THE INFLUENCE OF THE SOIL FACTOR ON TREE STABILITY IN BALMORAL FOREST, CANTERBURY, DURING THE GALE OF AUGUST 1975

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ABSTRACT

This brief study shows a relationship between depth to stones and susceptibility to windthrow. Line transects recording soil depth and percentage windthrow were made through single-aged stands of trees where definite patterns of windthrow occurred. Trees on soils with less than 20 cm depth to stones suffered less windthrow than those on deeper phases. The wind-firmness of the trees on very shallow and stony phases was attributed to their lack of root mat formation. Such root mats commonly formed in trees on the more windthrow-susceptible deeper phases.

INTRODUCTION

Balmoral forest (9300 ha) is situated in North Canterbury on the north bank of the Hurunui River midway between Waikari and Culverden. On 1 August 1975 very severe north-westerly gales resulted in extensive damage to the forest. Maps depicting damage to the forest after the storm (Fig. 1) show patterns of windthrow within single-aged stands of trees. It was considered probable that a soil factor was at least partly responsible for certain areas standing firm while others suffered severe windthrow. A brief study was undertaken to investigate the effect of soils on tree stability.

DESCRIPTION OF AREA AND SOILS

The area of the survey was on flat outwash gravels dissected by many old river channels and small terraces. The soils are mapped as part of the Balmoral set and are classified as shallow and stony soils associated with yellow-grey earths (N.Z. Soil Bureau, 1968).

Shallow (15-45 cm stone-free soil) and stony phases occur in a complex pattern and are interspersed with moderately deep phases (45-90 cm of stone-free soil). Figure 2 shows the vari-

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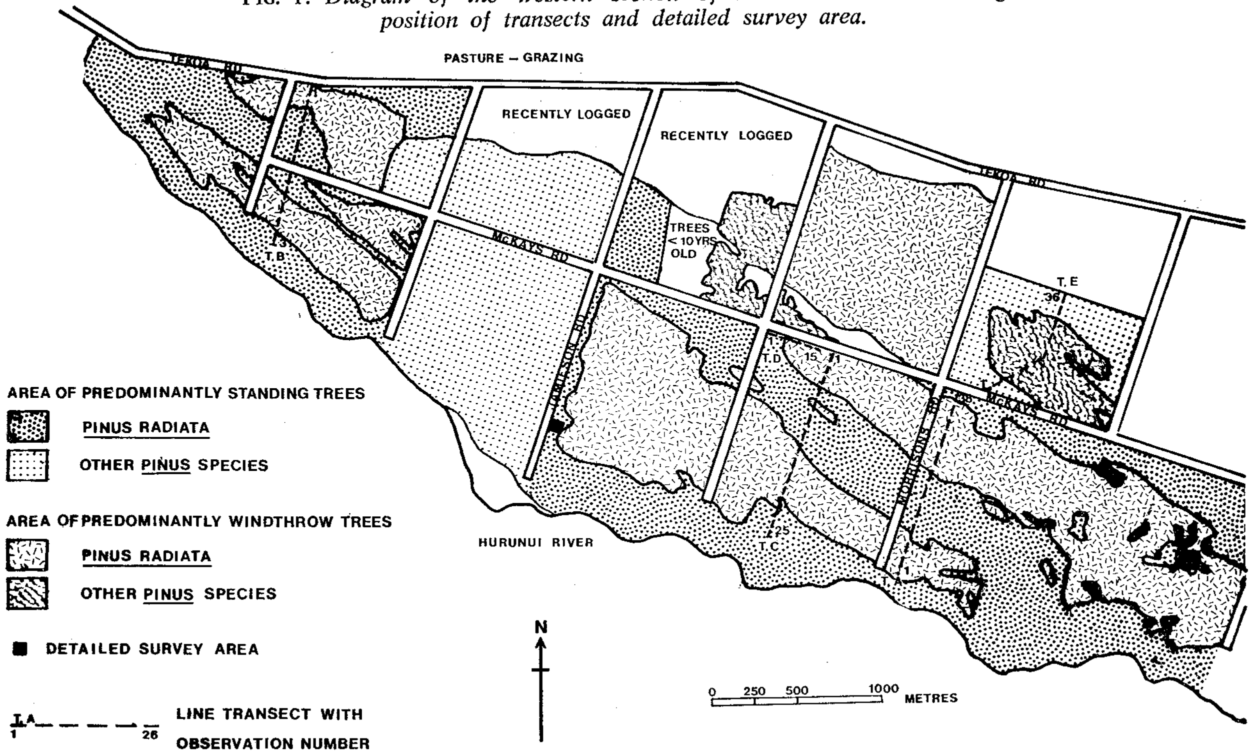
FIG. 1: *Diagram of the western section of Balmoral Forest showing position of transects and detailed survey area.*



ability of depth phases along line transects. The deeper phases commonly occur in narrow strips associated with former stream channels.

Prior to the strong winds of August 1975 the weather had been unusually wet and it is probable that the soils were near field capacity owing to low evapotranspiration rates (Wilson, 1976).

