# Harvesting: Its Effect on the Physical Properties of Soils[1]

K. BOYLE, E. P. FARRELL and J. J. GARDINER

Faculty of Agriculture,
University College, Belfield, Dublin 4.

## SUMMARY

A project on the effect of harvesting by tractor skidder on the physical properties of a soil was carried out on a surface water-gley. Skidding significantly increased bulk density and reduced total porosity under wheel ruts. To minimise damage on vulnerable sites careful consideration should be given to the methods and timing of extraction.

## INTRODUCTION

The use of heavy machinery to skid logs over the site exerts large pressures on the soil. This may result in soil damage on up to 25% of the area being harvested (Steinbrenner and Gessell 1955, Dryness 1965). The short term manifestation of this damage is seen in the bogging of skidders. Productivity of the subsequent crop may be adversly affected by the influence of compaction on soil pore space, gas exchange and water movement and by a deterioration in fertility following soil disturbance and organic matter losses. Any increase or decrease in pore volume is reflected in corresponding changes in bulk density (the mass of soil per unit bulk volume i.e. the volume of soil particles + pore space). Increases in soil bulk density following harvesting have been observed in a number of studies (Steinbrenner and Gessell 1955, Dryness 1965, Dickerson 1976, Mace 1970 and Moehring and Rawls 1970). While bulk density provides an indication of the severity of compaction, the relationship is complicated by other factors such as particle density and more particularly by organic matter content which markedly influences bulk density. Soil organic matter content on extraction paths may be displaced

1 This article is based on a final year elective project by the senior author for the B.Agr.Sc.(For) degree.

IRISH FORESTRY, 1982, Vol. 39, No. 2: 94-98.

by machinery and the rate of oxidation may be increased due to disturbance and mixing with mineral material. The particle density of soil organic matter is about 1.35-1.5g per $cm^3$ (soil minerals range in particle density from 2.5-2.8g per $cm^3$) so that variation in this component produces wide variation in bulk density. The bulk density of forest soils range from 0.2g per $cm^3$ in the organic layers to 1.9g per $cm^3$ in some sandy subsoils.

The recovery of soils from compaction is slow. Mineral soils often take up to 12 years to recover their initial bulk densities and porosities (Dickerson 1976). Timber volume losses of up to 15% have been recorded as a result of soil compaction during previous rotations (Greacen and Sands 1980). In an experiment on a gley soil with indurated material in Scotland, mean height of a replanted crop after six seasons on severely damaged plots was less then 70% of that in undamaged plots (D. G. Pyatt, Forestry Commission, Edinburgh, personal communication, 1982).

The objective of this study was to quantify the changes that occur in a moderately fine textured soil following harvesting by skidder. Bulk density, total porosity and organic matter content were measured along an extraction path used for thinnings.

## METHODS

The extraction path was located along the contour of a drumlin, in a 28 year old Sitka spruce (*Picea sitchensis* (Bong.) Carr.) stand, in the O'Rahilly plantation, Drumhierney, Co. Leitrim. The soil, belonging to the Garvagh series (Bulfin, Gallagher and Dillon, 1973), is classified as a surface water gley and texture varies from a clay loam in the solum to a clay at greater depth. A modified agricultural tractor was used to skid thinnings over the site. Samples were collected at 24m intervals on three cross-sections of the extraction path. At each cross-section samples were taken at three points.

1. Undisturbed, 4m from the centre of the path.
2. Under the wheel rut.
3. At the centre of the extraction path midway between the two wheel ruts.

Since extraction may have caused inversion of the soil in wheel ruts it was considered preferable to sample by arbitrary depth classes. Intact clods were taken at four depths 0-5, 5-10, 10-15 and 15-20cm. An inversion of organic material was found at one point, a layer of soil having been thrown up over the organic matter. This layer of organic material was rejected in sampling for bulk density or particle density determinations. Such inversion was not observed at other points. Bulk density was determined by the clod method. Organic matter content was determined by combustion. Particle density was determined from the weight of the soil sample and its volume. Total porosity was calculated from bulk density and particle density.

## RESULTS

The bulk density of 0.7g per $cm^3$ (Table 1) was due to the influence of organic matter in the sample referred to above. Although a layer of organic matter was rejected from the sample some mixing of organic and mineral material had occurred within the sampled clods. The bulk density under wheel ruts at 5-10cm and 10-15cm were significantly greater than the bulk densities either of the undisturbed area or of the area between wheel ruts (Table 1). Compaction resulted in a 45% increase in bulk density at the 5-10cm depth and a 15% increase at 10-15cm depth. No increase in bulk density occurred in the areas between wheel ruts.

Total porosity was reduced at the 0-5, 5-10 and 10-15cm depths under the wheel ruts. These actual reductions in porosity compared to the undisturbed soil were 12, 32 and 16% respectively.

