Management and renewal of fir stands under threat by climate change

by Jean LADIER

The Mediterranean area is considered to be one of the most vulnerable to the impact of climate change. The MED ForClimadapt project brought together a number of partners who carried out various technical trials with the aim of adapting natural Mediterranean areas to the expected changes. In France, the ONF, the national forestry commission, studied new ways of managing Mediterranean fir stands.

Introduction

Over the last decade, Mediterranean fir stands have been showing signs of weakness, with trees dying sporadically at first but, in some places, entire production stands have been killed off. Foresters have lacked adequate tools when faced with such a rapid decline whose causes are essentially climatic. It is for this reason that the ONF (French national forestry commission) became involved in the For Climadapt project focused on the "Adaptation of Mediterranean forest areas to the effects of climate change", as a way of testing, first, new ways of managing existing fir stands and, second, the replacement of the fir by the Atlas cedar.

Context

The situation of the silver fir in Mediterranean mountain areas

The silver fir occupies a significant place in the Pyrenees and in the Alps. In the eastern part of the Pyrenees and in the southern half of the Alps, the species is subject to the influence of the Mediterranean climate which limits its spread to the south. Even so, the fir stands growing in the southernmost parts of its area in France have major ecological importance and maintain a role as a source of wood.

Picture 1:
Fir stands on the Sault Plateau (Aude, France) are already affected by drought.

For more than thirty years, those firs located in "hotspots" at low altitude have been displaying variously clear signs of deterioration, particularly when infested with mistletoe. Such decline, previously without precedent, became very disturbing and resulted in die-back and death after the heat wave of 2003 and the drought period that lasted until 2007 in South-East France. The main cause of decline and mortality is considered to have been the drought stress brought on by the climatic conditions.

It is generally accepted that the anomalies in the climate occurring since 2000 are manifestations of the overall climate change now taking place as, indeed, is the evolution in average temperatures that have made the last decade the hottest on meteorological record. In relation to the silver fir's natural area of distribution, the scenarios for future climate change, notwithstanding their inherent uncertainty, all converge to predict major shrinkage of this fir's distribution to the point of its actual disappearance from the Southern Lower Alps area and from the Sault plateau in the Aude *département* (eastern Pyrenees). Though the species occupies little area in the Lower Alps where it makes only mediocre growth, on the Sault plateau it is widely reputed for its good yields. Furthermore, this small area bordering on the Ariège *département* to the west boasts a regional identity and landscape that is notably stamped by the presence of the silver fir.

Possible strategies and related questions

Two strategies are available to forestry managers for adapting the fir stands around the Mediterranean to climate change: either build up the existing stands' resistance and resilience or replace this fir by a species better suited to climatic hardship and the expected future climate.

Building up the existing stands' resistance and resilience concerns mainly regular plantations that are at an improvement stage as well as irregular stands. General recommendations such as maintaining associated species are standard in current management. In contrast, monitoring and controlling the moisture levels by a reduction of foliage is a more innovative and focalised concept emanating from forestry research and has yet to be tested in the south of France. The idea is basically simple: reduction in the canopy of woody plants reduces the interception of falling rain, thus raising the quantity stocked in the soil at the same time as it reduces evapo-transpiration from the stand.

This idea, which offers the huge advantage of being quick to put into practice at the time when felling takes place, raises a number of questions. First of all, the forester cannot directly control leaf surface area or LAI (leaf area index), the estimation of which is a tricky exercise. He can only intervene indirectly by modifying the density of the stand while remaining aware that there is no simple relationship between density and LAI. In effect, if a reduction in the density leads to an automatic short-term reduction of the leaf area, the closing over of the fir stand or the development of undergrowth will tend to compensate for the thinning, not to mention natural self-seeding which may be triggered by the felling. Such considerations entail very close monitoring that is hardly compatible with the large-scale extensive forestry methods characterised by infrequent but radical intervention which prevails in Mediterranean mountain areas. Furthermore, it is not sure that low densities are entirely beneficial for the trees left standing: the silver fir, a shade-loving species, can develop side growth and suffer sun damage.

