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France

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Country background

Forest history

During the Gallo-Roman period (1st–4th century AD), forests covered two-thirds of the metropolitan French territory (Huffel, 1926). During the Middle Ages this proportion decreased dramatically to only 15–17 % of the land area. This residual forest was then severely damaged during the Renaissance period (15th–17th century) by over-harvesting and anarchic management. When Colbert's Forest Ordinance was instituted in 1669 a gradual restoration took place. High forests produced mainly timber wood, especially for the navy and cask production, and coppices were used for firewood. This ordinance also marked the beginning of a true forest science, an approach which gained worldwide recognition.

Since the 19th century the land area of forests has increased owing to the impacts of various wars and a rural exodus which left considerable amounts of vacant agricultural land available for natural tree colonization. In addition, voluntary tree planting has occurred, often approved by governments for different objectives such as erosion control and increased timber production. In two centuries the forest area has increased by 67 % (Cinotti, 1996) and this trend is still important in transforming the landscape. Woodland area increases each year by an average of 68 000 ha (IFN, 2006), with additional areas being spontaneously colonized by woody species. From a management point of view, the decrease in the demand for firewood has led to the transformation of many coppices into coppices with standards, or to high forests, but this trend may be reversed in the coming years with the decreased use of fossil fuels for energy.

Topography and climate

France consists mainly of plains and hills, with two high mountain regions, the Alps in the east to southeast (with Mont-Blanc culminating at 4810 m) and the Pyrenees in the south (culminating at 3404 m), and four older smaller mountains, the Jura, the Vosges and the Ardennes in the east to northeast, and the Massif Central in the centre. The climate of France can be roughly divided in four main zones: Mediterranean, Atlantic, Continental and Mountainous; their climatic features are presented in Table 4.2. Mediterranean climate is characterized by very heavy rainfall in spring and autumn, and a long, warm, dry summer season prone to forest fires. Atlantic climate is wet with temperatures moderated by the ocean. Continental climate is characterized by marked extreme temperatures. In mountainous areas, where forests are present, the climate is cold and wet.

Forest and woodland area today

Woodlands now occupy 15.5 million ha in metropolitan France (IFN, 2006), i.e. 28.2 % of the total land area (Table 4.1). About 60 % of forests are probably native but, as described earlier, they have been greatly reshaped by human activities for one to two millenniums (Huffel, 1926). The remaining 40 % have been progressively planted since the beginning of the 19th century from abandoned agricultural lands (Cinotti, 1996).

Land use	Area (million ha)	Percentage (%)
Woodlands and forest	15.5	28.2
Agriculture	30.6	55.8
Urban	3.9	7.0
Other	4.9	9.0
Total	**54.9**	**100.0**

Table 4.1 | Land use in France (Agreste, 2006).

Table 4.2 | Climatic features of France.

Climate zone	Temperature (°C)				Annual rainfall (mm)
	Coldest month	Mean annual	Warmest month	Absolute minimum	
Mediterranean	6 to 8	14 to 15	23 to 24	-5 to -10	400–600
Atlantic	2 to 4	11 to 12	17 to 19	-10 to -15	600–1200
Continental	1 to 3	10 to 11	18 to 19	-15 to -25	500–800
Mountainous [a]	-2 to -4	6 to 8	13 to 17	-25 to -30	1000–2000

[a] At the altitudes of forest.

The metropolitan French forest is distributed over a large range of biogeographic zones. Most is temperate, with broadleaves dominating in the oceanic and continental plains and conifers in mountains. The Mediterranean area is mainly composed of evergreen species, often very sensitive to fire, so that forest vegetation management (FVM) in that area is almost entirely devoted to fire prevention. The average productivity is estimated to be 6 – 6.5 m^3 ha^{-1} $year^{-1}$ (IFN, 2006).

High forests (30 %) and mixed forest and coppice with standards (59 %) dominate French forests. The coppice alone is used for firewood and occupies 11 % of the land area (Table 4.3).

Table 4.3 | Surface area (1000 ha) of production forests (IFN, 2006).

