Risk Management and Sustainable Forestry

Bordeaux, France

8 September 2001

Michel Arbez, Yves Birot and Jean-Michel Carnus (eds.)

EFI Proceedings No. 45, 2002

European Forest Institute

Ministry of Agriculture
and Forestry, France

EFI Proceedings No. 45, 2002
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Publisher: European Forest Institute

Series Editors: Risto Päivinen, Editor-in-Chief
Minna Korhonen, Technical Editor
Brita Pajari, Conference Manager

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Email: publications@efi.fi
WWW: http://www.efi.fi/

Cover photo: Saku Ruusila
Layout: PihkaPojat Oy
Printing: Gummerus Printing
Saarijärvi, Finland 2002

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ISSN 1237-8801
ISBN 952-9844-93-X

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Introduction: Forestry and Risk Management – New Zealand in a Global Context

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Abstract

This paper provides an overview of risk management in forestry, with a particular emphasis on New Zealand's forests. The risks assessed include the biosecurity aspects of pests and diseases, fire, wind, climate, and trade. Pests considered include insects, pathogens, weed species, and vertebrates such as possums. Literature documenting the occurrence of these physical and biological risks in New Zealand and other countries is reviewed and, where possible, an international comparison of risk is made. Despite the sparse nature of the data and the lack of consistent reporting methods, the information suggests that the level of most risks in New Zealand is generally low in an international context.

Keywords: Risk management, pests, disease, fire, wind.

1. Introduction

Risk management of forests, especially planted forests, is becoming an increasingly important issue. Forest owners, particularly corporate forestry organisations and financial investment companies that own forests, are becoming increasingly risk averse and are seeking tools and techniques that enable them to assess and manage risk.

Important risks to forests include:

- biosecurity aspects of pests and diseases. Examples of pests include insects, weed species, and fauna, such as possums;
- climate, including climate change, wind, and snow;
- fire;
- wind; and
- trade.

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These risks will be assessed from a New Zealand perspective and, where relevant, links will be made to an international context. Two main points are made in this paper:

i. New Zealand is in a unique global situation. It is unique because it has an ecology that evolved separately from the rest of the world, resulting in unusual flora and fauna, and particularly the absence of terrestrial mammals. It is also unique in its geographical isolation. As a result, New Zealand's natural ecology is susceptible to the introduction of both carnivorous and herbivorous mammals but, because it is an isolated island, it is able to more effectively exclude pests than continental countries. For this reason, New Zealand is developing very stringent border surveillance regulations.

ii. Globalisation of trade, and its threat to biosecurity, is a significant risk to New Zealand's forest industry. As a result of increased global trade, New Zealand is increasingly exposed to new pests and diseases. However, it is noteworthy that while many native bird species quickly succumb to introduced predators, the indigenous forest appears to be relatively resistant to introduced pathogens and insects. In contrast, the exotic planted forests are expected to be most susceptible to pests that have evolved with the tree species in their native countries.

2. New Zealand's Unique Situation

Eighty million years ago, New Zealand split from Gondwanaland. The islands evolved isolated from other land masses and consequently developed a unique flora and fauna, free from grazing land mammals or large predators. The forests were primitive, in evolutionary terms, and were subjected to frequent damage from climatic and geological influences. At no time, the forests would have been a patchwork of areas damaged by wind, snow, volcanic activity and erosion, or by outbreaks of pests and disease, much as the native forests are today (Wardle 1984).

The arrival of Maori around 1000 years ago brought the first introduction of exotic pests and diseases. The transformation of New Zealand, beginning with Maori settlement and escalating with European colonisation is well known. Maori also introduced fire and burned large areas of the eastern coastal forests, which were replaced by grass and scrub (Cumberland 1961).

European introduction of exotic plants and animals was in many ways more destructive than land clearing for agriculture (Wardle 1984). Today New Zealand has 32 introduced mammals and 25 000 naturalised introduced vascular plants, 250 of which are 'controlled' by some New Zealand agency because of their threat to the ecology and economic productivity of the country (personal communication, B. Lee, Landcare Research). There are also numerous species of exotic fungi and insects that have taken up residence in New Zealand, and more are arriving each year.

In the following sections, each major risk category is briefly assessed.

3. Biosecurity aspects of pests and diseases

3.1 Insects and pathogens

Insects and pathogens pose major threats to New Zealand's planted forests and, as insects often vector pathogens, they should not be studied in isolation. There are many examples of this insect/pathogen interaction throughout the world, with perhaps the most widely publicised being the spread of Dutch elm disease (*Ophiostoma ulmi* or *O. novo–ulmi*).

A comprehensive paper has recently been published on the subject of threats to New Zealand's indigenous forests from exotic pathogens and pests (Ridley et al. 2000). This study concludes that, at least for New Zealand's native trees, the pathogens and insects of greatest concern are those that evolved with the same genera and families that are represented in New Zealand. According to Ridley et al. (2000), the notion that a pathogen can readily move from species to species is not supported by field and experimental observation. The scientific understanding is that pathogens co-evolve with their hosts so that the majority of pathogens are either limited to small groups of closely related species, or jump only short 'taxonomic distances'. This hypothesis is also applicable to herbivorous insects and is used to explain why there have not been any outbreaks of exotic insects or disease epidemics in New Zealand's native forests.

However, there are exceptions to this hypothesis, and several pathogens have jumped genera and even families. In Kenya and Malawi, an aphid that started in Mexican cypress is now attacking two indigenous trees, *Widdringtonia nodifolia* (Malawi's national tree) and *Juniperus procera* (Bright 1998). In Australia, the cinnamon fungus (*Phytophthora cinnamomi*), a relative of the potato blight fungus (*P. infestans*), used pine plantations as a route into eucalyptus forests.

Exotic tree species present a different ecological situation as they evolved with insects and pathogens that may stably co-exist with their host plants overseas. For exotic plant species, the key issue is to exclude the pests. However, even if exotic insects and pathogens do arrive in New Zealand, there is no guarantee that they will inflict serious damage on their natural host plants as the ecological conditions differ in New Zealand. For example, as mentioned previously, many fungi require specific insects to spread their spores, as is the case for Dutch elm disease and possibly pitch canker (*Fusarium subglutinans* O. *pini*). Thus, even if pitch canker found its way to New Zealand, it might not pose a major threat as there may not be appropriate insect vectors to spread it.

However, there is no room for complacency where pest vigilance is concerned and New Zealand has developed a multi-layered strategy to minimise the threats of pests and diseases to our exotic forests. This strategy incorporates:

- rigorous surveillance of imported goods at ports and airports;
- surveillance of plants in high risk sites, such as those adjacent to ports and airports;
- trapping programmes for known pests;
- regular surveillance of planted forest;
- diagnosis of pests and diseases on imported goods, from forest surveillance activities and on samples brought in by the public;
- maintenance of a comprehensive database; and
- maintenance of an incursion response capability.

History also shows that eradication of a pest incursion is rare. New Zealand possibly has the best international track record with at least containment of a number of major threats including Dutch elm disease, white spotted tussock moth (*Orgyia thyellina*), and gumleaf skeletoniser (*Uraba lugens*). But even for these, continued vigilance is necessary to ensure that outbreaks don't occur and there is no doubt that early detection increases the probability of a successful eradication.

Being an island country remote from neighbours, New Zealand has a better chance than most other countries of minimising incursions of exotic pests. However, it is not possible to be certain which organisms will be a problem in the New Zealand environment due to the different climate, the different genetic base of host plants, and a different suite of niche competitors and of predators/parasites. It is therefore prudent to ensure that appropriate import regulations are in place and, if necessary, restrict the types of material that may harbour organisms.

3.2 Introduced mammals

New Zealand has two native mammals, both of which are bat species. New Zealand's flora and fauna therefore evolved without pressure from mammalian predators. Since Maori and European settlement, numerous mammals have been intentionally and unintentionally introduced. These mammalian pests have had a devastating impact on New Zealand's indigenous biodiversity. Two of the most significant impacts are the threats posed by feral mammals (e.g. cats, rats, dogs, stoats, weasels) to the flightless kiwi and the damage caused by possums to our indigenous forests.

Introduced mammals pose less of a risk to New Zealand's exotic planted forests than they do to our indigenous flora and fauna. The focus is therefore on protecting our indigenous fauna by establishing refuges that exclude introduced mammals and by undertaking control and research activities to minimise possum damage to our native forests.

3.3 Weeds

New Zealand has 10% of the world's 250 000 vascular plants naturalised throughout the country. Of these, 250 have caused sufficient ecological and economic damage to be legally placed under the authority of a New Zealand agency for control purposes. To date there has been minimal risk assessment conducted to determine which plants are likely to cause the biggest problems and, consequently, very little if any action is being taken to reduce their potential impact.

In exotic planted forests, weeds are usually actively controlled by spraying prior to planting. Apart from these measures, the New Zealand forest industry does little to prevent or restrict the spread of weeds within its forests.

4. Wind

Wind is an important factor affecting both individual trees and entire forests in many temperate and tropical regions of the world. In some circumstances, damage caused by wind can be seen as a creative opportunity to promote ecological succession and structural diversity (Quine and Gardiner 1991). However, the effects of wind damage on forests are generally viewed negatively. Wind damage affects wood flows by increasing short-term wood supplies (as a result of the windthrow salvage), but ultimately decreasing sustainable yield due to a reduction in growing stock. The costs of salvaging wind damaged trees are higher than for conventional harvesting and there can also be considerable danger to workers associated with salvaging wind damage (Childs 1966). Revenues from salvage operations are generally reduced, particularly where there are high levels of stem breakage, but also because of fungal decay. Manley and Wakelin (1989) showed that this increase in costs and reduction in revenues reduces the present net worth of a forest by up to 11% for an annual level of damage of 1%.

This damage can also be exacerbated by insects and pathogens that colonize the fallen trees. For example, Ruth and Yoder (1953) noted that after a wind damage event in 1951 in the Oregon Coast Range, United States, an additional 12.3% of green timber was killed by the Douglas-fir bark beetle during the following summer. Needle damage (i.e. partial defoliation) to trees which survive the storm can also reduce growth rates. The woody debris resulting from wind damage can also increase the risk of fire.

In addition to its destructive effects, wind also has an influence on stem form and wood properties (King 1986; Larson 1963; Telewski 1995), it can affect the water balance of a forest (increased wind speeds generally result in increased evaporation rates), and it is responsible for the transport of water vapor, pollen, seeds and CO_2 fluxes (Bull and Reynolds 1968; Grace 1977; Jones 1992). Wind damage in the form of uprooting is also responsible for soil mixing; it is the most obvious form of floralturbation (Schaetzl et al. 1989).

4.1 A history of wind damage in New Zealand

New Zealand is a long narrow island country located in the temperate latitudes. Forest damage is usually the result of winds associated with sub-tropical cyclones or those enhanced by topography. Sub-tropical cyclones have caused damage in the northern and central areas of the North Island (Brown and Jones 1989; Carter 1989; Littlejohn 1984), while orographically enhanced winds have caused damage to forests on the Canterbury Plains (Prior 1959; Wendelken 1966; Wilson 1976).

Since records began in the 1940s, there has been at least 50 000 hectares of wind damage recorded in plantation forests (Table 1), with available records documenting at least eight million m^3 of timber salvaged following wind storms (personal communication, A. Somerville). These figures do not include damage from numerous smaller storms, much of which is undocumented. Based on data from 17 forests covering an area of 259 950 ha, Somerville (1995a) calculated that the average overall level of damage corresponded to 12.2% of the net stocked area for a 28 year rotation. While the least affected forests would lose only 5–6%, the worst affected would lose nearly all of their stocked area.

Table 1. A chronology of wind damage in New Zealand Forests* (adapted from New 1989).

Date	Region	Area Damaged (ha)
13 July 1945	Canterbury	1500
July 1956	Central North Island	166
July 1958	Central North Island	150
March 1964	Canterbury	5200
April 1968	Canterbury	1000
20 April 1968	Nelson	963
1 August 1975	Canterbury	11 000
1979	Central North Island	600
10 April 1982	Central North Island	6300
7 March 1988	Central North Island	19 000
7 March 1988	Northland	1484
November 1994	Hawkes Bay	500
April 1996	Central North Island	900
Total		48 763

* These records do not include damage from many smaller storms which have resulted in considerable volumes of timber being salvaged (e.g. Prior 1959; Chandler 1968; Irvine 1970).

4.2 How does wind risk in New Zealand compare to the rest of the world?

Because most countries (including New Zealand) lack a formal wind damage reporting system, it is difficult to make comparisons between regions within a country let alone between countries. In spite of this, Published data have been reviewed with the intent that it may provide a qualitative insight into how New Zealand compares with the rest of the world.

In order to facilitate comparisons with other countries, it is necessary to have an estimate of wind damage as a proportion of annual harvest as this is a common statistic reported in the literature. This calculation for New Zealand has been made by assuming that an average of 1000 ha are damaged in New Zealand by wind each year with the average volume per hectare in these stands being 400 m^3. As a result, the average annual volume damaged is roughly 2.7% of the annual harvest

New Zealand and Great Britain have many similarities in that they are both long narrow island countries of similar size which are located in the temperate latitudes. The productive forest area in Great Britain is approximately 2.45 million ha (Forestry Commission 2000) with the main species being Sitka spruce *(Picea sitchensis* Bong. Carr.) and Scots pine (*Pinus sylvestris* L.). In Britain, strong winds typically result from the passage of Atlantic depressions. Most depressions track to the north and west of Britain and their cumulative influence is responsible for the tendency to stronger winds in northern Britain. Winds are normally strongest in the winter months (Quine 1995). Occasional strong winds are experienced in the east of the country; for example, the area around Sheffield experiences lee-slope winds that have caused forest damage (Aanenson 1964). Major storms in 1953, 1968, 1976, 1987 and 1990 resulted in an estimated 9.6 million m^3 of timber being blown down in Great Britain (Grayson 1989; Quine 1991). On average damage from these storms accounts for approximately 5–6% of annual production (Atterson 1980). Damage from more frequent but less dramatic storms has constrained thinning regimes, reduced rotation lengths and limited profitability. Wind damage from these less extreme storms accounts for approximately 15% of annual production.

Wind damage has also occurred in many other European countries (Table 2). For example, storms in 1972 and 1973 caused damage to 19 million m^3 of timber in Germany. Of this, approximately 15 million m^3 were damaged in Lower Saxony which amounted to almost 12 times the annual sustained harvest from the region (Savill 1983). In the Czech Republic, more than 50% of the total timber yield between the years 1981 to 1990 had to be cut down due to damage caused principally by wind or snow damage (Slodicak 1995). In December 1999, three severe storms with wind speeds up to about 200 km/h caused major damage in Europe. France suffered the greatest impacts with approximately 140 million m^3 being damaged. In addition, Germany had 30 million m^3 of damage, Switzerland 13 million m^3, Sweden, 5 million m^3 and Denmark 3.5 million m^3. It was estimated that about 175 million m^3 of wind thrown timber resulted from these storms (ECE/FAO 2000). These storms caused severe economic and ecological impacts in the worst affected areas and prompted rapid and substantial responses from governments.

In North America, the risk of wind damage may not be the constraint on silviculture that it is in Europe. However, Mergen (1954) noted that losses due to wind damage and events other than fire account for 2.5% of the annual drain on the timber resource of the United States. A number of major events have occurred, including Hurricane Hugo which destroyed 1.8 million ha of pine and hardwood forests in South Carolina in 1989 (Sheffield and Thompson 1992), and Hurricane Andrew which hit Louisiana in 1991 causing an immediate impact on forest resources, with losses estimated to be worth $38.6 million (Leininger et al. 1997). Hurricanes have also caused damage to forests in the Northeastern United States (Everham 1995; Foster and Boose 1995). In the Pacific Northwest, a storm in 1951 damaged 24.6 million m^3 in the Oregon Coast Range

Table 2. A chronology of wind damage in European Forests (C. Quine, personal communication, Forestry Commission).

Date	Region	Volume damaged ($m^3 \times 10^6$)
November 1972/April 1973	Germany, Netherlands, Denmark	19
24/25 November 1981	Denmark	3
22 September 1982	Finland	3
6 November 1982	Massif Central, France	12
25 June 1984	Finland	0.4
November 1984	Germany	16
11 August 1985	Finland	0.5
26 October 1985	Finland	4
16 October 1987	France	7–8
25 January – 1 March 1990	NW Europe	100–115
7 February 1996	France	1
December 1999	Sweden, Denmark	20
December 1999	France, Germany, Switzerland	155
Total		372

(Ruth and Yoder 1953), while the Columbus Day storm in November 1962 caused damage to an estimated 13.5 million m^3 of timber. In British Columbia, Canada, wind damage is estimated to amount to 4% of the annual allowable cut (Mitchell 1995).

4.3 Mitigation measures to minimise wind damage

Somerville (1995a) notes that a number of general steps can be taken to reduce wind damage. These include:

- evaluation and selection of potential planting sites for low wind conditions;
- species selection – some species handle wind better than others;
- planting aged cuttings to reduce sail area;
- correcting toppling;
- avoiding late heavy thinning – or possibly all thinning;
- avoiding excessive edge effects;
- normalising age class distribution to reduce the impact of single events;
- utilising timely (even early) clearfelling; and
- avoiding clearfelling exposure.

5. Fire

Fire is not a natural part of New Zealand ecosystems as it is in Australia and North America, and few if any native species have developed adaptive traits to cope with frequent fires. Fires are a disturbance agent, and they can have positive effects on forest ecosystems including encouraging regeneration and biodiversity. They can also promote habitat for wildlife and remove excessive or decadent fuels. However, forest fires in New Zealand are generally considered negatively as they typically have devastating consequences for both our native and exotic forests, and for the people that depend on them for their livelihood.

Both the physical and economic effects of a forest fire depend on fire intensity and size, as well as factors such as species fire resistance. In many cases, salvage of fire-damaged timber is possible. However, wood flows are affected by increased wood supplies in the short-term, and this is exacerbated by the need for urgent recovery to minimise additional damage from insect and fungal attack. Salvage costs are higher than for conventional harvesting, and there can also be additional dangers to workers from falling dead trees. There will also be some losses due to fire damage as a result of rejection for a particular end-use; for example, fire damaged timber is more difficult to saw, while charcoal causes problems in pulping. Often there are also significant costs associated with fire suppression and even site rehabilitation. Forest fires can also affect off-site values as well as those on the area burned, and the impacts of nutrient loss, smoke drift, increased runoff and erosion should be considered in assessing overall damage.

5.1 Forest fire history in New Zealand

Despite the generally correct perception that New Zealand's fire climate is not as severe as many other parts of the world due to its maritime location (Geddes 1995), periods of hot, dry and/or windy conditions occur in most parts of the country every year. Historically, periods of high regional fire danger coincide with a source of ignition that about once a decade result in major fires which have involved significant property losses, including forest resources (Table 3). The 1946 Taupo fires burned more than 30 000 ha of which about 11 000 ha was planted forest, while Canterbury, in particular, has also experienced several major forest fires, including Balmoral in 1955, Ashley 1973, Hanmer 1976 and Dunsandel 1988 (Pearce and Alexander 1994).

Little is known on the risk to New Zealand's native forests as historic fire statistics do not typically distinguish between exotic and indigenous forest losses, and this continues to be the case in modern fire reporting systems. However, it is generally accepted that, in most circumstances, native beech and podocarp forests are less flammable than their exotic counterparts. This does not imply that they will not burn, and major fires have occurred in the past, particularly in beech forests.

Despite the lack of good quality historical data, it is apparent that the risk from fire ranks below wind, and pests and disease as major threats to both native and exotic forests. However, New Zealand has a large number of distinct climatic regions, all with their own characteristic fire weather. This leads to wide regional variation in fire weather severity and associated fire risk. In general, the eastern and northern parts of both islands tend to have the most severe fire climates as they are most prone to foehn wind and drought conditions. An analysis of regional fire danger ratings by Pearce (1996) identified Canterbury and Gisborne/Hawkes Bay as having the most severe fire climates, while Taranaki, Southland and the West Coast were the least severe.

5.2 How does fire risk in New Zealand compare internationally?

Compiling statistics on international forest fire losses is difficult, due to a lack of consistent reporting methods. In many cases, it is especially difficult to separate the area burned for forests from that for other vegetation types, and to then distinguish the proportion of these losses that occur in commercially important forest as opposed to conservation and protection forests and non-productive woodlands. However, a major project funded by the United Nations aims to

Table 3. Significant forest fire events in recent New Zealand history.

