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Timber Harvesting Impacts on Soil Respiration Rate and Microbial Population of *Populus tremuloides* Michx. Stands on Two Contrasting Soils[1]

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두 가지 서로 다른 토양에 형성된 *Populus tremuloides* Michx. 임분의 수확이 토양호흡률 및 토양미생물상에 미치는 영향[1]

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ABSTRACT

Timber harvesting impacts on soil microbial populations and respiration rates were examined in naturally regenerating trembling aspen(*Populus tremuloides* Michx.) stands on two contrasting soils, an Omega loamy sand(sandy mixed, frigid Typic Udipsamment) and an Ontonagon clay loam(very fine, mixed Glossic Eutroboralf). Five timber harvesting disturbances were simulated during winter of 1990 and spring of 1991, including commercial whole-tree harvesting(CWH), winter logging trail+CWH, logging slash removal+CWH(LSR), forest floor removal+LSR(FFR), and spring compaction+FFR. Regardless of soil types, total soil respiration rates of each stand decreased slightly or remained the same after harvesting while microbial population increased progressively during the first two years following harvesting. Microbial populations increased more rapidly and constantly at the sandy site than at the clayey site, which may indicate that the soil physical and chemical conditions changed more drastically for microbial activity following timber harvesting at the sandy site than at the clayey site. However, two kinds of treatment applications-three levels of organic matter removal and two levels of compaction-did not result in significant differences in microbial population or total soil respiration rate at each site during the first two post-harvest years. Total soil respiration of the aspen stands, sum of root respiration and microbial respiration, was a poor index for the microbial activity in this study because aspen kept an active root system for the successive root-sprouts even after harvesting, which resulted in a large portion of root respiration in total respiration.

Key words : *total soil respiration rate, soil fungus, soil bacteria, timber harvesting,* Populus tremuloides *Michx., soil types*

요 약

본 연구는 서로 다른 두가지 토양에서 천연갱신되어 자라고 있는 trembling aspen(*Populus tremuloides* Michx.) 임분의 수확이 토양미생물상 및 토양호흡률에 미치는 영향을 조사하며 토양호흡률이 토양미생물상 변이의 지표로 활용될 수 있는지에 대한 연구 결과이다. 다섯 가지의 수확처리(지

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상부 전체 임목수확, 겨울철 수확통로, 수확 잔재목 제거, 수확 잔재목 및 낙엽류 제거, 춘계 답압)를 1990년과 1991년 사이의 겨울 및 봄 사이에 시행하였고, 1991년 및 1992년의 2년간에 걸쳐 수확후 산림토양의 동태를 조사하였다. 각 임분의 토양형에 관계없이 토양호흡률은 수확후 약간 감소하거나 변동이 없었으나 미생물수는 수확후 2년동안 점차 증가하였다. 미생물수는 식질토양에서 보다 사질토양에서 보다 급속하고 지속적인 증가양상을 나타내었는데, 이것은 수확 결과 미생물 활성에 영향하는 토양의 이화학적 특성이 식질토양보다는 사질토양에서 큰 변화가 있었음을 시사한다. 그러나, 두가지 종류의 처리(세 수준의 유기물 제거 및 두 수준의 답압 처리)는, 두 지역 모두, 수확후 2년간의 미생물상이나 토양호흡률에 유의차를 나타내지 않았다. 본 연구의 대상임분이었던 trembling aspen은 수확후에도 뿌리의 활력이 떨어지지 않고 맹아발생을 위한 대사를 진행하여, 뿌리의 호흡과 미생물의 호흡을 포함하는 전체 토양 호흡에서 뿌리의 호흡이 차지하는 비율이 높은 결과를 낳아, 전체 토양 호흡을 미생물의 활력도 변이의 지표로 활용하기 어려웠다.

INTRODUCTION

Timber harvesting may be accompanied by substantial changes in the soil environment, which may affect below-ground metabolism of forest ecosystem (Jurgensen *et al.*, 1979 ; Smith, 1985 ; Alban and Perala, 1990). Timber harvesting usually results in drastic changes in soil nutrient pool, temperature, and moisture conditions. Thus, timber harvesting may lead to higher rates of microbial activity caused by increased soil temperature, moisture content and nutrient availability (Aber *et al.*, 1978 ; Covington, 1981 ; Entry *et al.*, 1986).

Since logging slash may temporarily increase the amount of organic matter and nutrients in the forest floor compartment, removal of logging slash and/or forest floor is expected to affect the harvested soil ecosystem. Timing of harvesting also influences on soil physical properties such as bulk density, which may result in differences in soil microbial activity and other below-ground metabolism.

