years, the first beeches appear, especially the *nire*

FIG. 7. The *chilco* (*Fuchsia magellanica*) grows exceptionally well after a forest fire.

and *roble*. From this period on, there is a gradual progression toward the climax forest described earlier. In observing the various stages of such a progression, I estimated that the climax forest of beeches would occur probably in 30 to 40 years, provided that fires were non-existent.

It is not difficult to determine the general effects burning has had on soil and water resources in the Lake District. It is quite apparent that moderate to heavy erosion has occurred and is continuing in the unforested regions, particularly on some steep slopes where annual burning and grazing are carried out. This will accelerate with a progressive reduction in soil fertility under present agricultural methods, especially if the steeper slopes and higher lands continue to be converted to agricultural use. Accelerated erosion will occur on such terrain despite the rapid growth of vegetation which is now helping to prevent erosion at lower and flatter elevations. The entire removal

FIG. 8. *Michay* (*Berberis darwinii*) dominates burned, cleared areas of former rain forest land in six to eight years.

of the rain forest in south Chile will sufficiently disturb the ecosystem so that generally adverse effects will occur on soils, water table, and degree of agricultural potential of the land. These effects can only be partially compensated for by conservation practices, which, at present, are practically non-existent. In the final analysis, whether the Lake District of South Chile is eventually employed almost entirely as an agricultural and grazing area, or whether a part will be left in rain forest for other purposes, rests on the values and intentions of those in a position to exercise control. The problems of continued settlement and adverse land use require strong action if they are to be solved for the long-term, instead of the short-term, benefit of both the land and the people. To do this it will be necessary for governmental authorities concerned with natural resources to formulate and implement policies based on an evaluation of the total resource potential of the entire Lake District. This

approach, to be effective, must embody considerations based not only on sound land use, but also upon conservation principles.

CONCLUSIONS

Before the turn of the 20th century the scarcity of population and lack of incentive for commercial exploitation limited demands on the Chilean rain forest to a modest local scale. However, with an increase in population, need for more agricultural land, the growth of towns and cities, advent of a national railroad and highway system between Santiago and Puerto Montt, and subsequent demands for wooden materials, the Valdivian rain forest suddenly became a prized and valuable resource. South Chile contains the major part of the remaining forests and woodlands of the country, with an estimated 80 to 85 percent by area of the total forested land and 96 percent of the total area of commercial forests.

The conservation outlook for the Valdivian rain forest is improving but still not encouraging. Agriculture on new lands is at present the only means practicable for part of the expanding population to subsist. There is a great need for educating the people to take a sound interest in the remaining tracts of rain forest, thereby introducing forestry and conservation principles and techniques. In the past few years the Chilean government has agreed in principle that the rain forest needs protection and sound scientific management. The federal police now have the authority to arrest farmers for negligently burning forest land, and special fire-fighting teams of federal police have been organized in the Lake District to combat uncontrolled forest and brush fires. These are moves in the right direction, but much more needs to be accomplished. Perhaps the most effective measure in the near future will be strictly controlled forest preserves in the Lake District. Chilean conservationists have been pleading for national forests and parks to be created in the zone before the ecosystem is destroyed forever.

The future of the Valdivian rain forest of south Chile lies in a balanced program embodying education, economic development, and strong conservation measures. If the unique ecosystem is to be saved, there must be concerted effort to establish working man-land rela-

tionships based on a concept that the rain forest is a distinct physical and biological entity. Effective steps must be taken soon to preserve a portion of this unusual forest, thereby at the same time helping to save the soils, water, and wildlife of the zone. The end result of such action will be a long-range view in regard to proper land use and conservation of natural resources.

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