Year	Fire	Location	Forest Type	Total Area Burnt (ha)
1940	Eyrewell	Canterbury	Exotic plantation	469
1946	Tahorakuri	Taupo	Exotic plantation + scrub	30 738
1955	Balmoral	Canterbury	Exotic plantation	3152
1970	Mawhera	West Coast	Exotic plantation	400
1971	Slopedown	Southland	Exotic plantation	295
1972	Allanton	Otago	Exotic plantation	139
1972	Rankleburn	Southland	Exotic plantation	422
1973	Ashley	Canterbury	Exotic plantation	194
1973	Mohaka	Hawkes Bay	Exotic plantation	368
1975	Waimea	West Coast	Exotic plantation	370
1976	Hanmer	Canterbury	Exotic plantation	798
1977	Wairapukao	Bay of Plenty	Exotic plantation	432
1980	Mt Thomas	Canterbury	Native beech	900
1981	Hira	Nelson	Exotic plantation	1972
1983	Ohinewairua	Central North Island	Native beech + tussock	15 000
1988	Dunsandel	Canterbury	Exotic plantation	185
1995	Berwick	Otago	Exotic plantation	255
1997	Aupori	Northland	Exotic plantation	260

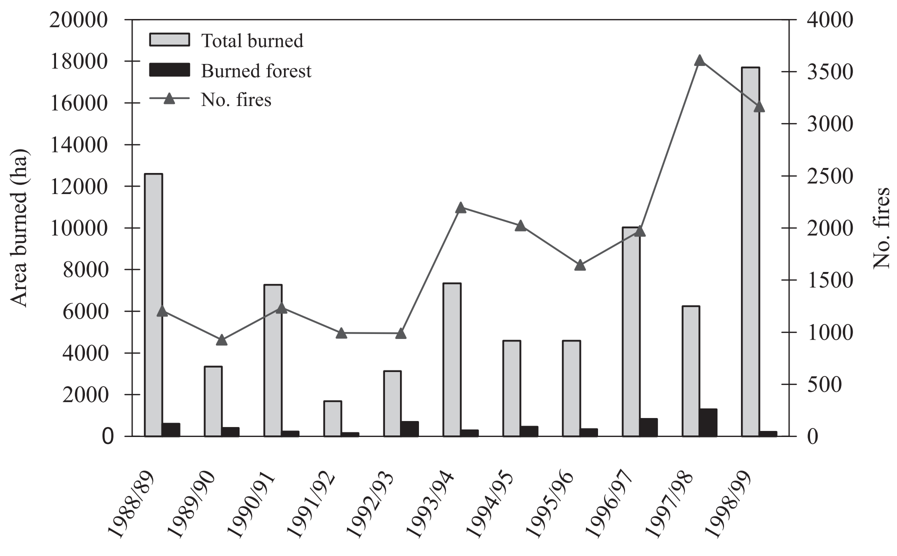

Figure 1. New Zealand rural fire statistics for the period 1988/89–1998/99, including total number of fires and area burned, and forested area burned (Source: NRFA 1999). On average New Zealand experiences around 2000 vegetation fires each year, burning some 7000 ha in total (Figure 1). Of these fires, only 1–2% are started from natural causes, mainly lightning, and the remainder are human-caused fires, with escapes from land clearing burns (both permitted and unpermitted) a frequent cause. Over the period 1936–99, more than 30 000 ha of exotic forest have been destroyed by fire, equivalent to an annual average loss of about 620 ha (or 0.04% of the planted forest estate).

compile a Global Vegetation Fire Inventory. The fire statistics are collected and evaluated by the UN-ECE Trade Division, Timber Section and include data for all Western and Eastern European countries, countries of the former Soviet Union, the United States and Canada. A recent data set covers the period 1995–1997 (ECE/FAO 1998). This information has been combined with that from other available sources to compare relative forest fire risk (Table 4).

Fire is a major cause of forest damage internationally, although its significance is not directly proportional to either the number of fires or their spatial extent (Table 4). Canada has the highest average burned area, followed by the Russian Federation and China (the data for the United States includes burned area for vegetation types other than just forest). These countries also have the largest forest areas, and the highest rates of public ownership. However, the 'exploitability' of some of the stated forest area may be questionable, so that the proportion of commercially viable forest burned is lower than that depicted. For example, Simard (1997) notes that 76% (or 318 million ha) of Canada's 417 million ha of forest area is commercially productive, and that an average of 736 000 ha or 0.232% of this commercial forest is burned each year. This equates to a loss of about 74% of the area harvested each year, or 70 million m^3 of wood with a value of about $1 billion. In addition, $384 million is spent each year on fire suppression.

Forest fires are also very important in southern Europe, where a high population density and small-scale forest ownership combine to increase the likely significance of a particular fire. In Turkey, political events have also been found to be correlated with increased forest fire losses (Pyne 1995). In contrast, Scandinavian countries demonstrate the lowest fire risk, primarily as a result of the short fire season and large-scale private forest ownership. With an annual loss of about 0.04%. New Zealand ranks in the bottom half of the countries for which reliable data could be found.

5.3 Minimising forest fire risk

To minimise the risk of forest fires and the associated damages, forest managers must maintain an adequate fire management system. Successful fire management depends on effective fire prevention, detection, and pre-suppression, having an adequate fire suppression capability, and consideration of fire effects (Merrill and Alexander 1987):

- risk reduction/mitigation through fire prevention activities aimed at reducing fire occurrence;
- maintaining a state of readiness by carrying out pre-suppression preparedness activities in advance of fire occurrence;
- responding to a given fire situation through fire suppression, by undertaking activities concerned with controlling and extinguishing a fire following its detection and
- recovery strategies following the fire.

6. Climatic Risks

6.1 Climate change

Climate change poses a significant risk to New Zealand forests. However, there is much uncertainty surrounding the effects that a changing climate may have on the ecology of New Zealand's native forests and on the productive capacity of our planted forests. A warming

Table 4. International comparison of forest fire losses for selected countries, and comparative details on forest area and ownership

Country	Forest Area (10^6 ha) [a]	Forest Ownership [a]	Averaging Period	Area Burned (ha/y) [c]	Area Burned/ Forest Area (%)	Source
Portugal	2.4	91% private	94–97	73 053	2.989	
Canada	112.1	94% public	88–98	2 500 000	2.230	Hirsch (1999)
Spain	6.5	70% private	94–97	88 716	1.364	
Greece	3.4	83% public	94–97	30 145	0.897	
China	113.7	100% public	50–92	946 000	0.832	Wang et al. (1995)
USA	198.1	72% private	90–99	1 476 263[d]	0.745	NIFC (1999)
Italy	6.0	60% private	95–97	34 442	0.573	
Russia	351.1	100% public	94–97	1 120 396	0.319	
France	13.9	75% private	80–94	30 600	0.220	Teusan (1995); Barthod (1996)
Turkey	6.6	99% private	94–97	11 720	0.178	
Switzerland	1.1	70% public	94–97	619	0.057	
NZ [b]	1.4	80% private	88–99	510	0.036	NRFA (1999)
United Kingdom	2.4	60% private	95–97	486	0.020	
Germany	10.2	60% public	94–97	922	0.009	
Sweden	21.8	70% private	94–96	1583	0.007	
Finland	18.8	70% private	94–97	1046	0.006	
Norway	7.2	80% private	94–97	371	0.005	
Denmark	0.4	70% private	95–97	4	0.001	

[a] Data on ‘exploitable’ forest area and forest ownership valid as of 1990 obtained from UN/ECE. 1997. UN/ECE Timber Database: Forest and Forest Industries Country Fact Sheets. Online. http://www.unece.org/trade/timber/tim-fact.htm

[b] New Zealand data on forest area obtained by averaging information for the period of record contained in MAF. 1997. New Zealand Forestry Statistics. Ministry and Agriculture and Forestry. Forest ownership statistics quoted from the same source for 1990 and 1993 respectively.

[c] Unless indicated otherwise, the source of information on burned forest areas was obtained from UN/ECE Timber Committee. Forest Fire Statistics 1995–1997. Timber Bulletin, Vol. LI, ECE/TIM/BULL/51/4. Online. http://www.unece.org/trade/timber/ff-stats.html

[d] Area burned for the USA includes fires on forest and other wooded land, and other land, so that the resulting % Area Burned may be artificially high.

trend will see a shift in the optimum locations for our plantation species and in the distribution of biodiversity as northern species move south. However, the more destructive aspects of increasing climatic extremes are more difficult to predict (personal communication, J. Leathwick, Landcare Research).

6.2 Snow

In New Zealand, most South Island sites and higher altitude North Island sites experience snowfalls (Somerville 1995b). The moist, maritime environment means that New Zealand snow is wetter and denser (up to three times) than that of a continental climate. Rime conditions resulting from snow freezing on contact can increase snow loading as successive snow layers laminate and build up. High snow loadings can lead to topple, and stem and branch breakage. Wind causes drifting of dry snow, and greater damage is therefore likely in highly stocked stands where air movement is less. Slope can also exacerbate the problem, with the snow load accumulating on the downhill side thereby increasing canopy weight.

There are considerable differences in the vulnerability of species and of the exotics, Douglas-fir in particular, is better adapted than radiata pine (Somerville 1995b). Indigenous beech forest is also subject to snow damage, especially heavy snowfalls at low altitudes. Most snowstorms cause minimal damage with only occasional twigs and branches broken; however, heavy snowfalls can cause young beech stands to be flattened, and large trees uprooted, badly tilted or bent. Main stem breakage is quite common on beech trees up to 30 cm diameter, crown damage is often frequent, and even the largest trees can be stripped of branches (Wardle 1984).

As a result of the largely unpredictable nature of snowfalls, the relatively low levels of loss, and the fact that little can be done to reduce the risk, snow damage is generally accepted and tolerated. However, the risk of snow damage can be minimised through appropriate species and site selection. Snow damage is often followed by insect and fungal attack, for example by pinhole beetles (*Platypus* spp.) and associated *Sporothrix*, while *Armillaria* also increases substantially in beech forest after massive disturbance (Wardle 1984), so that salvage needs to be incorporated into harvest planning in snow-prone areas.

6.3 Frost

Most New Zealand sites experience frosts from late autumn to early spring, and some inland sites can have frosts at any time of year. Grass cover increases the severity of frost as grass reduces light absorption and increases the surface area for heat loss at night. There are also significant species differences to frost tolerance. For example, a winter frost of –13ºC, or an out of season frost of –7ºC, can kill newly established radiata pine. Douglas-fir, on the other hand, which forms a true dormant bud, is more tolerant to a mid-winter frost than radiata pine but is more vulnerable to out of season frost (Somerville 1995b). Injury related to winter frosting does not usually affect beech trees growing naturally within the stand; however, frost could be a major factor preventing extension of beech forest to sites above the tree line and into naturally treeless valleys in mountain regions. Death of beech seedlings after unseasonal frost is common, but does not typically kill larger saplings and trees (Wardle 1984).

In addition to appropriate species and site selection, there are a few simple measures that can be taken to help reduce the risk of frost damage. These include (after Somerville 1995b):

- keeping the site weed free for up to 2 years after planting;

- avoiding the creation or planting of concave surfaces that trap cold air;
- using healthy planting stock and good planting practices to promote growth and increase endurance; and
- planting at the end of winter when seedlings are harder, and most severe frosts are over.

7. Trade Risk

For the New Zealand forest industry, a major risk is the likelihood that free-trade in forest products will be seriously curtailed because of a perceived chance of accidental transmission on export products of a pest or disease to other countries. New Zealand recently faced this threat when the United States Court ruled that no further import permits for New Zealand and Chilean radiata pine or Russian larch would be issued by the United States Department of Agriculture's Animal Plant and Health Inspection Service (APHIS). This action was taken because of the perceived threat to native United States forests by diseases and insects carried on logs, lumber and chips. The recent concern over the Asian long-horned beetle in New York and Chicago, and the requirement that all solid wood packaging material entering the United States from China be treated, provides a good indication of the costs associated with biosecurity issues.

As the World Trade Organisation moves to develop a more open framework for world trade, some nations may impose non-tariff barriers, including those based on environmental and biosecurity issues. The ban on new import permits for radiata pine into the United States was the result of successful lobbying by American environmental groups, concerned about native biodiversity but also seeking to reduce wood consumption.

There are several other examples of countries imposing stringent controls over imports, such as the spread of 'leaf yellowing', a phytoplasma disease transmitted by aphids that is now devastating palms in Central America and elsewhere and threatening the world palm industry. European nations have embargoed green lumber from British Columbia in an effort to exclude the pine wood nematode (*Bursaphelenchus xylophilus*), which has reputedly caused considerable damage in Japan.

7.1 Minimising trade risk

There is currently considerable tension between the groups pursuing free trade and those wanting to protect biodiversity. Faced with these adversarial positions, it will be a challenge to ensure that free and 'safe' trade can continue. One path forward is to educate the industry on the potential biosecurity risks and to take measures to ensure that trade can be conducted safely. A coordinated effort in international biosecurity research and information transfer would be one step forward.

There is a large amount of biosecurity research being conducted throughout the world, primarily as fundamental entomological and pathological research. However, in most circumstances, this research is not coordinated internationally or, in many cases, even nationally. The focus of the research is often on immediate problems and protecting a country's forests. It is generally not focused on the goals of simultaneously maintaining free trade and biosecurity. There is a major opportunity to coordinate this research by involving international forestry companies, industry associations, universities, and government departments to ensure that the research is focused on trade as well as on forest protection. It is also important that the information be communicated to relevant users.

8. Conclusions

New Zealand is a safer country than many others in which to grow most exotic plantations, with the possible exception of Australian tree species. As an island, isolated in the South Pacific from other land masses, New Zealand's borders are more readily protected than most other countries and, importantly, New Zealand has a reasonably comprehensive biosecurity system.

New Zealand's almost total reliance on a single plantation species, radiata pine, does present a slightly increased risk to the forest industry than if several major species were grown. However, the historical reasons for focusing on radiata pine include the fact that it is more disease tolerant than many other conifers that have been tested. A strong forest health research focus, vigilant border security and surveillance, and an informed public provide reasonable lines of defence against permanent foreign establishments.

New Zealand is a country of low fire risk and moderate wind risk. However, the incidence of fire is increasing as the forest estate expands and encroaches on more-heavily populated areas, and the number of fires from malicious causes increases. Destructive forest damage from wind is relatively low.

It has been hypothesised that our indigenous forests are relatively safe from most overseas insects and diseases, and are at greatest risk from pests that have co-evolved with related plant genera in other countries.

Trade risk is perceived as a major threat. It may not be enough to protect borders and keep insects and pathogens at bay. It may also not be enough to 'treat' logs and lumber before it is shipped to foreign markets. Whether real or not, the perceived risk of disease and insect transmission to overseas forests may impact negatively on trade in wood products. It will be insufficient to understand the potential impacts of a disease reaching New Zealand. We will need to know the likelihood of New Zealand logs and lumber spreading harmful pests to the forests of other countries.

One mechanism by which trade restrictions may be addressed is to ensure that the biophysical risks confronting forests are well understood. This issue should be of concern not only to New Zealand, but to all countries participating in the international wood trade.

Acknowledgements

This paper is a revised version of a presentation made to the New Zealand Institute of Forestry Annual Conference in April 2000. The authors gratefully acknowledge the contributions of Bill Dyck, Ruth Frampton from the Ministry of Agriculture and Forestry Biosecurity Authority, Margaret Dick and Geoff Ridley from *Forest Research*, and Peter Buchanan, Bill Lee and Peter Williams from Landcare Research.

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Climatic Hazards and their Consequences for Forest Management – an Analysis of Traditional Methodological Approaches of Risk Assessment and Alternatives Towards the Development of a Risk Control System

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Abstract

After briefly analysing the impact of climatic hazards such as storm and snow on forest management within the past decades the paper firstly deals with discussing traditional approaches of risk assessment, mainly statistical approaches, e.g. logistic regressions. The limits of these methods are outlined. The paper then describes a new methodological approach for risk assessment especially in secondary coniferous forests based on regular management records using an artificial neural network. Database of the investigation are records of incidental exploitations due to storm damage in the period of 1967 to 1991 and of inventory data for a State Forest in the Schönbuch area of South-West Germany (state forest Bebenhausen). The data on incidental exploitations were recorded on the stand level. The results of the study clearly demonstrate that a neural network is able to better classify forests susceptible to wind damage than a logistic model, especially when the frequency of the undamaged and damaged forest stands differs significantly. The development of a permanent risk control-system based on this technology is outlined.

Keywords: Neural network, logistic regression, sensitivity

Climatic hazards as a hindrance to regular forest management

Climatic hazards, causing damages to forests mainly in the form of storms or snowbreakage have reached a level that is constantly threatening regular forest management. The storm of

Michel Arbez, Yves Birot and Jean-Michel Carnus (eds.)
Risk Management and Sustainable Forestry
EFI Proceedings No. 45, 2002

February 1990 caused more than 100 million m^3 of damage to the forests of Europe. Nykänen et al. (1997) estimate the yearly damage due to snow at 4 million m^3. After the catastrophic gale of December 26th, 1999 in France and Germany, where more than 30 m^3 of timber were blown down only in the south-west of Germany (Baden-Württemberg), a necessity of proper risk management is obvious. Beside these catastrophic events we have to consider a constant high level of so-called ‘incidental exploitations’. An investigation of Hanewinkel (2001) showed that the percentage of exploitations that were not the result of planned silvicultural interventions but were due to the impact mainly of storm and snow reached 44% for the period of 1980 to 1994 in the state-forest of the northern Black Forest. Looking at that, we might come to the conclusion that forest management in Central Europe is only partly a planned activity but mainly a reaction on climatic hazards.

The purpose of the present paper is to analyse which methodological approaches of risk assessment may be useful and whether there are alternatives to the traditional approaches. A proposal to enlarge the methodology using a technology in the field of artificial intelligence, especially artificial neural networks (ANN), is made. In a case study the performance of ANN to predict wind damages compared to common statistical approach is investigated and the development of a risk-management system based on artificial intelligence is proposed.

Traditional methodological approaches of risk assessment

There are several distinctly different ways for risk assessment: The first one is actually only partly a scientific approach: Based on an extensive literature review or even only on local experience, an expert system assigns forest stands and/or site units to risk classes using more ore less simple expert rules. An example for such an expert system is a scheme to estimate the risk for storm damage in forest stands in South Germany by Rottmann (1986: p. 96), or a similar approach for snow damage by the same author (Rottmann 1985: p. 111). Mitchell (1998) has developed a diagnostic framework for windthrow risk estimation in Canada that is very similar to an expert system.

The most common way to assess risk on a scientific base is the use of statistical models. A deterministic approach is to derive transition probabilities for age classes of stand types on defined site units. The theory behind these models has mainly been developed by Suzuki (1971) based on Markov -chaines. This approach has been widely applied in eastern Germany for forests dominated by Norway spruce (Kurth et al. 1987). However, the standard tool to predict risk for forest or forest stands is usually a variant of a regression model. The logistic regression model is commonly utilized as the traditional statistical approach to examine wind damage to forests (Hinrichs 1994; Valinger and Fridman 1997, 1998, 1999; Jalkanen and Mattila 2000). This technique may be successful when it is applied for numerically analyzing influential factors causing wind damages.

As a classifier for wind damage to forests, the logistic model did not always perform as well as one might expect. Its ability to predict damages to forest stands decreases, especially when the number of undamaged and damaged stands in the sample data set to which the logistic model is fitted, differs significantly. The study of Valinger (1997), for example, showed that with the specific data set used in the investigation, the predicted proportion of damaged plots was highly over-estimated. The number of the predicted damaged plots was about 8 times higher than the observed damaged plots. The implicit requirements of the data-sets and the low performance of the classic models necessitate efforts to find new approaches to classify wind damage to forests.

In addition to expert systems and statistical models mechanistic models or empirical mechanistic models such as HWIND or GALES (see Kellomäki and Peltola 1998) have been developed as generic tools for risk assessment. Both of these tools require a very high quality of input data and are meant to be used to evaluate the risk linked to a particular regime of management.

Artificial Neural Networks (ANN) – an alternative approach for risk assessment due to climatic hazards

An Artificial Neural Network (ANN) is a technology in the field of artificial intelligence that is especially designed to deal with complex and ill defined problems, for example pattern recognition (Patterson 1996). ANNs are able to learn from incomplete, disturbed and 'noisy' data-sets. Therefore, they should be especially suited to deal with data concerning risk like in the present investigation. Applications of ANNs in forestry mainly deal with mortality estimation (Guan and Gertner 1991a; Guan and Gertner 1995), uncertainty assessment of forest growth models (Guan et al. 1997) or multi resource forest land use planning (Nogami 1991).

In this paper, the possibilities of using an artificial neural network as an alternative approach to identify forest stands susceptible to wind damage are presented based on an investigation by Zhou et al. (2001). The first step to start a risk analysis using artificial neural networks is to define the decisive input variables that will be used for the input layers of the network. In a next step the topology (the architecture) of the neural network to be used has to be defined. As there is no general rule or recipe how to design the network (Nauck et al. 1994) this is a very complex trial and error process.

The different nodes of the neural network are connected to each other with weights. Each node evaluates the sum of the weighted inputs by a special activation function and 'fires' this result to each node to which its output is connected. The network used in this study was a general three-layered feedforward neural network with backpropagation algorithm. It was composed of one input layer, one hidden layer, and one output layer.

Every processing unit in the networks used a sigmoid activation function of the form:

$$f(x) = [1 + \exp(-x)]^{-1} \qquad (1)$$

with x = activation of the processing unit

excluding all the units in the input layer. Thus, the output from the proposed network can be explained as the estimated conditional probability of a forest stand being damaged given the input vector, since the response from the output unit is always between 0 and 1 (Hinton 1989; Guan and Gertner 1991b). To use the proposed neural network as a classifier, a training data set was presented to the net, in order to obtain a trained network through supervised learning. When the obtained network is applied to an unknown case, the output unit receives an activation, corresponding to each vector of inputs. Based on the achieved activation level the forest stand was classified as 'damaged' or 'not damaged'. Damaged stands exceeded the threshold of 0.5 for the activation level. All other forests were classified as 'not damaged' .

