

The Application of Planning Legislation: the RMA and Forestry

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Abstract

The paper examines for differences in treatment by district councils of forestry activities under the RMA and explores the underlying causes of the differences that are found. An analysis of 57 District Plans written using RMA guidelines is used to derive an index that captures the relative restrictiveness of the treatment of forestry in a District Plan. The index is compared to a range of demographic factors such as population, land use mixes, farming intensities and farm size which are believed to influence the treatment of forestry. The results suggest restrictiveness of rules generally increases with the intensity of farming. In particular, restrictiveness increases with the percentage of land under agricultural use and grazing productivity, and decreases with an increase in average farm size and population density.

Introduction

In 1991 the New Zealand government enacted the Resource Management Act (RMA). The RMA is an effort to streamline planning decisions, and to provide an integrated framework to manage New Zealand's natural resources. In particular, the RMA represented a move away from the prescriptive, rules-based District Schemes of the previous Town and Country Planning Act 1977 (TCPA), under which district planners were directed to plan for the "wise use of resources" as determined by the councils. In writing District Plans, the RMA now directs planners to achieve the "sustainable management of resources" based upon environmental effects and not on what Councils consider wise land uses.

The consequences for forestry activities are potentially significant, since during the TCPA regime, forestry was often considered an "unwise" land use by agriculture-oriented councils and planners. To stop forestry encroaching on "good" agricultural, land use planners, through the District Schemes, zoned forestry to the poorer soils and required substantial information to be supplied with forestry investment applications (Fowler and Meister, 1983).

Planning under the RMA is now achieved through District Plans. District Plans outline how activities will be controlled on the basis of the potential environmental effect(s) the activity may have in an area. Within the District Plans, activities are classified into five categories; permitted, controlled, discretionary, non-complying and prohibited. This classification system is used to ensure that the relative effects of each activity are reflected in the type of resource consent procedure required. Applicants seeking consent for any activity under the RMA must provide an assessment of the activity's effects on the

environment¹. This effects-based approach means that different activities should be treated equally. In other words, commercial forestry should be treated equally with all other land uses that have the same or similar effects (Ministry of Forestry, 1995).

One problem that can emerge is that although the RMA is a national piece of legislation, it requires land use planning to be implemented by City and District Councils. This is because District Plans are supposed to reflect the particular resource mix and social values that are unique to the Council's area. The RMA also contains transitional provisions where the District Schemes and their provisions, developed under the TCPA, can form whole or part of the Transitional District Plans and district rules under the RMA. This has resulted in many cases where Transitional District Plans, based on old prescriptive District Schemes, were operative while the new District Plans were being drawn up. In some cases the new District Plans are based on the old activities based framework. This has resulted in prescriptive District and Regional Plans under the RMA, possibly reflecting a continuation of attitudes from the TCPA regime in some Councils.

The implication of the local application of the RMA is that there is the potential for differences in the treatment of forestry between districts. Examination of District Plans shows that rules applied to forestry range from permitted to non-complying activities, and to combinations of activity types that relate to agricultural zoning within a Council. Since resource consents are required for conditional, discretionary and non-complying activities, this can be seen as a reflection of some Council's having the attitude of protecting agricultural land from uses other than agriculture.

The purpose of this paper is to examine if there are differences in the way Councils treat forestry in their District Plans, and explain reasons for the differences if they exist. There are a range of demographic factors such as population, land use mixes, farming intensities and farm size which could potentially explain differences in how councils would perceive the effects of forestry activities, and in turn the relative restrictiveness of planning rules related to forestry.

Method

There are a number of studies that have examined the effects of the application of planning legislation. The literature falls into two main approaches that can be referred to as qualitative and quantitative. The qualitative approach 'describes' the effects and extent of the regulations between planning authorities or changes over time within one planning authority. Although called qualitative it often involves numerical data, mostly in the use of visual aids. The quantitative approach 'quantifies' the effects of regulations using econometric models. This paper uses both approaches to examine the effects of the RMA on forestry.