NON-SOIL FACTORS INFLUENCING TREE STABILITY

Several site, biological, and forest management factors can influence tree stability.

In Balmoral Forest, site factors likely to have major effects on tree stability were considered to be either constant or slightly varying. The land surface is generally flat with shallow stream channels, the water-table is several metres below the rooting zone, and hills are 0.5 to 2.5 km to the north. Climate does not change appreciably over such a small area.

Different tree species have different abilities to withstand windthrow (Prior, 1959). Also younger trees are more wind-firm because they have more flexible trunks and branches and a lower centre of gravity. Trees may vary in their rate of root growth and number and strength of roots, which will have an effect on individual tree stability.

Several management factors such as logging, thinning, stocking rate, change of height between blocks of trees, and size of blocks may modify susceptibility to wind damage (Prior, 1959).

METHOD OF STUDY

Observations were designed to minimise the effect of biological and management factors on windthrow patterns. Sets of observations were taken within stands of single species of equal age. Most biological variation within a block would relate to individual tree variation which would be randomly distributed. Management factors, although varying between blocks, are assumed to be constant within any block and are most unlikely to account for the patterns observed.

Four blocks were studied where definite patterns of damage occurred within the blocks, which indicated that a soil factor rather than a biological or management factor could be responsible for the pattern of damage. Transects were made to traverse the wind-firm and windthrow areas (Fig. 1). Observations were made every thirty paces along these transects. At each point, depth to stones (measured by screw auger penetration)

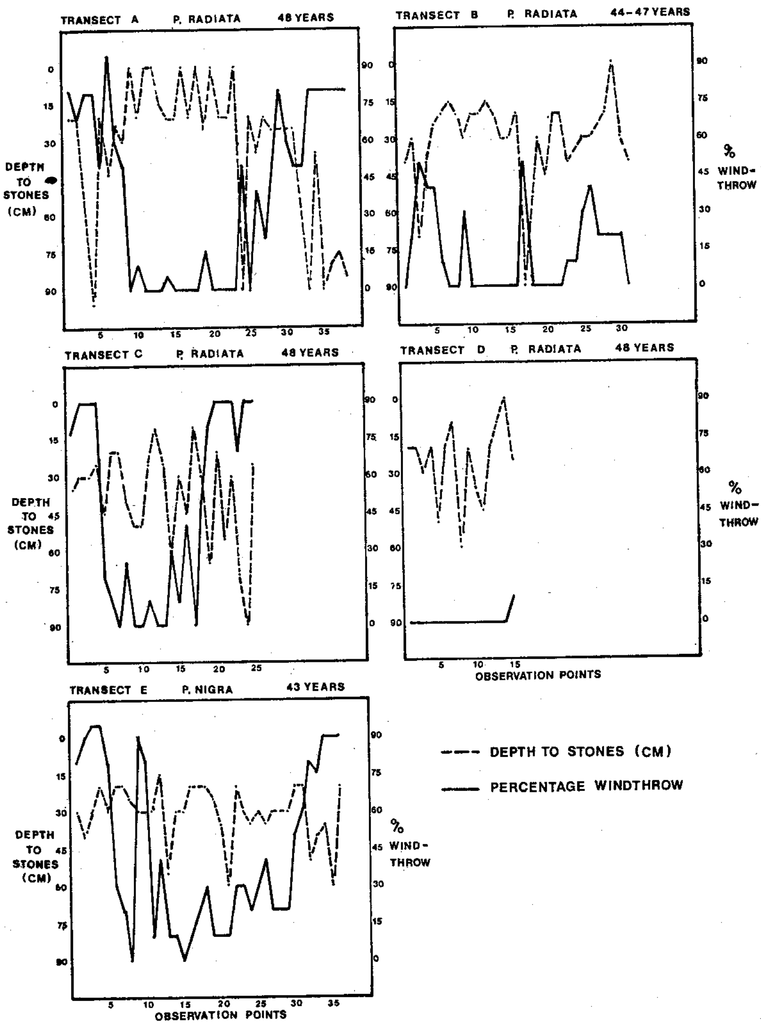


FIG. 2: *Recordings of percentage windthrow and depth to stones (cm) for each observation point along transects.*

and percentage of windthrow and percentage of standing trees were recorded (broken trees were counted as standing). Trees were counted within about a 5 metre radius.

A small detailed study was made near Jamieson Road where standing and windthrown trees occurred in close association (Fig. 3). Observations were made at grid intersection points (3 paces × 3 paces), noting depth to stones and position and condition of individual trees.

