Managing for long-term site productivity

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ABSTRACT

Forestry operations that remove nutrients from harvested material, displace nutrients into piled logging slash, and redistribute nutrients by disturbing topsoil, may have a negative impact on future site productivity. A comparison of the distribution of N in mature radiata pine stands in Woodhill and Kaingaroa Forests shows that Woodhill has much lower N reserves than Kaingaroa with a greater proportion of its N capital in the trees. Evidence from Kaingaroa Forest indicates that logging slash and soil displacement may result in a substantial decline in productivity. Forest managers need to be aware of the implications of forest operations on long-term site productivity. More research is required to produce guidelines for different sites.

In the past a great deal of research emphasis has gone into establishing a productive first crop of radiata pine (*Pinus radiata* D. Don) on a range of sites throughout New Zealand. The soils vary widely from young, highly-productive volcanic soils to old, strongly-weathered nutrient-poor podsols formed on deeply-weathered sedimentary materials. Podsols usually require large inputs of fertilizer nutrients to support productive radiata pine forestry (Hunter and Skinner 1986), whereas the young soils of the pumice plateau in the central North Island have adequate reserves of nutrients and fertilizer additions are generally not required, at least in the first rotation (Will 1985). Many sites are now supporting a second or third crop of trees.

We believe that attention should now focus on maintaining and, where possible improving, the long-term productivity of these sites. Long-term site productivity will depend primarily on three factors: (1) the nutrient reserves of the site; (2) the amount of nutrients removed in harvesting; and (3) the type and intensity of post-harvesting site preparation operations. The implications of forest operations on long-term site productivity are discussed.

NUTRIENT RESERVES

When soil nutrient reserves are low nutrient removal, as by harvesting, will likely have an immediate negative impact on site productivity. Many New Zealand soils are deficient in one or more nutrients and require fertilizer during the first rotation (Will 1985). Nitrogen is often the most troublesome nutrient as it is taken up in the greatest amounts by plantations and is the only nutrient element derived virtually completely from the atmosphere (through N fixation). Furthermore, responses to N fertilization are generally short-lived and unreliable and uptake of fertilizer-N by the trees is usually low (Mead and Gadgil 1978). To illustrate the possible effects of nutrient removal and displacement on site productivity we examine N distribution in two contrasting radiata pine forest ecosystems.

Nitrogen Distribution in Kaingaroa and Woodhill Forests

Kaingaroa Forest is planted on highly productive yellow-brown pumice soils which generally do not require the application of fertilizers (Will 1985). The recent coastal yellow-brown sands on which Woodhill Forest is located are less productive, growth being primarily limited by N supply (Gadgil *et al.* 1984) although moisture may also be lacking at times (Jackson *et al.* 1983). Tree lupin (*Lupinus arboreus* Sims) is employed as a nitrogen fixer.

The distribution of N has been measured in mature radiata pine stands in both Woodhill (Pinaki sand) and Kaingaroa (Pekepeke sand) Forests and a comparison is shown in Figure 1. Despite the difference in stand age (42 years for Woodhill compared to 29 for Kaingaroa), the above-ground biomass of the stands is similar, as is the amount of N contained in the forest floor and tree components (Table 1). The most obvious difference between the two forests is the large amount of N contained in the pumice soil compared to that in the coastal sand. The greater accumulation of N in the pumice soil can be ascribed to its greater age, and the presence of buried organic matter; the remnants of old forests that were covered in volcanic ash.

Compared to other forests throughout the world, the pattern of N distribution in Woodhill Forest is unusual in that 76% of the N in the ecosystem is contained in above-ground tree components and the forest floor. In an average temperate coniferous forest 7% of the N is contained in above-ground tree components and 9% is in the forest floor (Cole and Rapp 1980). Kaingaroa is more typical of coniferous forests elsewhere in the world, as 11% and 8% of the N are contained above-ground and in the forest floor respectively.

