The Uncertainties of Wind-damage in Forest Management? [1]

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INTRODUCTION

It is most undesirable to have the uncertainty of large scale wind-damage when preparing long term forest management plans. Looking ahead, I do not think that wind-damage will necessarily be inevitable within acceptable economic rotations in Britain, but there are many areas where, in the first rotation at least, wind will be the deciding factor. As a first step therefore it is necessary to be able to recognise those sites where wind-damage will occur so that account can be taken of them in forecasting production, and decisions can be taken on whether or not to try preventative measures.

The occurence of storms of sufficient strength, and with a high frequency is of course the basic requirement for wind damage, but there seems little doubt that this condition will be fulfilled in most upland parts of Britain, and probably Ireland. Wind-damage takes two forms, stem break and uprooting, so that it will occur anywhere where conditions are such that the trees are unable to develop their stems or roots fully.

There are numerous ways in which the silviculturist can affect the development of both the roots and the stem of trees, so that a better understanding of the response of trees to different treatments will help in deciding on the most effective preventative measures.

Many factors are involved in the problem of wind-damage, but studies over the past few years have indicated that the main concern is uprooting of the spruces on poorly drained soils, and stem breakage of a range of species on freely draining soils. My own investigations have therefore been directed towards these two aspects, though exceptions have been noted, when they occurred.

This division between freely draining and poorly drained soils is a convenient one, and it will, I hope, become apparent that it is most important to be able to recognise these soil types and treat them differently.

Poorly drained soils.

This category includes surface water gleys, peaty gleys (peat up to 24 inches deep) and frequently deep peats. Other soil types may be included, but these three account for the major proportion.

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It is not really known at what stage excess soil moisture becomes harmful to tree roots, but if the soil remains saturated for prolonged periods, at any depth, rooting will be restricted.

There is some difference between species in their ability to tolerate water-logging, but Sitka spruce seems to be as vigorous as any under these conditions.

In the most severe conditions the roots will be restricted to the familiar flat plates seen on uprooted trees, but under slightly better conditions short sinkers may develop under the lateral roots. Rooting depth may vary from as little as 10 inches on the wettest sites to about 20 - 24 inches on some of the better deep peats. Uprooting will therefore be the predominant kind of damage, and it can be expected to start with small groups of trees blowing over, any time after the crop has exceeded about 35ft. in height.

Once wind-damage has started it is likely to continue at an accelerating rate until most of the crop has been affected. Changes in soil type, crop size or species will frequently form a boundary at which the damage stops.

The onset of wind-damage in these sites may also be associated with a slowing down in height growth in the remaining crop ; probably due to a combination of damage to roots, and to increased exposure.

Here then is one situation where some uncertainty can be removed. A fairly quick reconnaissance with a spade, in a crop which has just started to show signs of wind-throw will reveal how far it is likely to extend. Observations of the rate of extension for a season or two will soon indicate the time when action should be taken to clear the crop. A number of factors can initiate the wind-throw, perhaps the most common are thinning and drain maintenance, which respectively expose the remaining trees, and result in roots being severed.

However, while delayed or heavy thinning may make matters worse, early thinning does not appear to have any advantage, and only the complete avoidance of thinning would seem to help prolong the life of the crop slightly. Where rooting is bad, however, wind-throw is inevitable.

Freely drained soils.

This category includes brown earths of a range of depths, and a complex of podzolic soils, which may or may not have a pan, or a peat layer.

Under these conditions most species, especially Sitka spruce, will develop deep sinker roots, often almost tap roots under the stem of the tree, and rooting depths from 2 to 7 ft. are common. Except where rock or an indurated layer physically restricts the rooting the predominant type of damage will be breakage of the stem. In Britain this type of damage is most often found on fertile sites where height growth is rapid and delayed thinnings depress girth growth of the stems.

The first thinning suddenly exposes the trees, and small groups can be snapped off. It may or may not then extend, depending on the growth of the remaining trees, and the nature of the soil. Uprooting may also occur on these soils where depth is physically restricted by rock or induration.

RESULTS

These then are the two main problems that the forest manager must face, but before discussing ways and means of overcoming the problems it is, I think, worth having a look at recent research results which will provide some evidence to support recommendations.

We have for the past few years been studying the root development of various species, but mainly, Sitka spruce, on a range of soil types, and have some measure of trees' resistance to break or uprooting from the tree-pulling investigation. We also have some data on the forces which will be applied to trees, as measured in wind tunnels, and although the research is nowhere near complete, the available results from the two lines of investigation have been linked up. The results, while being far from decisive are I think still worthy of close inspection because they do fit remarkably well with field observations.