A case-study – predicting storm damage-classes for the state forest 'Bebenhausen' using the ANN – technology (Zhou et al. 2001)

Database of the present case-study (see Zhou et al. 2001) were booking records from the 4000-hectare -state forest unit 'Bebenhausen' in the Schönbuch area of South-West Germany (Hinrichs 1994). The original data set contained historical records of wind damage to more than 2800 forest stands in the years 1967 to 1991. In addition, regular inventory data of the periodical forest management and a site classification characterized the forest stands in terms of species composition, growing stock, age, height and site unit. A GIS was used to determine the position of each stand and to assign the site units to the forest stands. This data set was reduced by filtering out all stands younger than 30 years. Stands with no recorded growing stock were also removed. As a result, a total of 1600 stand records was obtained. The reduced data set was then used to generate the training and test sets for the neural network. A test set (TTS) was generated by randomly selecting 400 stands (25%) from the reduced data set. The rest of 1,200 stands was used as training set (TGS). Five pairs of training- and test sets were obtained by repeating this procedure. In the following they will be referred to as: TGS-1 / TTS-1; TGS-2 / TTS-2; TGS-3 / TTS-3; TGS-4 / TTS-4; TGS-5 / TTS-5, respectively.

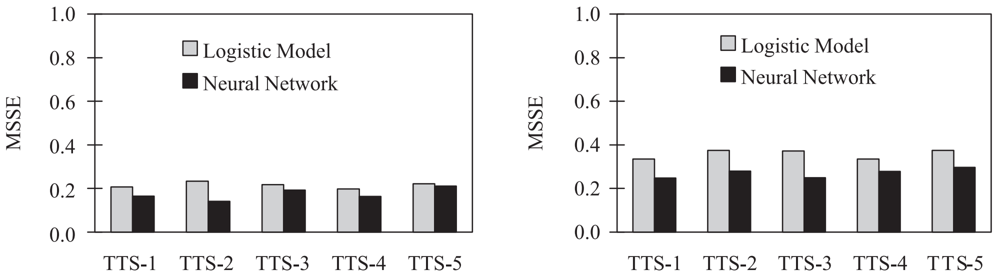
In this study, the degree of damage (damage rate) was calculated as a percentage by dividing the recorded damage due to wind by the standing volume of the forest stand. A predefined value of damage rate was set as the cut line between 'undamaged' and 'damaged'. Specifically, a forest stand was classified as 'undamaged' (encoded as 0) if the observed damage rate was below 2%, otherwise as 'damaged' (encoded as 1). To determine the effectiveness of the cut value, a damage rate of 5% was also used. The stand age, the dominant height of the stand, the tree species, the site stability for Norway spruce, the aspect, elevation, slope, and Topex[1] of the site were selected as preliminary input variables.

In order to evaluate the performance of the neural network model compared to a classic statistical approach, a logistic regression model was also fitted to the data set. In the present study the mean squared sensitivity error (MSSE), a performance measure introduced by Lawrence et al. (1998), was used. Since the sensitivities that were calculated using a 2x2 confusion matrix take values between 0 to 1, a lower MSSE indicates a higher performance. Compared to the overall proportion of correct classification, MSSE as a performance measure has the advantage of giving equal importance on each class, instead of learning from the most common class.

Figure 1 shows the performances of the trained network and the fitted logistic model measured by MSSE when they are generalized to the test sets. Figure 1a demonstrates for each of the five test sets that the median of the MSSE for the neural net is lower than the MSSE for the logistic model when the cut value between the undamaged and damaged stand is set at a damage rate of 2%. This indicates that the neural network performs clearly better than the logistic model. Further, figure 1b shows that the performance of the network can be more promising compared to the logistic model, if 5% is used as cut value. In addition, it can be observed that both models tend to perform worse when the cut value changes from 2% to 5%. an increase of the cut value from 2% to 5% actually changes the distribution of the frequency of both the undamaged and damaged stands in the training and test set. More specifically, a change of the cut value from 2% to 5% results in a reduction of the proportion of the damaged stands from around 30% to 20%. Consequently, both the trained network and the fitted logistic model show a lower performance, since the number of the damaged stands is further reduced in favor of the undamaged stands. Thus, the results of the present study demonstrate that the neural network is preferable as a classifier compared to a logistic model, when the frequencies of the classes vary significantly.

Figure 2 shows the sensitivity of the models when they are applied to the test sets under different cut values between 'undamaged' and 'damaged'. The corresponding numerical values are listed in Table 6. Both figures, 2.a0 and 2.b0, demonstrate that the sensitivity for

1 The Topex score is assessed by measuring the angle of elevation in degrees from a fixed point to the horizon for a predetermined number of compass directions (Pyatt 1969). The sum of all the angles taken at each sample point is the Topex score. In the present investigation, the Topex was calculated based on the GIS and the digital terrain model.



a. Damage rate 2% as cut line between undamaged and damaged stand

b. Damage rate 5% as cut line between undamaged and damaged stand.

Figure 1. Performance of the logistic model and the neural network when they are applied to test sets, including: TTS-1, TTS-2, TTS-3, TTS-4 and TTS-5. The performance is measured by mean squared sensitivity error (MSSE). The MSSEs for the neural network are the median value of the MSSE of 10 trials.

the argument 'undamaged stand' is in most cases somewhat lower for the neural network than for the logistic model. This means that the ability of the neural network to correctly classify undamaged stands may sometimes be lower than the logistic model. However, looking at figures 2.a1 and 2.b1 it should be noted that the neutral network performs much better than the logistic model in identifying damaged stands, especially when the cut value between 'undamaged' and 'damaged' is set at 5%. Figures 2.a2 and 2.b2 give the total sensitivity for both models. Under this overall evaluation criterion, the performance of the neural network is only slightly different from the logistic model. As a general observation it can be noted that the network has a distinctly stronger ability to identify damaged stands, compared to the logistic model. This significant advantage may be accompanied by a slight loss in precision on the side of the undamaged stands.

Outlook – application in a risk management system

Despite the fact that we obviously need a broad database for a risk prediction, this database should also reflect the actual situation and the recent past. The risk assessment tool that is described here will be included into a decision support system for conversion/transformation purposes on the forest unit level. A system that only reflects a historical situation will be of little use for practical forest management. With every change of the situation of the environment (e.g. a new storm event) the value of the model decreases if the data base is not updated. Therefore, it has to be secured that the database of the learning algorithm of the neural network or a combination of fuzzy sets and neural networks can be updated regularly without causing excessive costs of data-assessment and -processing.

Based on the historical analysis and the methodology used in the present investigation the system will be kept up to date by the use of regular yearly booking data (records of storm, snow, insect damages on the stand level) stored electronically at least since 1985 in the public forests of Southwest Germany. The risk assessment tool will hereby extend the learning process to the actual situation and improve the decisions of a forest manager by anticipating

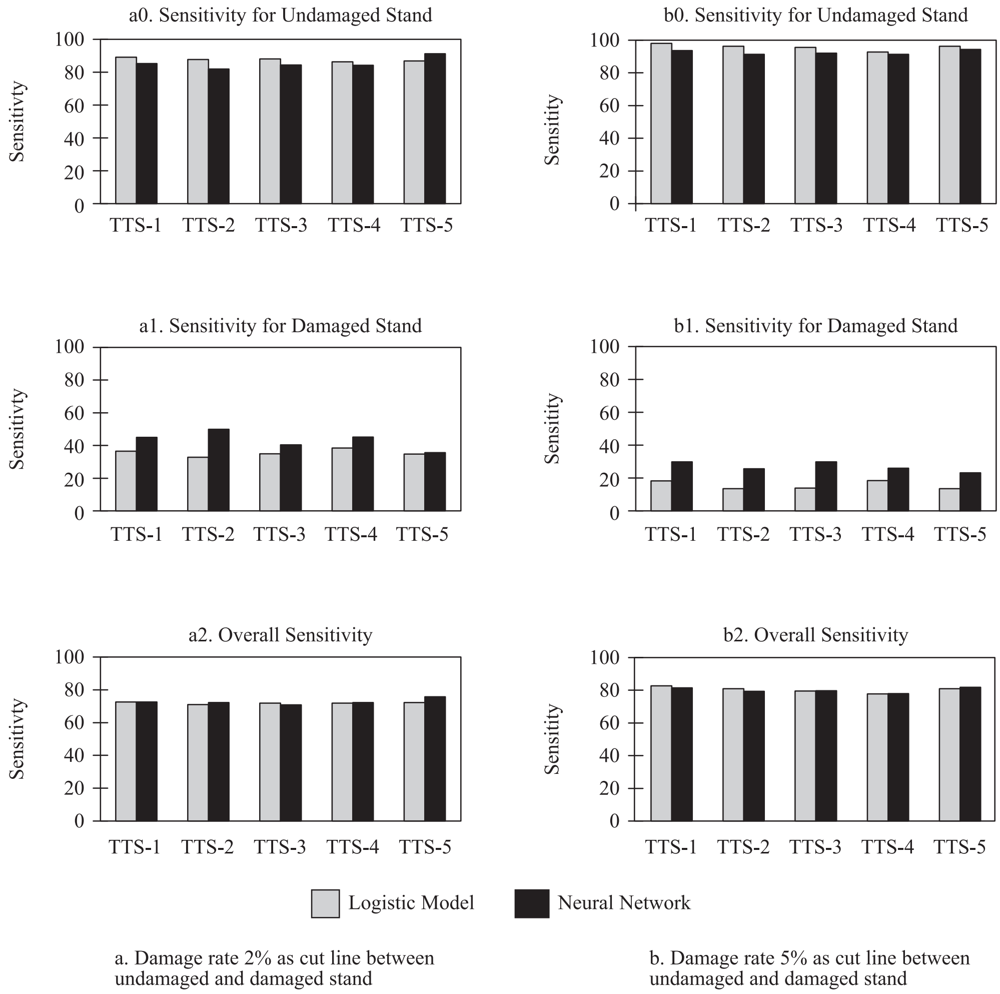


Figure 2. Sensitivities of the logistic model and the neural network when they are applied to test sets, including: TTS-1, TTS-2, TTS-3, TTS-4 and TTS-5. The sensitivities for the neural network are the median value of the sensitivity of 10 trials.

further risk events in the future. This will avoid the situation we are facing at the moment that the risk - analysis is almost always an 'ex-post' analysis with limited facilities concerning the future. What we need in terms of risk assessment is a system that can be flexibly adapted to changing environmental situations, a system that is able to learn from the current situation even if the database is not perfect or rather fuzzy. Together with digital (encoded) stand descriptions, permanent inventory data, a GIS including the site information and the geometries of the stands and a meteorological model that predicts wind speed or snow load depending on the position of the stand and the meteorological situation we should be able to create a database that can be updated yearly. In this case artificial neural networks or fuzzy systems or a combination of both that are able to process disturbed data and learn from regularly stored data from day-to-day management can be a promising technology.

Acknowledgements

I want to thank Christian Schill and Wenchao Zhou who both contributed to the research project on which the present paper is based. The research has been supported by the German Ministry of Formation, Research and Technology (BMBF) under the grant number 0339732/5. The information in the paper is partly based on a manuscript that is at present (September 2001) in review by Forest Science (Zhou et al. 2001).

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Modelling the Climate Response to Increasing Greenhouse Gases

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Abstract

Model projections indicate that the climate of the Earth will undergo an important change during the 21st century, with a global predicted surface warming in 2100 ranging between 2°C and 6°C: half of the uncertainty is due to the economic projections, half to the complex behavior of the climate system. The lower bound of these estimates already represents an important perturbation and would induce significant changes in precipitation rates or areas, in storminess or cyclone tracks. These regional consequences are, however, difficult to predict in detail.

An important feature of the forthcoming changes is therefore their partially unpredictable character. Many of the local events accompanying a global climate change will arise unexpectedly, and the rate of change will be the primary factor of danger. It is probably too late to stop climate modification, although there is still time to reduce the emissions and thus create a situation where the adaptation to the impacts will be much easier.

1. Introduction

Since the mid-19th century, the composition of the Earth atmosphere has started to change in a manner that was unprecedented during the Quaternary era.

The concentration of carbon dioxide (CO_2), for example, has raised from the pre-industrial value of 280 ppmv (parts per million in volume) to more than 360 ppmv. Similarly the methane (CH_4) concentration has raised from 0.8 ppm to 1.6 ppm. The concentration of other gases (N_2O, CFCs) has also increased dramatically. There is no doubt that this situation is the result of human activities: energy consumption, industrial or agricultural activities and deforestation. As most of these gases have a long residence time in the atmosphere, where they tend to accumulate, we may expect the level of these perturbations to increase strongly throughout the 21st century.

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What are the consequences to be expected? The only tools which are available to estimate what the future climate may look like are numerical models, whose development has been one of the important achievements of the community studying the Earth global environment during the last decades. But these models are not free from uncertainties, and the purpose of this paper is to discuss the degree of accuracy to which their results can be trusted. We will show that: (i) models unanimously describe a risk of important climate change in the decades and centuries to come, (ii) there remains significant difficulties that prevent the scientific community from providing details on what may occur at a regional or local scale.

2. The amplitude of the anthropogenic forcing on the climate system

The changes in the atmospheric composition which have been recorded since the beginning of the century have no equivalent over the last millennia. Altogether these gases are responsible for an increased radiative forcing – defined as the perturbation of the Earth radiative balance at the tropopause- of about 2.5 Wm^{-2} (IPCC 1994). This value may appear modest compared to the mean absorbed solar radiation, which is about 240 Wm^{-2}. But it is expected to last over a long period of time, because the residence time of CO_2 in the atmosphere is about one century, while that of methane is about a decade. And this 1% perturbation of the Earth energetics, although small in relative value, is absolutely non-negligible in absolute values and is able to cause significant changes of a few degrees at the global scale. A change of a few degrees of the global temperature is a very large perturbation when compared with the very stable climate of the last millennia, where natural fluctuations have apparently never exceeded a few tenths of a degree (in average global values).

This greenhouse gas perturbation is not the only effect resulting from human activities: there are at least two other radiative effects, which must be considered. One is the formation of tropospheric ozone from nitrogene oxides mainly during the summer over the continents. The other effect is that of the aerosols, some of which are also emitted by human activities: sulfate, nitrate, black carbon, and waste products from burning biomass. In the future, we expect the effect of the gases with a long atmospheric life (CO_2, CH_4, CFC) to be the dominant ones, as they tend to accumulate within the atmosphere, whereas the aerosols have a very short residence time. The role of the aerosols should therefore be limited to delay rather than suppress the climate evolution in response to the greenhouse gases (IPCC 1994).

3. The model evaluation of climate modifications

To understand the potential impact of the anthropogenic effects, one therefore needs to dimension the response of the climate system to a forcing of a few Wm^{-2}. The models which are used to simulate this response are global models of the atmospheric and oceanic circulation, where the equations of fluid dynamics or radiative transfer throughout the atmosphere are discretized over a grid of a few hundred kilometers in the horizontal, and a few hundred meters or a few kilometers in the vertical. Such models represent explicitly many features of the observed climate: seasonal cycle, tropical cells, mid-latitude cyclones and anticyclones, monsoons, interannual variability associated with

El-Nino or the NAO. But they fail to represent small-scale features such as the convective redistribution of heat and moisture within the atmosphere, or cloud-radiation interactions, which have to be predicted explicitly.

This has several consequences. As clouds may serve as an amplifier of climate changes through their greenhouse effect or their interaction with the solar radiation, uncertainties or inaccuracies in the representation will affect the range of the predicted climate changes. Current estimations (IPCC 2001) indicate that in 2100 the value of the global temperature increase should lie roughly between 2 and 6 degrees. In broad terms, half of the range corresponds to the difficulty of estimating the future increase of greenhouse gases emissions, the other half reflecting the difficulty of accurately simulating the change in cloud cover and cloud properties in a warmer world.

The precipitation distribution will also change. Figure 1, taken from an intercomparison of different models carried out by Le Treut and McAvaney (2001) shows a broad agreement of these models in terms of very large-scale structures, whereas the local features are largely different from model to model.

The same can be said of all extreme events: tropical cyclones, mid-latitude storms, drought spell. There is a real danger that they may occur in new locations – their intensity may even increase because a warmer climate is largely moister, with more extreme meteorological events triggered by a larger latent heat release. But the location of these events, the time of their occurrence, cannot be predicted in more than a broad statistical sense.

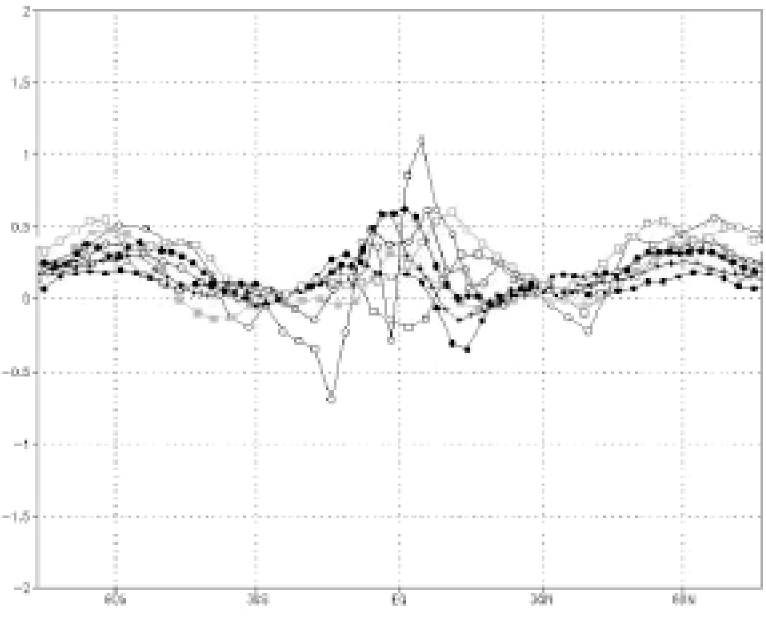

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Figure 1. Change in precipitation on the conditions of a CO_2 doubling (to be expected within the next decades). Mean zonal averages for a number of different atmospheric models coupled to a simplified ocean. In most cases the warmer conditions increase natural tendencies: moist regions get moister, whereas dry regions get drier. But there is a very large uncertainty attached to any kind of local projection.

4. The slower components of the climate system

We have focused so far the discussion of model accuracy on the role of the atmosphere. These effects may dominate the climate response during the 21st century. However, the recent years have seen a growing awareness of the role played by the other components of the climate system, role which may be dominant to explain the response of climate to present emissions in a more remote future.

The contribution of the ocean, for example, may first be viewed as only bringing inertia to the system: the small surface heat imbalance, resulting from the radiative forcing and the atmospheric feedbacks, is accumulated within the ocean surface layers, an effect which structures the long term-evolution of the climate system. A first complexity is being brought by the vertical physics of the ocean. At low latitudes the ocean layer in contact with the atmosphere is rather shallow. At high latitudes on the contrary, in the regions of deep ocean water formation (in the North Atlantic, or around Antarctica), it can reach a few hundred or even thousand meters, a column with a considerable thermal inertia, which strongly delays climate change.

But the oceans may also change the course of their circulation, and this has become a matter of very serious concern. Ice cores and deep-sea sedimental records have shown that in the past there has been very strong oscillations of the North-Atlantic circulations, triggered by changes in the salinity, and model studies confirm the general instability of the North-Atlantic circulation. These features correspond to one of the most important threats of the anthropogenic greenhouse increase: a decrease of the North Atlantic surface salinity, or a warming, might destabilize the thermohaline circulation and bring adverse climate conditions over Europe. This happens for example in the recent integrations using the IPSL ocean/atmosphere model submitted to a 1% CO_2 yearly increase. The pioneering experiments of Manabe and Stouffer (1994) have shown that in their model a small perturbation of the thermohaline circulation was reversible, but that there was a threshold (in their case about 4 times the present CO_2 level) above which changes could become irreversible. This has of course strong implications on the reduction level of greenhouse gases emissions that should be attained. At the same time, it reveals some other limits of the present models: the capacity of coupled ocean/atmosphere models to maintain a stable thermohaline circultion in the absence of artificial “flux-correction” methods is still uncertain.

Another important threat associated with climate warming is the perspective of sea-level rise, which will result from ocean thermal expansion and from the melting of mountain glaciers: these processes should bring a sea level rise from 20 to 90 cm in 2100. But in the following centuries there might also be a contribution from the melting of polar ice sheets. This is much more difficult to assess in details and requires numerical models of the ice dynamics, and its response to changing atmospheric conditions. Such studies are in their infancy. But the risk associated which such an evolution, however difficult to assess, would be enormous.

The biochemical or chemical components of the environmental system also constitute key issues. About half of the CO_2 emitted by human activities stays in the atmosphere, whereas the other half is recycled in the ocean or the continental biosphere. This latter portion may diminish in a warmer world (Friedlingstein et al. 2001), an effect, which may amplify climate changes. A comprehensive climate model, relevant for decision-makers, should therefore consider as input parameters the carbon emissions, which one may wish to reduce, and not the CO_2 atmospheric content, which is linked to the first quantity by a complex and non-linear carbon cycle. Such models begin to exist, but are in their infancy. The same remark applies to the other tropospheric or stratopsheric chemical cycles which control the atmospheric composition.