Logging slash and forest floor material contain a higher proportion of easily decomposed material than soil organic

TABLE 1: Biomass distribution in mature radiata pine stands in Woodhill (age 42 years) and Kaingaroa Forests (age 29 years)

Components	Biomass ($t\ ha^{-1}$)		Nitrogen ($kg\ ha^{-1}$)	
	Woodhill	Kaingaroa	Woodhill	Kaingaroa
Foliage	7.4	8.3	67.5	116.6
Cones	4.7	9.3	8.6	22.2
Dead branches	4.4	13.0	5.0	20.9
Live branches	24.5	25.6	72.6	57.8
Stem bark	47.6	32.3	36.2	67.9
Stem wood	315.7	337.3	93.8	149.0
Roots				
Coarse (> 5 mm)	91.7	79.5(1)	23.5	35.0(1)
Small (1-5 mm)	2.9(2)	0.6(3)	8.1(2)	2.8(3)
Fine (< 1 mm)	3.4(2)	1.8(3)	16.1(2)	21.3(3)
Shrub tops	4.4	n.a.	46.6	n.a.
Forest floor	36.3	32.6	467.7	302.0(4)
Soil (1.0 m)	8.3(5)	400.0(4)	144.0(5)	3049.0(4)
Total	551.3	940.3	989.7	3844.5

Unless otherwise noted, Woodhill data are from Dyck, Beets, and Oliver (unpubl.) and Kaingaroa data are from Webber and Madgwick (1983).

(1) Estimated using Webber unpubl. plot data and equations of Jackson and Chittenden (1981). (N conc. from Will, 1966).
(2) Santantonio (unpubl.) for a 17-year-old stand on the same soil type.
(3) Santantonio (unpubl.) for a 14-year-old stand on a similar soil type.
(4) From Webber unpubl. data and Sims unpubl. equation for Kaingaroa pumice soil (%o.m = 1.92%C + 2.69).
(5) Values are the increases in soil organic matter and N 45 years from bare sand (bare sand N = 0.005%).
n.a. Not available.

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matter and thus represent a very important source of nutrients (Heal 1979; Beets and Madgwick 1987). N especially is supplied from decomposing slash and forest floor material and practices that remove or displace this nutrient source may reduce future site productivity, even when soil N reserves are large.

HARVESTING

The amount of nutrients removed in a harvesting operation increases disproportionately with more complete tree removal because greater amounts of most nutrients are contained in crown material compared to stems, especially in young stands (Madgwick *et al.* 1977). Unfortunately there has been very little long-term research on the effects of nutrient removal through harvesting on site productivity, although many short-term studies indicate that repeated harvesting will lead to productivity declines on some soil types (see Messina *et al.* 1985). Concern over the possible effects of whole-tree thinning in Norway prompted a series of trials which showed a 7% reduction in residual tree volume growth after 10 years, due to the removal of crown material alone (Bjorn Tveite, Norwegian Forest Research Institute, pers. comm.). Results from an unreplicated study in Kaingaroa indicate that whole-tree harvesting followed by litter-fall removal annually for 17 years reduced radiata pine stem volume by 12% and significantly lowered foliar B and N levels (Ballard and Will 1981).

Similar information is not available for Woodhill Forest although a recently-established intensive harvesting study will begin to provide information in a few years' time. Because N reserves at Woodhill are low, we believe that the consequences of removing organic matter on next-rotation growth will be much more detrimental than for Kaingaroa Forest, depending on the intensity of the harvesting operation. For example, in a conventional stem-only harvest, 66% of the total biomass (including plant material and soil organic matter) contained in the ecosystem would be removed, but only 13% of the N (Table 2). More intensive harvesting, either for product recovery or because of the type of equipment used, would remove up to 73% of the total biomass and approximately 29% of the site's N. Should the forest floor be removed, either through burning or rootraking, but leaving the mineral soil in place, slightly more than 80% of both the total biomass and the N reserves of the site would be depleted. Regardless of treatment, however, the N content of the ecosystem at the start of the next rotation will likely be higher than it was at the start of the first rotation. The opportunity for the forest manager, therefore, is to increase productivity during the second rotation by managing the nitrogen capital of the site. As in the first rotation, lupins or other N-fixers could be encouraged.

SITE PREPARATION

Burning volatilizes some nutrients, such as nitrogen, and transforms others from organic form to inorganic forms in which they are more available to plants but also more readily leached (Raison 1979). Losses of up to 1000 kg N/ha have been shown to occur in very hot slashburns (Feller *et al.* 1983). Windrowing and rootraking displace nutrients in slash and topsoil; however, the effect of such operations on subsequent crop growth is not always straightforward and may be complicated by factors such as weed competition (Tuttle *et al.* 1985). Foresters often employ techniques such as windrowing partly to control weeds as well as to improve access.