Reduction in organic matter was only significant at the 5-10cm depth under the tyre ruts. Organic matter at this point was 25% lower than in the undisturbed soil at the same depth.

**Table 1. Bulk densities on and off the extraction path (g per $cm^3$).**

| Depth cm | Treatment Means Undisturbed | Wheel rut | Path centre | SE of Location mean |
|---|---|---|---|---|
| 0- 5 | 0.83ab | 1.02a | 0.70b | 0.028 |
| 5-10 | 0.93a | 1.36 | 0.94a | 0.004 |
| 10-15 | 1.26a | 1.45 | 1.14a | 0.033 |
| 15-20 | 1.33a | 1.39a | 1.30a | 0.043 |

**Values at each depth bearing same letter are not significantly different (5%) from each other.**

**Table 2. Total porosity % on and off the extraction path.**

| Depth | Treatment Means | | | SE of |
|---|---|---|---|---|
| cm | Undisturbed | Wheel rut | Path centre | Location mean |
| 0- 5 | 61.03a | 53.34 | 65.49a | 1.55 |
| 5-10 | 60.60a | 40.79 | 59.51a | 2.05 |
| 10-15 | 47.86a | 39.83 | 51.88a | 1.31 |
| 15-20 | 46.40a | 41.56a | 45.91a | 1.24 |

**Values at each depth bearing the same letter are not significantly different (5%) from each other.**

**Table 3. Organic matter % on and off the extraction path.**

| Depth | Treatment Means | | | SE of |
|---|---|---|---|---|
| cm | Undisturbed | Wheel rut | Path centre | Location mean |
| 0- 5 | 16.02a | 11.02a | 18.80a | 2.77 |
| 5-10 | 10.76a | 7.85 | 11.17a | 0.62 |
| 10-15 | 7.39a | 6.42a | 7.85a | 0.47 |
| 15-20 | 6.61a | 5.81a | 6.40a | 0.34 |

**Values at each depth bearing the same letters are not significantly different (5%) from each other.**

## DISCUSSION

The results show that extraction of thinnings by skidder can cause soil compaction. The bulk densities measured in the 5-10 and 10-15cm zone under the wheel rut, may be close to the maximum values attainable under prevailing moisture conditions on a soil of this texture and organic matter content. (Bodman and Constantin 1965).

Total porosity in forest soils varies from 30-65% (Pritchett 1979), so the reduction shown in Table 2 may not seem critical. However, changes in non capillary porosity were not measured in this study so that the type of pores lost through compaction and the consequent effect on soil air and water movement could not be assessed. This deterioration of the soil is due in part to organic matter losses which also represent a decrease in the nutrient capital of the site.

The use of a tractor skidder has been detrimental to the site. During thinning this damage is confined but in clearfelling up to 25% of an area may be traversed and the loads carried will be greater. Serious soil damage can result from even a few passes over a path. Hatchell, Ralston and Foil (1970) found that only 7% of the sites they studied required more than four trips to reach their final bulk densities. The soils of the Garvagh series are extensive in Co. Leitrim (27,277ha) and are among the most productive in the country (Bulfin et al 1973). Our results demonstrate the vulnerability of these poorly drained clay loams. It is important that foresters recognise the risk of damage particularly in wet weather. Careful consideration should be given both to the methods and the timing of extraction on these sites.

## ACKNOWLEDGEMENTS

Samples were collected from the O'Rahilly plantation Co. Leitrim.

## REFERENCES

BODMAN, G. B., and CONSTANTIN, G.K. (1965). Influence of particle size distribution in soil compaction. Hilgardia 36. 567-91.

BULFIN, M., G. GALLAGHER and J. DILLON. 1973. Forest production. Co. Leitrim Resource Survey. Part 1.

DICKERSON, B. P. 1976. Soil compaction after tree length skidding in Northern Mississippi. Soil Sc. Soc. Am. Proc. 40:965-966.

DRYNESS, C. T., 1965. Soil surface conditions following tractor and high lead logging in the Oregon Cascades. J.For. 63:272-275.

GREACEN, F.L. and R. SANDS. 1980. Compaction of forest soils. A review. Aust. J.Soil Res. 18:163-89.

HATCHELL, G. E., C. W. RALSTON and R. R. FOIL. 1970. Soil disturbance in logging. J.For. 68:772-775.

MACE, A. C. Jr. 1970. Soil compaction due to tree length and full tree skidding with rubber tyred skidders. Minn.For. Research Note. No. 214:4p.

MOEHRING, D. M., and J. W. RAWLS. 1970. Detrimental effects of wet weather logging. J.For. 68:166-7.

PRITCHETT, W. J., 1979. Properties and management of forest soils. John Wiley and Sons, New York. 500pp illus.

STEINBRENNER, F. C., and S. P. GESSEL. 1955. The effect of tractor logging on physical properties of some forest soils in Southwestern Washington. Soil Sci. Soc. Am. Proc. 19:372-76.