5. Conclusion

Model studies of our global environment have improved enormously during the last decades. They can treat in a consistent physical framework a very large amount of information and mechanisms. Models agree in many features: they all predict an important warming (from 2 to 6 degrees by 2100) in response to the anthropogenic greenhouse gas increase. This occurs in spite of the large increase in the variety of processes, which are now taken into account in the model. Models predictions also begin to receive some support from the observations: there are clear indications that climate change is very likely to have begun.

On the other hand the simulations of future climate suffer from uncertainties. Some of those result from the youth of the models, which have not yet reached their maturity. Some are the consequence of the inherent complexity of the system, a complexity which is slowly revealed by present studies. Nature is probably not completely predictable. But one should not hold this uncertainty as a factor ignorance. On the contrary, it determines areas of environmental risks, and should induce us to remain humble: if human activities begin to induce irreversible changes in the climate system, there is no way we will be able to control such a complex system. And the amplitude of the perturbation which would be sufficient to trigger irreversible climate changes is unknown to us.

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Causes of Forest Fires in the Mediterranean Basin

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Introduction

Fire is the main cause of forest destruction in the countries of the Mediterranean basin. About 50 000 fires sweep an average of 500.00 hectares of Mediterranean forest each year, causing enormous economic and ecological damage as well as loss of human life.

In comparison with the previous decades, the 1980s and particularly the 1990s show that the problem is becoming increasingly serious, in terms of both numbers of fires and the area burnt. This paper discusses the different factors, which have contributed to this increase.

Climatic factors

The predominating climatic conditions of the Mediterranean basin are significantly affecting the forest situation. Long summers (extending from June to October and sometimes even longer), with virtually no rain and average daytime temperatures well over 30ºC, reduce the moisture content of forest litter to below 5%. Under these conditions, even a small addition of heat (a lightning, a spark, a match, a cigarette butt) can be enough to start a violent conflagration.

Together with the heat and lack of moisture, wind is another influential climatic factor. The inland summer winds characterized by high speeds and strong desiccating power, for example, the tramontana of Catalonia and Italy, the mistral of France, the khamsin in Lebanon and Syria, the sharav in Israel, and the sirocco in the Maghreb, as well as the poniente in Valencia and the levante in the Straits of Gibraltar, cause atmospheric humidity to fall below 30% and contribute to the spread of fires by carrying sparks over great distances.

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The dry and cold winds of the Mediterranean winters can also increase the danger of fire. For example, the foehn that blows southwards over the northern Italian Alps, and the southerly wind that blows across the north of Spain from the Central Meseta, often fan small, deliberately set fires out of control.

Forest vegetation as fuel

As a reflection of the prevailing climate with its long summer droughts, Mediterranean forests are frequently characterized by fire climax species, i.e. those that depend on the presence of fire in their reproductive cycle. Pines form the largest tree stands on both the northern and the southern shores of the Mediterranean. These species are characterized by physiological mechanisms that link natural seeding with fire, e.g. the opening of pine cones exposed to intense heat. These species also tend to have a particularly high content of resin or essential oils, making them extremely inflammable.

Other species, particularly the evergreen sclerophyll oaks, have developed a morphological resistance to fire. For example, Q. suber has developed a characteristically thick bark that isolates the cambium, enabling it to resist sporadic fires. Likewise, the presence of a large number of dormant buds in oaks ensures the production of shoots and sprouts if the aerial part of the plant is reduced by fire.

However, these adaptive reactions do not provide permanent protection. After repeated fires, the trees are replaced by a woody shrub cover that is not merely resistant to fire but typically pyrophytic, as with the dehiscence of rockroses (Cistus), or other species that produce seed with a thick isolating tegument or rhizomes or running roots.

To this natural evolution of flora must be added human-induced changes caused by attempts to restore the tree cover in areas where excessive fire or other uses, such as overgrazing and fuelwood extraction, have caused a high level of degradation. Reforestation is usually carried out using pioneer species, predominantly pines established in monospecies stands. This in itself increases the risk of fire due to the continuity of fuels in closely spaced plantations as well as the concentration of fine, highly inflammable fuels.

Socioeconomic conditions

The current socioeconomic situation in the European Mediterranean countries may be characterised by the following events:

a) Depopulation of rural areas through greater incentives in urban areas.
b) Relinquishing traditional uses in rural environments as a result of depopulation.
c) Tendency for forest use to disappear as a raw material producer, or at least to be reduced noticeably.
d) Tendency for traditional uses (grazing and firewood) to be relinquished.
e) Tendency for recreational uses to increase both hiking, hunting and river fishing.
f) Continuous growth of the forest-urban land interface.

Thus, socio-economic reasons are bringing about changes in the relationship between rural and forest uses (forest farmland interface) and between urban and forest activities (forest-urban land interface).

The new relationships resulting are not established harmoniously; further conflicts arise or old ones are modified. These conflicts manifest themselves in several ways, one of which is fire, which, as statistics show, becomes more frequent and more violent as the process advances.

Conflicts in the rural interface

Persistence against 'slash and burn' for agricultural purposes

The conflict arises from of the use of fire to eliminate forest vegetation and its subsequent replacement by agricultural crops. However, currently there is little demand for slash and burn and thus the conflict is dying out. Only in places where irrigation is possible, which is usually highly profitable in the Mediterranean countries, can this kind of land demand still be seen. Obviously, irrigated lands are highly limited in space because of water availability. In addition, EEC policy for preventing surpluses (CAP) is deterring further settlements on forest land which are usually low productivity type lands due to their quality or slope.

The conclusion is that this conflict is tending to disappear.

Relinquishing the land

The conflict arises as a result of rural activities ceasing on marginal lands, either spontaneously or encouraged by the aforesaid policy against surpluses. Leaving the land enables the invasion by forest species in a process, which would lead to the future regeneration of the forest. This invasion very quickly generates the most dangerous types of fine fuel accumulations, in which fires breaking out easily, take on high speeds and intensities and are extremely difficult to fight.

This conflict can be controlled by regulations the change in use from farm to forest, with funds to make it viable and prevent fuel accumulations. However, the process of giving up the land is outpacing and outspreading the different countries' current policies. In addition, this process makes owners who might request subsidies disappear. It is difficult to get owners to invest the difference of the cost-up to 100% to protect something that does not directly produce anything for them.

The conclusion is that this conflict is tending to become more serious.

Grazing land and the use of fire

The conflict arises from the use of fire to maintain pastures and get rid of ligneous vegetation. In general, the legislation of all countries forbids fire in forest areas and in a belt around it (e.g. 200 m in France, 300 m in Portugal and 400 m in Spain). Outside this area, authorisation must be applied for from forest services which will be granted depending on the danger index. In general, there are rules establishing the fire season in which authorisation cannot be given in any event.

Nevertheless, this preventive legislation is indirectly countered by regulations for protecting people living in the mountains.

The EEC incentive policy consists of subsidies per head of sheep and goats with no relation to the area of land on which these animals will graze. In addition, they are allowed to migrate seasonally to new pastures.

The people who turn to these subsidies are those who know how to apply for them and are often from the urban environment. Afterwards, they use shepherds to look after their livestock. The lack of relationship between landowner and use of the land leads to shepherds applying fire in a more uncontrolled fashion, thus causing wildfires.

The conclusion is that this conflict is not sufficiently discussed nor clarified to the public, resulting in a lack of attention from administrations to prevent undesired effects of the incentives.

Systematic burning of agricultural waste

The conflict arises from the use of fire to get rid of harvest remains (stubble burning) and prepare the land for further sowing. This is a traditional operation on cereal growing land. It is also performed to remove underbrush and weeds and anything which interferes with farming.

Currently the burning is increasing. In fact, farmland is becoming a mere support for the crop, whose organic matter is destroyed every year by burning and has to be fertilised, i.e. it is a completely artificial method of agriculture.

Declaration of specially protected areas

The conflict arises from the limitations, which this declaration brings to local populations. When a region is declared a national park, Natural Park or other protected area, certain restrictions are directed towards the conservation or restoration of natural resources. This has an immediate influence on the lives of the area’s inhabitants and may clash with their uses and customs. Confrontation can occur, of which the forest fire is a symptom.

The tendency in protectionist policy is to recognise these potential conflicts and take compensatory measures, which should be extended, to these protected regions’ area of influence.

The conclusion is that this conflict will tend to spread, even though it may be controlled by good management of protected regions.

Forest plantations

The conflict arises from the actual use of the forest. Its production function can be undertaken if it generates raw materials as required by industry. The Mediterranean forest is not exactly the ideal structure for supplying timber to industry, for example. Consequently, when there are suitable land and humidity conditions, it is possible to turn such land into a forest plantation. To do so, it is often not necessary to alter the ecosystem but to act on land previously disturbed, for instance, by grazing or which is simply abandoned.

This is a conflict that should be handled by applying technical knowledge, and the public should be informed of these measures.

Conflicts in the urban interface

Transformation into urban use

The conflict is caused by the rapid spread of urban areas, which occupy bordering agricultural land and then move into forest lands further away. The efficient transport systems which current technology provides are making distances to the urban area irrelevant, which means that an even greater proportion of the land has urban development potential.

Some people say that burning can make it easier to get the land use status changed into urban use, but there is no clear evidence of this. These allegations should be investigated.

Expansion of recreational uses in the forest area

The conflict is the result of forest areas being used for recreational activities such as hiking and hunting. The ever growing presence of people in the forest turns into a higher likelihood of negligent use of fire in open air cooking or by smokers. Hunters may even use it to force animals out to open.

The current tendency is to enforce regulations, intensifying surveillance and limiting travelling in the forest. In Spain, for instance, the practice of placing barriers at the entrance of forest roads, which thus are no longer public thoroughfares, is spreading. These roads were not originally public, but were allowed to become so, through habitual use.

Another practice, typical of the 1960s and 1970s, i.e. building barbeque areas in the forest, is being abandoned. Existing areas are being dismantled and open air fires within forest areas are being banned for good.

Fires starting from recreational areas are all caused by negligence. Bearing in mind the degree of information provided to the public with respect to the fire danger, it really is 'culpable negligence'. In the future, there will probably be penalties for it within the legislation.

This conflict is growing in importance but can be contained with means such as education and deterrent surveillance.

Garbage tips kept going by fire

This conflict is becoming more important with the amount of waste being produced in urban areas. The enormous amount of rubbish in the larger cities have required heavy investments in processing equipment. However, in medium to small towns, garbage is still piled up and burned. As these tips are badly controlled, fire escapes and turns into a forest fire.

This is a conflict requiring greater attention from local authorities, who are responsible for planning garbage disposal system.

Conflicts not directly related to the use of land

Vengeance

This may be vengeance against individuals or against society. In the former case, fire is one of the many means of harming a person due to a private disagreement.

In the latter, there may be many reasons for vengeance. For example, the hunter who cannot find a place to hunt and expresses his protest by setting fire to the forest. Terrorism can also be included in this category, although there is not much information on the topic.

Delinquency

In this case, fire is used either to hide another offence or to help in perpetrating it. Poachers can be mentioned here too.

The frequency of these causes can be classified as follows:

– High frequency in all regions
  • Grass burnings
  • Agricultural burnings
  • Garbage burning
  • Vengeance and vandalism
  • Recreational activities (barbeques, smoking)

– High frequency in some regions
  • Declarations of protected areas
  • Labor market
  • Hunting conflicts
  • Resentment against old reforestation policies

– Low frequency
  • Smuggling and other criminal activities
  • Change of land use from forest to urban one
  • Timber market

Forest policy for prevention

These problems can be summarized in the Figure 1. The Figure 2 presents the answers of a comprehensive forest policy to each of them. A special emphasis is to be given on preventive silviculture.

Species selection and woodland structure

A definitive solution to fire cannot be found by replacing certain species with others, for practically all species burn under the tough conditions imposed by the Mediterranean summer. Accordingly, if we cannot base vegetation measures on intrinsic resistance, we must try to hamper spreading by creating discontinuities, avoiding extensive, monospecific surface areas and by creating patchworks of different inflammability levels that ‘disturb’ the fire. In particular, wherever there is sufficient humidity, especially watercourses, the opportunity should be seized to plant species that make use of it.

The aim should be to create mosaics of species by integrating other activities that increase discontinuity, such as roads, electricity line fuel breaks, cultivations, and recreational areas. Likewise, in exploiting the wood, an effort should be made to maintain its density to limit undergrowth.

It is also worth keeping hillsides that face the prevailing winds well covered with high vegetation that acts as a windbreak, while opening fuel breaks on the leeward side, avoiding ridges.

Forest areas should be split up by fuel breaks of up to 200 metres in width, within which discontinuity should be enhanced by means of pruning, ground clearance, plantation differentiation, and pathways. In certain cases, fuel-breaks areas are always necessary at the edge of woodlands, to separate forest areas from agricultural or urban land.

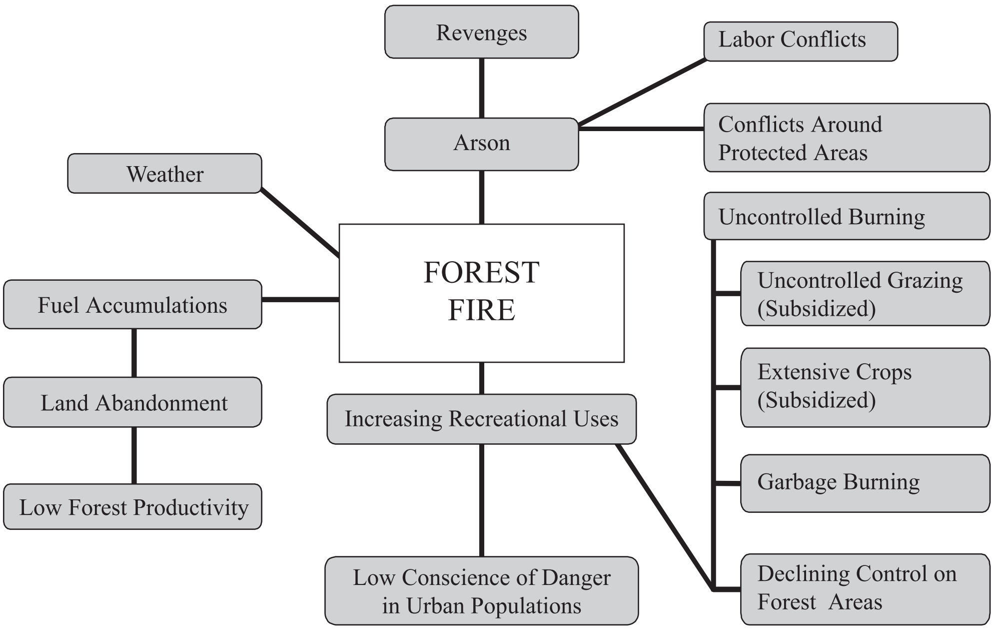

Figure 1. Forest fires, their reasons and consequences.

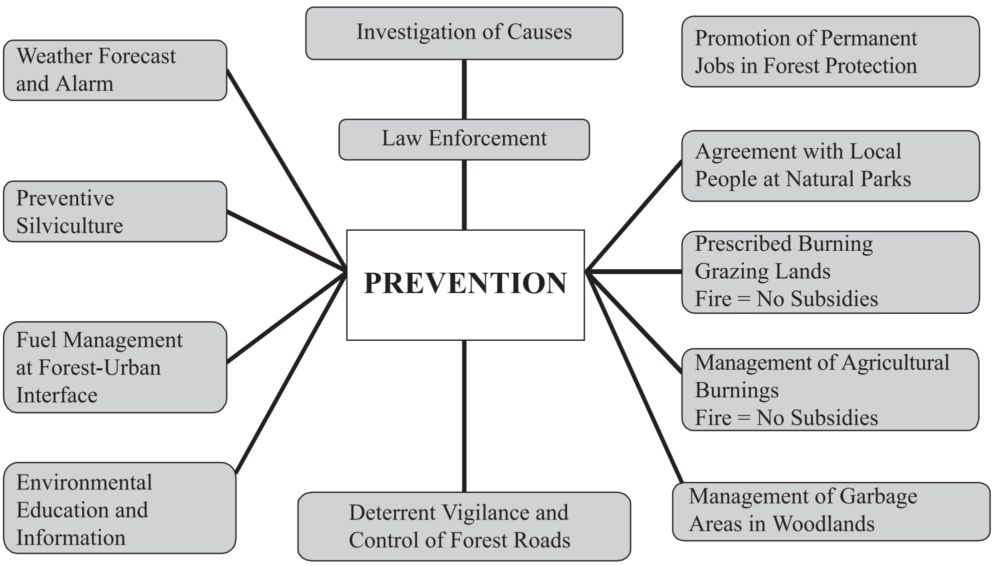

Figure 2. Prevention of Forest fires.

Methods of reducing combustible matter

Creating both horizontal and vertical discontinuities requires a variety of techniques for the elimination of inflammable matter. These include mechanical and manual clearance, manual pruning, restricted burning, controlled pasturage and the use of phytocides.

In choosing the most appropriate techniques for each case, social, ecological and economic conditions should be taken into consideration. For example, in areas of high unemployment, manual clearance is to be preferred. If there is a demand for land on which to raise cattle, controlled pasturage is likely to be a good choice, since it makes for an economic return as well as clearing fuel-breaks areas.

Prescribed burning is a very economical technique which nevertheless requires specific training. When combined with controlled pasturage, it can be highly recommended. One of its most promising forms is the burning of agricultural and scrubland zones, organized collectively in areas in which the rural population traditionally uses burning as a means to rejuvenate vegetation. Naturally, it requires intensive agricultural extension work in order to create a consensus in favour of using it and thereby rationalizing the use of fire by the rural population.

The use of phytocides should always be highly restricted, in view of the difficulty of controlling its effects outside the treatment zone.

Mechanical ground clearance requires the use of machinery that is suitable for the various types of combustible material and terrain. Such machinery might include harvesters to collect and transport woody fuels to power plants producing electricity by burning them. However, at present it is questionable whether such exploitation is economical, given its cost in comparison with product prices. It could really only be made economically attractive through subsidies, which would be justified by the necessity of clearing and pruning in order to establish discontinuities in inflammable material.

Conclusion

In too many cases heavy investments are made in fire-fighting equipment (planes and fire engines) rather than in prevention through improving woodland self-protection. Concrete measures coordinated among the Mediterranean countries concerned are therefore highly recommended.

In the Mediterranean region, forestry can seldom be based on production objectives because of the ecological factors. On the contrary, protection of the soil and water resources is a must for every forest policy, but fire can ruin any program for sustainability.

Then such a policy has to contain a strong program of preventive silviculture, on one hand, and an intelligent program to deal with the described socio-economic causes.

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Phytosanitary Risks

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Abstract

This paper discusses the causes of forest disturbances e.g. forest fires, storms and droughts. Stands with disturbed resistance can be considered as 'phytosanitary risk' stands and can provide conditions favorable for disease and pest outbreaks. The first part of the paper discusses the possible consequences of the most harmful abiotic natural events and how they influence phytosanitary situation in the forest. The second part is devoted to the specific situation in the Moscow Region, which has been chosen as an example for illustrating threats, and phytosanitary risks, which can arise as a result of the impact of a number of coinciding factors. During the relatively short time period of 1998–2000, the Moscow regional forests have been subjected to the influence of windstorm, drought, fires, spring frosts and outbreak of spruce bark beetle. Finally the strategy to reduce phytosanitary risks in the Moscow Region is discussed.

Keywords: forest disturbances, phytosanitary risks, pests, diseases.

1. Causes of forest disturbances and phytosanitary risks

Forest ecosystem disturbances are caused by a variety of reasons, usually divided into abiotic, biotic and anthropogenic. Their impacts can vary in the duration, character and degree of influence and can cause reversible or irreversible changes in forest stand conditions (Vorontzov et al. 1991) (Table 1).

Abiotic factors include climatic and soil conditions, which can cause a number of dangers for forest ecosystem health, and thus phytosanitary risks. Wind and snow can damage trees by uprooting and breakage, warm and dry weather can cause forest fires, droughts lead to plant weakness, insect outbreaks and massive stand dying. Various changes in soil, swamping or sudden shortage of ground water can also cause disturbances in the normal forest ecosystem functions.

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Risk Management and Sustainable Forestry
EFI Proceedings No. 45, 2002

Table 1. Classification of factors influencing forest stand conditions

Classification of factors	Type of factors
By nature, by origin	• climatic (drought, over-damping, etc.) • disasters (storm winds, snow avalanches, etc.) • pyrogenic (fires) • geomorphogenic (topographic features, erosion processes, soil salinity, soil swamping, etc.) • zoogenic (defoliators, ungulates, etc.) • phytopathogenic (forest diseases) • anthropogenic (wrong forest management, industrial pollution, etc.) • complex
By period or duration of impact	• impulsive, instant (fire, snow avalanches, etc.) • lengthy, lasting (industrial pollution, recreation) • permanent
By character of impact	• gradually increasing or decreasing • in stages, periodically or non-periodically changing • cumulative or non-cumulative
By degree of impact	• low, medium, high
By appropriate forest changes	• reversible or irreversible

Stands with disturbed resistance can be considered as a ‘phytosanitary risk’ stands and can provide favorable conditions for disease pathogens and stem pests which may increase tree mortality and often cause complete stand degradation and death. The first part of the paper describes the most harmful abiotic damage and their influence on the forest phytosanitary situation. Most examples and illustrations are typical of temperate and boreal forest zones of the Central and Northern Europe with their typical forest-forming species – Scotch pine (*Pinus sylvestris)* and Norway spruce *(Picea abies).*

1.1 Forest fires

Forest fires are the most common natural disasters in forests. With their negative influence on influence many processes of forest life including changes in forest formations and forest successions. Forest fires can be divided into *surface, crown* and *ground* (or *peat*) fires. The type and extent of changes caused by the fires depend on the forest type, fire area and intensity and the season (spring, summer, autumn). This paper limits its focus on the influences on forest stands and burned areas as spots of forest pest outbreaks.

