Forestcheck Soil Disturbance monitoring

PROGRESS REPORT

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Introduction

This report covers the 2001/2002 assessments of seven Forestcheck sites at Carter (gap and TEAS), Thornton (gap and TEAS) and Kingston (gap, shelterwood, and TEAS) forest blocks. External controls were not used in this study as the variation in soil type across the landscape make these physically distant sites inappropriate as reference sites for bulk density measurements. In addition, there is no reason to suspect that disturbance on the treatment plots adjacent to the internal control plots (TEAS) would alter soil physical properties on these internal control plots. Consequently, external controls are not required for the soil disturbance monitoring.

The objectives of this work were:

1. To monitor the intensity and extent of changes to soil physical properties induced by logging.
2. Establish a database to examine the change in these properties over long time periods.
3. Examine the relationship between visual assessments of soil disturbance and soil compaction
4. Commence the establishment of a database that over time and across sites could enable the use of visual assessment as a surrogate for bulk density measurements.
5. Examine the relationship between visual assessment of soil disturbance and shear strength.
6. Examine the relationship between bulk density and soil shear strength.

Sampling issues encountered

I planned to stratify the sampling on the basis of soil disturbance classes (Rab 1989, Whitford 2001). This could only be attempted at the most recently logged site (Carter), as it is inappropriate for retrospective sites. Unfortunately the logging at Carter was not sufficiently recent for the signs of disturbance to be clear. The assessment of the disturbance strata on this site was not of a high standard and consequently does not serve objectives 3, 4 and 5 well.

At the older retrospective sites sampling was stratified on the basis of operational categories (eg. landing, snig track, harvested area, etc). Though easier to identify than disturbance classes, these strata are of a lower quality and include greater variability than disturbance classes. On these older sites some snig tracks which were clear on old aerial photographs could not be identified on the ground. This failure to clearly identify some snig tracks lowers the quality of these operational category strata.

The sampling program was too ambitious. The collection of soil moisture measurements along with the shear strength measurements significantly increased the time required to collect this information. I underestimated the amount of time required for this. The intensive collection of this large number of bulk density sample was too physically demanding, and this work needs to be spread out over a greater time period, or amongst more people.

Sample processing

No unforeseen problems occurred in sample processing. The costs of sample processing were correctly estimated. The dust extraction system installed was successful.
My original proposal made greater use of Department staff. These staff were not available to assist and consequently more funds were spent on casual employees than was originally proposed.

Database establishment

There were no unforeseen problems in establishing the database.

Preliminary results

The sites and treatments assessed and measured are listed in Table 1. Table 2 gives the means and standard errors for bulk density, soil shear strength and gravel content of operational categories at seven Forestcheck sites. As low numbers of measurements points occurred in some the snig track operational categories, Table 3 shows the means for combined snig track categories.

Visual assessment of disturbance classes was only possible the most recently logged site (Carter gap). This assessment is not appropriate at the retrospective sites where evidence of disturbance has changed over time.

At this stage sampling intensity appears to be adequate but the analysis needs to be completed is before a conclusion is reached.

Table 1. The number of assessment points and sample or measurements collected at each Forestcheck site. The disturbance classes and operational categories used are described in the Forestcheck operating plan.

Site	**Site code**	**Disturbance class sample points**	**Operational category sample points**	**Shear strength sample points**	**Total bulk density sample points**	**Soil moisture samples**
Kingston gap	M2		160	160	160	54
Kingston Shelter	M3		100	100	100	41
Kingston TEAS	M4		40	40	40	14
Thorton Gap	M6		166	166	166	52
Thornton TEAS	M7		40	40	40	14
Carter Gap	M8	338		152	152	51
Carter TEAS	M9		40	40	40	14
TOTAL		**338**	**546**	**698**	**699**	**240**

Table 2. Bulk density, soil shear strength and gravel content of operational categories at seven Forestcheck sites.

Site	Site code	Operational category	n	Fine earth bulk density (g cm^{-3})	SE	Gravel content (%)	SE	Shear strength (kPa)	SE	n
Kingston gap	M2	HA	68	0.798	0.023	32.0	2.4	446	24	67
		LL	20	1.123	0.037	22.4	2.8	1156	111	20
		OST	11	0.891	0.058	40.9	6.4	386	56	8
		ST0	3	1.173	0.055	12.1	2.1	824	196	3
		ST1	23	1.007	0.030	30.3	2.7	689	48	23
		ST2	30	0.935	0.040	32.5	4.7	625	38	27
		ST3	5	0.863	0.030	49.6	4.7	714	108	5
Kingston shelterwood	M3	HA	66	0.931	0.022	8.1	1.2	365	20	66
		LL	21	1.196	0.042	13.3	2.2	697	97	21
		ST1	4	0.864	0.049	19.5	5.0	1280	262	4
		ST2	9	1.100	0.045	11.7	3.3	685	112	9
Kingston TEAS	M4	OST	1	1.156		9.6		490		1
		UA	39	0.925	0.022	9.8	2.9	347	21	39
Thorton gap	M6	HA	75	0.984	0.025	16.6	2.2	358	34	75
		LL	23	0.732	0.035	59.2	2.0	264	24	23
		ROAD	11	1.322	0.036	6.6	1.4	678	98	11
		ST0	7	1.205	0.025	58.9	2.5	1550	384	7
		ST1	4	1.019	0.004	22.3	0.3	775	111	4
		ST2	34	1.167	0.028	8.9	2.0	401	46	33
		ST3	12	1.144	0.053	4.1	2.4	427	47	12
Thorton TEAS	M7	UA	40	0.756	0.036	46.8	3.1	306	17	38
Carter gap	M8	HA	137	0.795	0.013	35.4	1.3	383	18	137
		LL	5	0.932	0.082	29.5	3.6	628	62	5
		ST1	1	1.053		24.2		1098		1
		ST2	5	0.904	0.078	38.6	10.5	698	118	5