Climate zone	Broadleaves	Conifers	Mixed	Total
High forest	2686	1227	488	4401 (30%)
Mixed forest and coppice with standards	5400	2224	1066	8690 (59%)
Coppice	1546			1546 (11%)
Felled, awaiting reforestation				166 (1.1%)

The area regenerated each year is estimated to be 150 000 ha, including forests where different stages (from young to mature) coexist at the same place and time (for example some parts of the Mediterranean, Alpine and Pyrenean forests). The cost per hectare to ensure tree establishment (to a height of 3 m) varies from €1500 to €2500 to more than €6000 according to forest species (for example Douglas-fir versus oak), site (acid versus rich soil) and requirements for fencing, depending on populations of browsing mammals present. The average can be estimated at €3500–€4000 ha^{-1}.

Species composition

At the country scale, broadleaves and conifers represent 71 % and 29 % of the land area, respectively. The main broadleaved species are the oaks (penduncolate oak: *Quercus robur*, sessile oak: *Q. petraea*, downy oak: *Q. pubescens*) which represent 23.7 %, European beech (*Fagus sylvatica*, 9.2 %), sweet chestnut (*Castanea sativa*, 5.3 %), and other broadleaves like *Acer, Fraxinus* or *Prunus* genera (32.1 %). Conifers are dominated by pines, with maritime pine (*Pinus pinaster*) covering 1 million ha concentrated in the Landes in southwest France (7.3 %). Other pines represent 10.3 %, Norway spruce (*Picea abies*) and white fir (*Abies alba*) 8.3 %, Douglas-fir (*Pseudostuga menziesii*) 2.9 %, and other conifers 1.0 % (National Forest Inventory: IFN, 2006).

Ownership

Seventy per cent of metropolitan French forests are privately owned, each having generally only a small area: 1.1 million owners share 10 million ha, with a mean of 3.1 ha (IFN, 2006). Twenty-nine per cent of owners have different occupations, 25 % are farmers and 21 % retired. The remaining forests are public lands, owned by the government (12 %) or local communities (18 %). Government forests are generally very large, with 1.8 million ha divided among 1714 forests.

Forest establishment or perpetuation

High forest is renewed or perpetuated by planting seedlings or natural regeneration. Both systems have been used for a long time but today regeneration and species diversity are favoured as much as possible. The windstorm of December 1999 that damaged more than 800 000 ha, including the complete destruction of 450 000 ha (Wencélius, 2002), has particularly contributed to this trend. The coppice is renewed by cutting. Afforestation on former agricultural land is mainly by planting and sometimes by direct seeding.

Statistical data about forest areas, planted or naturally regenerated, are not available. An estimation based on a renewal rate of 1 % gives a figure of 150 000 ha every year for existing forests, along with an estimated 166 000 ha temporarily unforested area every year (IFN, 2006). Added to this is the afforestation of former agricultural lands, probably representing several thousand ha each year, although this is now becoming less important.

Policy drivers – certification

Each year sees an increase in certificated forest area in France. The PEFC (Pan-European Forest Certification) is the most frequently used certification system. Almost all public forests are certified (1.6 million ha for government forests and 1.2 million ha for communal forests), and the area for private properties is increasing (1.5 million ha; PEFC-France, 2006). Therefore, at present, nearly a third of the forest area is certified. More than 1000 French companies linked to the wood sector have also chosen a PEFC control. The PEFC does not forbid herbicides or pesticides but limits their use, particularly in sensitive areas like river banks and water catchments. Some owners also adhere to different charters like Natura 2000, and many local community organizations establish territorial charters for their wooded areas.

Herbicide use

As mentioned earlier, herbicides are not forbidden in French forests, even when they are certified, but their use is strictly controlled and very limited in comparison with agriculture (Table 4.4): about 50 000 ha of forest stands are treated each year out of a total of 15 million ha (Gama *et al.*, 2006). Herbicides are generally used from 0 to a maximum of 3 times during the life-cycle of a forest stand (generally more than 80 years), to ensure tree establishment in natural regeneration or tree plantation. To be used in France, a herbicide must have an authorization from the French government; this is granted for a given culture and for a precise use. There are three main categories of herbicide use: brushwood clearing before crop tree set up, clearing of vegetation around established young trees, and suppression of stumps or sprouting of standing trees. The number of commercial compounds authorized for use in the forest is continuously decreasing, about 38 today, and only 23 are commonly marketed (Gama *et al.*, 2006). The use of specific herbicide application is also regulated, for example recommendations are made for the minimum no-spray buffer zones from rivers and drains, for disposal of herbicide packaging, and the health and safety of operators.