The question of the replacement of the silver fir as a species arises when stands have arrived at the stage of renewal and, obvi-

ously, whenever stands have been ruined through high levels of mortality. The species most often envisaged is the Atlas cedar. Naturalised in France for over a century, the species profits well from a Mediterranean mountain climate, achieving strong growth, providing quality timber while its aesthetic qualities enhance the landscape.

However, in France the Atlas cedar grows mainly in the supra-Mediterranean zone and information is lacking about its use in the mountain zone. Thought the first and second generations are in good health overall, the mortality observed in its original habitats highlights the limits to its drought resistance.

The trials undertaken

Three experimental sites were developed within the framework of this project: two on the Sault plateau in the Aude *département* and one in the Alpes-Maritimes *département* in the lower Alps around Grasse. The three sites are complementary and aim at obtaining some sort of answer to three questions.

The state-owned forest of Comefroide-Picaussel, situated on the Sault plateau between 900 m and 1,000 m altitude, has suffered major mortality following the recent drought periods. We have been studying the relevance and efficacy of low-density silviculture.

The state-owned forest of Callong-Mirailles is situated on the Sault plateau between 1,000 m and 1,100 m altitude. A plantation of Atlas cedar has been installed on the site previously occupied by the deteriorating fir stand that was unable to ensure its own natural regeneration. The plantation includes an experimental section whose aim is to compare four French provenances.

The state-owned forest of Nans is situated on the first slopes of the Lower Alps around Grasse. The climate there is warmer and more contrasted than on the shadier slopes only a few kilometres away where the lowest fir stands grow. The climate is comparable to that which will prevail throughout the 21st century on slopes presently under fir. We are studying the relevance and efficacy of low-density silviculture in a young cedar plantation.

Relevance and efficacy of low-density silviculture in fir stands growing in an ecologically critical situation

At the Comefroide-Picaussel site in the Aude *département*, the objective, starting with a homogeneous stand managed according to current norms, is to observe the impact of a major reduction in density. In this approach, the success of such experimentation depends on the choice of site. For this reason, the site must satisfy several requirements. Firstly, its ecological characteristics: we were looking for a “warm” fir stand located at low altitude at the species’ ecological limits but free of symptoms of decline: this is because, according to previous trials with deteriorating fir stands, the reduction of density by the removal of weak trees does not stop their decline. The required stand also had to display good fertility because any differences are easier to

Pictures 2 et 3:
Block 1 of the Picaussel configuration.
Control (on the left) and thinned (on the right) plots
Author J. Ladier /ONF

highlight when growth is good. Moreover, the challenges really involve the most productive fir stands, whatever their other non-productive roles. Secondly, its silvicultural characteristics: preferentially, a regular forest of standard trees, or with only one stratum, because monitoring competition is easier in a regular stand, thus facilitating comparison of the various parameters. Lastly, a fir stand that should not have undergone any recent intervention and have an average age of between 50 and 100 years. Young plantations were excluded because they are less subject to the effects of climate change and old ones because they are more vulnerable and, in any case, their condition will call for earlier renewal rather than limiting competition. And overall, the site had to offer a sufficiently large homogenous area.

The experimentation was set up on two distinct forest plots, a 75-year-old fir stand on a slope and another aged 55 on the flat. The uniform areas chosen each cover around 1 hectare.

Their initial density was 400 trees per hectare. This density was maintained as a control over half the area. The other half underwent a severe thinning at the start of 2012 to end up with 200 trees/ha. This brutal culling reduced the density to the target density in one go whereas classic forestry management considers this should be done progressively over two or three culls. The experimental protocol thus involved two repetitions of two measures, resulting in four experimental units altogether.

Several types of observation are made in order to follow the evolution of the stands: the growth and health of the conserved promising trees, natural regeneration, the development of the undergrowth. At the level of the stand, inventories permit the calculation of the basal area and the average diameter. Thus, the growth of the stand can be assessed along with the shortfall due to the radical thinning. The leaf surface area is estimated using a cover analyser, both to permit an assessment of the moisture levels and to attempt to correlate the LAI to dendrometry. The volume and composition of the competing plant cover are recorded to quantify the potential competition from the undergrowth in an open stand and to assess the concomitant increase in combustibility.