From the phytosanitary point of view, fire is one of the main reasons for stem pest outbreaks and burned areas can serve as a source of infestation for neighboring stands. Pest species’ composition, degree and character of infestation are closely connected with tree species, the thickness of tree cork layer (and consequently with tree age), as well as with the type and intensity of forest fire. After *crown fires*, there is no danger of pests of the surrounding stands. As a rule, their complex consists of species characteristic of dead wood. In particular, after high intensity fires in young growth forests with completely destroyed coniferous stands burned areas are typical of Mediterranean conditions and rather rarely occur in the Central and Northern Europe. Continued *surface fires* that burn roots, butts and lower parts of stems, injuring living issues of inner bark and cambium are the most significant potential factors causing pest outbreaks. They create aggregations of trees with various degrees of weakness susceptible for pest attacks with an amount of food resources for the pests.

Forest fires influence pine and spruce stands in different ways. For example, in the conditions of the Moscow region, pine demonstrates a high degree of resistance to surface forest fires in comparison with spruce and birch which usually die during the next two years following the fire.

Different European geographic regions have a rather homogeneous species composition of insects in burned areas of pine forest with only the proportion and dominance of certain species varying (Table 2). Ecological groups of pests in burned areas are usually formed depending on the time of fire and the type of forests.

Table 2. Dominant species in burned areas of pine forests (Vorontzov 1978)

Northern areas of forest zone	Southern areas of forest zone and island pine forests of steppe
Tomicus piniperda *L.*	Tomicus piniperda *L.*
T. minor Hart.	*T. minor* Hart.
Ips sexdentatus Boern.	*Ips acuminatus* Eich.
Trypodendron lineatum Ol.	*Ips sexdentatus* Boern.
long horn beetles of g. *Monohamus*	*Spondylis buprestoides* L.
Rhagium inqusitor L.	*Criocephalus rusticus* L,
Acanthocinus aedilis L.	*Asemum striatum* L

Fires in spruce stands usually spread out on more slowly than in pine forests. The intensity of the fire is rather low but its destructive consequences are more intense. After the fire, the process of stand die-back occurs usually rather rapidly.

There is no great difference in the content of pest species based on the time of the fire and geographic zoning. Dominant pest species in burned areas of spruce forests include long horn beetles of g. *Monochamus*, bark beetles *Ips typographus* L., *Pityogenes chalcographus L., Ips duplicatus Schalb., Poligraphus poligraphus L.* In spring (May) in burned areas, *Tetropium castaneum L. (Cerambicidae)* and *Urocerus gigas L. (Siricidae)* usually occur. Trees with partly burned and dry stems or cracks are usually attacked by long horn beetle *Acanthocinus aedilis L.* and bark beetles *Hylurgops palliatus Gyll., Trypodendron lineatum Ol.* (Vorontzov 1978).

Burned areas in broad-leaved forests can also serve as a source of pest infestation and predispose to their population increasing in neighboring stands. These areas are characterized by some dominant pest species (Table 3). All these complexes of the pests usually inhabit burned areas during 2 to 4 years after the fire.

After pest invasion of burned areas, the reverse process of their immigration and spreading in surrounding territories usually occurs, and local outbreak areas of bark-beetles in coniferous forests and buprestids in broad-leaved forests are formed. In this case, the burned area could be used as a so-called trapping area with the purpose of entirely eliminating pests to prevent their spreading.

Table 3. Dominant pest species in burned areas of broad-leaved forests in the middle part of the forest zone in Russia (Vorontzov 1978)

Damaged tree species	Dominant species Stem	Crown
Aspen, poplar	*Xylotrechus rusticus* L.	*Agrilus viridis* L., *A.subauratus* Gebl.
Birch	*Xylotrechus rusticus* L *Tremex fuscicornis* Fr. *Scolytus ratzeburgi* Jans. *Trypodendron signatum* F.	*Agrilus viridis* L
Oak	*Plagianotus arcuatus* L. *P. detritus* L.	*Agrilus hastulifer* Ratz., *A.angustulus* Tll.

1.2 Wind

Wind-impact is a serious factor causing phytosanitary risks. One of the main destructive results of storm winds is massive windfall – huge amounts of windbroken and windfallen trees. There are many examples of devastating consequences of storm winds in the history of forestry in Europe (Butovirsch 1971; Kataev 1977; Worrel 1983; Coutts and Gace 1995; Quine et al. 1995; Wermelinger et al. 1995; Drouineau et al. 2000). An incomplete list of most harmful storms includes Germany, June 1946; Germany and Czechoslovakia, December 1954 and January 1955; Carpathian Mountains, December 1957; Sweden, 1966–67; Latvia, October 1967; Southern Norway, November 1969 as well as 1975 and 1976; and the central part of Russia, June, 1998. The latest exceptionally destructive storm in Europe in December 1999 had severe consequences on forestry in France, Germany, Switzerland, Spain, Denmark and Austria (Drouineau et al. 2000). Usually mountain forests, old-growth and over-mature forests, tree species with shallow root system, located on thin soils, along cut area edges and on swamps are the most damaged.

Infections of trees by stem, butt and root rots predispose them to windfall or wind breakage. Table 4 contains a list of the most common fungi pathogen species typical of forest zones in Northern and Central Europe, which are associated with forest windfall and wind breakage.

The size of massive windthrown area can reach hundreds and thousands of hectars and its exploration and timely removal are very problematic. The main phytosanitary risk in such conditions is the outbreak of stem pests.

The most harmful species in the complex of bark beetles on spruce damaged by storms is *Ips typographus* L., which is usually accompanied by *Pityogenes chalcographus L., Poligraphus poligraphus L., Trypodendron lineatum Ol.* and long-horn beetles *Tetropium castaneum L., Monohamus sutor L.* In pine stands, broken and fallen trees depending on the time of injury are usually attacked by bark beetles *Tomicus piniperda L.* and *T. minor Hart.* in shadow habitats and by *Ips sexdentatus Boern.* and *I .acuminatus Eich.* in lightening habitats. Common species of long-horn beetles on pine are *Acanthocinus aedilis L., Monohamus galloprovincialis Oliv., Rhagium inquisitor L.*, and buprestid *Phaenops cyanea F.* (Vorontzov 1978).

Bark beetles can attack windbroken and windfallen trees as well as trees with partially injured crown and root systems. They can also attack stored barked wood and stumps. Windbroken trees are attacked by insects more actively and rapidly than windfallen trees. This could be explained by the fact that root systems of fallen trees keep in partial connection with soil and can resist

Table 4. Most common fungi pathogen species associated with windfall and wind breakage.

Scientific names	Injured trees
Root rots	
Heterobasidion annosum (Fr.)Bref.	coniferous
Armillaria mellea (Vahl.:fr.) P.Kumm	coniferous and broad-leaved
Stem rots of coniferous species	
Phellinus pini (Thore: Fr.) Pil.	pine
Ph. chrysoloma (Fr.)Donk.	spruce, pine(more rarely)
Onnia triqueter Lentz.:Fr.	coniferous (mostly spruce)
Stem rots of broad-leaved species	
Phellinus igniarius (L.:Fr.)	birch, willow, aspen and others
Ph.tremulae (Bond.)Bond.et Borisov in Bond.	aspen
Laetiporus sulphureus (Bull.) Bond. et Sing.	oak, willow, poplar, lime and others
Phellinus robustus (Karst.) Bond. et Galz.	oak
Polyporus squamosus Huds.: Fr.	oak, elm, lime, maple, poplar and others
Fomes fomentarius (L.) Gill.	birch, lime, ash, beech and others

insect attacks for some time (Vorontzov 1978). While exploring the damaged areas, there is no reason for keeping separate standing trees or group of trees because they can serve as intermediate units and reservations for stem pests' further invasions to neighboring stands.

1.3 Snowfall

Snow and wind have similar impacts on forests, e.g. abundant snow can cause trees falling out. However, there is a considerable difference in that snowfall and snow breakage usually occur in rather young stands, where they can cause stem pest outbreaks. As an environment for pest invasion, this type of trees will correspond with winter windfall and wind breakage. The most harmful snow impact can result in snow avalanches, where pest outbreaks usually occur more in aged stands.

1.4 Water regime disturbances

Water regime disturbances can result from natural disasters. This paper focuses on drought problems. Droughts can result in upper soil layers drying, ground water level decrease, and even in the death of acting parts of root systems, all of which reduce the tree is water and nutrient supplies. Finally, it causes losses of height and diameter increment which can be considered as an integral index of stand condition deterioration. Droughts cause losses in oleoresin and gum productivity and change its composition as well as reduce the pressure in resin vessels.

Spruce stands are most sensitive to droughts because of their well-developed shallow 'superficial' root system. Most examples of stem pest outbreaks in weakened spruce stands with their subsequent death are connected with droughts. Obvious dying usually occurs during the year after a heavy drought or the year after the next one. Two dry years in succession represent a particular danger for spruce stands. Growing on heavy soils, spruce stands become attacked by stem pests and die especially in micro depressions where its root system is most shallow. At the same time, on light soils after a dry period spruce usually die on high relief elements where the root system is deeper, but the ground water is also very deep (Maslov 1972; Kataev 1977; Vorontzov 1978).

2. Moscow Region forests and phytosanitary risks in 1998–2000

The Moscow Region has been chosen by the author as an example to illustrate the threats and phytosanitary risks that can arise as a result of the impact of a number of coinciding factors. During the relatively short time period of 1998–2000, regional forests have been subjected to the influence of windstorm, drought, fires, spring frosts and outbreak of spruce bark beetle.

2.1 Moscow Region forests

Moscow Region forests are unique in nature. They are located closely to the city of Moscow – the capital of Russia – with the population of about 10 million inhabitants. Moscow Region is characterized by considerable forested area covering about 40% of the total area of the region. The total area of forestlands is 1.54 million hectares, including forest area of 1.0973 million hectares. Forest plantations cover 230.4 thousand hectares. Total standing volume is 293.4 million m^3, including 158.9 million m^3 of coniferous (pine – 71.94, spruce – 86.51, others – 0.42). The total amount of annual increment is 5.5 million m^3. Species composition includes coniferous (pine, spruce) which dominate, hardleaved and softleaved (oak, ash, maple, elm, birch, aspen, alder, lime, poplar, willow and others). A considerable part of forests constitutes of premature, mature and overmature stands. Large areas comprise forests of the so-called ‘first group’ which have water protective, protective and sanitary functions, including National parks and reserves.

2.2 Windstorm, drought, fires, spring frosts and outbreak of spruce bark beetle

In June 1998, windstorm struck the territory of the Moscow Region, causing considerable damage to forest stands. The area of forests affected by the storm is estimated to be more than 9,400 hectares and volume of windthrown wood is 1.792 million cubic m^3. The most damaged forest areas are located in northern and northwestern parts of the region.

The summer of 1999 was characterized by a heavy drought. The hot and dry weather led to a reducing ground water level. Firstly it affected the growing conditions of pine and birch stands growing in relief depressions. As a result, current mortality of pine and birch increased to 10–15%. Dry summer caused an overall weakness in spruce stands. According to the report on forest pathology monitoring, the average number of weakened and heavily weakened categories of spruce trees increased to 10%.

In 1999, forest fires occured as a result of the exceptionally hot weather. According data of the Moscow Forest Protection and Monitoring Center, during the last five years (Figure 1), there have been two sharp increases in forest fire areas observed in similar weather conditions (in 1996 and 1999). After sustained surface and ground fires, which are most characteristic of the region, stand weakening and dieback are usually reported during further 3 or 4 years. In the very hot weather conditions of 1999, stands lost their biological resistance in only 2–3 months.

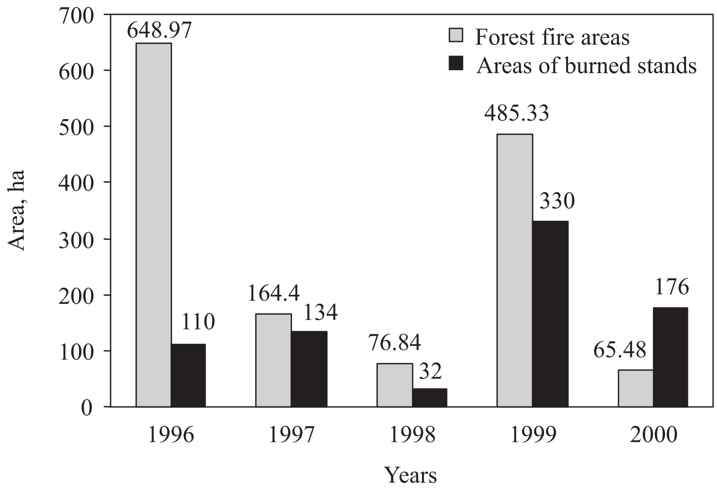

Figure 1. Dynamics of forest fire areas and areas of burned stands 1996–2000.

In 2000, numerous outbreak areas of *Ips typographus* L. were observed in spruce stands in Moscow Region. The Moscow Forest Protection and Monitoring Center reported more than 6000 hectares infested areas and considered the ongoing process as a regional outbreak of the pest. The reason of this process is the influence of two factors – the consequences of the storm of 1998 and the summer drought of 1999 – that provide favorable conditions for the development of *I. typographus'*. Huge volumes of windthrown trees which were explored only partly or could not be explored at all have increased the feeding basis of the pests. Also the hot and dry summer of 1999 was favorable for the successive development of young generation. The drought of 1999 created favorable conditions for the active development of annosum root rot and caused a total weakening of aged spruce trees. Probably, among additional causes provoking the spruce weakening process were also the number of rather dry seasons since 1994 and the abnormally cold spring weather with frosts in 1999 and 2000.

Additional reasons for spruce forest weakening could be considered as current forestry management system shortcomings, in particular selective sanitation cuts and renovation cuts led to critical losses in stand density. Another reasons are uncontrolled melioration and accumulation of old-growth spruce stands in widely spread system of strictly protected areas with limited forest exploration regime of.

As a consequence of all listed disturbances, the areas of dead forest in the region were 6169 hectares at the end of the year 2000 (Figure 2) including 6114 hectares of coniferous stands (data of the Moscow Forest Protection and Monitoring Center). 83.9% of these areas are stands dead as a result of the outbreak of the complex of stem pests. In comparison with the previous year, this index increased to 77%. The dominant species in the complex is *Ips typographus* L.

2.3 Biology and ecology of the spruce bark beetle

The spruce bark beetle, *Ips typographus* L. (Coleoptera, Scolytidae) is a well-known, widely spread and the most destructive bark beetle in the coniferous forests of Eurasia. Norway spruce, *Picea abietis* (L.)Karst., is its principal host tree. The biology and life-cycle of the spruce bark beetle are well known. Adult beetles fly usually in the middle of May (late April

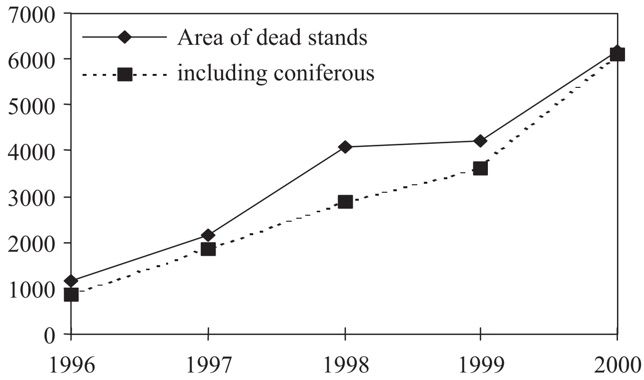

Figure 2. Area (ha) of dead stands (1996–2000).

to late May depending on the geographical region). A polygamous male attacks a tree or a log attracting both males and females by aggregating pheromone. Its family can include up to 5 females. Each of them bores an individual egg gallery in the phloem and deposits eggs in special cameras on its walls. Hatched larvae feed on phloem and finally pupate at the end of larvae gallery. Young beetles feed beneath the bark for a limited time and then bore exit holes and fly out. The whole development lasts about 60 to 70 days. Most adult beetles hibernate in the litter at the base of the tree and about 10–15% hibernate in the bark of the host tree. Depending on geographical zone and weather conditions, 1–2 (even 3 in the South) generations can be produced each year. If the brooding tree is overpopulated, parent beetles may leave initial tree and produce so-called sister broods in other trees in June or July. Sister broods are usually less numerous. Because of the ability to produce two general and some sister generations, the spruce bark beetle can multiply the abundance within one season.

This species is a typical inhabitant of spruce forests. At low population level, it usually occurs on single weakened (by e.g. rot), dying, dead or windthrown trees and slash, which in this case, serve as a reserves where low abundant bark beetle populations survive. But *I. typographus* outbreaks turn the species to aggressive behavior and to active tree killing. In Europe, in particular, outbreaks may lead to the destruction of hundreds of thousands of hectares of spruce forests. Repeated outbreaks of the pest have been reported in the history of forestry of numerous countries in Central Europe since the 17th century (Kataev 1977; Christiansen and Bakke 1988). Epidemic problems can last 2–3 years and up to 30 or even 50 years and can even lead to the reduction of gross national product (GNP). In the 1970s, the *I. typographus* epidemic in Norway, the death of 5 million m^3 of spruce timber supposedly led to a reduction of GNP by some 500 million Norwegian kroner (Worrel 1983). Outbreaks of spruce bark beetle have occurred at irregular intervals. They are usually associated with environmental disturbances (droughts, storms, defoliation by non-moth) or management neglect.

2.4 Population characteristics of the spruce bark beetle and possible consequences of the outbreak development

In 1999, *I. typographus* produced two generations in conditions of Moscow Region. In 2000, most part of the populations produced one generation and only 10% of them produced two.

About 30% of populations gave sister broods. The main population characteristics of the pest are listed below:

- Occurrence – 82.4%
- Sex ratio – 1.9
- Density – 1.87 families per sq. dm (ranged from 1.0 at the lower and upper parts of the stem, to 2.8 at the middle part)
- Ecological density of parent generation – 5.42 beetles per sq. dm
- Length of the egg gallery – 5.5 cm (ranged from 1.5 to 8.2)
- Number of eggs per 1 cm of egg gallery – 7.1
- Female fertility – 39.3
- Ecological density of pupae – 17.4 pupae per sq. dm
- Average of exit holes – 5.8 holes per sq. dm
- Regeneration coefficient – 1.07

Comparison of population characteristics of the pest with data on spruce stand status and conditions makes it possible to make preliminary conclusion that the year 2000 was the first year of culmination in outbreak development. It is possible to predict further population growth but with lowering tempo and the formation of migration outbreak spots around or in the neighborhood of acting outbreak areas.

The data of forest health monitoring show that locations of *I. typographus* outbreak territories are associated with spruce stands at the age of 60 and more. So, first of all, middle-aged, mature and overmature spruce single-species stands or forests with spruce dominance will be subjected to pest infestation. In accordance with the forest account, the total area of the stands of this type in the Moscow Region is 239 thousand hectares. The analysis of the structure, content and location of these areas from the phytosanitary point of view shows that the formation of stem pest outbreak areas can be predicted on the territory of about 44 thousand hectares. Besides that further pest spreading is predicted in the neighboring Moscow Region areas.

Thus, in the year 2001, we are facing the real threat of dying spruce stands at the age of 50–60 years and more in the Moscow Region and in the considerable part of European territory of Russia as a result of spruce bark beetle activity. The implementation of planned protective measures will make it possible to reduce the scale of forest dying. At the same time, it is important to underline that it is practically impossible to interrupt the course of the outbreak. In the case of favorable weather conditions the areas can widely spread on the territory of European part of Russia during the next two years.

3. Strategy of phytosanitary risks reduction in spruce bark beetle outbreak areas

In the intensively managed spruce forests of Central Europe, the normal practice for dealing with *I. typographus* is connected with silvicultural methods to maintain stand viability as well as sanitation methods to eliminate infested trees and logging debris. In the past, de-barking all logs in the forest prevented the infestation of newly harvested timber. In some European countries, bake beetles populations are also managed by the trap-tree method with 5 trap trees usually felled for each infested spruce. Trap trees are then removed and treated after they become infested with spruce beetles (Berryman 1986).

In the conditions of the Moscow Region, the system of urgent forest protection measures should be targeted to elimination and localization of spruce bark beetle outbreaks. In the situation of outbreak culmination, it should basically consist of three parts:

1) well-developed forest health monitoring in spruce stands;
2) sanitation and protective measures of different types – clear and selective sanitary cuts, removal of infested trees and debris, using trap-tree and pheromone trap methodology and
3) preventive work.