There is a range of qualitative tools available. The earliest qualitative studies used dot maps or bar graphs to compare development application numbers to evaluate green belts by comparing areas with similar characteristics but different development regulations (Gregory, 1971). This method was later extended to show differences in one area over time for national parks (Anfield and Curry, 1989), applications for new dwellings inside and outside of green belts (Keyes, 1986) and applications for planning permission to build farm houses (Gill and Kelly, 1996). Fowler and Meister (1983) used bar charts to measure the restrictiveness of forestry controls imposed by the TCPA, where restrictiveness was measured as the difference between the amount of area which had potential for forestry and the actual area of forestry. However, problems are encountered when using more than a few variables to examine how planning legislation has been applied, because interpretation of the results becomes difficult. When there are a number of variables a multivariate statistical technique is required.

Cluster analysis is a group of multivariate techniques used to classify objects or individuals into homogenous groups called clusters when little is known *a priori* about the clusters or their membership (Malhotra, 1996; Punj and Stewart, 1983 and Hair *et al.*, 1995). Cluster analysis is used in this paper since the technique suited a need to group councils based on similar demographics, land use mix and attitudes towards forestry investment.

Clustering algorithms can be classified into two general categories: hierarchical and non-hierarchical. Hierarchical algorithms are stepwise procedures that either form nested clusters by grouping (dividing) objects into bigger (smaller) clusters until all cases form a single (separate) cluster(s). In contrast non-hierarchical algorithms form clusters by placing cases within a pre-specified distance of cluster seed (Hair *et al.*, 1995; Norusis, 1990).

There are a number of hierarchical algorithms available. It is generally concluded that Ward's minimum variance algorithm gives the best coverage of objects and handles outliers best (Aldenderfer and Blashfield, 1984; Milligan, 1980). Ward's algorithm minimises the variance within the clusters and maximises the variance between clusters (Hair *et al.*, 1995; Norusis, 1990 and Malhotra, 1996). Non-hierarchical algorithms, frequently referred to as k-means clustering algorithms, form clusters by selecting clustering centres (seeds or centroids) and placing objects closest to the seeds. Non-hierarchical methods have been shown to be superior to hierarchical methods as the results are less susceptible to outliers (Hair *et al.*, 1995). However, non-hierarchical methods have the disadvantage that the number of clusters needs to be specified *a priori*.

To overcome the problem of *a priori* specification of clusters in non-hierarchical techniques Punj and Stewart (1983), Milligan (1980), Hair *et al.* (1995) and Malhotra (1996) suggest a two-stage approach, incorporating both hierarchical and non-hierarchical algorithms. The first stage involves using a hierarchical algorithm to obtain a preliminary solution to identify and select the appropriate number of clusters, identify the cluster centroids and

identify any outlying objects. Ward's method is one of the most popular methods for selecting the initial cluster seeds (Malhotra, 1996; Punj and Stewart, 1983 and Helsen and Green, 1991). The second stage runs the stage one solution through a non-hierarchical algorithm.

The qualitative approach provided by the cluster analysis will identify any differences in the way planning rules have been applied forestry, but it will not provide information about the relative importance of different demographic variables in determining the outcome. To overcome this problem, a quantitative approach using regression analysis is also employed.

Data

There a number of factors, or demographic descriptions, that could be important in determining the type and extent of planning restrictions on forestry. The key factors, based on previous studies, were believed to be those that related to farming intensity and population density. In addition, it was believed that the land use mix, particularly the existing amount of forestry and thus experience with this land use would also be important. In the end, nine variables for which district council level data could be obtained were selected, covering 57 District Councils.

Population is used as a proxy for development potential and the degree of urbanisation. Population (POP) is measured using population density, as at 31 June 1994.

The land use mix variables were used to measure the extent of any particular land use activity. Land use mix is measured by each of, percentage of land used for agriculture (AGL), percentage of land used for exotic forestry production (FOR), and percentage of land used for other rural use (OTH), such as native tree production. Area data to calculate the percentages were obtained from the 1994 Agricultural Statistics (Statistics New Zealand, 1997).