Picture 4:
Young Atlas cedar at bud-break, spring 2013. Callong-Mirailles site.
Author J. Ladier /ONF

The density and height of the fir saplings are similarly monitored. In each experimental unit the height and circumference of 40 selected specimens are monitored and of these 40, a sub-sample of around 15 trees are the object of a health assessment: lack of foliage, dead branches, presence of mistletoe, etc.

This protocol will be followed over at least eight years so as to obtain reliable knowledge needing time to acquire. As the project comes to an end after one season of growth, we have garnered only a hint of future results: as expected, the selected specimens show a greater increase in diameter in the thinned-out units. This direct effect of reduced competition should last and become stronger. On the other hand, as yet there has been nothing to distinguish their state of health. The lack of foliage has increased a little overall, with great disparity from one tree to another, but no interpretation can be given at present.

Conversion of fir stands with comparative planting of French provenances of Atlas cedar, after failure of natural regeneration

This second site is situated in the Callong-Mirailles forest which is also in the Aude *département*. The cedars, planted on 8 hectares in spring 2013, rooted well. Grazing damage was limited by the use of a repellent. Some plants were grubbed by wild boar.

The non-experimental unit has been planted with the Rialsesse provenance which is assumed to be the most suitable because the nearest geographically. The experimental portion covers 0.7 hectares. Our intention had been to compare the performance and adaptation of all French Atlas cedar provenances but problems of availability and seed

batch quality have limited our choice to four southern provenances:

– *Rialsesse*: this is a "local" provenance. The source trees are situated in the western Corbières mountains in the Aude, some 50 kilometres from the Callong-Mirailles forest. However, the trees are located at a lower altitude in a supra-Mediterranean climate, on a silicaceous soil;

– *Mont-Ventoux*: the cedar stands here are registered as "tested". They are in Upper Provence towards 1,000 metres above sea level in a supra-Mediterranean climate, on hard limestone;

– *Saumon*: also registered as a tested stand. It is situated in the southern Lower Alps at 1,000 metres above sea level above Digne-les-Bains in a supra-Mediterranean climate, on hard limestone;

– *Issole*: this provenance is located in the southern Lower Alps in the Issole valley around 1,300 m above sea level in a sub-mountain zone on hard limestone.

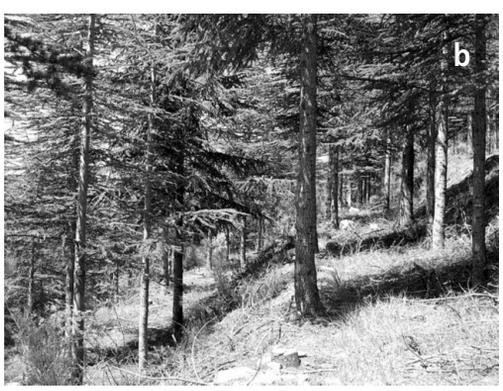
In order to obtain reliable results and highlight the differences in behaviour between the various provenances, the configuration of the experiment is in several blocks. Each block is made up of the four provenances to be investigated and is thus a repeated pattern in a precisely defined ecological context. The overall structure of the configuration was finalised after the land had been prepared in the light of an inspection of the homogenous areas. It is constituted of twelve complete blocks, each block made up to a standard format: four rows, one for each provenance, containing 24 seedlings, thus making a grand total of more than 1,000 trees.

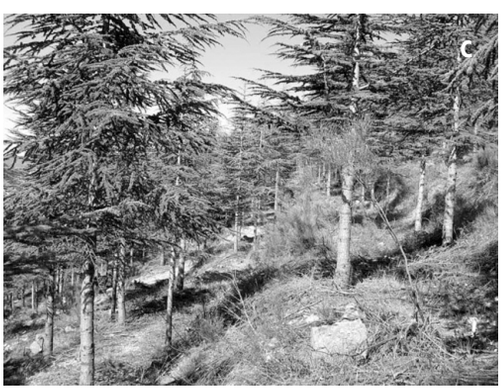
This plantation will be monitored for at least fifteen years so as to obtain concrete information about the use of these cedar provenances in the context of fir forest.

