The Increase in Forest Fires in Natural Woodland and Forestry Plantations in Chile[1]

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Summary

The problem of forest fires affecting natural woodland and forest plantations in Chile was analysed, characterizing the occurrence and the damage caused by this phenomenon. National Forestry Corporation data base was used to undertake the study. Once the problem of forest fires had been profiled, we debated the factors which would explain the increase in occurrence and the scale of the damage recorded to date. The information compiled indicates that the occurrence of forest fires has increased at an almost exponential rate from 1973-74 to the present time, this increase being closely related to the increase in surface area planted with highly inflammable species; the community's rejection of this type of crop; and the application of intensive silviculture which produces a high available fuel load and adds fire risk factors to the forest environment. In recent years the interaction between city and woodland is an added element which produces numerous fires on the rural-urban interface. The greater surface area of damaged natural vegetation is explained by the fact that this resource does not have sufficient protection all over the country. Moreover, a high proportion of this vegetation is located in inaccessible places, for which reason there is no suitable arrival point at the fire source and the topography does not allow effective fire-fighting. Consequently many fires affect a large surface area.

Introduction

In Chile, the occurrence of forest fires has significantly increased over the last 25 years, even exceeding 7,500 fires in the 2002-2003 season, compared to less than 1,000 fires per season before 1972. This increase seems not yet even to have reached its maximum, since no decline has been observed in the number of fires, in spite of the efforts made by prevention programmes. These programmes are run by private companies, as well as the National Forestry Corporation (CONAF) which is the state authority with legal responsibility for fire forest fire prevention and fire-fighting.

Traditionally the occurrence of forest fires was concentrated in the Mediterranean climate area, which extends from the Valparaiso Region to the Bío Bío region. However, in the last few years, a significant increase has been observed in temperate areas which include the Chilean regions 9 and 10. To the greater occurrence of forest fires is added the fact that during the last few seasons, due to a greater fuel load and drier climate, the intensity of fires is greater and many have catastrophic consequences. These fires are very difficult to control, have grave consequences for the population and the safety of fire-fighters, and also have a more negative impact upon the environment. The best example of this was seen in the 1998-1999 season when more than 20,000 ha burnt in 5 days in region 8, most of

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these being *Pinus radiata* and *Eucalyptus globulus*, plantations, two species which have highly inflammable foliage (oils, resins and waxes).

Without doubt, for any forest fire protection organization this increase in forest fire occurrence must be its main concern. However the problem becomes even more complicated, since in the case of Chile, at least 99 per cent of fires are caused by the activity of human beings. Either fires are used intentionally, as is agriculture or forestry, or forestland is used negligently and carelessly by the population at large. Lastly, we have the action of pyromaniacs.

In view of the above scenario, this study characterizes the problem of fires in forest plantations and natural forestland in Chile, and analyses the factors which determine the dynamics of this phenomenon. The information produced serves to understand the problem and may be used to establish strategies which would reduce the occurrence of forest fires and minimize damage to associated flora and fauna.

Characterisation of the problem of Forest Fires in Chile

Characteristics of forest fires

The accumulation of biomass and dead fuel in natural forests and plantations, added to a physical and social environment which favours the occurrence of forest fires, gives rise to fires with very particular characteristics which are summed up as follows: a) high annual occurrence, b) high intensity and propagation of the fire, producing uncontrollable fires; c) increase in provoked (actionable) fires; d) major occurrence of satellite fires; e) high frequency of fires in the same location within less than 12 years; f) urban-rural interface with high incidence of fires; g) concentration of forest fires in regions 7 to 9; and h) Major economic impact, both social and environmental.

The majority of these characteristics perfectly fit forest plantation fires, however in natural forestland the main characteristics are the increase in fires in 8th and 9th region, particularly intentional fires, causing a greater environmental impact due to the diversity of vegetation and fauna, and because these accidental fires occur in high mountain areas which are difficult to access and where fire-fighting is also more complicated. It should be underlined that fires involving natural vegetation propagate less than forest plantation fires but may cause a great deal of harm, as some of these become underground fires which transfer a great deal of heat to the mineral soil and in other cases cover a huge surface area.

Another important problem the protection programmes face is the frequency of fires in the same areas and their high level of intensity. Added to this is the fact that a large number of these occur on the wildland-urban interface (WUI) which becomes a major threat to cities in regions 7, 8 and 9 where woodland more often surrounds the city (Peña 1996). Moreover, due to the high loading and the continuity and homogeneity of the fuel, fires in recent seasons have been fairly catastrophic in their behaviour, from the point of view of intensity, propagation speed and the severity of economic, social and environmental impact.

The extreme behaviour of high propagation, intensity and the major occurrence of satellite fires make control very difficult and puts the population in the affected sectors at risk, as well as the fire-fighters involved in control. High intensity fires will most likely become more frequent in the future, due to the high loading and continuity of fuel in plantations' major surface areas. Added to this is global climate change and the greater interaction with the human population and their activities of production (Peña 2003).