Farm intensity is measured by three variables. These include average farm size (AFS), number of farms (NOF) and the animal stocking rate (ASR). Average farm size for each district was calculated by dividing the total area under agriculture by the number of farms (Statistics New Zealand, 1997). Data on the animal stocking rate was obtained from dividing the weighted average of the main classes of stock by the area used for agricultural production. Classes of livestock are beef cattle, dairy cattle, sheep, deer and goats (Statistics New Zealand, 1994; Statistics New Zealand, 1997).

An index (STE) was calculated to measure the suitability of radiata forestry based on site index. Suitability for forestry was derived by calculating the average site index for each territorial authority from an iso-site index map published by the Ministry of Forestry (1991).

The RMA index (IND) measures the restrictiveness of forestry rules in the District Plans. This variable is a two-part index based on a subjective analysis of how District Plans written under the RMA have treated forestry. Part one of the index, restrictiveness, was measured by the activity classification given to forestry.

If forestry is a permitted activity then it is assigned a value of 1, if a conditional activity a value of 2, if a discretionary activity a value of 3 and if a non-complying activity then a value of 4. If a district council has more than one zone with differences in the designation of forestry activity, then a weighted average for the district council was calculated. Due to a lack of data on the size of each zone in a District Council, it was assumed that each zone within the District Council had the same proportion of forestry activity.

The second component of the RMA index was a measure of the information requirements for forestry developments. A value of 1 was assigned if information was required in the district plan, and a value of 0 if no information was required.

Both of these factors increase the effective cost and difficulty of undertaking forestry. The RMA index was formed by adding the value for the activity classification to the value for the information requirement. The value of the RMA index could range between 1, the minimum requirement and 5, the maximum requirement.

Although Regional Plans and Policy Statements, written by Regional Councils, influence land uses they were excluded from this study. This is because plans written by City and District Councils are written for the purpose of land use planning while Regional Plans and Policy Statements are written to deal with issues regarding soil, water and air. In addition, District Plans are assumed to be consistent with their associated Regional Plans and Policy Statements, however, this may not be the case if District Plans were written and notified before the Regional Plans.

Results and Discussion

Cluster analysis was carried out using the two-stage process discussed previously. Stage 1 involved applying Ward's hierarchical algorithm to 7 variables covering

population density, average farm size, percentage of total area under each of agricultural, forestry and other uses, number of farms, and animal stocking rate, for the 57 councils that provided details of their forestry planning rules. Ward's algorithm was performed using the statistical package SPSS. Stage two involved a non-hierarchical algorithm, QUICK CLUSTER in SPSS, using the cluster centres saved from the hierarchical solution in Stage 1.

There are no statistically valid procedures for determining the appropriate number of clusters. The clustering solutions, alone, provide little information on the correct number of clusters. This can be a problem, especially when non-hierarchical clustering procedures require that the number of clusters be selected before any clustering takes place. In addition, hierarchical methods usually produce a series of possible alternative solutions that range from k clusters to a solution with one cluster (Milligan and Cooper, 1985).

In absence of a statistical test, a number of authors, including Malhotra (1996) and Hair *et al.* (1995), have provided guidelines on how to determine the appropriate number of clusters. Following Malhotra (1996) and Hair *et al.* (1995) solutions for different numbers of clusters were computed. A combination of looking at the distances which the clusters combined and using practical judgement resulted in a seven cluster solution. In addition, the averages of two additional variables that were not used to derive the clustering solution, suitability for forestry and the RMA index, were reported as a further check of the correct number of clusters.

The cluster analysis has essentially reduced the wide variation in the application of the RMA in terms of forestry to seven groups of councils with similar land use characteristics and forestry planning regulations. The grouping of councils in the seven cluster solution are reported in Table 1 and average values of the variables used in the clustering for each cluster are given in Table 2.