In particular, *urgent protective measures* can involve the following:

- clear sanitation cuts in areas with the degree of stand injury more than 30%; using trap-trees, pheromones and strictly controlled insecticide treatment;
- limitation of main cuts instead of cuts in injured stands;
- sanitation cuts with removal of newly infested trees;
- obligatory cuts of infested trees followed by their immediate debarking or removal before the emergence of young beetles generation during spring and at the beginning of summer (May–June);
- use of pheromone traps for population monitoring and as an additional tool to reduce the number of beetles;
- in some cases, near large infested areas, harvesting weakened spruce trees, using them as trap-trees and placing on them pheromone dispensers to increase tree attractiveness and catch ability with further debarking and removal of those trees;
- removal of forest debris left after the storm all over the damaged areas;
- assistance to natural regeneration or creation of forest plantations.

Forest protection system on stabilization of phytosanitary situation in the Moscow Region should be agreed and coordinated with forestry administration of territories neighboring spruce bark-beetle outbreak areas.

With the aim of *preventing I. typographus* outbreak and as a factor of improving of spruce stands resistance it is recommended to review forest management system in the spruce stands of the Moscow Region. The main objectives of the review should be the improvement of biological sustainability of spruce stands and the improvement and harmonization of its age structure. It will require a review of the existing system of thinnings in spruce stands, activities on assistance to natural regeneration and others. Preventive measures may include:

- increasing stability of forest stands by thinning which improves wind firmness of trees with well-developed root systems;
- implementing thinning preferably at an early age of stands;
- removing harvested timber from forest areas in time to protect logs from *I. typographus* colonization;
- avoiding Norway spruce growing in lowlands and drought-prone areas until old age. Overaged unstable stands represent a potential danger to neighboring forests serving as breeding sites for *I. typographus* beetles;
- introducing other age groups or tree species which will reduce habitat continuity, and may play a preventive role against *I. typographus* proliferation;
- creating stand edges made with regard to maximum stability, taking advantage of natural windbreaks and well-rooted trees, as *I. typographus* frequently attacks the wind-affected and sun-exposed trees.

Conclusion

It is obvious that the implementation of the whole system of measures against *I. typographus* will require additional expenses and resources. ‘Bark-beetle danger’ as a danger of specific forest fire will require obligatory fire suppression. Therefore, the importance of the problem cannot be underestimated.

Acknowledgements

I would like to thank Prof. E. Mozolevskaya and Dr. E. Sokolova (Moscow State Forest University), Dr. M. Kobelkov (All-Russian Forest Protection Center) and staff of the Division of Forest Protection (Ministry of Natural Resources of the Russian Federation) for their help and consultation.

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Genetic Risks in Forestry

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Abstract

This paper raises two major questions: (1) Do forestry operations modify genetic processes that would increase exposures of tree populations to future losses or hazards? (2) Do genetic activities per se (selection, tree improvement, biotechnology) lead to increase susceptibility to risks? A general frame for the analysis of genetic risks is first presented by outlining the effects of different genetic attributes or processes on the exposure or tolerance to risks. Then a review of the various risks generated by species of population transfer, silvicultural and management regimes, tree breeding activities and biotechnology is given. Main concerns in these activities are the potential erosion of genetic diversity, the strong modifications of the distribution of genetic diversity due to artificial seed flow, the disruption of genetic processes maintaining diversity, and the potential release of genetically modified trees. To cope with these concerns most countries and institutions have adopted conservative measures as dynamic conservation programmes of genetic resources.

Keywords: genetic diversity, breeding, seed transfer, risks

1. Introduction

By raising the question of genetic risks in forestry, we are faced with two major issues:

1. Do forestry operations currently in practice or natural acting processes modify genetic processes that would increases exposures of tree populations to future losses or hazards?
2. Do genetic activities per se (selection, tree improvement, biotechnology) lead to increase susceptibility to risks?

The first question originates naturally from the observation that silvicultural operations or natural processes involved in the dynamics and evolution of managed or unmanaged forest

Michel Arbez, Yves Birot and Jean-Michel Carnus (eds.)
Risk Management and Sustainable Forestry
EFI Proceedings No. 45, 2002

stands operate on gene pools. Regeneration methods, thinnings, logging, plantations contribute to modify genetic attributes of populations as population size, gene flow, and allele frequencies. Hence genetic indicators of sustainability have been recommended in some countries for risk assessments (Namkoong et al. 1996). The second question emerges from the tremendous progress made in the field of biotechnology and selection methods and the concerns raised by their dissemination in operational forestry.

Risks are understood in this contribution as expected losses in sustainability or economic return due to these activities. In the two issues that were raised, natural or human mediated genetic processes are the key clues for the answers. In most cases risks are unknown, and only exposures to potential hazards can be indicated. Uncertainties in risk assessments are due to either the absence of experimental results or the lack of knowledge on the impact of genetic processes. This is why I will first discuss the major uncertainties and subsequently address the various exposures to genetic risks in forestry.

2. An illustration of exposure and tolerance to genetic risks in forestry

In its simplest formulation, a forestry landscape can be subdivided in two major components: a set of genotypes and a set of environmental conditions. This is the formal subdivision of the genetic and environmental entities used in genetics. Both are dynamic and non-static genetic processes as mutation, human or natural mediated migration and drift contribute to the evolution of the genetic entities, whereas ecological changes and human interferences induce variations of the environmental factors. A further important feature is that the two entities do not evolve independently. Environmental changes impose selection pressures that induce shifts in the allelic frequencies. As a result, at a certain point in time, the two components may match in such a way that the set of genes available in the populations ensures the absence of risks for sustainability and economic return. This is exactly what is predicted in population genetics by the shifting balance theory of Wright (1977) suggesting that given combinations of genes will confer to a population a fitness peak within certain environmental conditions. One cannot exclude that there might be a multiplicity of optimal peaks (combination of genes). We will use this general frame to illustrate the genetic risks taken in forestry operations (Figure 1A), by quantifying the exposure to risks as the distance to the peak. Let us consider in its most simple form that sustainability, economic return are controlled by only two genes in the genomes and let us consider that the optimal combinations of allele frequencies (the peaks) conferring minimum risks are known. We can represent our population on a two dimensional graph with the dimensions corresponding to the two genes. Let us assume that the peak (absence of risk) is located at the origin of the graph and the population under consideration is located at a certain distance from the peak. This schematic representation illustrates how exposure can actually be modified.

Any forestry operations, genetic operations in tree improvement, or environmental changes can be illustrated as a ‘walks’ going to or further apart from the peak. There are several genetic attributes or mechanisms that have to be considered and that illustrate the various alternatives that would limit or increase exposure to risks.

Genetic diversity can be considered as a *buffer zone,* within which exposure to risks is limited to acceptable levels (*tolerance to risks*). It can graphically be represented by the *circle* of acceptable risks on Figure 1A. The higher the diversity available in the population, the higher the tolerance to risk (Figure 1C, where tolerance is equal to exposure). Higher diversity can also be illustrated by more dimensions on the graph and more alternative walks will be possible to attain the peak.

Genetic adaptedness of the population can be considered as the *proximity* (to the peak on Figure 1) of the genetic make up of the populations to the peak (Gregorius 1995). Strictly speaking, if adaptedness of the population is high, genetic diversity may be less needed. For example, short-term artificial selection programs aim at producing genotypes that would be as close as possible to the peak and consequently may tolerate reduction of diversity (Figure 1B, where exposure is lower than tolerance).

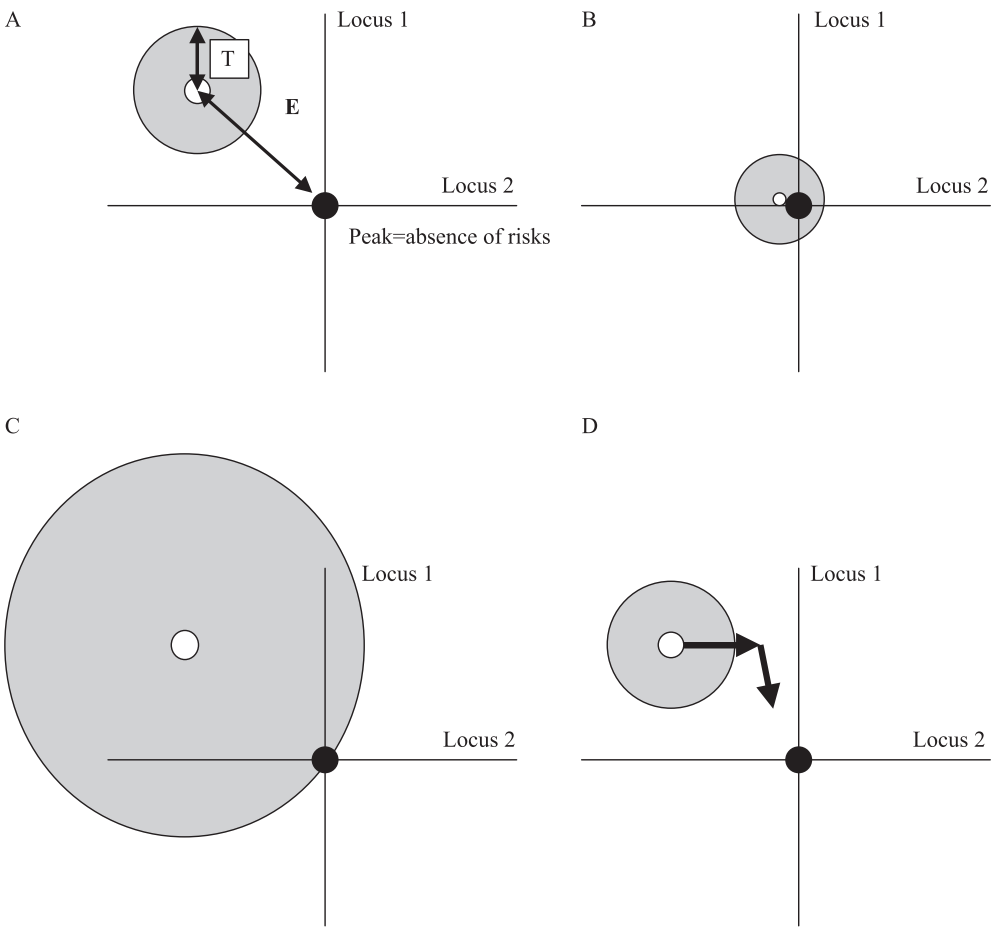

Figure 1. A graphical representation of genetic risks and exposure to risks.

A. The peak where limited risk is attained is at the center of the graph. The distance of a given population to the center indicates the exposure to risk (E). The axis represent the two genes controlling sustainability or economic return. The hatched circle around the population represents the level of genetic diversity that resides within the population, the tolerance to risk (T).

B. An example of a population of a high adaptedness that can tolerate a low diversity to withstand the risk.

C. An example of population that has limited exposure to risk as a consequence of a larger diversity.

D. An illustration of genetic process (adaptation or selection) that will reduce exposure to risks.

Genetic processes as gene flow, natural or artificial selection, that would improve adaptation can be illustrated as *trajectories* towards reduced exposure to risks (Figure 1D). Natural evolutionary processes are likely to proceed gradually by small changes. Unless the initial start is far apart for the peak, it is likely that in the long run, natural processes will end up within the surface of genetic diversity. However, the 'walk' may take a long time. Artificial human mediated operations can actually proceed by long distance 'jumps'. Long distance jumps may also increase exposure. However, the procedure may be much more rapid and as such modifications of the pathway are more flexible, and a wrong move can rapidly be repaired. An example may be given by artificial selection that will produce new combination of genes, not likely to occur under current natural conditions.

Genetic processes as drift, foundation effects, bottlenecks may be considered as *trajectories of unpredictable direction.* Because forest trees have usually large population sizes under natural conditions (except disseminated species), drift is not likely to occur. However, it can be associated to the production of reproductive material from tree improvement programs (synthetic or multiclonal varieties). Foundation effects may also occur when exotic species are introduced and when a limited amount of seed material was collected.

Genetic processes as inbreeding, long distance seed transfer may also be illustrated as *trajectories* on Figure 1 but that would actually move away from the peak. Since most forest trees have a high genetic load, they are usually extremely sensitive to inbreeding depression (Williams and Savolainen 1996). However, under natural regeneration conditions, inbred seedlings are rapidly eliminated due to strong natural selection. However, inbreeding is to be considered in artificial population of low population size manipulated in selection programmes.

3. Major questions and uncertainties

3.1 How much genetic diversity is needed to limit exposure?

Genetic diversity has been quite often advocated as a major means to limit exposure to risks, especially because forest trees harbour important levels of diversity (Hamrick et al. 1992). As quantitative genetics predicts and as was verified in most tree improvement programs, there is a linear relationship between the response of a population in the next generation and the level of the genetic diversity in the previous generation (Falconer and Mackay 1996). There is, however, a number of uncertainties concerning diversity that limits its current application as indicator of tolerance to risk.

First of all, genetic diversity is, for the time being, measured at anonymous regions of the genomes. Most molecular methods employed so far monitor polymorphism of markers of unknown function or roles. As a result, there is no evidence that support a causal relationship between molecular diversity and exposure to risks. Assessments of diversity for targeted areas in the genomes involved in tree adaptation are not yet operational, because these regions are not yet localized. The only existing alternative is to evaluate diversity of phenotypic traits involved in tree adaptation in traditional field testing or common garden experiments, however, these experiments are too expensive and are therefore limited to a few populations.

Even though we would be able to assess the level of diversity responsible for tree adaptation, there remains the major question of how much diversity is needed to limit exposure to a certain level. There is no clear answer to this question. In natural populations, the rule of thumb is to maintain the extant levels of diversity, implicitly assuming that evolutionary history has proven sustainability. One may as well consider that diversity is the legacy of the life history traits that generate polymorphism (gene flow, population size, outcrossing) and that extant levels are not necessarily needed to ensure sustainability. In artificial populations (varieties originating from tree improvement programs), theoretical models have been developed to provide information on the genetic composition of reproductive material.

3.2 How fast do tree populations evolve?

This is a major issue in evolutionary biology of forest trees, and especially in the frame of the predicted global changes. How fast can tree populations respond to environmental change and modify their trajectories towards the moving peaks of Figure1? Theoretical speculations advocate that the higher the diversity in the population, the more rapid the adaptation to the new conditions (Barton and Turelli 1989). However there is indirect experimental evidence coming from introduced species that forest trees may evolved much more rapidly than suggested by their long generation periods. Many tree species were introduced in Europe in the last two centuries. In a few species (Douglas fir or Northern red oak), comparative provenance tests were established comprising populations from the natural range and populations collected on introduced stands. Surprisingly, introduced populations deviated already significantly from the natural populations, indicating that significant genetic differentiation has already occurred in less than ten generations (Skroppa and Kohmann 1997; Daubree and Kremer 1993). As shown most generally in other exotics, there is rapid development of land races within the introduced populations (Zobel et al. 1987). Besides the evolution rate, trees have also developed powerful mechanisms to face environmental changes and to rapidly respond to those changes. The succession of glacial and interglacial periods during the quaternary era has undoubtedly favoured selection for species and populations that adapted to climatic changes by colonising new areas (Dynesius and Jansson 2000). Therefore many extant forest species have developed various sophisticated dispersal mechanisms as large distance pollen flow, efficient colonisation dynamics and hybridisation with other related species. These mechanisms are likely to be involved in the response of trees to ongoing global changes.

4. Exposures to risks induced by forestry operations

4.1 Modifications of gene pools

During the past century, a large number of species were introduced in Europe mainly from North America. In addition, native European species were transferred to new environments with the rapid development of reforestation. For example, in France the area of forest land has increased from 10 million to 15 million ha between 1900 and 2000, among which 70% were due to artificial plantations (Ministère de l’Agriculture et de la pêche 2000). These practices resulted in important changes in the genetic composition of autochthonous European forests. The genetic structures that were progressively established by natural processes during previous historical times have been in most cases modified by the extension of plantations and the introduction of new gene pools.

4.1.1 Introduction of new species

While popular in the past, introduction of exotic species has been limited more recently. In France, more than 150 exotic species were introduced in comparative tests (Arbez 1987;

Arbez and Lacaze 1998). Only a few have been widely used in commercial plantations for a wider use (*Abies nordmanniana, Cedrus atlantica, Picea sitchensis, Pinus nigra* subsp. *nigra, Pseudotsuga menziesii, Quercus rubra*). There were of course benefits gained from the introduction. The European forest flora was much diverse at the end of the tertiary era, and numerous species disappeared during the successive glacial periods. There is no doubt that the introduction of new species has restored partly the species richness. But besides benefits, there were and are still risks associated to the transfer.

Risks to the introduced species

Success stories about species transfer are well known (Zobel et al. 1987). Wordly dissemination of Monterey pine, eucalyptus, poplars and tropical pines illustrate the important adaptive potential of some of the exotic species. However, success stories are more limited than introduction failures. The prediction of the adaptability of a species on a new continent based on the conditions of its indigenous range cannot always be predicted (Zobel et al. 1987). Therefore introducing a new species is always associated to a potential risk of failure of the plantation. The failure can actually be delayed over several decades, after a preliminary quite successful introduction. For example, *Picea sitchensis* has been widely and successfully introduced in the western part of France during the second half of the past century, but older stands suffer today from sever dieback. Another illustration is given by *Pinus strobus* that has been severely attacked by *Cronartium ribicola* to the extent that the trees do not survive.

Finally, they may be risks to the introduced species generated by the foundation effect or bottlenecks associated to the introduction. If the seed lots collected for the introduction originated from a limited number of trees, allele frequencies of genes of interest may have deviated from the original gene pool and resulted in failure of introduction. This situation is rather unlikely to occur as introduction of a given species is usually achieved in several successive campaigns of seed harvests.

Risks to the indigenous species

Introgression. If the introduced species has a related indigenous species in the introduced area, and if the two are interfertile, alien genes may be disseminated in the indigenous species. Introgression may not be harmful especially if the recipient species occupies large areas and limiting therefore the spread of the alien genes. However, the risk of introducing non-desirable traits in an authochotonous gene pool may be quite significant if the recipient species has low population sizes. This is the case for the European black poplar (*Populus nigra*), which can intercross with the widely planted hybrids (either *P. deltoides X P. nigra*, or *P. deltoides X P. trichocarpa*) (Cagelli and Lefevre 1995). A means for preventing *P. nigra* resources from introgression is to implement a conservation strategy of native material as is actually recommended by the EUFORGEN network of *P. nigra* (Lefevre et al. 1998).

Demographic invasion and substitution with native species. The introduced species may be so aggressive that it challenges locally the maintenance of native species. *Quercus rubra*, a native species of North America, has been widely planted in Southwestern France. In several cases, adjacent stands of indigenous *Q. robur* are progressively being invaded by naturally colonisation of *Q. rubra*, due to a more aggressive regeneration dynamic of *Q. rubra* (personal observations). There are also examples where the introduced species may be more demanding in terms of water or nutrient resources and subsequently limit the regeneration and maintenance of the native species. An extreme case is the example of pines introduced in South Africa (*Pinus halepensis, P. pinaster* and *P. radiata*) that are competing indigenous tree species. Releasing insects feeding on seeds of the introduced species has planned biological control of the demographic invasions of the introduced pines (personal communication, Alain Roques).

Introduction of diseases to native species. Introducing a new species can lead to the introduction of pests and insects that will be later on transmitted to native species. This has recently been observed for *Cedrus atlantica*, a species that was introduced in the late 19th century in France. *Megastigmus schmititschecki* is a seed predator insect in this species. This insect has recently been infesting also seed of *Abies alba*, a native species of France (personal communication, Marianne Auger). Reciprocally *Megastigmus suspectus* that was specific to *Abies alba* has also been reported to infest seed of *Cedrus atlantica*.

4.1.2 Seed transfer in indigenous species

Plantations have been widely used to renew forest stands, especially in countries and areas where natural regeneration is difficult to obtain. Important seed transfers have been reported in the past, especially in oaks. Kleinschmit (1993) reported long distance transfers of acorns from South-eastern Europe to Germany in the 19th century, and introduction of oak stands in Sweden originating from polish stands. Since plantations increased in the last fifty years, regulations and recommendations have been applied throughout Europe to prevent the use of planting stock of low genetic quality (Terrasson 1993). For some species the genetic composition of extant forests is likely to resemble a mosaic of genotypes that has progressively blurred the initial structure inherited from the evolutionary history of the species. Since there is a trend now towards using natural regeneration, there are of course concerns to use introduced stands as sources of seed for the next coming generations. The consequences of seed transfer therefore extent to much longer time periods then the current generation.

Risk to the species as a whole: reduction of the genetic diversity
In the regulations concerning the collection and use of forest reproductive material precautions have been taken to maintain a large diversity within species by selecting a high number of seed stands and recommending that seeds of several seed stands are mixed within a provenance region, thus maintaining diversity within the seed lots, or collected from a large number of trees. There are no data available on how the recommendations are finally implemented at an operational level. Neither are there statistics on how many seed stands are actually harvested annually. Information taken from here and there has suggested that only a limited number of seed stands are actually collected each year, and that these are quite often the same from year to year. If this sparsely information is confirmed by available statistics, there might be concerns about a progressive erosion of the genetic diversity at the species level. At this stage, it would be worthwhile to make a survey on how seeds for selected seed stands have been disseminated throughout the different European countries in order to assess whether the risk of genetic erosion at the species level does really exist.