Increase in Fire Occurrence

The interaction of plantation characteristics and their physical and social environment have given rise to a situation of high forest fire risk and danger which translates into a high annual occurrence rate. In the last decade this rate exceeded 5,600 hectares burnt in each season.

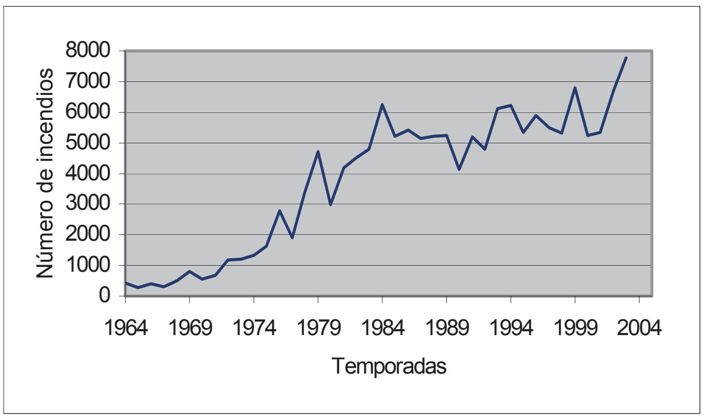

Figure 1— *Total number of fires per season for Chile (each season stretches from October to April of the following year. The value indicated for the season corresponds to the year the season ended).*

When analysing the occurrence of forest fires, it can be seen that the number of forest fires has increased exponentially from 1971-72, the first season when the figure for forest fires doubled, to reach a maximum of more than 6,000 fires in the 1983-84 season. In the following years there was a decrease in the number of fires, a trend which reverted again in 1992-93 when once again the seasonal figure exceeded 6,000 fires. Since that date virtually one of every two seasons gives figures close to or over 6,000 fires. This upward trend has been maintained, as in 2002-2003 a record figure of 7,500 fires was reached (figure 1).

It has not been possible to run an analysis of fire occurrence by vegetation type because the CONAF fire records do not undertake any sort of qualification. The reason is that in each fire different types of vegetation burns and it cannot be deduced whether this began in natural woodland or in a forestry plantation. This information may be very important, since to date there has been more damage in natural woodland, however this may be caused by a small number of fires and it may be that the majority of fires occur in plantations but affect a small surface area only.

The results, which show the increase in fire occurrence in each season, also lead us to postulate that current prevention campaigns have not had a positive result, mainly because few resources are invested in them and because they have concentrated only on changing people's attitudes but no fuel handling has been undertaken as a prevention method. Quite the reverse: a policy at national level of not eliminating waste from the harvest of natural woodland or plantations is still being applied, with the aim of leaving the maximum amount of organic material to benefit the chemical and physical properties of the soil.

Another major aspect to consider in the analysis of forest fires is the fact that the fire rate is increasing significantly in region 8 and 9 (figure 2). Both regions have a temperate climate with a large plantation surface area, however the most important factor is that region 9 has a large surface area of natural woodland, with many park and reserve areas. Due to the above, it is considered that fires in region 9 have a more severe negative impact on flora and fauna than in cases where the fire affects only forestry plantations.

CONAF's records indicate that in recent years the greatest occurrence has been in regions 8 and 9 (figure 2) where 50% of plantations are located (INFOR 2001). The explanation for this concentration in occurrence is because these regions have a high concentration of plantations; good accessibility to planted areas; are densely populated (human population); the woodland surrounds the urban areas; and the climate is Mediterranean, creating conditions propitious to the occurrence of forest fires. Further north, where the climate is still Mediterranean, plantations are not continuous and their growth rate is lower (lower fuel loading). To the south of region 9 the temperature is lower and fuel has a higher humidity content.

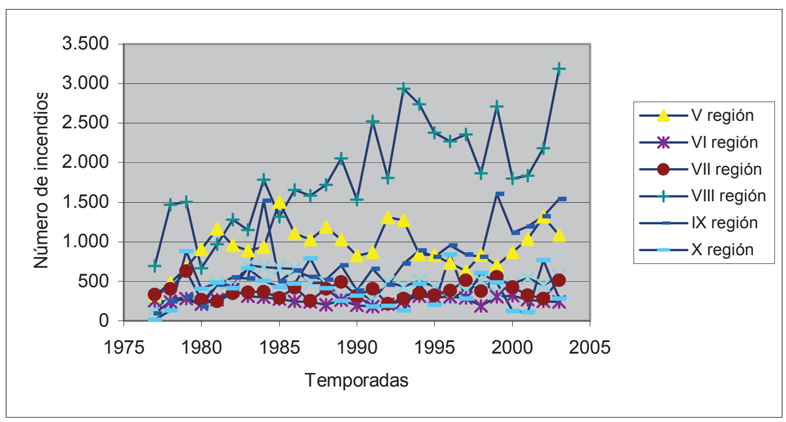

Figure 2 — *Fires by administrative region and season (regions with low forest fire occurrence are not included)*

Scale of damage from forest fires

On analysing the damage per season, it is observed that this shows a tendency to vary between 40 and 50,000 ha but shows major variations between seasons (figure 3). An extreme example of this variation can be seen in the 1998-1999 season when more than 100,000 ha burned, whereas two years later (2000-2001 season) the total burned surface area reached a second historic minimum of 10,804 ha. In this respect, experience indicates that a low percentage of fires, in general under 1 percent, produce extremely large fires which alone explain the major damage occurring in some seasons, amounting to at least 67% (CONAF 2003).