A major research effort investigating reasons for second-rotation decline of radiata pine forests in southern Australia showed that retention of the forest floor and logging slash is critical to maintaining productivity on infertile sites (Squire

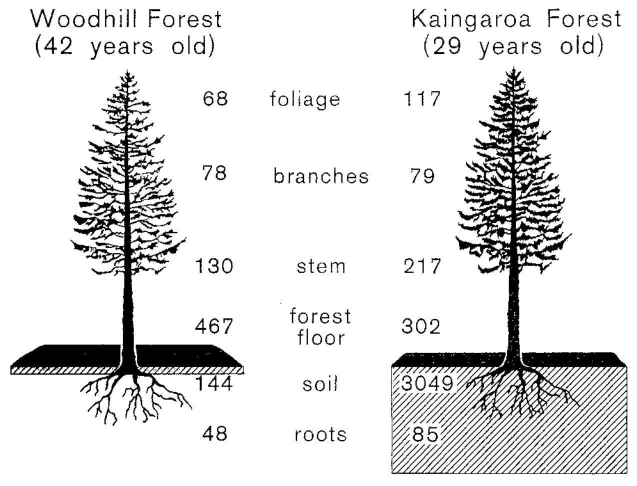

Fig. 1 Distribution of nitrogen in mature radiata pine forest ecosystems in Woodhill and Kaingaroa forests.

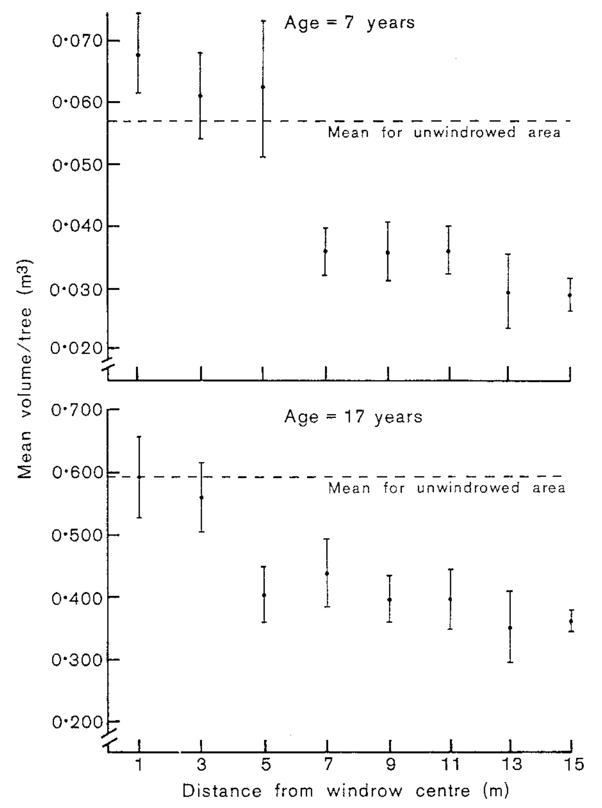

Fig. 2 The effect of distance from window centre on radiata pine productivity at age seven and 17 years (Mees and Dyck unpubl.).

TABLE 2: Biomass and N removed in harvesting and site preparation, radiata pine, Woodhill Forest

Management operation	Biomass		Nitrogen	
	t/ha	%	kg/ha	%
Stem-only harvest	363	66	130	13
Whole-tree harvest	404	73	284	29
Whole-tree harvest and[1] forest floor removal	445	81	798	81

[1] Removal from planting site by windrowing or burning

1983). Kaingaroa Forest soils are also susceptible to productivity decline despite the relatively large reserves of some nutrients. In one of the first rootraking operations in the forest

Photo 1 Windows formed during site preparation following logging of *P. radiata* in Kaingaroa State Forest (1969).

(Photo 1) approximately 2.5 cm of top soil was scalped from the soil surface and pushed into the windrows along with the logging residue (Ballard 1978). At age seven the trees growing on the windrows (representing approximately 25% of the area) were much larger than those growing in the inter-windrow sites and slightly larger than those in the adjacent unwindrowed area. It was speculated (Ballard 1978) that this "windrow effect" would become less with time as tree roots extended from the inter-windrow sites into the windrows. However, at age 17 the effect was still pronounced and standing volume in the scalped (interwindrow) area was approximately 40% less than that in an adjacent unwindrowed area (Figure 2) (Mees and Dyck unpubl.).