Table 4.4 I Estimation of herbicide and pesticide application number per year and area treated for different crops in France (Rabaud and Cesses, 2004 and www.quid.fr/2007/agriculture).

Crop	Total crop area (‘000 ha)	Mean herbicide application number (per year)	Area treated by herbicide (%)	Area treated by herbicide (‘000 ha)	Pesticide application number (per year)	Area treated by pesticide (%)	Area treated by pesticide (‘000 ha)
Wheat	5288	2.3	98	5182	3.7	96	5076
Barley	1610	1.9	97	1562	2.9	93	1497
Maize	1633	2.4	98	1600	1.3	38	620
Sugar beat	396	9.7	100	396	2.8	96	380
Potatoes	147	2.1	98	144	14.1	100	147
Forest	15500	0.02 [a]	0.3	50	?	?	?

[a] One application every 50 years.

Target species

Weeds in French forests develop to varying degrees mainly according to light and fertility, and are often highly diversified. In some circumstances, forest plots can be entirely colonized by certain social species that rapidly occupy the whole available space (Table 4.5). These species can be problematic because they can jeopardize tree regeneration and seedling growth through competition for resources (water, nutrients, light) and therefore FVM is often designed to control their development. Conversely, they can favour tree establishment through direct facilitation of nutrients (e.g. by supplying nitrogen), or indirectly, such as a bramble bush suppressing a light-demanding competitor (Frochot *et al.*, 2002). In Table 4.5 species considered as competitors are annotated with C, and those as facilitators with F. Their importance in the understorey of established forests has been assessed by the French National Inventory (IFN in Gama *et al.*, 2006) but the abundance of some light-demanding species found in open-field plantations could be underestimated.

Table 4.5 | Abundance of some social plant species found in French forests and their effect on crop tree seedlings.

Species	Frequency (%) in the forest understorey[a]	Interaction type when abundant: C = competition, F = facilitation		
		Infertile acidic soil	Acidic to neutral soil	Calcareous dry soils
Rubus fruticosus Bramble	63.5	F	C	F
Pteridium aquilinum Bracken	29.1	C	–	–
Carpinus betulus Hornbeam	29.0	–	C or F[b]	F
Castanea sativa Sweet chestnut	21.0	C	–	–
Cytisus scoparius Broom	13.6	F	C	–
Brachypodium pinnatum False brome	12.9	–	–	C
Calluna vulgaris Heather	12.5	C or F[c]	–	–
Molinia caerulea Purple moor-grass	11.5	C	–	–
Ulex europaeus Gorse	7.6	C	–	–
Juncus spp. Rushes	7.0	C	C	–
Deschampsia cespitosa Tufted hair-grass	6.8	–	C	–
Clematis vitalba Traveller's-joy	6.6	–	–	C
Agrostis spp. Bents	5.3	C	C	C
Robinia pseudoacacia False acacia	5.0	C or F	C	C
Epilobium angustifolium Rosebay willowherb	2.0	C	C	–
Carex brizoïdes Sedge	0.6	C	–	–
Phytolacca americana American pokeweed	0.5	C	–	–
Calamagrostis epigeios Wood small-reed	0.4	C	C	–

[a] Source: IFN in Gama *et al.* (2006).
[b] Can be used as facilitator if controlled.
[c] Competitor or facilitator depending on the tree species considered, e.g. oak and spruce or pine, respectively.

The list of species shown in Table 4.5 is not exhaustive: species such as *Salix caprea* (goat willow), *Betula pendula* (silver birch), *Cirsium* sp. (thistles), and other grasses, e.g. *Holcus* sp. (soft-grasses), *Brachypodium sylvaticum* (false brome) can be added. In addition there are species of open areas, usually in the case of afforestation of former agricultural lands, mainly opportunistic grasses such as *Agropyron repens* (common couch) and *Agrostis* sp. (bents). Bramble is by far the most frequent species in French forests (63.5 % of the surveys) and is able to colonize most sites. Bracken is also well represented but only in acidic soils (29.1 %). Other ferns are also very abundant together with tall forbs, e.g. *Cicerbita* sp. (blue sow-thistle), *Adenostyles alliariae* (name ?), in wet mountainous forests. Around 10 species are important with frequency rates ranging from 5 to 14 %. The effect of some species, competition or facilitation, depends on the fertility of the soil. For example the high and dense cover of bramble in fertile and well-watered soil can inhibit crop tree growth, whereas a low cover of bramble in infertile or dry soil may conversely indirectly facilitate crop tree survival.