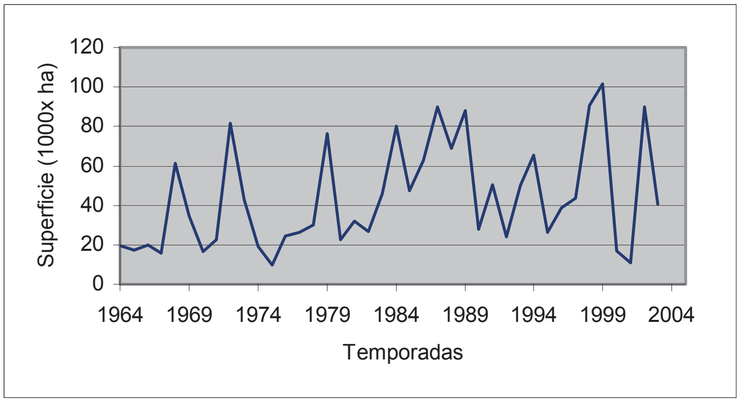

Figure 3 — *Total surface area affected by forest fires by season in Chile*

In order for some fires to damage large surface areas, they must occur in years of drought and/or days on which high temperatures are reached, there is low relative humidity, and winds over 30km per hour. The conditions described above occur from time to time in Chile. Of the 40 seasons for which forest fire occurrence records exist, 9 of these (25 per cent approximately) indicated damage of over 60,000 hectares.

On comparing fire occurrence (figure 1) with damage per season (figure 3) it can be seen that due to the high variability of damage, there is no relation between the number of fires and the surface area damaged. This can be explained by the fact that the protection programmes are increasingly more effective in detecting and fighting each individual fire source. For this reason, the average surface area affected by each fire is increasingly lower (figure 4). The damage only increases when atmospheric conditions are favourable to rapid propagation, as is the case of the presence of winds which accelerate propagation speed and increase the possibility of satellite fires at a considerable distance from the main fire front, normally 500 or more metres away. As the presence of conditions which are favourable to fire is irregular in terms of time, damage levels per season also shows major variations.

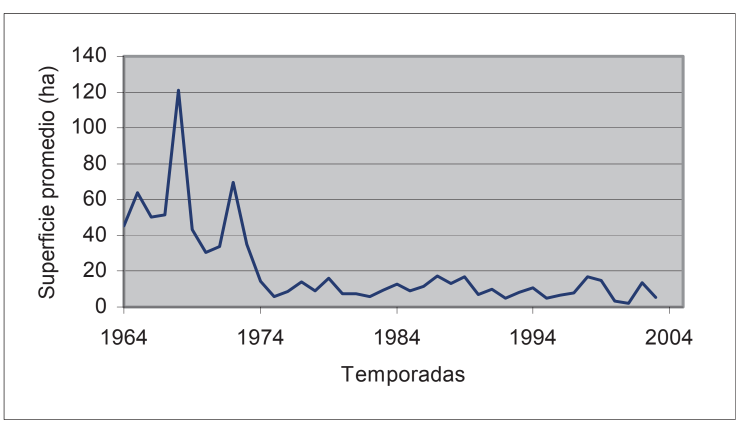

Figure 4 —*Average surface area affected by each forest fire*

In the 1973-1974 seasons the average surface damaged by each forest fire dropped to less than 15 ha from an average of over 45 ha in the past. From that date onwards the average has remained at around 10 ha (figure 4 and table 1). The results of average surface area damaged in each fire indicate that it is no longer possible to significantly improve in this regard, confirming the need to concentrate efforts on the prevention of fire occurrence. This greater effectiveness in fire-fighting coincides with the period when the forestry companies took over the cost of forest fire protection (creating their first fire brigades) and the CONAF professionalised their brigades by ruling out volunteers and hiring better skilled staff, trained for fire-fighting. Simultaneously the infrastructure available for forest fire protection programmes was improved, particularly the detection of fire sources and extinction in the shortest possible time.