		ST3	4	0.959	0.124	36.5	4.3	310	53	4
Carter TEAS	M9	UA	40	0.777	0.025	54.8	2.2	243	13	40

Table 3. Mean bulk density, soil shear strength and gravel content of operational categories at seven Forestcheck sites. Operational categories ST0 and ST1 have been grouped as category ST01, and categories ST2 and ST3 have been grouped as category ST23, and

Site	Site code	Operational category	n	Fine earth bulk density (g cm^{-3})	SE	Gravel content (%)	SE	Shear strength (kPa)	SE	n
Kingston gap	M2	HA	69	0.803	0.023	31.8	2.4	450	24	68
		LL	20	1.123	0.037	22.4	2.8	1156	111	20
		OST	11	0.891	0.058	49.0	6.4	386	56	11
		ST01	23	1.027	0.032	26.2	2.3	721	52	23
		ST23	37	0.926	0.033	36.2	4.1	632	34	34
Kingston shelterwood	M3	HA	66	0.931	0.022	8.1	1.2	365	20	66
		LL	21	1.196	0.042	13.3	2.2	697	97	21
		ST01	4	0.902	0.064	18.0	5.4	1393	248	4
		ST23	9	1.083	0.051	12.3	3.4	635	72	9
Kingston TEAS	M4	OST	1	1.156		9.6		490		1
		UA	39	0.925	0.022	9.8	2.9	347	21	39
Thorton gap	M6	HA	75	0.984	0.025	16.6	2.2	358	34	75
		LL	23	0.732	0.035	59.2	2.0	264	24	23
		ROAD	11	1.322	0.036	6.6	1.4	678	98	11
		ST01	7	1.205	0.025	58.9	2.5	1550	384	7
		ST23	50	1.150	0.023	8.8	1.6	438	37	50
Thorton TEAS	M7	UA	40	0.756	0.036	46.8	3.1	306	17	38
Carter gap	M8	HA	137	0.795	0.013	35.4	1.3	383	18	137

		LL	5	0.932	0.082	29.5	3.6	628	62	5
		ST1	1	1.053		24.2		1098		1
		ST2	5	0.904	0.078	38.6	10.5	698	118	5
		ST3	4	0.959	0.124	36.5	4.3	310	53	4
Carter TEAS	M9	UA	40	0.777	0.025	54.8	2.2	243	13	40

Table 4. Mean bulk density, soil shear strength and gravel content of disturbance classes at the Carter site.

Site	Site code	Soil disturbance class	n	Fine earth bulk density ($g\ cm^{-3}$)	SE	Gravel content (%)	SE	Shear strength (kPa)	SE
Carter gap	M8	D0	77	0.787	0.015	0.342	0.016	367	19
		D1	23	0.818	0.044	0.277	0.033	407	38
		D2	26	0.850	0.035	0.374	0.033	451	42
		D3	26	0.826	0.033	0.429	0.028	463	70
Carter TEAS	M9	D0	40	0.777	0.025	0.548	0.022	243	13

Table 5. The total area of the fallers block, the area of snig tracks and landings identified at each Forestcheck site, and the proportion of the block area that has been disturbed by snig tracks and landings. Snig track classes are first order (ST1), second order (ST2), third order (ST3), old snig track from a previous logging that has been reused (OST) and an old road that has been reused as a snig track. Snig track area calculations are based on measurements of snig track lengths and assumed widths of 4.90m for ST0, 4.67 for ST1, 4.46 for ST2, and 4.13 for ST3.

Site	Site code	ST1 (m^2)	ST2 (m^2)	ST3 (m^2)	OST (m^2)	Old Road (m^2)	Total snig track area (m^2)	Landing area (m^2)	Block area (m^2)	Proportion of block disturbed
Kingston Shelterwood	M3	1538	1635	318			3491	941		
Kingston gap	M2	2739	5251	1217	454		9662	1410		
Thorton gap west	M6	1663	2582	1605		1562	7412	1792		
Thorton gap east		1566	1998	182			3745	1942		
Thorton gap total		3229	4580	1787		1562	11158	3734	133,773	0.111

Bulk density and shear strength observation discussion points

- The results reaffirm that fine earth bulk density is a more meaningful measure of soil disturbance than total bulk density. The total bulk density at Carter TEAS is higher than the total bulk density for harvest area (HA) at Carter gap. This is not the case for fine earth bulk density highlighting the reasons for using fine earth bulk density.
- The use of reference sites for comparisons of soil impacts is problematic as the undisturbed soil at the reference site can have higher bulk density than disturbed soil on a logged site.
- The Kingston TEAS site seems to provide a good reference site.
- It makes more sense to use the undisturbed harvested area as a reference rather than the TEAS, even though the HA will have some increase in bulk density due to disturbance.
- The bulk density on the log landings (LL) is highly variable because the landings have been ripped.