If the turning moment at the base of the tree, that will be applied by any wind velocity, is calculated and the result equated with the turning moment that trees on a given site are known to resist from tree-pulling studies, it is possible to find the critical wind velocity for any size of tree. This critical velocity can then be plotted against size of tree for a range of sites, so that a family of curves as shown in Figure 1 are produced.

All that is now required to predict the size that a crop will reach before being blown over is a knowledge of the frequency of gales of any velocity. It seems from still fairly limited observations that on upland sites a mean hourly wind speed of 40 knots can be expected quite frequently: probably in 2 out of 3 years. It can be seen then that trees on peaty gleys and surface water gleys would be blown at 50 ft.; deep peat at 60 ft. and brown earths at 70 ft. by such a wind. This accords well with observations. In sheltered valley sites the maximum wind velocity may only be 30 - 35 knots allowing correspondingly taller trees.

This now gives us a base line against which we can judge the likely benefit from silvicultural treatments such as spacing, ploughing, draining and thinning. It also gives us a better idea of the relative susceptibility of different soil types, and something on which to base estimates of rotation length. It should however be made clear that the curves shown are the average of several sites in different forests, and that there is quite an amount of variation about each line. Thus some deep peats may be as poor as peaty gleys and others nearer brown earths.

As already mentioned Stika spruce and, as far as can be seen, most other species will develop deep sinker roots, given a free draining soil. On these sites however lateral root development is very much affected by the proximity of neighbouring trees.

This is clearly illustrated by the measurements of root spread of trees pulled over in two spacing experiments, in Radnor and Clocaenog