Table 1 - Cluster Solutions

High Population Centres	Peri-Urban, Semi-Intensive Farming	Rural, Semi-Intensive Farming	Extensive Plantation Forestry	Intensive Farming	South Island West Coast	South Island High Country
Christchurch Hamilton Manukau North Shore	Dunedin Lower Hutt Porirua Wellington Ashburton Central Hawkes Bay Clutha Gisborne Gore Kapiti Coast Marlborough Otorohanga Papakura Rangitikei Rotorua Ruapehi Wairoa	Invercargill Palmerston Nth Banks Peninsula Hauraki Horowhenua Hurunui Masterton Sth Wairarapa Stratford Timaru Waitomo Wanganui	Nelson Upper Hutt South Waikato Tasman Taupo Thames Coromandel Whakatane/ Kawerau	Franklin Hastings Manawatu Matamata-Piako New Plymouth Rodney Selwyn Southland Waikato Waipa Western Bay of Plenty Whangarei	Buller Grey Westland	MacKenzie Queenstown Lakes

Table 2 - Variable Averages by Cluster

Variable	High Population Centres	Peri-Urban, Semi-Intensive Farming	Rural, Semi-Intensive Farming	Extensive Plantation Forestry	Intensive Farming	South Island West Coast	South Island High Country	Cluster Median
POP	879.50	89.58	37.06	28.46	16.38	2.03	1.2	28.46
AFS	29.87	241.54	201.16	101.03	106.39	188.82	1856.94	201.16
AGL	75.79	83.22	86.04	42.67	83.77	45.25	90.10	83.22
FOR	12.20	8.52	6.03	38.42	7.17	7.88	0.33	7.88
OTH	5.75	7.57	7.22	18.25	7.21	46.78	9.55	7.57
IND	2.52	1.11	2.40	1.57	1.77	1.00	3.00	1.77
ASR	11.43	8.72	9.90	10.79	12.25	7.53	1.08	9.90
NOF	370.25	772.18	689.75	715.14	2226.17	293.67	269.5	689.75
STE	2.51	2.48	2.60	2.46	2.93	1.41	1.17	2.48

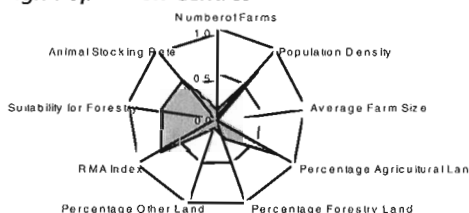
Because of the multi-dimensions of the clusters, communicating the results of cluster analysis is difficult (Dunn and Walker, 1989). Graphical analysis can be useful for showing visual differences and also expresses the results of the cluster analysis in a way that differences and similarities between clusters can be easily seen. This study uses a simple graph that can express multi-dimensional data in two dimensions similar to the type used by Dunn

and Walker (1989). The graph used is a radar graph with nine equally spaced rays drawn radiating from the middle of the star. Each ray relates to a variable used to explain differences in RMA forestry rules. The length of each ray is made proportional to the cluster average of the values for each cluster scaled to fit between 0 and 1.

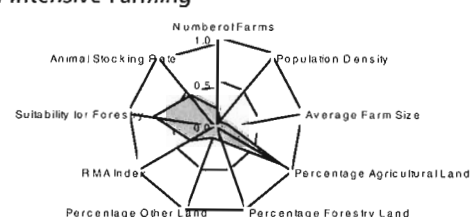
The radar graphs for each variable are shown in Figure 1.