In addition to the main problematic species shown in Table 4.5, other less represented species can also be competitive when combined, which emphasizes the interest of functional classifications based on species traits and effects on crop species (Table 4.6). It does not mean that each species belonging to a group is always a competitor but it could be in some circumstances and must be considered with care.

Table 4.6 I Forest vegetation classification according to life forms, functional traits and main effects on crop tree species (Frochot *et al.*, 2002; Balandier *et al.*, 2006); bold = most common effect.

Growth form	Potential inhibitor effect	Potential facilitator effect	Example of species or genera
Graminoids	**Water** Nutrient		Perennial grasses, *Carex, Juncus, Luzula*
Forbs and legumes with a dense cover	**Light** Water Nutrient	Inhibition of graminoid growth Nitrogen supplying (legume species)	*Epilobium* *Trifolium* *Rumex*
Dwarf shrubs, climbers and ferns	**Light** Water + allelopathy *(Calluna)* + crushing *(Clematis, Pteridium)*	Inhibition of graminoid growth Climatic protection Protection against predators	*Rubus fruticosus* *Rubus idaeus* *Calluna vulgaris* *Clematis vitalba* *Pteridium aquilinum* *Ulex europaeus* *Cytisus scoparius*
Mid-storey shrubs	**Light** Water	Inhibition of graminoid and small shrub growth	Social woody perennials *Salix* sp. *Corylus avellana* *Cornus mas*

The graminoid type includes grasses, rush and carex, which are highly capable of taking up water and nutrients to the detriment of crop trees. Vegetation surveys made after the storms and subsequent windthrow of December 1999 showed that the frequency of graminoids was 28 % for a total of 23 species, whereas each of them taken alone was not very abundant (Mangin and Lacombe, 2006).

Sorting vegetation by functional types (Frochot *et al.*, 2002; Balandier *et al.*, 2006) widens the notion of competitive species and allows better identification of potential interactions with crop tree seedlings. The competing vegetation can have some inhibitory effects, reducing tree seedling growth but also in some cases leading to seedling death and so preventing tree regeneration. Conversely, it can help seedling establishment in some circumstances and especially favour the future stand quality. Therefore characterizing both the competitive and the facilitating effects of different vegetation types helps to design better FVM strategies.

Treatments and alternatives

Background and current knowledge

Most of the French forest area is extensively managed, and often with multipurpose objectives such as quality wood production, recreation, landscape or environmental conservation. In that context, the main goal of FVM is to favour tree stand establishment rather than improving tree growth rate. A stand is considered established when trees are sufficiently high to dominate the vegetation and tolerate large herbivore damage (i.e. 2 to 3 m tall). The objective is to control weeds impeding tree establishment, without eradicating them, and with a minimization of costs and number of technical operations (Frochot *et al.*, 2002; Frochot, 2006).

When the forest is intensively managed (e.g. *Pinus pinaster* in the Landes, *Pseudotsuga menziesii* in central France), tree growth rate improvement is added to the necessity of warranting stand establishment by FVM. Finally in the Mediterranean forest, the main goal of FVM is to prevent fires starting or spreading.

Methods and strategies adpoted for managing weeds in French woodlands

Chemical control

Herbicides are generally used when forest weeds are likely to jeopardize tree seedling survival and growth (Gama *et al.*, 2006). When forest sites are invaded by potential competitive social perennial species such as *Pteridium aquilinum*, *Rubus fruticosus* and *graminoids*, one foliar application of a herbicide is usually made before tree regeneration; it is generally effective for between 2 and 4 years (e.g. asulam on bracken, Table 4.7). After tree planting, treatments are only used when essential, with selective herbicides applied along tree seedling rows. However, in intensive plantations non-specific herbicides (e.g. glyphosate) are applied locally around tree seedlings, often over a period of several years.

When correctly managed, herbicides control weeds efficiently, durably and selectively directly around tree seedlings. They can also drive the vegetation dynamic towards a species composition more favourable to tree seedling establishment and growth. However, the impact of synthetic pesticides on the environment is often questioned by forest managers, and more generally by society, whereas herbicides are economically defended in some silvicultural systems (for example *Pinus pinaster* in the Landes region). Some studies have shown that the composition of flora is relatively unaffected by herbicide treatment (Dreyfus, 1984; Gama and Dumas, 1999). One point in favour of herbicides is that fewer interventions are needed compared with mechanical treatments, and thus overall disturbance is generally lower.

