The use of aerial photography for assessing soil disturbance caused by logging

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ABSTRACT: When harvesting takes place in forest plantations, it is common for logging machinery such as skidders and crawler tractors to traverse 50% or more of the area. The damage caused to the soil through compaction and soil removal ranges from slight to severe and may lead to slower growth of the subsequent tree crop and an increased probability of erosion. A technique is described for classifying and mapping this disturbance using small-format colour aerial photographs. Also mentioned are some aspects of the role of aerial photography in harvest planning and in determining the effect of soil disturbance on tree growth.

1 INTRODUCTION

Each year throughout the world millions of hectares of forest are logged using skidders and crawler tractors. In New Zealand alone, the area logged by these machines amounts to about 15 000 ha annually. As the logs and logging machines pass over the forest floor, it is not uncommon for 50% or more of the total forest area to be disturbed by compaction and removal of the various soil horizons (Murphy 1984). The soil's airspace is reduced, its bulk density increased, and its moisture regime altered (Steinbrenner and Gessel 1955).

With more and more forests in New Zealand moving into their second and subsequent rotations, attention is being focused on the growth losses which may occur in the new crop through the disturbance done to the soil during thinning and harvesting the old crop. If the area disturbed is large, the effect long term, and the reduction in tree growth significant, the potential exists for a very serious and expensive problem.

Some years ago, the New Zealand Forest Research Institute (FRI) decided to investigate harvesting-related soil disturbance and its effect on tree growth. The research was divided into four phases.

1. Classifying the disturbance.
2. Mapping the disturbance.
3. Investigating the relationship between soil disturbance and tree growth.
4. Finding ways to reduce soil damage and improve the soil.

It was soon found that aerial photography had a significant part to play in this research and some aspects of its role are outlined below.

2 CLASSIFYING AND MAPPING SOIL DISTURBANCE

A brief walk through a thinned or logged forest soon reveals that the disturbance caused by logging machinery may range from nil (soil is completely undisturbed) to severe (the litter and top soil have been completely removed and the subsoil compacted into an impervious rock-hard mass). Murphy (1982) has divided this disturbance into five visual damage classes or strata:

0 - Machines have not travelled over the area.
1 - Machines have travelled over the area but have not broken through the litter layer.
2 - Machines have broken through the litter layer and started to compact the topsoil.
3 - Most of the topsoil is puddled, and subsoil compaction has begun.
4 - Subsoil is puddled and compacted.

Murphy (1984) has successfully used his classification to assess 18 logging sites around New Zealand using a line transect method similar to that tried by Dyrness (1965). However, walking to and fro over logging slash can be very arduous. In addition, the transect method, while providing good overall disturbance proportions, is not suitable for producing maps showing the pattern of the disturbance. It was thought that by using aerial photography to bring the logged area into the office, the assessment of soil disturbance could be done easily and more effectively.

The specifications for the photography were:

Camera	-	Hasselblad
Format	-	55 x 55 mm
Film	-	Colour negative
	-	Colour transparency
Negative scales	-	Between 1:5000 and 1:15000

Three people were asked to interpret the aerial photographs using Murphy's classification and then to check their efforts in the field. The results were disappointing with differences of up to 59% being obtained.

It was therefore decided to modify Murphy's classification so that the strata more closely reflected how soil disturbances appear on the aerial photographs. Furthermore, objective elements of interpretation were introduced where possible.

The system shown in Table 1 was devised. Its main components are:

1. the existence and importance of the skid trails, and
2. the colour difference between the top soil and the subsoil.

This new classification was tested by several people using various sets of aerial photographs of different logged areas. Consistent results were obtained between interpreters and there was good agreement with the ground truth, differences being under 10%. Subsequent experience with the method showed that the photographs should be taken as soon after logging as possible before weed growth obscurs valuable detail. It was also found that large negative scales (> 1:10000) are not as useful as smaller ones (1:10000-1:20000) because the large scales emphasised irrelevant detail.

Table 1. Strata descriptions for classifying soil disturbance on aerial photographs.

Stratum	Description
0	Undisturbed areas
	There is no evidence of soil disturbance either from log pulling or machinery travelling over the area. The litter layer is present in an undisturbed state, and there is no soil compaction.
1	Lightly disturbed areas
	Lightly disturbed areas are created when machinery and/or logs move over the ground once or twice only. The litter layer is still present in this stratum, although it may be disturbed slightly and, in sloping country, it may have been moved a short distance by rain. Soil compaction is low.
2	Minor skid trails and moderately disturbed areas
	As the soil disturbance increases, clear skid trails form. On minor skid trails, litter and vegetation are still present, usually mixed with the topsoil. The strip down the centre of the trail still has litter present. Stratum 2 also consists of areas between the minor skid trails where the litter layer has been removed by log pulling or other means. Soil compaction is moderate.
3	Most major skid trails
	As the minor skid trails meet and soil disturbance increases further, major skid trails form. The litter has gone completely, revealing the topsoil, which gives the stratum its colour. Subsoil may sometimes be seen mixed with the topsoil. Soil compaction is usually high.
4	Landings and some major skid trails
	The topsoil and litter layer have been completely removed, revealing the subsoil, which gives the stratum its colour. The subsoil has been penetrated to a significant degree and is usually severely compacted.