Figure 1 - Graphical Representation of the Seven Cluster Solution

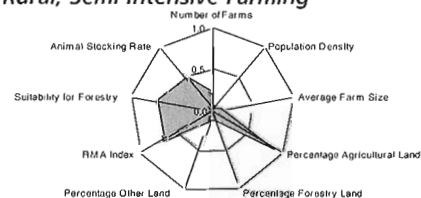
High Population Centres



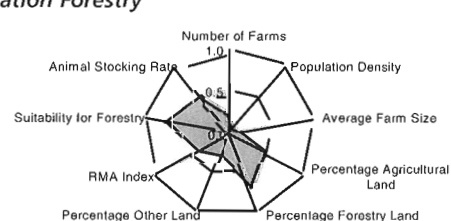
Peri Urban, Semi-Intensive Farming



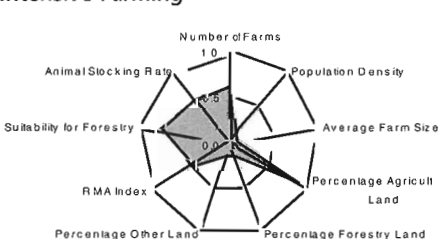
Rural, Semi-Intensive Farming



Extensive Plantation Forestry



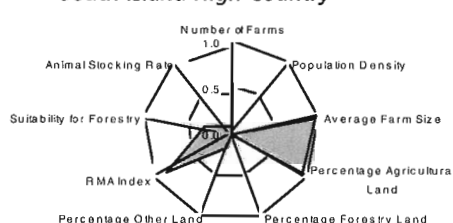
Intensive Farming



South Island West Coast



South Island High Country



The High Population Centre cluster is largely defined by Councils with the highest population densities. Although there is a large percentage of land in agriculture in this cluster, the farms are relatively small, and are generally life style blocks or small holdings. A combination of small holdings and suitability for forestry mean that this cluster has the second highest percentage of area under plantations. In spite of the extent of forestry activity, the cluster also has a relatively high RMA index, meaning that the forestry rules are not as encouraging to forestry. Within these urban councils there are concerns about the effects of exotic forestry on landscape values, on the effects of logging trucks in built up areas, and externalities from forestry and logging activities.

The Peri-Urban, Semi-Intensive Farming cluster is defined by a relatively high population density and the largest average farm size outside the South Island High Country. This cluster has the second lowest RMA index, reflecting the fact that many of the councils in this cluster see forestry as an important activity. For example, the Porirua City council has a policy of favouring primary production, which includes exotic forestry. Other Councils, such as Wairoa District Council and Ashburton District Council, see the benefits of forestry in soil conservation.

The Rural, Semi-Intensive Farming cluster is distinguished from the Peri-Urban, Semi-Intensive Farming cluster by a much lower population density, smaller average farm sizes, a higher average animal stocking rate, and 30% less area in plantations. On average, this cluster is more rural in nature and grazing is more productive. A key difference between the two clusters is that this cluster has a high RMA index, indicating that it is less favourable to forestry. This could be due to a carrying over of the rules from the TCPA which were biased towards agriculture. In some cases, such as the Timaru District council, there is also concern with landscape values and the adverse effects of forestry. Some Councils in this cluster have made forestry a permitted activity, but have attached information requirements to the development.

The Intensive Farming cluster again has a large proportion of its primary production area in agriculture, but is identified by having a population density and average farm size which are about half of the Rural, Semi-Intensive Farming cluster, and the highest animal stocking rate of all clusters. The districts in this cluster have dairy farming as a major land use, and are also used for intensive horticulture. The RMA index for this cluster is at the median value for all clusters. Councils in this cluster, such as Manawatu District Council, New Plymouth City Council and Hastings District Council tend to categorise forestry as an agricultural activity and do not differentiate between land based primary production, including forestry.

The Extensive Forestry cluster is distinguished by having the highest percentage of primary production area in exotic forestry. This cluster also has the second smallest average farm size and a relatively high animal stocking rate, showing that agricultural lands are also intensively farmed. The RMA index for this cluster is relatively low,

although it is not the lowest of clusters. Since historically forestry has been important to many of the Councils in this cluster, Councils would have experience with forestry activities. With the larger scale of forestry though, identifying forestry activities for planning may be more of concern than with the Peri-Urban, Semi-Intensive Farming cluster. Some Councils in this cluster, such as the Thames-Coromandel District Council, have explicit policies to encourage production forestry.