Table 4.7 | Some examples of herbicides used in France. The area treated annually is estimated to be 50 000 ha (Gama *et al.*, 2006).

Active chemical compound	Utilization rate	Purpose
Asulam Hexazinone (*until 2007*) N-phosphonométyl glycine (glyphosate, sulphosate)	High	*Pteridium aquilinum* control Pine and other conifers: weeding Control of *Rubus fruticosus*, *Clematis vitalba* and other plants
2,4-D (alone or associated) Dichlorprop (associated with 2,4-D) Fluazifop-p-butyl Propyzamide Quizalofop-ethyl Triclopyr (alone or associated to 2,4-D)	Medium	Woody species devitalization Woody species devitalization Grass control Grass control Grass control Small shrub control
Clopyralid Oxyfluorfene (associated with propyzamide)	Low	*Cirsium* sp. control Broadleaves and some conifers: weeding
Dichlobenil	Very low	

The shelter technique

The shelter technique aims to preserve part of the stand cover during harvesting so that light in the understorey is sufficiently low to prevent or slow down the development of light-demanding weeds but above the threshold that allows tree seedling growth (Pagès *et al.*, 2003; Pagès and Michalet, 2003). In the past the technique was particularly applied to shade-tolerant species such as *Fagus sylvatica* (beech); today it is especially used in individual or group selection silviculture. However there are problems with the technique. First, it is mostly based on empirical knowledge and requires future research in order to become widely used, as, for example, the proportion of adult tree cover or the light requirement of different tree species. Second, it is difficult to harvest crop trees without damaging tree seedlings.

Nurse species

The nurse species technique aims at sheathing crop trees with other tree species or tall shrubs. The objective of the nurse vegetation is to improve tree growth, to improve tree bole form quality and to protect trees against large herbivores. It also helps to decrease crop tree density. The technique is often used in oak (*Q. petraea, Q. robur*) plantations in forest stands with good water availability (Démolis and Jamey, 1988; Collet *et al*., 1998). Natural woody species, e.g. *Betula* sp. (birch) and *Carpinus betulus* (hornbeam), are used as nurses and prevent site colonization by perennial grasses. The technique is also used in afforestation of former agricultural lands, mostly with valuable species, e.g. *Juglans* sp. (walnut) and *Prunus avium* (wild cherry) (Van Lerberghe and Balleux, 2001). In this situation, the nurse trees are planted, and the cost linked to that operation limits maximum tree density to a level needing a control of additional vegetation (by herbicide, mulch) during the first few years.

Cultivation

The cultivation technique is widely used, with traditional tools (plough, disc) attached to a tractor. The goal is to decompact the soil before planting and slow down weed colonization. Cultivation on its own can be sufficient in dry or unfertile soil to assure tree establishment but on fertile sites additional operations are needed as forest weeds may rapidly recolonize the stands afterwards. The technique cannot be used after tree planting because of the risk of damage when applied too close to the crop tree, where weed competition is the most intense. However, a scarifying tool with spaced blades is sometimes successfully used to partially uproot bramble (*Rubus fruticosus*) in natural oak or beech regeneration. Soil cultivation is also often used in intensive silviculture between rows to control weeds in well-developed stands with the aim of improving crop tree growth, e.g. *Pinus pinaster, Populus* sp. (poplars).

Small mechanical tools attached to a mini-tractor (Photo 4.1, page 63) have been successfully used for some years for local soil preparation, rather than the whole surface, before the planting (Wehrlen, 1998, 2006). A mechanical hoe can also be used to suppress weeds directly around the crop tree seedling instead of manual harrowing. These mechanical mini-tools are supple and easy to use. They can penetrate established stands without disturbing the soil structure too much and their relatively high cost is balanced by both the reduction of the cultivated surface and their efficiency.

Mechanical mowing and brushcutting tools

These tools are frequently used to reduce the height of tall weeds shading crop tree seedlings. Manual tools (scythe, lopping knife) are used in plantation and natural regeneration to clear the vegetation around the canopy of small trees, but the operation often has to be repeated several times before crop trees dominate. Tractor-driven tools are sometimes used in natural regeneration but more usually to crush the vegetation between some rows, to allow access and enable checking of the health of the tree seedlings. They are also used in the Mediterranean region to suppress the inflammable vegetation of the understorey, even in rugged topography. However both manual and motorized tools strongly disturb the habitat, especially for animals, and they destroy bird's nests during the breeding period.