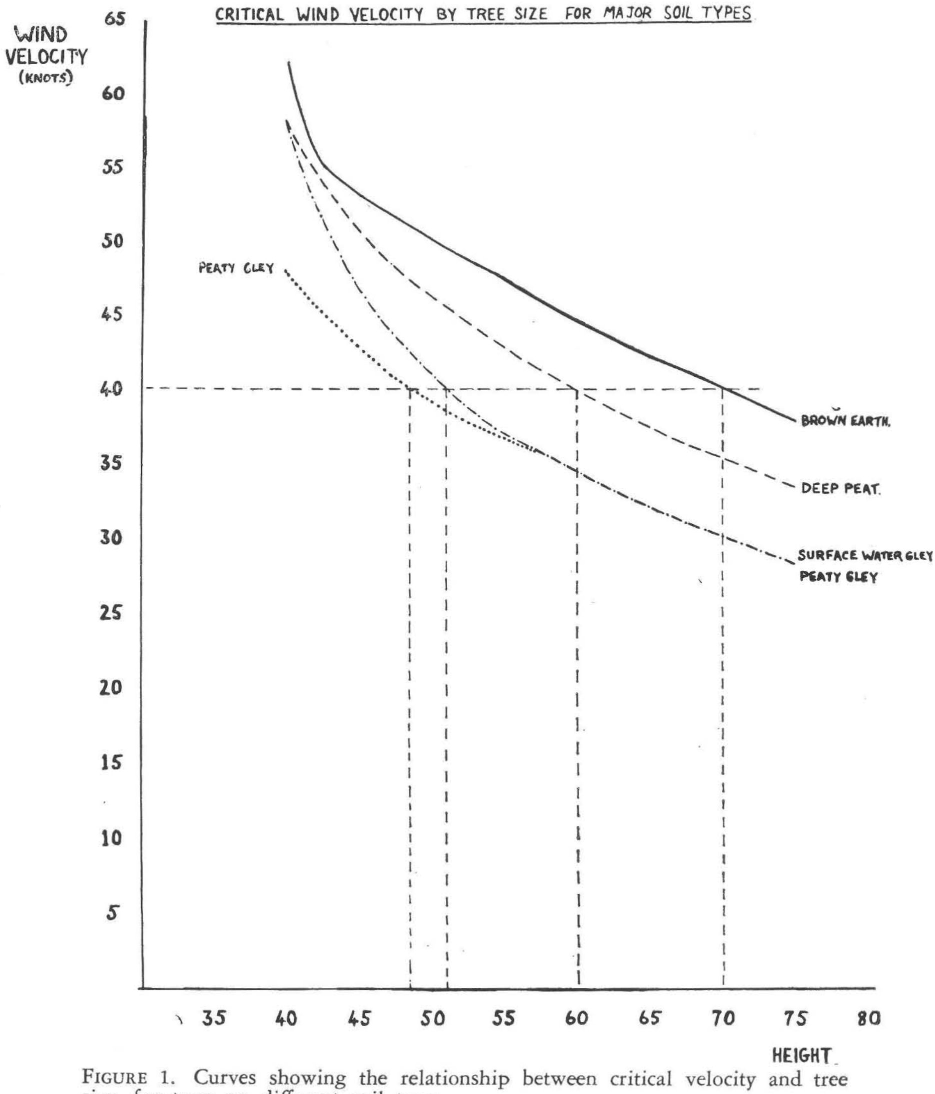

FIGURE 1. Curves showing the relationship between critical velocity and tree size, for trees on different soil types.

forests in North Wales. Both sets of plots were planted in the same year, but one which grew more rapidly had been given thinnings, while the other was still unthinned when pulled. Both plots were 28 years old when pulled over, and the thinned plots averaged 45 ft. tall, while the unthinned ones were 39 ft. tall.

TABLE 1

Root development related to spacing on thinned and unthinned Sitka spruce at Radnor and Clocaenog forests.

UNTHINNED		THINNED		Years Since First Thinning
Spacing	Root Diameter	Average Spacing	Root Diameter	
3 ft. × 3 ft.	4.2 ft.	$5\frac{1}{2}$ ft. × $5\frac{1}{2}$ ft.	5.2 ft.	8
$4\frac{1}{2}$ ft. × $4\frac{1}{2}$ ft.	5.0 ft.	$8\frac{1}{2}$ ft. × $8\frac{1}{2}$ ft.	6.6 ft.	8
6 ft. × 6 ft.	6.2 ft.	11 ft. × 11 ft.	6.2 ft.	4
8 ft. × 8 ft.	7.6 ft.	13 ft. × 13 ft.	8.7 ft.	4

Rooting depth varied from 2 - 3 ft., according to the depth of soil. It can also be seen from these figures that the response after thinning is quite slow, and in the closest spaced plots, the root spread is still less than the spacing after eight years.

On poorly drained soils the situation is quite different ; directly comparable figures are not available, but two other experiments are of interest.

One of these was an experiment at Forest of Ae in South Scotland where pairs of dominant Norway spruce were selected when the crop was 11 years old, and one tree of each pair randomly chosen for isolation. These trees have been maintained as isolated dominants while the other one of the pair has been left in the unthinned crop. The trees were pulled over when 25 years old.

The second experiment was a thinning experiment at Kielder in North England in Stika spruce, where four plots were marked out in a 14 year old crop. The plots were then heavily thinned in turn (one third of the stocking removed at each thinning) on a three year cycle, so that the first thinnings were given at the age of 14, 17, 20, and 23 years respectively.

Although the plots were not replicated and one was eliminated because of a difference in soil type it is interesting to study the relationship between rooting diameter and depth for these two experiments as seen in Table 2. The trees were 30 years old when pulled over

Compared with the freely draining soils, the root systems of these trees have responded much more to opening up in terms of lateral root spread. On the other hand there has been a detrimental effect on rooting depth which was not nearly so apparent on the freely drained soils.

TABLE 2

Effect of spacing on root diameter & rooting depth in two experiments (see text).

Species		Effective spacing	Rooting diameter		Rooting depth		Years since thinned
NS	isolated	5.7 ft.	6.6 ft.	+	21.0 in.	+	—
	dominants			— 0.5		— 1.72	
	experiment	12.7 ft.	10.1 ft.		14.6 in.		14
SS	thinning	8.5 ft.	8.2 ft.	+	15.0 in.	+	10
		10.0 ft.	9.2 ft.	— 0.6	13.2 in.	— 0.7	13
	experiment	12.0 ft.	13.2 ft.		9.8 in.		16

The resistance to pulling over, comparing similar sized trees on the various treatments is the same, but of course the wind forces applied to the trees in the open plots will be much greater.

One possible explanation of these results is provided by considering the effect of the crop on the moisture regime of the soil. In the close spread crops, the interception of rainfall and removal by transpiration will be greater than in the widely spaced crops, because of the denser cover and the greater crown surface area. This could result in an appreciable drying out of the site and improved rooting conditions. Is this an argument in favour of no thinning on badly drained soils which are susceptible to wind-damage?