Table 1— *Occurrence and damage from forest fires in Chile by five year periods from 1965-2003*

5-year period	Number of fires	Average surface area affected, by 5-year period (ha)	Average surface area affected by fire (ha)
1963 - 1968	383	26,767	70
1968 - 1973	883	39,682	45
1973 - 1978	2207	21,891	10
1978 - 1983	4239	40,679	10
1983 - 1988	5451	69,853	13
1988 - 1993	5090	47,617	9
1993 - 1998	5653	53,269	9
1998 - 2003	6346	52,348	8

Source: Soto 1995 and CONAF 2003

The analysis of the total surface area damaged, broken down between plantations and natural vegetation show that the greatest damage occurred in natural vegetation, which alone received more than 80% of the damage. Nevertheless, it should be underlined that the total damaged surface area varies considerably. In the case of plantation damage, however, this tends to remain fairly homogeneous over the course of all the seasons. Only 7 seasons out of a total of 27 record damage over 10,000 ha. Damage to natural vegetation in general exceeds 20,000 ha per season but only one third of this damage is to natural woodland. Even when the damage suffered by natural vegetation cannot be associated to a specific number of fires, it is assumed that this is caused by a small number of fires which become uncontrollable due to inaccessibility and the difficulty of fire-fighting.

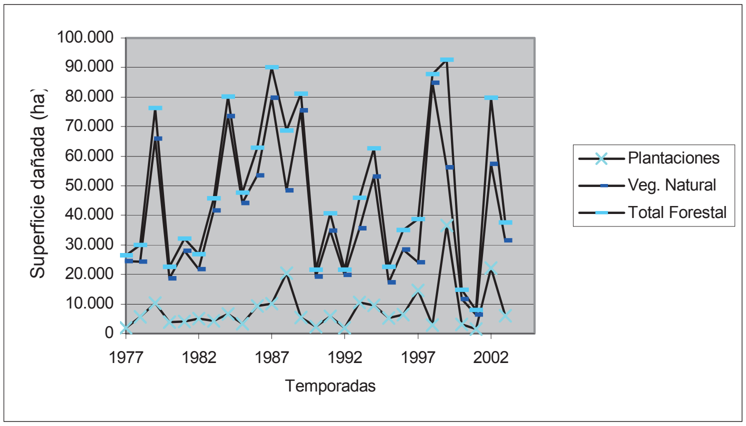

Figure 5 — *Total damaged surface area of plantations, natural vegetation and forestland*

The major difference in damage to natural vegetation and to plantations is explained by the level of investment made to protect each resource. Natural vegetation is mainly in the hands of CONAF (state-run organization) which invests less than US$ 1 per hectare, compared to the high investment to protect plantations made by private companies who invest more than US$ 7 per hectare. Moreover, the natural woodland is spread over the entire country and the plantations are concentrated in the south central area of Chile, facilitating their protection.

Causes of forest fires

The CONAF and private companies which have fire protection programmes keep records of the causes of these fires but in most cases there has been no thorough investigation done. Over the last few seasons, considering the importance of the causes of fire in prevention planning, brigades have been set up which more accurately determine the causes of each fire.

On improving the research, it has been detected that many of the fires are actionable (intentional). This is easily seen when comparing the causes of forest fires in region 8 between the decade 1990 to 2000 with the causes at national level. For region 8, 60 per cent of fires were intentional, as opposed to 26.2 per cent at national level in historical records covering all seasons (table 2). Over the last 10 years, at national level, an increase in intentional fires has also been seen, however a significant proportion of this increase is explained by the high rate of intentional fires in region 8.

The historical record at national level indicates that the main cause of forest fires is transit and transport through forestland, and second come intentional fires (table 2), a trend which has notoriously been reverted over the last few years, with intention moving into first position. This is an important message for protection organizations because they must determine what the motivation behind this intention is and with this information restructure the forest fire prevention campaigns.

Table 2.—*Distribution of occurrence of forest fires in region 8 and at national level by general causes*

Original cause	Region 8 Seasons 1990-2000 (Percentage)	National Last decade 1994-2003	National Seasons 1977-2003 (Percentage)
Forestry work	3.7	5.5	8.8
Farming work	2.5	5.1	8.0
Sport and recreation	1.3	3.4	3.0
Children's play	1.1	5.5	7.8
Transit and transport	19.3	28.3	27.4
Other activities	1.1	2.8	2.9
Intentional	60.0	37.1	26.2
Other causes	1.5	2.1	1.5
Unknown	9.5	10.1	14.4
Total	100.0	100.0	100.0

Source: Conaf 2003.

Factors explaining the increase in forest fire occurrence

Increase in planted surface area and plantation characteristics

If the forest fire occurrence curve (figure 1) is compared with the increase in surface area planted (figure 6), one can see that the increase in occurrence is closely related to the dramatic increase in surface area covered with plantations which was recorded from 1975 onwards. Before that season, between 1965 and 1974 an average of 6,000 ha was planted annually (Lara and Veblen 1993), however from that year onwards an average of over 70,000 ha were planted annually.