Risk to the newly established plantations: misadaptation
Introduction of planting stock from another part of the natural distribution may result in the misadaptation of the newly introduced stand. This is likely to occur when seed transfer has occurred over long distances. Stories of failure of plantations due to the wrong use of provenances have been reported in a few demonstrative examples. In the late 1940s vast forest fires destroyed important areas of maritime pine forest in the Southwest of France. As there was an important shortage of seed to replant the area, seeds were imported from Spain and Portugal in the 1950s. In 1985, an unusual severe frost occurred that destroyed about 50 000 ha of maritime pine forest. It was shown later on with the help of gene markers that the forests that were destroyed by the frost originated from the Portuguese seed sources. Other examples were reported for beech where transfer from Southeastern Europe to France have

resulted in failures (Teissier Du Cros et al. 1997). However, success stories were also reported, even concerning long-distance transfers, as for example the use of Polish resources of *Pinus sylvestris* in France (Bastien and Fernandez 1993) or Ukranian and Rumanian origins of *Picea abies* recommended in France (Van de Sype 1994). As for species introduction, there is no possibility to predict the risk, expect if there is relevant information available about the patterns of intraspecific variation based on provenance tests that are locally established. Information from provenance tests established in other areas may not be free of genotype-environment interactions.

Risk to the local resources: introgression
Introgression of new genes in the local populations following the transfer of material is potentially a risk. However, in the case of misadaptation of the introduced populations, there are only minor chances that the genes would disseminate in the local neighbouring stands of the same species.

4.2 Changes in silvicultural and management regimes

Exposures to genetic risks due to silvicultural regimes and treatments have been investigated only recently (Savolainen and Kärkkäinen 1992) The investigations quite often limit their objectives to the comparative estimation of levels of diversity under different silvicutural treatments (Ratman et al. 2000; Glaubitz et al. 2000). However, response of levels of diversity are usually delayed after several generations following human interference. More interesting is therefore the impacts of silvicultural regimes on processes contributing to genetic diversity. There is an ongoing body of literature looking at silvicultural impacts on mating system (Murawski et al. 1997), gene flow (Stacy et al. 1996), or inbreeding (El-Kassaby 2000) that is partly summarised here.

4.2.1 Reduction of genetic diversity in uneven- vs even-aged forests

Low census population size, and generation overlapping in comparison to even-aged forests characterize uneven-aged stands. One may therefore expect that genetic diversity may actually decrease as a general response of effective population size under uneven aged structure. This hypothesis has been confronted to a large study conducted in South Germany and Switzerland with *Abies alba* as model species (Konnert and Hussendörfer 1999). Genetic diversity was monitored in 9 uneven-aged and 17 even-aged stands. The genetic diversity was, with only a few exceptions, lower in the uneven-aged than in the even-aged stands. There was also in the case of the uneven-aged stands a tendency towards a higher genetic differentiation between the natural regeneration and the adult stand. If these results are later on confirmed by other observations, one may conclude that the progressive change from irregular high forest (or coppice) to high forest that was recommended in silvicultural practices during the last century actually contributed to maintain higher levels of genetic diversity.

4.2.2 Increase of inbreeding under natural regeneration

Are naturally regenerated forests exposed to the increase of inbreeding? Expectations are that under limited gene flow neighbouring trees are likely to be genetically related by sib-sib relationship. Preferential reproduction among neighbouring trees would therefore contribute to continuously increase levels of inbreeding. Investigations have been conducted in different ways to test this hypothesis. First of all, spatial analysis of genotypic data indicated most generally that there was only a weak spatial genetic structure, e.g. that genetic relationships were only significant when trees were separated by rather small distances (less than 100 meters) and that genetic correlation among neighbouring trees was overall low. These results were found in most out-crossed wind pollinated trees (see Streiff et al. 1988 for a review). These results were further confirmed by low fixation indices. The second part of the evidence comes from studies on inbreeding depression. Out-crossed wind pollinated forest species harbour an important genetic load, and are subjected to important inbreeding depressions (for a review see Williams and Savolainen 1996). Seedlings originating from crosses between relatives are frequently less viable and lower growing; as a result they are eliminated by natural selection when hundreds of seedlings per m^2 are competing for resources and light. An exception to this is in *Abies* species where frequently higher inbreeding levels have been reported, probably because of the overlapping of generations under uneven silvicultural regimes (Fady and Conkle 1993). Results of species having different mating system or dispersion mechanism may be different from those reported so far.

4.2.3 Disruption of gene flow due to fragmentation

As deforestation is going on at large scales in many tropical areas, there are concerns on whether the fragmentation had some impacts on gene flow among populations. There are conflicting results on the effects on fragmentation especially in tropical areas. On the one hand, there are reports that deforestation may interact with pre-existing genetic structures and lead to bottlenecks as gene flow is disrupted among conspecific trees (Aldrich et al. 1998). Other reports emphasized the long distance pollen flow that was detected by paternity analysis; as a result remnant trees following exploitation act as trap trees or even stepping stone for gene flow among remaining patches of trees (Chase et al. 1996). Part of the controversy is due to the variability of the genetic system among tropical species where variation of breeding units ranges from a few hundreds to less than 1 km^2 (Nason and Hamrick 1997; Nason et al. 1998).

A similar situation may occur in European disseminated species in contrast to more social species. Silvicultural treatment favouring a limited number of species may consequently result in an increasing fragmentation of the so called minor species. Preliminary results available on a few disseminated species (Oddou-Muratorio et al. 1999 in *Sorbus torminalis:* Morand et al. 2000 in *Fraxinus excelsior*) suggest that there is slightly less gene flow between populations than in social species.

5. Exposure to risks due to genetic improvement and breeding activities

Genetic improvement programs are run worldwide on fast growing short rotation species. These programmes started in the early 1960s and have entered in several cases into the 3rd or 4th generations. A number of concerns have recurrently been raised about the risks that breeding activities would introduce to plantations of fast growing species (Hubert and Bastien 1999). The central main question is whether risks are increased due to the widely use of material originating form artificial selection. Is the genetic make up of improved varieties modified in such a way that the trees are not able to respond to future threats?

5.1 Reduction of genetic diversity in commercial seed lots

5.1.1 Seed orchards

Studies that compared levels of genetic diversity in material originating from seed orchards with material originating from natural stands most generally concluded on the lack of differences in diversity. (Smizdt and Muona 1985; Savolainen and Yazdani 1991; Stoehr and El Kassaby 1997; Williams et al. 1995). Since neutral markers respond mainly to drift and migration, differences in diversity are not expected between the two gene pools, as long as the number of genitors in the seed orchards are higher than several tens. However, most of the authors monitored diversity by using only expected heterozygosity which is known to vary only according to the most frequent alleles; allelic richness may be more exposed to genetic erosion in seed orchards, and rare alleles are likely to be absent from the commercial seed lots originating from seed orchards.

5.1.2 Clonal varieties

A major concern arising from the use of clonal forestry is the maintenance of stand viability facing a catastrophic loss due a biotic or abiotic agent not anticipated at the time of population establishment. Does the increase of the number of clones used contribute to a decrease of stand viability? These questions have been investigated theoretically by considering simplified situations in which susceptibility to the unknown hazard (Roberds et al. 1990; Bishir and Roberds 1999) is controlled by one single diallelic locus. The results varied according to the frequency of susceptible genotypes and the level of acceptable stand mortality. If the former is higher than the latter, then increasing the number of clones will increase the susceptibility of the multiclonal variety. If the former is low, then increasing the number of clones increases the probability of success, but the increase of probability of success occurs mainly up to 10 genotypes. To cover most of the situations, Roberds and Bishir (1997), and Bishir and Roberds (1999) recommend using clonal mixtures comprising between 30 to 40 genotypes.

5.2 Reduction of genetic variance in breeding populations

The reduction of the number of genotypes in the breeding populations has two negative consequences:

- The decrease in the genetic variance for the traits that the populations are selected for (diversity of target traits) as the result of the selection scheme.
- The increase of inbreeding in the breeding population.

The main concerns are whether genetic gain and diversity can be simultaneously maintained at reasonable levels over successive generations during the whole selection programme, and whether the decrease in heterozygosity due to an increase of inbreeding does not lower the average fitness of the breeding population. As many operational tree breeding programs conducted in fast growing species are entering in their third or even more advanced generations, these questions have raised theoretical and experimental approaches to provide guidelines to geneticists.

Solutions are basically a genetic issue and consider size, structure and management of breeding populations. A consensual solution was adopted among the geneticists which consists in subdividing the breeding population in multiple subpopulations following the pioneer suggestions of Burdon and Namkoong (1983). These options have since been reinforced by theoretical findings (Namkoong et al. 1998) and simulations (King and Jonsson 1993; Mullin and Park 1995). The subdivision in multiple populations will allow to maintain larger genetic variance than a single large population and to contain levels of inbreeding at reasonable levels. The breeders have furthermore developed methods to monitor the evolution of diversity within their breeding population, by assessing the coancestry within the population or measuring effective population sizes (Lindgren et al. 1996). For most traits, the conduction of a breeding programme based on several hundreds of genotypes subdivided in a few subpopulations allows to maintain reasonable genetic gains over at least ten generations. Furthermore conservation strategies implemented for important forest crops can enrich the genetic base of a breeding programme at any moment.

5.3 Risks due to the release of genetically modified (GM) trees in commercial varieties

Gene transfer is currently being tested in most forest species undergoing intensive breeding activities (Radiata pine, Sitka spruce, Norway Spruce, Scots pine, eucalyptus, poplars). In conjunction with other biotechniques as somatic embryogenesis, rapid and important genetic gains can potentially be transferred to forestry. Transgenesis has been considered as an attractive tool for genetically improving trees for pest and insect resistance, wood properties and lignin content (Jouanin 2000). Benefits expected from transgenesis are to increase ecological and economic efficiency of wood production by improving and homogenising target traits, increasing adaptability and resistance to biotic and abiotic stresses and limiting the use of undesirable insecticides and pesticides. For example, poplar, European larch, white spruce have been engineered for a gene encoding and insecticide toxin from the soil bacterium *Bacillus thuringiensis* (Bt). In total, to date there are 117 experimental plantations with GM trees belonging to 24 trees species around the world (http://www.panda.org/resources/publications/forest/gm/) [is this a reference to this Internet page or to the paper GM technology in the forest sector: a scoping study for WWF. By Rachel Asante Owusu, 1999?], but no commercial plantation has been reported. As for annual crops, the potential use of transgenic trees in forestry has raised concerns in the public and among foresters and scientists and has motivated in some cases terrorist actions. Experimental plantations of genetically engineered poplar trees were destroyed in Great Britain (Jouanin 2000), and research facilities were fire bombed (Bradshaw 2001) (http://seattlep-i.nwsource.com/opinion/24580_bradshawop.shtml). These unfortunate events illustrate the sharp controversy existing in the public and the scientific community. There is an urgent need for an in-depth debate on benefits and risks associated to transgenic technology in forestry, considering scientific, economical, social and ethical aspects. This debate is behind the objective of this contribution, that limits its scope to the main genetic questions and risks. These risks are considered from the point of view of traditional quantitative and population genetics and do not address social and ethical issues.

5.3.1 Genetic risks

The main genetic risk concerns the expression of the inserted genes and other genes of the recipient genome. Because insertion of new genes in a genome is a random process that is not location specific, questions are raised as to whether physiological processes are affected by the genomic modifications caused by the transformation. The alteration of physiological processes can also be delayed in time, and influence traits that can be expressed only at later stages of the lifetime of a tree. Traditional forest geneticists are regularly faced with the problem of low juvenile-mature correlation. It is now well know from results accumulated in tree breeding programs that early evaluation of genotypes may be misleading as trait expression is not stable through time. For example in the case of volume, experience has shown that effective genetic selection in fast growing pines is only possible when trees have reached one third of the rotation (Lambeth 1980; McKeand 1988). Similar questions can also be raised about the stability in different environments and the existence of genotype-environment interaction. As a result, problems that tree breeders faced decades ago are actually amplified in the case of GM trees due to the lack of any biological information concerning gene expression in transgenics. The same questions may be raised today for traits that were genetically transformed: what is the level of expression of these traits, how stable is it through time and space, and is the level and stability expression of other traits modified? Only experimental tests will help to answer these questions. Risks will persist as long as results from experiments are not available.

5.3.2 Environmental risks

Dissemination of GM trees and their negative consequences within the environment are the main risks that forests have to face. Dissemination can occur in two different ways. First of all, genes may be disseminated by introgression of local resources due to cross hybridisation with related species. Since hybridisation is possible among species of many genera (*Populus*, *Pinus*, etc.), these concerns have been raised as immediate threats to local resources. Of course dissemination is also possible and much more rapidly in stands of the same species. Several reports have shown that wind pollinated forest tree species can effectively transmit genes at extremely long distances (several kilometers). The rate of invasion of an inserted gene depends of course on the selective value of the gene. If it contributes any phenotypic advantage, then it will rapidly diffuse through the stands. Considering the extremely powerful and diverse mechanisms that trees have developed to disseminate their genes (pollen flow, hybridisation, natural vegetative propagation), it would be extremely difficult to eradicate a transgene that would express any detrimental character and that was earlier introduced in commercial plantations. This reasoning has leaded molecular biologists to work on genetically engineered trees for sterility. Although attractive, accidental release of pollen of so called ‘sterile’ trees cannot be excluded and may have dramatical consequences in native populations especially if the pollen transferred is associated to other phenotypic advantages (higher growth potential, for example).

The release of insect resistant forest trees may also induced an invasive behaviour of the genetically engineered species and disrupt population dynamics of the insect that may become more aggressive on other species. More generally, invasions of GM trees could threaten the different components of forest biodiversity.

5.3.3 Limitation of genetic diversity resulting from the use of GM trees

Genetic improvement by gene transfer is, for the time being, limited to traits that are encoded by single locus. To our knowledge, there is no trait of economic importance that has been reported to be single gene controlled, although QTLs (Quatitative Trait Loci) analysis have reported that some traits are being controlled by a low number of loci. Because QTLs are usually detected in single full sib families, they do not account for all those loci that are not polymorphic in the parents, but exhibit other alleles in natural populations. As a result genetic improvement by genetic engineering may only be foreseen in the case of within family selection (where a major QTL has been detected). Furthermore, because gene transformation is done on a few genotypes, it has to be amplified by vegetative propagation in order to used on a commercial basis. This is why gene transformation is usually associated to somatic embryogenesis. These technical operations are likely to result in clonal varieties originating to the best from a limited number of genotypes, and we are back to the risks associated with the use of clonal varieties (paragraph 5.1.2).

6. Conclusion

While this contribution has mainly raised the various exposures of managed or unmanaged forest to genetic risks, it did not address the solutions suggested for decreasing exposures. There is no universal solution to be recommended, as there are numerous case studies that differ markedly. However, a general observation is that strategies that have been adopted or recommended in different countries refer to conservative approaches that aim at increasing tolerance to risks, by maintaining high levels of genetic diversity in natural or artificial populations. There are different suggested ways to maintain diversity (Eriksson et al. 1993) that are behind the scope of this contribution. An interesting perspective is that for naturally regenerated species, maintenance of diversity may be achieved through slightly modified silvicultural methods, without implementing any in situ or ex situ strategies. At the other extreme, for intensively cultured species that are bred for specific objectives, adequate management of breeding populations has also been recommended as a way to maintain diversity (Namkoong et al. 1980). The conservative attitudes adopted are further amplified by the uncertainties concerning critical levels of diversity needed so that tolerance to risks is achieved. Research is needed in this field, combining both theoretical and empirical approaches. Input from short rotation species may also be considered.

Less conservative actions that would associate restoration methods in the risk management have not yet been proposed, although suggestions have been made to anticipate climatic changes by transferring populations from the south of Europe to more northern latitudes.

Acknowledgements

Comments and suggestions from Catherine Bastien, Gille Pilate and Marianne Auger-Rozenberg are deeply acknowledged.

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Reports of the Working Groups and Conclusions of the Roundtable Session

Climatic Hazards

Moderator: Y. Birot

The group first identified the main climatic hazards affecting forests: wind, snow, frost, avalanches, draught and fire, flooding. A given hazard may occur at frequencies more or less known, and its effects strongly depend on the *exposure* of a stand or forest to this harmful factor. Basically, exposure is linked to geographic location, topography, soil and site conditions and adjacent landscape with some interactions with tree species and silviculture/management regimes. One main issue is to define the critical threshold or limit of a phenomenon (e.g. wind) which makes it a hazard (e.g. storm). The discussion stressed also the importance of the secondary effects of a given hazard. In some cases (e.g. forest gales), the secondary damage (e.g. bark beetles) can be of the same order of magnitude as the primary one (e.g. up-rooting and stem breakage). Environmental consequences of climatic hazards, linked to damage, have also to be taken into consideration as well as the economic losses arising from the damage itself (loss of income). Environmental consequences in relation to important destruction of forest areas due to catastrophic events can be of different nature, local (impact on biodiversity or water regimes) or global (increased carbon emission)

The participants pointed out the necessity in risk assessment to forecast forest development together with risk models. The interest of modelling approaches based on growth and risk models was underlined, however, with some questionmarks regarding our ability to predict extremes. In risk assessment and management, more data are needed to understand the relationships between hazard characteristics and damage (dose/response). The participants agreed for considering that in particular, better empirical data, as well as better experimental data allowing a deterministic approach, are still required, although efficient operational measures can be taken without having a deep understanding or explanation of the phenomenon looked at. In other words, it is important to know what kind of explanation we want and why.

The discussion group spent some time on the issue of quantitation and economic valuation of damage. First of all, the damage itself has to be evaluated, and in some cases, the task is complicated by the size and the/or the spread of the damage and the lack of reliability of modern assessment techniques (remote sensing and satellite imagery). The valuation of the damage is also difficult because it very much depends on the socio-economic and industrial context. In the case of a catastrophic event, the prices can be dramatically reduced, but the ability to sell the wood is linked also to the absorbing capacity of the local (or at least not too distant) industrial sector. The economic analysis has finally to be matched with the probability of occurrence of the harmful event.

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The group emphasized also the tremendous importance of the *policy dimension* and its implication for a good risk management and sharing in forestry. Properly directed subsidies can help to reduce the exposure to hazards and the damage, and to better integrate the economic dimension into SFM. Sound policies of insurance combining the private sector and governmental responsibilities are still to be developed in many countries. Conversely, bad policies can ruin everything.

The issue of “naturalness” of climatic hazards was also raised: “if the hazards are of natural origin, should we try to counteract or to fight them? We could be blamed for that.” In spite of its ethical and philosophical connotation, this question is however controversial at least in the managed forest areas.

Finally, the group emphasised the importance of using a proper terminology when dealing with risks. The word risk itself is understood with several meanings: the probability of an adverse event, the hazard itself, the size of the damage and its value, etc.

Global Change and Sustainable Forest Management

Moderator: G.M.J. Mohren

Global change has many different aspects, and in its widest definition includes global land use change, air pollution, and climate change, all of which may have an impact on forest ecosystems and hence on conditions for sustainable forest management. When considering global climate change in particular, it is anticipated that site conditions for forest growth will change as a result of CO_2 increase, temperature increase, and altered ecosystem hydrology (changes in precipitation patterns, increased drought, etc.). As a result, growth in many areas of Europe is expected to increase, notably under conditions where temperature is limiting, such as in the boreal and temperate zone. Under conditions where growth is limited by water, growth reductions may occur, as in the Mediterranean. As tree species will react differently to changing site conditions, forest dynamics in mixed stands is likely to change, possibly leading to altered species mixtures in the long run. In as far as such aspects of stand dynamics are included in considerations for ecological sustainability, forest management will have to adjust and adapt to these new conditions.

Apart from gradual changes in site conditions for growth, forest management will have to account for the consequences of possible increases in large-scale disturbances by extreme events such as windthrow or fire. As a general result, it appears that uncertainty about the risk for future damage (i.e. economic loss) needs more explicit consideration in forest management planning. Most climate impact predictions seem to suggest that the risk for adverse effects (partly decreasing growth due to increased drought, partly increase of disturbances through extreme events due to climate instabilities) will increase over large parts of Europe. The reliability of economic returns, as considered under more stable ecological conditions, may very well decrease as a result of global climate change. Evidently, there may also be an economic advantage in increased growth, if conditions of risk for disturbance remain small.

To take account of changes in risk for damage and economic loss or more in general: to consider adverse effects for forest functioning due to global climate change, forest functioning and provision of goods and services under climate change will need to be considered in detail, accounting for regional differences in Europe. For this purpose, it will be important to analyse possible changes in forest functioning from a user perspective, taking into account various stakeholders with their different interests and values, and perceptions of sustainability (e.g. ecological, economical and/or social).

On a more technical note, it was felt that explicit consideration of climate induced risks would provide a better frame for decision making, and for evaluation of different options for the evolution of forest functions under global change. It was noted that in other sectors of society, e.g. in insurance, techniques would be available for quantitative evaluation of risks. Also, it was noted that a clear distinction should be made between risk and vulnerability, and actual damage, where the latter would involve an economic interpretation.