Little work has been done yet on studying the effects of initial ploughing treatment on the development of the root systems in the thinning stage. However, observations definitely indicate that on freely draining soils lateral root development takes place under the plough furrows and the tree stability is unlikely to be affected. On badly drained soils, especially if the depth of the plough furrow is almost the same as the depth of the permable top soil, lateral root development is restricted and in the absence of sinker roots the trees are quite unstable.

A much more important form of ground preparation is of course drainage which not only is the main requirement to prevent windthrow, but will also go a long way towards increasing the productivity of the site.

Unfortunately there is very little experimental evidence available at present to provide information on the response of tree crops to drainage either as improved root or shoot growth. One experiment, described in an earlier paper (Fraser 1962 a) has shown that a thicket stage crop will respond to drain deepening, but the experiment did not have drains up to present day recommendations. The prospects of major improvements in rooting are high if drainage is carried out at planting or in the first few years of growth, but it becomes a more uncertain operation when trying to save crops which have already reached thicket stage. The response seems unlikely to be enough to postpone wind-throw sufficiently to recover the high cost of the operation.

Economic calculations tend to confirm the view that drainage at planting is in all respects the most desirable, but that up to early thicket stage (say 10 years) it is still a profitable operation.

So far we have dealt with the soil and roots, and silvicultural treatments which can improve these and hence trees ability to withstand wind forces. The silviculturist can also influence the forces which are applied to the trees, by giving attention to crop structure and layout.

Wind-tunnel tests which have been described in detail elsewhere (Fraser 1962 b and 1964) have demonstrated the adverse effects of roads and thinning on the problem. Both of these factors result in very appreciable increases in the forces applied to the trees and, as has been discussed earlier, on the most susceptible soils trees are unable to resist these by developing better roots.

These same studies and field observations on forests growing in exposed sites, strongly suggest that the most effective method of reducing the forces on the trees in a crop is to achieve a smooth surface to the canopy. By doing this, the amount of energy which can be transmitted to the trees is reduced to a minimum, and it is confined to the tip of the tree, where the cross-sectional area is least. If a rough surface is developed, either by thinning or by felling small groups, turbulent flow is created, and much greater forces are applied to the main crown lower down the trees. On well rooted soils, the trees are likely to be able to withstand these high forces, and will probably develop roots in response, but on badly drained soils this is not possible and wind-throw will occur. Any kind of thinning tends to make the surface of the canopy rougher. Experiments are now in hand to throw more light on this topic.

CONCLUSIONS

With the results discussed so far, it becomes possible to rationalise any given situation and make plans with some prospect of adhering to them.

The first obvious step is to obtain some detailed knowledge of the soils in a forest, so that the likely extent of the problem can be assessed, and also so that treatments can be adjusted accordingly. A soil map is perhaps a luxury, but notes kept in compartment records can go a long way towards indicating soil type.

The second step must be to obtain a break down by age classes of crops on the susceptible soils, so that decisions can be made on the allocation of work. It has been found convenient in some cases to recognise three age-class groups, on susceptible soils.

1. Crops which are more than about 25 ft. tall; probably over 20 years of age. These will be in imminent danger of blowing over, and will almost certainly have passed the stage where drainage could be effective. Thinning in such crops will probably initiate some wind-throw.

   Such crops are almost certainly past saving, and consideration of anticipatory fellings seems eminently worth-while; this avoids the fluctations in work and output of produce which are inevitable if wind-throw is accepted as it comes.

2. Crops which are between 10 and 25 ft. tall; probably 10 - 20 years of age. These crops will be expensive to drain, but have a reasonable chance of responding. The resources available will decide whether drainage can be attempted, but they will be of low priority because of the uncertainty of success. On the other hand thinning and even brashing could be avoided with reasonable prospects of prolonging the life of the crop. (Avoidance of brashing reduces costs rather than increases stability).

3. Crops less than 10 ft. tall; younger than 10 years. These crops can readily be drained, and with improved techniques, at an acceptable cost. The response is likely to be large, and so wind-throw may well be eliminated or at least delayed long enough to make a decent income from the crop.

A fourth category of course are crops on non-susceptible soils, which, apart from being thinned early and regularly, need not be subject to other constraints.

Much useful information can also be obtained by studying any wind-damage that occurs in some detail. The frequency of damage, the soils on which it occurs, and the height of the trees that are blown over, are all useful guides as to how long younger crops will stand. This is invaluable if deciding on anticipatory fellings, which ideally should be the day before the trees would have blown over!

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