The South Island West Coast cluster is distinguished by having 46% of its primary production area in native forests and a very low population density. The establishment of plantations has been actively encouraged to provide an alternative to a declining harvest of native timber. Councils in this cluster, with a long experience with forestry and a desire to maintain forestry employment, have made forestry a permitted activity and do not require any information about the forestry projects.

The South Island High Country cluster is distinguished by having the largest average farm size, the lowest animal stocking rate, the smallest population density of all of the clusters, and almost no forestry. It comprises the South Island High Country councils where the main land use is extensive fine wool production. The RMA index for this cluster is the highest of any cluster, largely based on a concern about the effect of plantations on landscape values, but also reflecting a lack of experience with production forestry (Swaffield, 1994). Although site index makes this cluster look unsuited towards exotic forestry, this is because the index was for *Pinus radiata* that is not suited to the climate of this area. Other tree species, such as Douglas Fir, are better suited to the high country.

The results of cluster analysis identified that there are differences in the way planning rules have been applied to forestry by territorial authorities, and that these

Table 3 - Regression Results

Variable	Estimated Coefficient	t-ratio
Constant	1.816	(3.22)***
Number of farms	-0.00015	(-1.06)
% of land in Agriculture	0.026	(2.24)**
Average farm size	-0.0018	(-1.72)**
Population density	-0.0016	(-1.95)**
Animal stocking rate	0.002	(0.05)
Site index for forestry	-0.662	(1.53)*
Dummy for S.I. country cluster	3.882	(2.30)**
Dummy for high population density cluster	1.919	(2.59)***
R ²	0.2926	
F	2.48	
No. Observations	57	
*** Statistically significant at the 1% level		
** Statistically significant at the 5% level		
* Statistically significant at the 10% level		

differences appear to be linked to demographic factors in a particular district. In order to determine which of the demographic factors were most important in explaining the differences in rules, regression analysis was used. Table 3 reports the results of a regression analysis that used the RMA index as the dependent variable. Independent variables were the number of farms, percentage of land in agriculture, average farm size, population density, animal stocking rate, suitability for forestry, a South Island High Country cluster dummy variable and a dummy variable accounting for the councils in the High Population density cluster.

The coefficient for the number of farms is negative but statistically insignificant. The percentage of land in agriculture is positive and statistically significant at the 5% level. The positive sign is consistent with prior expectations and implies that Councils where agriculture is a major land use have rules that are less favourable for forestry. Average farm size is negative and statistically significant at the 5% level. This implies that more restrictive rules have been written in the smaller, more intensive and usually more fertile farming districts. Population density is also negatively correlated to the forestry index and is statistically significant at the 5% level. As was discussed earlier, this is correlated to the average farm size and the increase in small holdings and lifestyle blocks. The coefficient for the animal stocking rate is positive but statistically insignificant. The positive relationship can be seen as a reflection that rules have been written that are more restrictive for forestry on the more fertile land. Suitability for forestry has a negative relationship with the forestry index and is statistically significant at the 10% level. This implies that forestry rules are restrictive on the land that is less suited to forestry, likely reflecting the fact that forestry is most economically competitive with agriculture on less suitable sites, and thus more likely to attract attention in those areas. The two dummy variables are positive and statistically significant 5% and 1% respectively. This indicates that councils in the South Island High Country and High Population Density clusters which are more restrictive than would be the case in another council with similar demographics.

Discussion

The seven cluster solution provided evidence that there are differences in the way forestry rules have been applied by the territorial authorities in the District Plans. Three clusters, High Population Centres, Rural, Intensive Farming and South Island High Country, could be seen as having rules that make it more difficult to undertake forestry projects. Although these clusters had different demographic and land use mixes they had common planning stances towards forestry. The majority of councils in all three of these clusters were concerned about negative effects of forestry on landscape values or water catchment areas. Councils dealt with these issues by requiring forestry investors to obtain resource consents and/or requiring information regarding the proposed forestry project. This allowed Councils to dictate how and where the trees were planted in order to protect landscape values and water catchment areas. Types of concerns Councils had include

the adverse visual effects of forestry during harvest phase and the reduction in visual diversity that plantation forestry caused, and the impact that forestry had on obscuring views of importance.