The reason for the decline in productivity is not clear. Based on the fact that approximately 700 kg/ha N were displaced in topsoil and that foliar N and B levels in the inter-windrow area were marginal and foliar Mg was deficient (Ballard 1978), it seems reasonable to assume that it was primarily the nutritional effect of displacing the topsoil that resulted in reduced growth. However, N fertilization alone did not correct the problem as the windrowed area was topdressed with urea (200 kg N (ha) at age eight (L. Evans pers. comm.) suggesting that additional nutrients other than N or even more fertilizer N were needed. Changes in soil physical properties were not measured and it is possible that poorer physical conditions, such as greater soil bulk densities, also had a detrimental effect on growth.

Photo 2 The impact of site preparation and logging: aerial view in Kaingaroa State Forest (1986).

IMPLICATIONS TO MANAGEMENT

There are three important implications of these results to forest managers. (i) Even for relatively fertile sites such as Kaingaroa Forest, there is a potential for substantial loss in volume following harvesting and site preparation (Photo 2). In the study cited, it would take an additional seven years for the volume in the inter-windrow area to reach that predicted for age 30 in the unwindrowed area (Mees and Dyck unpubl.) (ii) In some cases a decline in site productivity may not be easily remedied as the reasons for this decline are obscure. (iii) Forest managers have site preparation options available to prevent such reductions. In fact, recent establishment has steered away from practices involving large-scale disturbance of the site. However, there are no clear guidelines as to what soil types are most susceptible to productivity declines or as to what practices are acceptable to prevent a loss of productivity.

The effects of forest harvesting and site preparation have not been fully examined on any soil type in New Zealand although some studies have recently been established. As the forest industry enters a period of greatly increased annual harvest, and on poorer soil types, forest managers should become aware of the possible effects of management decisions on both short- and long-term productivity. A greater research effort is required to produce guidelines applicable to different sites.

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INSTITUTE NEWS

NZIF comment on 'Report of the Review Committee on Education and Training in the Forest Industry'

The Institute believes that the Review Committee have adopted an overly simplistic, narrow approach to the issues. Their approach is dominated by short-term rather than long-term thinking and is unduly influenced by the uncertainty which characterizes the forestry sector consequent upon the massive disruption of the past two years. The Institute believes that, within a few years, the demand for well-rounded graduates in forestry, forest land management and related disciplines will greatly exceed the pessimistic projections made by the committee. Education and training can provide the linkage between the now separated aspects of administration and management.

Forestry is not simply plantation management. New Zealand has seven million hectares of indigenous forest upon which the demands of man will continue to increase and for whose management the Canterbury School of Forestry provides the only wholly relevant professional qualification currently available.

The Institute cannot find evidence in the report to cause it to depart from its previously expressed and firm view that there isn't any need for a separate NZCF training at a quasi degree level.

The School of Forestry would be better to formally combine with the other land and the forest management related disciplines at Canterbury and Lincoln College. There will then be increased numbers of students coming from a combination of technical, technological and other broad-based land management disciplines, perhaps in a "Department of Natural Resources".

The Institute is convinced that the educational and training requirements of forestry in the broadest sense can best be met by such an approach. In the circumstances the School would be able to justify the necessary numbers of staff to teach the wide range of disciplines involved.

The Institute is convinced that the transfer of the School to Waikato and the continuation of a separate NZCF in Rotorua would lead to a narrowing of the course substance to plantation management only, to fewer students and even greater difficulty in obtaining adequate staffing than the school has experienced in Canterbury.

P.J. Thode
President

FORSOC NEWS

For the students at the School of Forestry this has certainly been an interesting year. The departmental shake-up that now affects our future employment so much was not even a speculative rumour back when most of us chose Forestry as a career. Certainly the type of job I was aiming for no longer exists.

And now, more recently (and no doubt a direct result of the shake-up) an education review that proposes just as radical changes to the entire Forestry training and education system. There appears to be as many opinions among students here, on the school's future, as among any other interested group. But if there is one thing that all the students are in agreement on, it is the need for a greater range of subjects available within the School. This is not easily possible under either the current system or that proposed in the Probine report. Hopefully whatever direction the School moves off in (not necessarily physically) it will maintain its autonomy and develop a solid but broad base of forestry disciplines.

Another issue the students have become involved in is the attempt to save 'our' Ecological Reserve in Ianthe forest. It has been a valuable asset as a study tool during the 2nd Pro field trips for a number of years now but it looks like