Relevance and efficacy of low-density silviculture in a young cedar stand in a supra-Mediterranean climate

For the third site, in the state-owned forest of Nans in the Alpes-Maritimes *département*, the underlying principle is the same as for the experimentation in the fir forest of Comefroide-Picaussel but here applied to a forest which could well replace the fir stands in the climatic conditions which may prevail in the medium-term future. The conditions of plantation are thus similar in terms of homogeneity, fertility and structure but in a supra-Mediterranean climate; the cedar stand needed to be located close to the lower limit for the fir but in a much warmer context.

The configuration for the experiment was applied in a 35-year-old Atlas cedar stand whose dominant height overall was 12 metres, placing it in the second class for fertility. The stand is located on a sunny limestone slope at 1,050 metres altitude, at a few kilometres remove from the first fir forests in the Lower Alps. Between these locations, there is a difference in the mean annual temperature of 2°C.





Pictures 5, 6 et 7:
The Nans configuration.
Blocks:
a - Control
b - 600 trees/ha
c - 300 trees/ha
Authors C. Tessier /ONF et J. Ladier /ONF

The protocol for forestry management calls for the early selection of 300 designated trees per hectare of which 200 will be focus specimens. The first thinning of a stand classed 2 for fertility is normally carried out at 42 years old with an overall height of 16 metres, leaving a density of 600 trees per hectare.

Here, three levels of density are being tested:

– normal silviculture, without any intervention throughout the project;

– low-density silviculture: freeing the surrounds of the designated trees by removing two neighbouring trees, resulting in a density of 600 trees/ha. This corresponds to a normal thinning but 10 years earlier;

– very low-density silviculture: only the designated trees are retained. These are then left to grow freely for the duration of the project at a density of 300 trees/ha.

Follow-up will be the same as at the Picaussel site, notably the regular measurement of the same three aspects of the 40 chosen trees of which certain will be monitored for overall health. After two years, the radial growth of the focus specimens was negatively related to the density. At this site we have had the advantage of a supplementary diagnosis, carried out by the Avignon branch of INRA [1], measuring potential moisture levels and the conductivity of the branches. In comparison to the control, the trees in the thinned plots already display improved hydraulic behaviour and better nocturnal recovery during the summer.

Conclusion

Informed readers will already have realised that this project has its limits. In the first place, three years is obviously too short a period in forestry matters for obtaining results and the staggered deployment of the three experimental configurations can only accentuate such limits. For this reason, the follow-up monitoring is scheduled to last 8 to 10 years, indeed more depending on the evolution recorded.

Additionally, the statistical value and the representativity of the expected results are open to criticism, in particular concerning forestry trials in conditions with little water which do not involve many or any repeats. This drawback is already partially made up for by the existence elsewhere of two similar experiments in fir stands In regard to the Atlas cedar, it has long been the object of study, notably by INRA. While such studies have involved different ecological contexts and protocols, they should nevertheless permit the validation and sharing at a forest management level of the ensuing information and results.

Despite its limits, the ForClimadapt project has truly been a catalyst for a variety of innovative initiatives. In France, those led by the national forestry commission, ONF, have been integrated into an overall strategy of experimentation of new ways of management which will come to fruition in a few years time.

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1 - INRA : French national agricultural research institute.

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Summary

The issue forming the topic worked on within the framework of the European Climadapt project by the ONF –the French national forestry commission- involved the mountainous forested areas of the Mediterranean hinterland; specifically, the management and renewal of fir stands threatened by climate change. It has become clear that while fir forests constitute an outstandingly rich economic and ecological resource, their mortality observed over recent years has highlighted the fragility of such ecosystems when faced with climatic events and the difficulty forest professionals have in trying to preserve them. For the project, three experimental protocols were set up in the south of France to test different methods of management in real-life conditions. The first involved low-density forestry management of existing fir stands with the aim of improving their resistance to drought. The second protocol called for the plantation for purposes of comparison of Atlas cedar of four different provenances as a replacement for a former fir stand that had been decimated by the drought conditions prevailing from 2003 to 2007. In the context, it was considered that the Atlas cedar was the most promising replacement species. The third was a try-out of forestry management in a low-density cedar stand considered to represent what is likely to be the situation of fir stands in a few decades' time. Obviously, the results will only become available after a long period of monitoring, much longer than the three years of the ForClimadapt project.