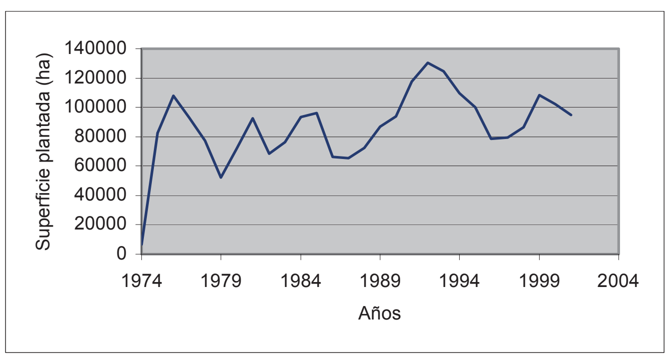

Figure 6 —*Surface planted annually in Chile seasons 1970 - 2000*

The main characteristics and conditions of Chilean forest plantations which could be directly or indirectly related to the increase in forest fire occurrence and to erratic behaviour (high intensity and spread of propagation), are listed as follows: a) single species (monocultures); b) large extension of planted surface area; c) spatial continuity of plantations; d) homogenous forest cultures (similar composition, age and density of stands); e) rapid growth, high biomass and dead fuel load; f) inflammable foliage; g) high density of stands or abundant underbrush; h) accumulation and slow decomposition of woodland waste; and i) location of numerous plantations on the urban-rural interface.

The characteristics and conditions listed above have drastically altered the natural conditions which existed before forestry cultivation, creating major fuel loading which, in most cases, is more likely to be affected by fire, and moreover that of an erratic and unpredictable nature. In this aspect, the flammability of *Pinus radiata* and *Eucalyptus globulus* is a very important factor to consider, as in summer, the humidity content of leaves and aciculae fluctuates between 90 and 135 percent (Aliaga 1999, Fernández 2001). These species burn easily, firstly, due to their high content of inflammable elements and, secondly, because their foliage is permanently low in humidity content in comparison with normal levels of humidity in the green foliage of conifers and latifoliates which varies between 160 and 200 per cent (Chandler et al. 1983).

Forest plantations accumulate major fuel loading over a period of 8 to 12 months which, on plantations, when interacting with a constant increase in fire occurrence, creates high susceptibility to catastrophic fires. Under these conditions, any fire which occurs will be high intensity, causing what is known as a fire storm. Fire storms create their own temperature environment, relative humidity and winds, making fire behaviour unpredictable, with all the effects this has on fire-fighting planning. Under the conditions described, fires become uncontrollable for the forest fire brigades and will only be detained or controlled when the fuel runs out or when the fire leaves the woodland and affects pastureland or brush. On the other hand, to facilitate plantation work, woodland waste is accumulated or piled up in bundles. When these areas burn, the fire is more intense and behaves more erratically. Moreover, a large number of satellite or spot fires occur, which endanger the lives of the fire-fighters and hinder fire-fighting tasks.

If the conditions described above come to be, it is very clear that if the forest fire occurrence factor is not reduced significantly in Chile, in some higher risk sectors plantations could be affected by fires of catastrophic characteristics approximately every 12 to 17 years (Peña 1999). Recent studies show that the frequency of fire in one same area may be as high as 9 to 11 years (Parra 2002), however this is lower than the rotation age used currently in the country for some plantations of species of *Eucalyptus*. In view of the above and the current organization of protection, with high fire-fighting efficiency (< 10 ha/fire, table 1), forest fire protection programmes should place more emphasis on forest fire occurrence, especially those which are catastrophic in nature, and not the increase in fire-fighting resources, since in fire storm conditions these resources are never sufficient.

Intensive Silviculture

The intensive silviculture which is practised on Chilean plantations is a factor which predisposes them to forest fires. This activity is characterized by the fact that work goes on over very extensive areas, with a small number of species - in many cases only one species or genus. Also a number of different forestry treatments are undertaken during rotation. Plantations of *Pinus radiata*, *Eucalyptos globulus* and *Pseudotsuga menssiezii* (this last to a lesser extent) are intensively worked, for which reason susceptibility to the action of fire increases, due to the availability of fuel as a result of the larger number of people and machines inside the stands.

The species indicated earlier are characterized by the fact that they have a large amount of available woodland waste material or fuel (branches, twigs, bark, leaves and decomposing material), as well as highly inflammable foliage. To this is added the continuity of the fuel (plantations) which in some cases may be over 20 km of continuous plantation. The effect of this continuity on the behaviour of fire was seen in the fires occurring in February 1999 in the vicinity of Concepcion, where fire-fighting was virtually impossible due to the high intensity and propagation of the fire and the occurrence of satellite fires. This same zone had burned in a fire of similar characteristics in 1988. Both experiences indicate that during a fire storm firewalls, forest tracks and other natural barriers are useless in stopping the advance of the fire, given that satellite or spot fires as far away as 2 km from the initial site may break out. In both cases the continuity of the fuel favoured the erratic behaviour of the fire.