Mulching

Primarily used for plantations on former agricultural lands, mulching consists of laying a material (a mulch) on the ground surrounding the tree seedlings which forms a screen to stop the growth of competitive natural ground vegetation. Mulching limits soil water loss and contributes to soil quality by regulating temperatures, improving structural stability and maintaining the availability of nutrients (Van Lerberghe and Gallois, 1997).

Many types of mulches are available. Black polyethylene films are the most commonly used owing to their low cost, high durability and their effectiveness in aiding tree growth (Van Lerberghe and Balleux, 2001; Frochot *et al*., 1992). Once worn, these plastic materials become wastes and need to be eliminated. Dumping, burning and burying are prohibited: the non-polluting solution is to collect and recycle them but it is expensive as it is entirely the forester's responsibility (Van Lerberghe and Six, 2004). In the past few years, new biodegradable products made of wood fibres (Photo 4.2, page 63), cork or natural fibres (linen, hemp and coconut) have performed almost as well as those made from plastic materials and as well as chemical weeding (Van Lerberghe, 2004). Their use is increasing and promising (Sourisseau, 2004). Some of these new products are being developed further to increase their resistance to biological and climatic factors responsible for their breakdown. They have already shown durability of between 24 and 36 months and sometimes longer.

Prescribed burning

Prescribed burning is essentially used to prevent fire initiation and spread in the Mediterranean area. The low vegetation is burned with care during periods of low fire frequency (mostly winter). The technique is especially useful in areas that are difficult to access. The technique is cheap but leads to important on-site disturbances.

Biological control

Vegetation control using biological agents (disease, insects) is not used in French forests. Controlled grazing in forests is not very common, except in the Mediterranean and mountain areas or in the case of plantations with wide spacing around valuable tree species. In these situations trees are specifically protected against grazing animals (Balandier *et al.*, 2002) and generally weeded locally around tree trunks during tree establishment to limit competition from grasses for water and nutrients (Balandier *et al.*, 2008).

The technique of cover plants or cover crops is at the experimental stage (Frochot and Balandier, 2005; Ningre and Koerner, 2004; Ningre *et al.*, 2004; Provendier and Balandier, 2004). It consists of controlling the most aggressive plants (i.e. the most competitive) by sowing a mixture of plants or crops that have a low competitiveness for resources (Reinecke, 2000). By colonizing the environment in time and space this mixture is expected to limit the growth of the most competitive plants, at least until tree seedlings have become well established (Photo 4.3, page 63). The sowing of cover plants has been practised for a long time in farming, especially in vineyards, with various aims: protection of soils against erosion and leaching of minerals, control of fruit production. Cereals and especially rye (*Secale cereale* L.) have been used in French woodlands in direct seeding mixtures with oak and pine seeds (Cotta, 1822). The technique is promising but needs to be improved, in particular for the selection of non-competitive cover plants adapted to different soils and climates.

Ongoing and future research

Ongoing research also aims at designing alternatives to herbicides or mechanical tools in FVM. For example, experiments are under way to test the efficiency of methods of ecological engineering like the use of mixtures of cover plants to limit the development of the most competitive natural graminoids. More environmentally friendly techniques like the use of biodegradable mulches or mechanical mini-tools are also being tested with the aim of controlling the main competing weeds. Future research, for example into techniques such as the use of shelterwood, will build on this trend. French teams often collaborate to conduct this research. Good links have been established with researchers in Germany, Sweden, Belgium, Spain, and with Canada, which will be expanded in the future.