The remaining four clusters, Peri-Urban Semi Intensive Farming, Extensive Forestry, Intensive Farming and South Island West Coast, had planning rules that made forestry investments less difficult to undertake. A number of District Plans in these clusters bundled into forestry and agriculture into a single land use called primary production, effectively treating forestry as another agricultural crop. Councils within this group either had previous experience in forestry or recognised some type of benefit from forestry, such as arresting erosion and soil conservation.

The regression analysis found that in general, the restrictiveness of forestry rules increases with animal stocking rate and proportion of land used for agriculture. In addition, councils in the South Island high country and High Population Density clusters were shown to have restrictive rules. The restrictiveness forestry rules decreases with number of farms, average farm size, population density and suitability for forestry. It appears from the results that in some districts, typified by the Rural, Semi-intensive Agriculture and South Island High Country clusters, that rules are still being written to protect agriculture from forestry.

Conclusions

This paper has used cluster analysis, graphical techniques and regression analysis to show the nature of the variations in the way councils have treated forestry in the District Plans in terms of the index of forestry rules derived in this paper. One of the main findings of this research was that there are differences in the way councils have applied the RMA to forestry. It appears that from the District Plans that some District Councils have changed from biasing forestry because of conflicts with agriculture to that of using the negative effects of forestry on landscape values as the main reason. To write rules in the spirit of the RMA research is required to find out what the landscape values are. While the negative effects of forestry are well documented in the District Plans, the positive effects of forestry appear to be conveniently left out. Thus, it appears *prima facie* that the rules pertaining to forestry in Councils that are less enthusiastic about forestry are *ad hoc* and are not based on any research. This leads to the necessity of further research to find out exactly what these landscape values are and how forestry adversely affects them.

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A fresh look at Operational Soil Compaction

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Abstract

The study aimed to quantify how much of a setting was adversely compacted during ground-based harvesting of an Orthic Pumice soil. Travel of harvesting machines was monitored using Global Positioning System (GPS) receivers fitted to the cabs. The resulting machine pass map was used to identify sites with 0, 1–3, 7–12 and 20–50 passes where physical properties of soil were measured. Two-thirds of the cutover was trafficked with 20% receiving more than 20 passes. Visual assessment classified the site as 87% disturbed, 6% showing deep disturbance (topsoil removal), and less than 0.2% rutted. One to three machine passes had no significant effect on soil physical properties. Although 20–50 passes led to a 60% decrease in the volume of air-filled pores, critical levels were not reached. Cone penetration resistance was >3 MPa below 34cm depth over 38% of the cutover and below 18 cm depth over 20% of the cutover.

Introduction

Nearly two decades ago, Greacen and Sands (1980) stated that although many forest managers were aware of soil compaction, the extent and degree of such compaction was not well documented. Researchers have since developed disturbance assessment methods based on either aerial photographs (Firth *et al.* 1984) or disturbance classification along transects (Murphy 1982, McMahon 1995a). The methods infer compaction where mineral soil is exposed or depressions from vehicle tracks are visible. Compacted areas over which litter or debris have been swept and areas where tracks are not visible are not detected, and compaction has been difficult to separate from soil disturbance. The proportion of a setting which has been trafficked has therefore been determined only indirectly.

The severity of compaction has been researched by measuring soil properties and tree growth. Trials have either compared areas with the same class of disturbance in operationally harvested forests, usually landings or skid trails and cut-over areas (Berg 1975, Hughes 1987), or plots subjected to controlled compaction by a known number of machine passes (Skinner *et al.* 1989, McQueen *et al.* 1996). Results from plot-based studies may be able to be related to disturbance within operational settings across a forest if the number of machine passes over each part of a setting could be determined. To do this requires a fresh look at field techniques for quantifying operational soil compaction.

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