RESULTS AND DISCUSSION

Trees along transects A, B and C all showed greater windfirmness in the soils with minimum depth to stones (Fig. 2). Transects A and B had significant positive correlation between percentage windthrow and depth to stones (Table 1). In transects A, B, and C, soils with 20 cm or less depth to stones formed the most wind-firm depth class, and this is illustrated in Table 2 where the percentage windthrow of trees on such soils is contrasted with percentage windthrow on deeper soils. The de-

TABLE 1: CORRELATION COEFFICIENT (R) FOR PERCENTAGE WINDTHROW AND DEPTH TO STONES

Transect	*No. of Observations*	*(R)*
A	38	0.71**
B	31	0.43**
C	25	0.30
D	15	0.01
E	36	0.13
A-D	109	0.52**

** $P < 0.01$.

TABLE 2: PERCENTAGE WINDTHROW IN RELATION TO SOIL DEPTH TO STONES

	Mean % Windthrow	
Transect	*Soil Depth ⩽ 20 cm*	*Soil Depth > 20 cm*
A	12 (19)	65 (19)
B	4 (12)	18 (19)
C	20 (5)	50 (20)
D	0 (9)	2 (6)
E	45 (10)	43 (26)
A-D	8 (45)	41 (64)

( ) Number of observations of each depth class within transect.

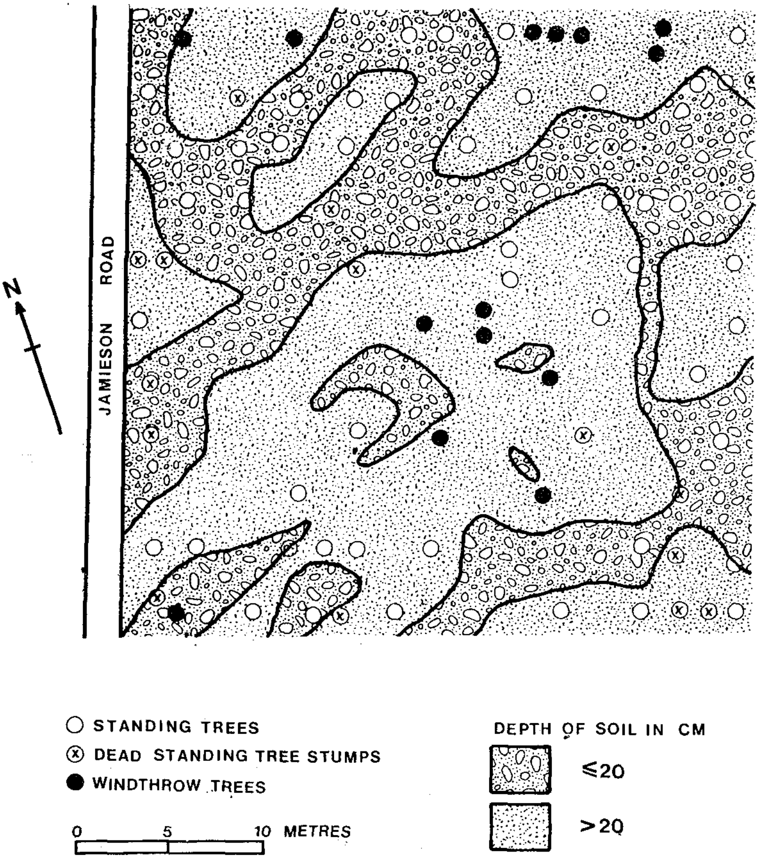


FIG. 3: *Detailed survey area showing two soil depth classes and tree position.*

tailed study area (Fig. 3) gives further support to the hypothesis that a 20 cm depth is critical. All but one of the windthrown trees occurred on soils with greater than 20 cm depth to stones. However, standing and broken trees were fairly evenly distributed over both classes.

The susceptibility of trees to windthrow on soils with a depth to stones of 20-90 cm may be related to their root distribution. These soils have a sharp contact between the fine material and the underlying very stony horizons, and tree roots do not readily enter between the stones but instead form a mat of roots on top of them. This discontinuity of roots was observed at the base of many of the root bowls of overturned trees in the present study. Wendelken (1955) has found the same situation in Lismore soils (which are very similar to Balmoral soils) in Eyrewell forest. He considered that as a tree rocks back and forth the weight of the tree compacts the underlying stones and the constant stress at the contact causes a shearing of any sinker roots which may have penetrated between the stones, thus emphasising the discontinuity between non-stony and stony horizons. When a large gust of wind strikes the tree, it passes its point of balance and topples over with very little resistance.

In soils with a depth to stones of 20 cm or less, the tree roots penetrate amongst the stones. No preferential plane of weakness develops, unless there is a pan in the soil, and the weight of the tree is more evenly distributed throughout the rooting volume. When the tree is rocked by the wind it is more likely to stand firm or to break. Where trees growing on stony soils did blow over, their roots had an irregular distribution and had not formed a dense mat. On the other hand, some of the wind-firmness of the trees growing in stony soils may have been due to their having slower growth and therefore being smaller trees with less susceptibility to windthrow (Prior, 1959). No measurements were made of tree size.

Transects D and E do not show the same relationship. In transect D, variable soil depths were associated with 90% windthrow and there was little difference between percentage windthrow and the two depth classes. However, there were too few observations on this transect to give any weight to this result. Transect E had variable windthrow with similar ranges of soil depth, and had no difference between percentage windthrow and the two depth classes. A factor other than stoniness must account for the results of transect E. It may be that *Pinus nigra* has a different rooting pattern from *Pinus radiata.*

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