Ecosystem responses to FVM

Current knowledge

In French soil and climatic conditions, forest weeds surrounding young trees generally reduce their growth and eventually their survival (Frochot *et al.*, 2002; Balandier *et al.*, 2006). In open fields the inhibitory effect increases with the proximity to the tree seedling; the absence of vegetation on a radius of only 10 cm is sufficient to have a significant effect on tree growth, for example on *Populus* sp. (Frochot, 1984). The inhibitory effect depends also on the vegetation type, perennial grasses being generally more deleterious than forbs or bramble for example. In many cases the competition for water and, to a lesser extent, nutrients is responsible for those inhibitory effects. The order of plant establishment with time, their spatial arrangement, below- or above-ground, the availability and heterogeneity of resources, can greatly modify the relationships between vegetation and tree seedling. Even in closed or semi-closed forest stands the understorey vegetation can seriously deplete the water supply, as is the case of *Molinia caerulea* in *Pinus pinaster* stands (Loustau and Cochard, 1991). However, this relationship is also mediated by light availability. Most competitive species are light-demanding species, with their development increasing with light availability. Consequently, their development and competitive effect for water are highly dependent on the understorey light level. Negative interactions are also reported to come from allelopathic effects, for example with some *Erica* spp. (Gallet and Pellissier, 2002) or grasses such as *Molinia caerulea* (Becker, 1984). However a true allelopathic effect is often very difficult to demonstrate in natural conditions.

Conversely, the vegetation around young trees can have beneficial effects (Frochot *et al.*, 2002; Gama *et al.*, 2006). It may reduce tree seedling water demand by decreasing light, maximum temperature, wind speed and vapour pressure deficit (Michalet, 2007). Spring or autumn frost risks (decrease in night radiation) are also limited, at least for seedlings beneath the vegetation, e.g. *Fagus sylvatica*: Ningre and Colin (2007), *Fagus* sp. and *Abies alba* (silver fir): Michalet *et al.* (in press). Tree seedlings surrounded by vegetation can also have better stem elongation (Collet *et al.*, 1998) and be protected from large herbivores, especially in woody vegetation (Démolis and Jamey, 1988). Indirect facilitation is also encountered; for example adult trees and shrubs can have a beneficial effect on tree seedling growth indirectly through reduced competition from light-requiring forbs and grasses (Pagès *et al.*, 2003; Kunstler *et al.*, 2006); such an effect is also assumed to occur for *Rubus fruticosus* in particular conditions (authors' personal observations).

Ongoing research

Much of the ongoing research is related to the windstorms of December 1999, and particularly to forest reconstitution. In the context of reduced financial support for forests, whatever the considered tool, research focuses on the cheapest and consequently the most natural way to restore forest ecosystems. Research on FVM follows this trend, aiming towards a better understanding of natural vegetation dynamics in different soil and climatic conditions, forest weeds and tree seedling responses to changing light availability, and to limit technical operations only to situations when they are strictly needed, even if tree growth is reduced.

Future needs

A better design of efficient FVM would be based on a better understanding of fundamental knowledge on the competitive abilities of weeds in relation to tree seedling establishment and growth, in different environmental conditions. However a species by species approach is quite impossible and we obviously need to identify the critical traits that characterize weed competitive ability, not in absolute terms, but relative to tree seedling establishment, which could be quite different. This has to be included in a dynamic framework to take into account the effects of different FVM techniques, vegetation growth, and in the context of the current changing climate. We should also address the potential risks of invasion by exotic weeds. Finally we acknowledge that most of our focus has been on plants and we would like to stress the importance of conducting research on the effects of FVM on water quality and other organisms, such as insects, birds, soil fauna and microbes.

Society and vegetation management

No national survey is available on the practice of the different above-described methods of vegetation control. Some assessments suggest that only 25 to 30 % of the forest area that is renewed or created each year is treated by herbicides. Managers' perception of herbicides is very variable. Some, for economic purposes, utilize herbicides when needed as a complement to mechanical operations and in accordance with certification rules. This is particularly the case for intensive management systems and for plantations on former agricultural lands. However most managers are reluctant to apply herbicides, for ideological reasons, or simply due to the lack of knowledge about this tool. This behaviour is common in extensive management systems and public forests. Thus, they use traditional mechanical methods which are often less efficient and more expensive, or they do nothing. Consequently they are often expecting alternative techniques, as shown by their participation in technical demonstration days which show-case new materials such as mini-cultivation (Wehrlen, personal communication).

The place and future of pesticides in forests has been debated among non-governmental organizations, managers and researchers, with the supervision of the French Agricultural Ministry. Recommendations for safe and environmentally friendly use of those products in forests were subsequently issued (Barthod *et al*., 1994). However there is no real debate at the society level.

Ongoing and future research

To our knowledge, there is no ongoing research in France on the social acceptance of herbicides. For the future, social research is needed not only on FVM but more globally on the human role in forest ecosystems, which is often seen as thriving and producing many services to society with little or no help.

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