In addition, the plantations are worked intensively, involving a series of forestry work tasks such as weed control, pruning and thinning which add to woodland waste, contributing a large amount of additional dry material which in turn contributes to increasing the fuel load per hectare, thus increasing the danger of fire. If an accident occurs, the release of thermal energy will be extremely intense, causing greater damage to the affected area. Apart from the contribution of additional fuel, pruning work leaves a great deal of accumulated material around the timber, which increases the probability of more damage being caused to tree cambium or tree mortality during a fire than in an untouched stand. Some thick bark species, however, show a certain resistance to fire, as is the case of *Eucalyptus globules.* When bark thickness is greater than 1 cm, these trees survive and sprout profusely from buds beneath the bark (Daroch et al. 2000, Figueroa 1997 and Morales 1998).

Types of forestry treatment may increase the danger level of fuel on plantations but they also has some beneficial effects, as is the case of pruning. This cuts off the continuity between surface fuel and aerial fuel, preventing surface fires from becoming crown fires or the occurrence of crowning. Thinning interrupts the horizontal continuity of aerial fuel, thus avoiding fire propagation across the crowns. However, by reducing the density of a stand, growing space is freed up (water, light energy and nutrients) which allow vigorous growth of undergrowth, thus increasing available surface fuel which, in many cases, may become ladder fuel, enabling the fire to reach the crown of pruned trees. In addition, the forest floor receives more solar radiation, reaching a higher temperature, facilitating drying, and increasing the temperature of the fuel which therefore causes faster ignition (Chandler et al. 1983).

The slash or woodland waste resulting from forestry work also affects the effectiveness of fire control operations, since this has a direct effect on resistance to control, as fires are of greater intensity and satellite or spot fires occur. According to those in charge of private company protection programmes, over the last few years the practice of not burning to eliminate slash has had a major effect on the increase in damage. It is also indicated that in sectors where fuel was left in bundles, as a way of minimizing the fire problem, resistance to control is greater than in sectors which were traditionally treated with prescribed burning.

In natural woodland, as a result of thinning and/or selective felling, an increase has been observed in susceptibility to forest fires. This type of vegetation is directed mainly at fuel production, involving harvesting trees of small diameter, and leaving a large amount of slash. The resulting greater ingress of solar radiation favours ignition and propagation. This effect has been observed even in the humid tropical forests of Brazil which have low susceptibility to fire, however once ignited, since dead fuel remains and more solar radiation is received, this type of vegetation is more easily affected by fires than in natural conditions (Uhl et al. 1988).

Physical environment of plantations and natural woodland

The natural woodland has little human population, however during the summer season recreational activities significantly increase the presence of human beings in the woodland areas, increasing the risk of forest fires. Even where CONAF has no records, it is calculated that this occurrence is lower that that of the plantations but due to the difficulties of access and fire-fighting, the damage is greater.

The majority of Chilean forestry plantations are located in a physical environment which makes them highly susceptible to fire and when this occurs, fire behaviour is erratic. Their main characteristics are their location on terrain with irregular topography, in an Mediterranean climate area, surrounding cities. In recent years, added to the above is the phenomenon of global climate change which raises the atmospheric temperature and alters rainfall patterns, which in many regions may create conditions which favour the outbreak of forest fires (Peña 1993 and Woodward et al. 1991). Also, the phenomena of la Niña and el Niño occur cyclically, however there is no close relation with the occurrence of forest fires or greater damage from these (table 3). In order to establish a better explanation for this damage, background information is being compiled to determine whether or not this is related to episodes of the Puelche wind, a warm, dry wind which comes from the Andes mountain range.

In the 70s forestry plantations were begun on a massive scale in order to recover land degraded by farming and the felling and burning of natural vegetation in the coastal mountain range and the Andes in region 6 and 9. This land, or at least the most degraded areas, are located principally in the coastal mountain range, characterized by its irregular topography, a circumstance which favours the action of fire, since its gullies and canyons act as chimneys, increasing the force of the convection column and the propagation of the fire. The conditions described above increase the probability of fires which are very difficult to control and also hinder fire-fighting, since they present major resistance to control and create favourable conditions for the occurrence of fatal accidents during fire-fighting.

The major concentration of plantations, at least 58 percent of the total planted in Chile, are located in region 7 and 8 (INFOR 2001). Region 8 is the last region towards the south which has a Mediterranean climate. In part of its territory region 9 also has a Mediterranean climate, however in years of drought the whole region has this type of climate. This condition coincides with good plantation growth (over 20 m3 ha^{-1} $year^{-1}$) and the practice of intensive forestry, which creates a significant increase in the biomass and dead fuel per unit of surface area, thus creating an optimal environment for the occurrence and propagation of forest fires. Statistics for forest fires for the last decade confirm that more than 60 percent of fires which affect forestry plantations and natural vegetation occur in regions 7 and 9 (figure 2, CONAF 2003).