Relationship between bulk density, and shear strength and soil moisture

Several regressions were developed to examine the relationship between soil shear strength and bulk density. Additional variables included in this analysis were soil gravel content, and soil moisture content at the time of the shear strength measurement.

Regression relationships

1. Strength = -71.879 + 84.756*FEBD + 53.361*Gravel% + 128.748*Moisture content
   r^2 = 0.224 n = 234

2. FEBD = 1.149 + 0.00234*Strength - 0.571*Gravel% - 0.892*Moisture content
   r^2 = 0.482 n = 234

3. FEBD = 0.937 + 0.002197*Strength + 0.6087*Moisture content
   r^2 = 0.152 n = 234

4. TBD = 1.168 + 0.00239*Strength + 0.471*Gravel% - 1.127*Moisture content
   r^2 = 0.467 n = 234

5. TBD = 1.343 + 0.00251*Strength - 1.360*Moisture content
   r^2 = 0.301 n = 234

Equations 2 and 4 are the only regressions with reasonable r^2. These relate bulk density to shear strength and moisture content. However the r^2 of these relationships indicates that they would provide poor predictions of bulk density. I conclude that shear strength cannot provide worthwhile estimates of soil bulk density.

Comparison of sampling methods used

I attempted to identify sampling strata and stratify the sampling in a single survey operation. There were some problems in doing this. This resulted in some strata being over sampled and other strata being under sampled. This was a relatively minor problem. There were inefficiencies in the system I used to identify the sampling strata and in stratifying and labelling the sample points. I am not sure how to improve this, as other methods would be less efficient.

As noted previously the visual assessment of soil disturbance needs to occur soon after logging has finished, and is not well suited to sites where a post logging treatment is applied. Even the most recently logged site (Carter gap) was too old for visual assessment to be of a high standard.

Future tasks

Data entry and summary is complete. The areas of the Kingston gap and shelterwood treatments need to be determined to complete Table 5.

Discussion

Stratification

- The description and measurement of soil disturbance across a logging site requires the grouping of measurement points into identifiable strata with common intensity of disturbance.
- Soil disturbance classes are best determined a short time after completion of logging. The required delay of 2 to 3 years between logging and vegetation assessment on Forestcheck sites makes the use of disturbance classes inappropriate for this monitoring system.
- Operational classes are distinguished more readily than disturbance classes for a longer period after logging. However post logging treatments can obscure these classes. At the Carter gap treatments the post logging machine disturbance and fire made identification of operational classes impossible.
- Operational categories were difficult to distinguish at all sites.
- Few snig tracks could be identified on the Kingston shelterwood treatment. Consequently bulk density and shear strength were measured at regularly

spaced grid points rather than at points of known operational categories on the grid.

Shear strength

- Fine earth bulk density could be related to shear strength gravel content and soil moisture. However the r2 was low indicating that FEBD predicted in this manner would have large errors associated with it. In addition this predictive model required soil moisture and gravel content which are difficult and expensive to collect. The necessity of determining these values reduces the efficiency of using shear strength measurements to an extent that the more expensive but considerably more meaningful bulk density measurements are cost effective.
- Shear strength measurements were clearly effected by gravel (particularly large and angular gravel) and plant roots in the soil. This necessitated repeated measures at most measurement locations and the rejection of unusually high values. This repeated measurements and the judgement required to identify erroneous measurements lower the value of shear strength measurements.
- All of these factors indicate that these shear strength measurements have limited value for long term monitoring of soil disturbance in gravelly soils.

Conclusions

- The extent of soil disturbance cannot be readily determined on retrospective sites or recently logged sites that have experienced post harvest silvicultural treatments and/or fire.
- The intensity of soil disturbance cannot be successfully determined from visual assessment on retrospective sites or recently logged sites that have experienced post harvest silvicultural treatments and/or fire.
- On retrospective sites, operational categories are best identified when good quality aerial photography collected a short time after the completion of logging is available, and no post harvest soil disturbance, such as machine knock down, has occurred.
- Soil shear strength is unlikely to provide meaningful information on the long term changes in soil condition because of the influence of soil moisture and the effect of gravel and roots in the soil.
- The design of Forestcheck, which is intended to accommodate a wide variety of monitoring exercises, is unsuited to monitoring the extent of soil disturbance. This is best done shortly after the completion of logging operations.
- Similar the intensity of disturbance from logging operations is best determined shortly after the completion of logging operations.

- Soil disturbance monitoring within Forestcheck is best confined to measurements of bulk density at known locations with clearly identified operational categories or disturbance classes that could be used to determine the changes in the intensity of disturbance over time at representative sites.