In view of the magnitude of global climate change, and the importance of global change impacts on forests and forestry, the following actions were required to be undertaken by the forestry research community:

1. Clarification of definitions and concepts of risk, damage, time-frames for decision making, etc., so as to establish a common platform for discussion.
2. Assessment and quantification of impacts of global change on forests, as well as impacts on forest functions (goods and services from a user perspecive), accounting for regional differences, gradual vs. discontinuous effects, etc.
3. A critical analysis of available information and understanding. Decision making deals with a multitude of uncertainties, not only regarding future climate. In some parts of Europe, reliable forest (inventory) data is still lacking. Also, historical data will be of value in assessing the time perspective of climate change impacts. A critical analysis of available models should be carried out, so as to clarify model constraints, e.g. due to underlying historical data, and to identify areas where model development is most needed.
4. An analysis of existing concepts concerning risk and damage control and decision making under uncertainty, and and assessment of their applicability in forestry. It was felt that lessons could be learned from a comparison of analysis as being done by insurance companies, whereby different decision making contexts would have to be considered (e.g. stand, management unit, regional economy, national policy levels).
5. Reconsideration of options for forest management, as global change impacts in combination with changes in decision making will require adaptive management strategies, mitigating adverse impacts, and using new opportunities as provided by changing site conditions and other demands from society (e.g. for carbon sequestration).
6. As to European initiatives in this field, it was thought to be important to clarify, in addittion to quantifying various biophysical impacts, which different decision making processes are of relevance in different parts of Europe, and how these could be analysed in a nested approach that accounts for different levels of decision making.

For forest research in particular, it was noted that there is a strong need for interdisciplinary approaches, with combinations of fundamental and applied science, focussing both on the overall European scale as well as on clearly defined case studies. EFI could very well be instrumental in bringing this together

Forest Fires

Moderator: Francisco Rego

The discussion started with comments related to the excellent presentation by Ricardo Velez focusing on major causes of forest fires in the Mediterranean basin, and it was concluded that more research should be done to understand the social processes involved, many that have to be addressed in a small scale and especially those resulting in fuel accumulations on forests.

The importance of reducing wildfires in order to achieve sustainability in the Mediterranean forests was stressed, and discussions started on the prevention and suppression activities that should take place. It was concluded that while different countries have different situations, integration and coherence of prevention and suppression activities should take place. In general, much more emphasis and resources should be given to prevention activities, especially those included in forest management.

Sustainable forest management in fire prone areas was considered to have to integrate fire risks, especially by adequate silvicultural practices that prevent excessive build up of fuels in the understory of forests. In this context, thinning was mentioned as a silvicultural practice that should be considered, and a special emphasis was given to the integration of prescribed winter fires in the sustainable management of forests.

Possible European scale actions were then discussed. First, it was concluded that there is a need for research on methodological approaches in order to provide a framework within which the two components of risk (probability and impact) could be evaluated and proper management actions could be taken. This was considered as a possible idea for an EFI-led project.

Secondly, it was concluded that European society, which is highly urbanised, should be made fully aware of the many values that are at stake with forest fires, including those related to CO2 emissions and climate change, water resources, and other ecological considerations.

Finally, it was stressed that European institutions, like the EC, should consider the full value of losses with forest wildfires in their policies, and especially when designing financial mechanisms for the protection of forests.

The possible role of EFI was considered to be an important one, in its different activity areas, from the discussion of the methodological approaches to the carbon sequestration issues, and to the policy and economics implications.

Phytosanitary Risks and Wildlife Damage

Moderator: David Burdekin

This group was small but fortunate in that there were experts from Russia, France and Canada who had recently suffered serious pest outbreaks. These had followed severe storm damage in these countries. In these circumstances, it was considered vital to monitor pest populations, especially bark beetles. All countries had adopted similar procedures, making use of pheromone traps to follow the build-up of beetle numbers.

The group felt that there were risks other than those associated with wood supplies. In particular there were likely to be serious effects on the biodiversity of a forest area caused by widespread death of trees. Some measure of this impact should be made by assessing the subsequent development of fauna and flora.

The group also drew attention to the risks from imported pests. Mention was made of several important non-indigenous pests which had been transferred both ways across the Atlantic Ocean (e.g. Dutch elm disease and Pine wood nematode). Vigilance and appropriate regulations should always be maintained.

As to future research, the following topics are worthy of further study:

a) Prediction of outbreaks – monitoring by the development of specific pheromones.
b) Spatial distribution of pest outbreaks – provides clues to pest preferences for suitable sites.
c) Economic evaluation – the threat of economic disaster often prompts emergency action to control a pest outbreak. However few economic evaluations have been made to justify action taken.

d) An international database of information on pest outbreaks would be invaluable for those who suffer *de novo.*

Genetic Risks

Moderator: Maciej Giertych

There were 12 participants in the working group and Philip Wardle agreed to act as rapporteur. The discussion started by complimenting Antoine Kremer on the quality of his paper “Genetic risks” and the richness of ideas he presented. The following ideas arose from the discussion of the topic:

1. Genetic risk is a long-term issue. It boils down to the fear that since improvement programs lead to a reduction of genetic diversity this may have negative consequences in the future.
2. It was pointed out that the measured level of genetic diversity is similar in material derived from:
   - seed orchards vs. from stands,
   - even-aged stands vs. uneven-aged

   However, these results could be misleading because genetic diversity measured by isozymes concerns primarily neutral variation (not affecting the functionality of the enzymes studied).
3. Genetic modification on a population level occurs rapidly, within one generation. There is sufficient variation within each generation to allow for considerable reduction of genetic polymorphism allowing survival of only those genotypes which are adapted to the given set of new conditions. This rapid adaptation is observed:
   - in response to global change
   - in response to pollution
   - on introduction to a an alien environment
4. Documented success of introductions requires long-term observations. Thus it is necessary to:
   - maintain trials for a long time
   - reactivate old abandoned trials
   - share data on an international level
5. International co-operation is also needed to:
   - produce reference maps for genetic fingerprinting.
   - share responsibility for gene conservation
6. Time is needed for long term testing of any improved material. This concerns also genetically modified trees (GMTs). However demonstration of their productivity is not enough. There is the added danger that they may interbreed with wild populations, possibly polluting the natural gene pool. Thus in forestry GMTs have to be treated much more carefully than in agriculture.
7. It is necessary to monitor the fate of improved material also after it has been introduced into forestry practice. It is insufficient to follow reproductive material till planting time. The plantation itself must be monitored for long term consequences of using improved material.
8. Some discussion was devoted to the genetic consequences of such accidents as the Chernobyl disaster. There are genetic consequences and these should be studied. It was pointed out

however that the risk problem involved is beyond the realm of forestry and there is nothing in particular that foresters can do to reduce or manage it. When discussing risk management in forestry we should concentrate on issues that depend on what those dealing with forests do.

Panel Discussion

Rapporteur: Thies Eggers

Panel members:
- Mr. Heinrich Spiecker, Germany, Freiburg University, Head of the Institute for Forest Growth
- Mr. Yves Birot, France, INRA, National Institute for Agricultural Research
- Mr. Patrice Mengin-Lecreulx, France, ONF, Office National des Forêts
- Mr. Fredrik Klang, Sweden, AssiDomän
- Mr. Franz Schmidthüsen, Switzerland, University of Zurich, Head of the Chair of Forest Policy and Forest Economics

1. Statements of the panellists

Mr. Spiecker:

In forest management it has always been a challenge to deal with long-term horizons and to live with risks. As neither the future conditions nor the effects of forest management can be predicted, forest management had and has to deal with uncertainties. Even after several decades of forest management there seems to be a lack of knowledge in how to deal with risks. What are the reasons for these deficits?

Risk is attached to extreme events which are rather seldom and by this it is partly forgotten. The temporal scale is extremely important. Some researchers have ignored extreme events and put them to the category of 'unwanted errors'. By this also some long-term plots have been abandoned after they had been damaged by storm.

We are uncertain how to deal with risks. The forests have changed over time (e.g. tree species composition, forest management, forest fragmentation) and also the soils, plant-soil and plant-plant interactions, and climatic conditions etc. Also, the society has also changed over time: it has changing needs and values from the forests. The third factor is that the economic demands to the forests have also changed. New markets need new potentials and the economy needs time to adopt. All these have effects on risk and risk management

The tools for risk and risk-management (RRM) have improved and thus forest management can implement RRM in a better way. Prevention of risk by better understanding of the functioning of forests, especially after extreme events is possible and can nowadays also include other stakeholders and the markets. We need an adaptation to risk, i.e. being aware to live with risks. Uncertainties have to be considered, when making decisions in forestry and forest management.

Mr. Birot

Every time after a catastrophe we are at the same point and start nearly from the beginning again; the human brain must have a short-term memory for such severe events like storms and other natural hazards. Risk assessment is not well implemented in forestry by now, which must be changed in the near future. The necessity for risk assessment needs the knowledge of risks and losses. This assessment must be improved.

Policy makers, who have to deal with the damages in the forests afterwards and in advance, have the habit to either under- or overreact and so there is a disproportion.

The lack of research funding is obvious when nothing happens and suddenly when something occurs the money flows. This procedure is rather unfavourable to a risk-research which really can improve the quality of risk assessment. We need to know more about: (i) hazards, (ii) stand dynamics, (iii) respond strategies, and (iv) resulting damages from storms. The important factor is that risk-assessments are needed first on local scale and then should be moved up to a larger scale.

Politicians should invest more in research on risk assessment to prevent the lack of knowledge in case new hazards occur.

Mr. Mengin-Lecreulx

The ‘problem’ with risks and storms is that they have a rather high intensity but just a small occurrence. But never the less it is important to take into account the markets as they are the responding factor to e.g. large amount of wind thrown timber.

Another important factor is the communication with public bodies as they are beside the foresters and the forest industries also large stakeholders with many-sided interests. The scientific community must not be silent as other groups might take this place and use it for their purposes and so it is up to us to get things going on. We need a joined strategy to face upcoming hazards and damages in the forests. How to face the future problems: (i) better understanding of natural factors, (ii) development of small-scale predictions on wind and their impacts, (iii) better characterisation of the stands, and (iv) also regard the stand structure (even aged <-> uneven aged).

Up to now the observations did not change the management largely but they have improved the methods.

Mr. Klang

The main question from the economists’ point of view is towards a stable investment and thus forest managers should avoid hazards. But as a economist it is every days life to work on an optimum risk level and by this risk is a natural part of a foresters business. In case that a risk occurs, this can lead into a reduction of the expected output. To minimise possible negative effects of risk, foresters need a higher variance and thus e.g. a higher diversification in their forests. But all this is nothing new: forest management takes risk already into account and risk can also have positive effects as a stimulation to gain the highest possible profit.

Mr. Schmidthüsen

Risk is nothing unnatural at all – the whole life is full of risks. Most of the risks we face every day are overcome and make us stronger. It has stimulation effects e.g. a company wants to gain money and takes a chance / risk.

But not only the economists have to deal with risk. Risk is a social phenomenon and thus risk management is a political issue. This makes it easier for us as political systems are capable to deal with risks and have the experience of several centuries. Risks show how important it is to have interdisciplinary approaches and practice also in forestry. Our today forests include beside the economical points political, social and cultural aspects. This leads in a need to combine natural, social and economic sciences to face and do research on risks in the forests. We do not have to be afraid on this interdisciplinary approach; it should be seen as a stimulation to come closer together and work jointly on a better risk understanding and risk assessment.

2. Notes from the discussion:

- Forests combine more that just the merchantable tree species. Forest ecosystems are multi-level systems with various aspects and so it is important to regard the many-sided functions like protection and social aspects.
- To help the single researcher, information should be available in a database – even though this might be a long process, as it needs a rather long time to make all data available.
- Radioactive pollutions and their impacts on evolution must be also regarded, when looking on risks linked to industrial activities.
- With the upcoming interdisciplinary research on risk and risk management it is a unique chance to identify new research directions, which can be a possibility for new research funding and might be coordinated by EFI.
- The main focus had been until now on the forest stand level. Now it is time to make use of these results to ecosystem approached and perform deterministic approaches.
- The rapid adaptation of some parts in the forests is risky for forestry. There are similarities to the research on air pollution, where much research and money had been spend. Forests can adapt to this harmful factors and so we should be careful with statements.
- If we talk about sustainable forest management it is difficult to fully take into account temporal and spatial aspects of individual positions. In general we should be careful with introducing new or genetically-manipulated species; there might be interactions with the natural forests.
- Regional actions should be favoured as they should be better to perform. On this level decisions are easier to be made that on the level of really small scale forest owners.
- The affinity to risk is highly dependent to the stakeholder: some are afraid of taking risks – others are not.
- Risk can have also positive effects: the higher the risk, the higher the profit might be.
- The usefulness of multiple research on risk and risk management is essential. It is needed to prove the success of applied measures and methods. But this has to be seen in the long term, as this will not be that easy to perform.

Poster Abstracts

Maxibravo – A Model for Optimisation of Maritime Pine Rotation Age According to Fire Risk Level

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In Portugal, forest plays a very important role yet every year an enormous amount of forest area is destroyed by fire. In a certain extent, this situation can be explained by local climate, which is characterised by dry and hot summers. There is also a lack of forestry management devices, which take into account risk factors in the wood yield optimisation.

Traditionally, the valuation of the optimum rotation age does not consider risk factors. However, the entrepreneur may be interested in reducing the rotation age, in order to diminish the expected loss, even if it implies lower yield levels.

The forestry sector is a potentially wealthy resource when it is well managed. Thus, the main objective of the ongoing research is to build a decision tool for forestry management. Our model's main purpose is to evaluate a new optimum rotation age taking into account the risk of fire. "Maxibravo" is a time discrete economic optimisation model which allows the simulation of different scenarios including the effects of major factors plantation costs, stumpage prices, interest rates, probabilities of fire incidence, the risk profile of decision makers, etc.

The structure of the model applies Operational Research Techniques (decision theory and risk management and analysis) and Forestry Management Techniques (maximisation of wood yield theories without risk factors). In order to calculate the optimum rotation age, both "land expectation value criteria" (Also known as Faustmann's Formula) and "decision trees" techniques were used.

The emphasis of "Maxibravo" is mainly economical, assuming the decision-maker's objective strictly as a profit maximisation of wood yield.

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EFI Proceedings No. 45, 2002

Silvicultural Factors Influencing Windthrow in Maritime Pine Stands

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Silvicultural strategies and site characteristics are critical factors to consider when assessing the vulnerability of forest stands to strong winds. Windthrow hazard depends upon the interaction of numerous factors whose relative importance has yet to be assessed in the specific context of maritime pine plantations in South Western Europe. Following the December 1999 storm which caused the windthrow of 30 million m^3 in Aquitaine Region (> 3 annual harvest), different studies were undertaken at stand level to analyse the effects of silvicultural factors on stability. The main factors analysed were stand density and fertilisation. Data were mainly collected on two large experimental sites which were severely damaged by the storm. Those two sites were initially set up to study different silvicultural regimes (old stand) and nutritional levels (young stand). Preliminary results are presented and provide some information to be considered in the management of forests to reduce the risk of wind damage.

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A Comparative Study between Different Storage Methods for Maritime Pine Logs: Influence on Timber Quality and Environmental Impact

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After the 1999 storm that damaged a large part of the maritime Pine forest in Aquitaine – about 30 millions m^3 of timber – several areas were used for the wet storage of logs, mainly using a water sprinkling technique. The main objective was to prevent the development of blue stain in the sapwood of the logs, which affects the quality of timber for many uses. Due to the lack of experience regarding the long-term storage of maritime pine, and its potential effect on processing and quality, a large experiment was set up at INRA Cestas Pierroton in 2000, with the aim of comparing different storing techniques (including complete immersion in water, water sprinkling and chemical treatments) in terms of environmental impact and timber quality. 2300 m^3 of logs are stored for a period of 3 years. Quality control tests, consisting of a visual inspection combined with ultrasonic measurements and vibration tests are performed at regular intervals on selected logs. Parts of these logs, which are randomly selected, are then processed into beams for one half, and veneers for the second half. The MOE and MOR of beams are measured, and compared to the non-destructive measurements. After visual inspection of their surface quality, the veneers are used to produce pulp in laboratory conditions, and the quality of the pulp is analysed.

The environmental impact of the different storing techniques has been examined by monitoring the quality of inlet and waste-water during the first period of the experiment. The preliminary results of the study are presented in this poster.

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Forest Damage after the 1999 Storm – Comparison of Stem Wood Properties and Root Architecture Between Uprooted and Standing Mature Maritime Pine Trees

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The northern part of the Maritime pine forest of Landes de Gascogne was heavily damaged by the 1999 hurricane. A mature stand was studied after the storm: a damage inventory yielded 10% of uprooted trees in the interior of the stand whereas the western border suffered 100% windthrow. 12 uprooted and 12 standing trees were sampled inside the stand. Geometrical characteristics of the aerial parts were recorded. One log was taken from each tree at DBH. The root systems were excavated with a caterpillar and cleaned with an air-knife. Wood radial density profiles were measured with a resistograph in four perpendicular directions, twice in each log. The root systems were digitised in 3 dimensions with a low magnetic field digitiser. The technique was adapted for large root systems from that developed by Danjon et al. (2000). Architectural analyses were performed using the AMAPmod software.

The stem density measurements did not show significant differences between uprooted and undamaged trees, but high intra-tree variability was found in each tree, depending on the direction in the log.

The measurements of the root systems are time consuming (1 to 2 weeks per root system) but this work is indispensable for a fine analysis. Only 12 root systems have been analysed up to now. The vertical growth of all root systems was limited either by a hard pan or by the water table. Root systems generally had numerous long horizontal superficial roots on the windward side and shorter but thicker and oval surface roots in the leeward side. Additionally, there were many branched secondary sinkers on the windward side and only one, two or three big sinkers on the leeward side. The variability of the structure is very high, however, results can be related to the stability of the tree. Previous research has shown that the windward lateral roots are extremely important in anchoring the tree, and that these roots confer greater mechanical resistance when highly branched, compared to the leeward roots, which need to be thicker in order to resist failure under compression.

Michel Arbez, Yves Birot and Jean-Michel Carnus (eds.)
Risk Management and Sustainable Forestry
EFI Proceedings No. 45, 2002

Assessment of Sanitary Risks in Wind-damaged Forests: the Aquitaine Experience

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On 1999 December 27, the Aquitaine Region experienced the strongest hurricane ever recorded. The total volume of wood from windthrown trees (mainly maritime pines) represented more than 30 million m^3 (equivalent to 4 times the annual harvest) increasing dramatically the food supply material for bark beetles. It was immediately decided to conduct a survey of the health status of forest stands in order to identify the more threatening pest species, to evaluate their damage and monitor the spread of their epidemic populations at the regional level. Two different approaches were applied. In the first monitoring network, fifty damaged stands were randomly sampled where 5 trees were assessed three times a year by foresters to detect the presence/absence of bark beetles. In the second network, a hundred stands were selected according to a factorial combination of storm damage, tree age and site conditions. In each stand a cluster of a hundred trees was assessed once a year, in late summer, by forest entomologists to detect all the biotic agents. The quality of the information provided the year following the storm by the two monitoring systems is presented and compared. The potential use of the data for the risk assessment and the application of control treatments at the regional scale is discussed.

Michel Arbez, Yves Birot and Jean-Michel Carnus (eds.)
Risk Management and Sustainable Forestry
EFI Proceedings No. 45, 2002

Risk and Risk Premiums on Discount Rates

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Financial economists have often treated risk by adding a premium to the discount rate. Forest economists too have sometimes followed this practice when assessed crops subject to climatic and biotic hazards. If the hazard is completely destructive and occurs at a constant level through a cycle of crop growth, this is a convenient and accurate short-cut for appraising the value of a single crop cycle. However, it makes no sense when the hazard varies through the crop cycle (as with fire) or through time (as is increasingly expected with storm damage), or when an outcome short of complete destruction of the crop may be the result of the hazard (as with insect defoliation). Moreover, the value of successor crop cycles is not actually decreased, in relation to that of the initial cycle, by hazards which accumulate only through each individual cycle. Where hazard is constant through time, it happens that the risk premium approach gives the optimal financial rotation. However, it underestimates (seriously, at low base discount rates) the land expectation value of a series of crop cycles: this value can be estimated by a more explicit integration of the value of repeated cycles.

Michel Arbez, Yves Birot and Jean-Michel Carnus (eds.)
Risk Management and Sustainable Forestry
EFI Proceedings No. 45, 2002

Cartography of the December 1999 Storm Damage to the Aquitaine Region Maritime Pine Forest Derived from Satellite Remote Sensing

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Following the storms at the end of December 1999, the National Forest Inventory (IFN) of France was given the task of mapping and estimating the forest damage over approximately half of France's national territory. For the Aquitaine region's maritime pine forest, particularly favorable conditions of geography and species composition made it possible to use a procedure based on remote sensing images to produce a map of the damage at short notice. In this procedure the IFN relied on a method of detecting changes similar to that which it had developed for monitoring the maritime pine forest resource in Aquitaine, supplemented by a stage of spatial aggregation. The map, showing 5 levels of damage intensity, was then combined with the IFN's dendrometric and cartographic data bases to estimate the wood volumes concerned.

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EFI Proceedings No. 45, 2002

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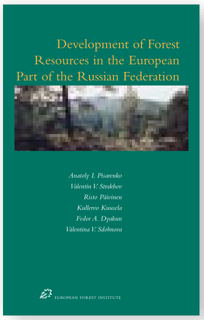

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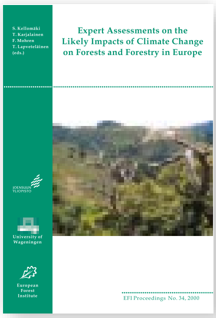

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