The expansion of plantations and the growth of cities creates a transition area which is very susceptible to the occurrence of forest fires. Over recent years, fires on the urban-rural interface have been frequent in regions 5 and 8. In the latter area they have caused major damage to housing and are a serious threat to human life, as was the case of the fires in Feb 1999 which completely destroyed numerous houses and threatened hundreds of lives. It is calculated that these occurrences will be even more serious in the future (Peña 2003). Added to the significant human presence on the interface is the increase in accessibility all over Chile, particularly to the woodland areas, linking the main cause of forest fires with vegetation. The most dramatic case is the Curanilahue commune in region 8 where 93 percent of the surface area of the commune is covered with plantations (CONAF-CONAMA-BIRF 1999) and where there is a dependency on this resource. At the same time, however, the plantations are a major threat to the population, given the probability of the occurrence of forest fires.

The phenomenon of el Niño causes drought in the south central area of Chile. This may have an effect on the occurrence of and damage caused by forest fires. When comparing the seasons of greatest damage (more than 60,000 ha burned) with the occurrence of forest fires (occurrence: 500 more fires more than the general trend) with the phenomenon of el Niño, no close relationship was found. In table 1 it was observed that out of a total of 12 seasons of greatest damage, only 5 coincide with the season with the highest occurrence of fires: 3 seasons coincide with the phenomenon of el Niño and another 4 seasons coincide with la Niña. A coincidence was considered to be when the season began in a year when either of these two climatic phenomena occurred. This lack of a significant relationship between damage and the occurrence of forest fires confirms that the greatest damage depends on certain atmospheric conditions; wind – high temperature – low relative humidity, which occurs from time to time in areas where woodland is concentrated. It should be underlined that one of the most recent events with major damage occurred in February 1999, coinciding with two consecutive years of la Niña (table 1) when, in region 8, over the course of five days, more than 20,000 ha burned, exceeding the figure of 100,000 ha damaged for the first time in that season.

Global climate change, mainly the greenhouse effect, could produce a climate even more favourable to forest fires, and many temperate regions could develop a climate similar to Mediterranean areas, since a direct result of this phenomenon would be an increase in the average temperature of at least 1.5 to 4.5 ºC , accompanied by altered rainfall patterns, with some regions becoming drier than in the past (Graham et al. 1990, Schwartz 1991 and Woodward et al. 1991), coupled with increasing susceptibility to forest fires in those areas. Vegetation will be drier and more ignition-prone, and fire behaviour and intensity will be more difficult to predict with current models of propagation. This will directly affect fire control actions, it will increase losses (economic, social and environmental) and also the risk of fatal accidents in fire-fighting.

Table 3 —*Seasons with highest occurrence of forest fires and years of occurrence of the el Niño and la Niña phenomenon in Chile.*

Season with highest occurrence	Season with greatest damage	El Niño phenomenon [1]	El niño phenomenon [2]	La niña phenomenon [1]
				1967
	1967-1968			
1968-1969		1969		
				1970
				1971
1971-1972	1971-1972	1972	1972	
				1975
1975-1976		1976	1976	
1977-1978				
1978-1979	1978-1979			
		1982	1982	
1983-1984	1983-1984			
	1985-1986	1986	1986	
	1986-1987	1987		
	1987-1988			1988
	1988-1989			
		1991		
1992-1993			1992	
1993-1994	1993-1994			
		1997	1997	
	1997-1998			1998
1998-1999	1998-1999			1999
				2000
2001-2002	2001-2002			
2002-2003				

Source: [1] Meteorology Agency of Japan
[2] Meteorology Directorate of Chile

The situation described earlier could occur in the south of Chile in region 9 and 11, where there is low forest fire frequency. This frequency only increases when there are consecutive years of drought. In this case the greenhouse effect would leave this area in a situation of greater susceptibility to forest fire. Moreover, as these regions have a high fuel load, conditions would be favourable to catastrophic fires, especially underground fires, with severe damage to the region's ecosystem. Fires caused by electric storms could also increase. This has been confirmed in recent seasons in the Andes mountain range where forest fires caused by lightning have been recorded. Formerly these did not occur.

The above analysis is based on the premise that there will, in effect, be an increase in temperature. In this respect it should be mentioned that a number of researchers indicate that, to date, the estimated temperature rise has not occurred. Others even consider that there are factors other than greenhouse gases which have a negative effect on this phenomenon, producing a drop in temperature. These have not been considered in the models used (Levi 1990 and Schlesinger 1988).

Social Environment of Plantations and natural Woodland

In Chile, statistics on the causes of forest fires show that the majority of fires are anthropic in origin (table 2). It should therefore be accepted that a very particular social environment exists which leads individuals to have a careless or negligent attitude towards forestry resources, in spite of the fact that directly or indirectly these provide the basis of the national economy. It seems that plantations involve much more complex conditions than native woodland, since they are concentrated in areas of human population. Below is a list of a number of factors which may affect this attitude, some of which are discussed in detail.