3 RELATIONSHIP BETWEEN SOIL DISTURBANCE AND TREE GROWTH

When a forest manager is confronted with soil disturbance, his main concern is whether it is detrimental to tree growth. To study this problem, FRI has established several trials of various designs throughout New Zealand. While it will be a few years before these trials are completed and firm conclusions can be drawn, there are some interesting preliminary results.

For example, in a trial situated on a sandy soil in Esk Forest there was little difference in height between trees in strata 0, 1, 2, and 3 (Figure 1, based on 25 nine-tree plots per stratum). There was a 19% reduction in height for trees in stratum 4. If this trend has a long term nature, then for this soil type the five soil disturbance strata can be reduced to two:

1. landings and major skid trails where the subsoil is visible and ground heavily compacted, and
2. all other areas.

This reduced classification would make soil disturbance mapping much simpler and easier where there is a distinct colour difference between the subsoil and the other soil horizons. Tests have shown that in this situation, panchromatic photography can also be used. Because this film type is normally used by mapping agencies in New Zealand, photographs are readily available for most areas.

The existence of panchromatic coverage of many New Zealand forests means that we can address the all important question, "If soil disturbance reduces tree growth, how long does the effect last?" The oldest of FRI's soil disturbance growth trials is described by G. Murphy (unpubl. data). This trial, situated on Tairua Forest

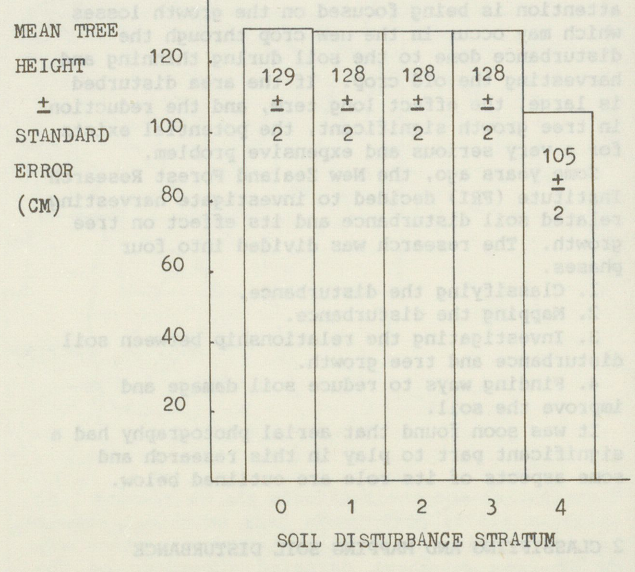

Figure 1. Relationship between tree height and soil disturbance for Pinus radiata age 2 years.

clay soil, has demonstrated that heavy soil disturbance (strata 3 and 4) can have a marked effect on radiata pine growth even seven years after the disturbance has occurred.

It is intended to use old aerial photographs to extend observations beyond the seven year period to a full rotation, which for radiata pine in

Table 2. Area of soil disturbed in areas A and B

	Percentage of area disturbed		
	No disturbance (Stratum 0)	Light/medium disturbance (Strata 1 + 2)	Heavy disturbance (Strata 3 + 4)
Area A No restriction on machine travel	20	63	17
Area B Machine restricted to designated trails	77	3	20

New Zealand is 30-35 years. A search will be made among stands currently approaching maturity for stands which were photographed (aerially) at the time of their establishment. The soil disturbance will be mapped on the old photographs using the strata in Table 1 and then the skid trails will be relocated in the field. Trees growing on the skid trails will be measured for volume. The results should indicate the nature of the long term effect of soil disturbance on tree growth.

4 REDUCING SOIL DAMAGE

One way of reducing soil disturbance is by good planning, for which aerial photography can be an invaluable asset. This was demonstrated recently at an FRI trial on the heavy clay soils of Ngaumu State Forest (W. Blundell, unpubl. data). A gently sloping logging coupe was halved into similar areas A and B. In area A, the operator of the logging machine (FMC 220) followed his normal practice of driving to each log, hooking it up, and dragging it out along the most suitable route. In area B aerial photographs taken before logging were used to design a network of skid trails. The FMC 220 was confined to these trails and the operator was required to pull the winch rope out to each log. After the entire coupe had been logged, more aerial photographs were taken to determine the area of soil disturbed in A and B (see Table 2). The results showed that a markedly greater area of soil was disturbed in area A compared with that in area B. For regions which are susceptible to erosion, this difference will probably be an important consideration. As far as tree growth is concerned, however, it will be some years before the trials show whether the area of soil disturbance is a significant factor for the Ngaumu clay soils.

5 SUMMARY

The amount of soil disturbance which takes place during harvesting operations is substantial. Aerial photographs are proving to be invaluable assets for classifying and mapping this disturbance and useful aids in designing trials to determine the effects of soil disturbance on tree growth. As the results from these trials come to hand, aerial photography will continue to provide a valuable role in reducing soil disturbance to a minimum through good planning and wise choice of machinery.

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