The main factors are:

a) Rapid change in production patterns from agricultural and livestock rearing to forestry, causing the displacement of the traditional peasant, leaving many people with a feeling of rejection towards forestry plantations.

b) Land ownership concentrated into major wood product companies who do not allow neighbouring communities access to their estates, or only a number of these provide this type of benefit. Thus, recreational, fishing and hunting areas are lost, as well as grazing land, the possibility of fuel removal, and the use of other forest products.

c) Harvesting and transportation of forest products causes damage to paths and local infrastructure, as well as noise pollution and pollution by solid particles in air and water sources.

d) Conflict with rural communities over water supply, due to the fact that the plantations demand more water as a result of their rapid growth. This causes a drop in the flow of springs and streams.

e) Lawsuits over land ownership and demarcations.

f) Low salaries and temporary seasonal migratory work. This creates conditions of economic instability and a certain degree of separation of the family group, due to employment far from the area of residence.

g) Environmental pressure groups which either rightly or wrongly create a negative environment for the plantations, which in turn produces a negligent attitude to forest fire protection for these areas.

The first impact of plantation-based forestry production was the displacement of traditional peasants who, in many cases, were forced to migrate to the cities (87% of Chile's population lives in urban areas), or to retrain to do a job unfamiliar to them and which offered less stability than farming or animal husbandry. Along with this, land ownership was concentrated within the major forestry companies, directly or indirectly limiting the options for use and even transit through forestry estates.

In addition, the State has no recreational areas in the vicinity of towns, or those that exist are poor quality or very small in size. This creates a major gulf between what is actually available and the demand for this type of activity, and since the public cannot use cultivated forest areas, they feel these areas offer them no benefit whatsoever, thus increasing their feelings of rejection. Over the last few years this situation has been changing on the basis of a good neighbour policy implemented by some forestry companies. This consists of maintaining good relations with communities, granting them a number of benefits, and has resulted in a significant decrease in forest fires.

Another element to consider in this analysis of the hostile social environment for the plantations is the situation of temporary or seasonal migratory work. Most forestry work is done on a services rendered basis (contractors) with workers located in camps far from their permanent residence and family. There are a number of fundamental reasons for this from the viewpoint of output and work efficiency, however this also involves long periods away from home which deeply affects family life, since the major responsibility for the family is left to the spouse. Major problems also arise in the stability of marriages, with all the consequences this brings for the offspring and the family structure. All the above, combined with low salaries, make forestry work appear to be a low-priority opportunity for the labour force, in spite of the fact that this employment supports the family and indirectly affects the family environment. This circumstance of lack of benefit for the community has been confirmed in a number of preliminary studies undertaken in communes in region 8, the results of which indicate that the community sees little gain from forestry work, or that these benefits cannot be broken down in order to assess their contribution to the economy and local welfare (Ispizúa 1999 and Riquelme 1998).

The analysis undertaken in the previous paragraphs offers the view that probably many communities, with or without reason, feel rejection towards the forestry sector and particularly towards the plantations. The final result of this aversion towards the sector is that there is no motivation to protect the resource and a careless and negligent attitude to the use of fire still prevails, even producing intentional fires. These have increased significantly over recent seasons, particularly in region 8, where statistics for 1990-2000 show that 60 percent of forest fires in that region are intentional, compared with 37 percent for the country over all (table 3). What is happening in region 8 is alarming, as intentional fires are too prevalent for a resource which is one of the mainstays of the economy. These figures show clearly that the plantations have no social support and confirm the need to change the community's perception of woodland resources and particularly of plantations.

Final Comments

The high rate of forest fires and the trend towards the occurrence of catastrophic events from the viewpoint of fire behaviour (high intensity and speed of propagation) and scale of the damage, is determined by a series of factors inherent in the vegetation and the physical and social environment surrounding this resource. Natural vegetation has a high degree of continuity in the Andes range and due to its inaccessibility limits fire-fighting action. The plantations cover a major surface area and provide continuity of homogeneous and inflammable fuel which facilitates the action of fires. To the above is added the intensive silviculture which frequently intervenes in areas of natural vegetation, increasing and altering fuel, thus increasing the danger and susceptibility to forest fires. This interacts with the high risk due to the presence of workers and machinery in woodland areas, and the social environment which still does not fully accept forestry production, especially the forestry plantation industry. Thus, an atmosphere which is hostile towards forestry resources is created and the community takes a negative and careless attitude which produces a major number of forest fires, many of them intentional. The result of all this fire-prone environment is a high level of occurrence and damage which, to date, in spite of all the prevention and fire-fighting efforts, has been impossible to minimize.

In order to effectively reduce the occurrence and damage of forest fires, since in Chile almost 100 percent of fires are anthropic in origin, better research into the causes of these events must be undertaken, and the motivation behind intentional fires determined. This information will reinforce the prevention programmes, which should be oriented towards modifying human behaviour, as well as preventive silviculture which would reduce the fuel load and modify the conditions of continuity and homogeneity which characterize them.

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