Soil respiration rate, or CO_2 evolution rate, can be used for assessing biological activity of forest soils and for evaluating the impacts of harvesting practices on forest ecosystem function (Gordon *et al.*, 1987 ; Weber, 1990 ; Edwards, 1991 ; Jurik *et al.*, 1991). However, it should be noted that total soil respiration rate is largely dependent upon the above-ground vegetation of each forest stand, sometimes even after timber harvesting.

When trembling aspen is killed or cut, suckers appear in vast numbers, sometimes 100 to 150 thousand per hectare. They sprout from horizontal roots that may extend more than 25 meters from the parent tree. The suckers are supported by the already established root system of the parent tree, and as a result, the young trees grow very rapidly (Graham *et al.*, 1963 ; Schier *et al.*, 1985). Thus, lots of efforts need to be given to study below-ground activities of the stand.

Two objectives of this study were (1) to compare the microbial dynamics with two aspen stands on contrasting soil types after timber harvesting ; and (2) to evaluate the suitability of total soil respiration rate as an index of soil microbial activity.

MATERIALS AND METHODS

Study Area

The study sites were located on the Brule River State Forest, Wisconsin, USA, and primarily contained 35- to 45-year-old trembling aspen (*Populus tremuloides* Michx.) stands on two contrasting soils. One stand was located on a clayey soil and the other on a sandy soil. The two sites were 30km apart and the climatic condition was slightly different because of proximity to Lake Superior.

The dominant soil types of the two stands were an Omega loamy sand (sandy mixed, frigid Typic Udipsamment) and an Ontonagon clay loam (very fine, mixed Glossic Eutroboralf). The sandy site was almost flat (0 to 3% slopes), while the clayey site was gently undulating (0 to 10% slopes) with some pits and mounds partly due to wind-throw of trees. Both sites had thin O horizons (1cm thick) with

Table 1. Soil physical properties of each soil horizon before timber harvesting at the two experimental sites (n=3)†.

Soil Horizon	Thickness (cm)	Sand	Silt (%)	Clay	Bulk density (g/cm^3)	Soil texture
			Ontonagon clay loam			
A	7.5±0.5	50±4	36±6	14±3	0.94	Loam
E	8.8±2.6	44±4	30±4	26±4	1.17	Loam
E/B	6.3±0.9	38±2	26±2	36±5	1.38	Clay loam
$2Bt_1$	16.7±4.4	27±3	15±2	58±4	1.45	Clay
$2Bt_2$	27.0±2.7	23±2	22±4	55±6	1.46	Clay
2BC	>100	25±2	22±2	53±3	1.56	Clay
			Omega loamy sand			
A	5.7±1.2	86±1	10±2	4±1	0.94	Loamy sand
Ap	16.7±5.5	86±1	10±1	4±1	0.93	Loamy sand
Bw_1	23.0±3.1	90±2	5±1	5±1	1.38	Sand
Bw_2	41.3±5.2	89±3	7±2	4±1	1.67	Sand
C_1	18.7±3.8	90±1	5±0	5±1	1.55	Sand
C_2	14.7±5.0	94±4	1±1	5±3	1.76	Sand

† Mean ± standard error.

Table 2. Mean soil chemical properties prior to timber harvesting at the two experimental sites (n=3)†.

Soil Horizon	pH	Total N (%)	OM (%)	Extr. P (mg/l)	Extractable (mg/l) K	Ca	Mg
			Ontonagon clay loam				
A	5.2±0.1	0.22±0.04	6.24±0.41	12.0±3.2	156±70	1270±254	424±159
E	5.2±0.2	0.08±0.04	1.07±0.09	6.0±1.5	65±2	349±70	153±27
B/E	5.2±0.2	0.04±0.00	1.14±0.11	4.0±0.6	91±18	767±153	488±142
$2Bt_1$	5.4±0.4	0.03±0.00	0.84±0.14	5.3±2.9	213±26	1865±113	1401±159
$2Bt_2$	7.4±0.1	0.03±0.00	0.44±0.19	2.7±0.7	218±3	3374±782	1874±164
2BC	8.4±0.1	0.02±0.01	0.41±0.12	2.3±0.3	189±8	4887±110	1545±127
			Omega loamy sand				
A	5.1±0.1	0.28±0.07	6.40±0.88	29.3±4.6	132±39	1088±337	155±45
Ap	5.3±0.1	0.05±0.01	1.35±0.27	45.7±4.6	62±2	321±77	55±9
Bw_1	5.5±0.2	0.02±0.00	0.41±0.15	46.0±6.7	29±2	238±16	40±5
Bw_2	5.7±0.1	0.03±0.01	0.29±0.12	44.7±9.8	39±9	202±61	37±8
C_1	5.6±0.1	0.02±0.00	0.58±0.07	21.0±7.9	28±5	320±27	76±17
C_2	5.8±0.2	0.03±0.02	0.21±0.16	21.0±9.9	21±4	275±53	71±28

† Mean ± standard error.

contrasting soil physical and chemical properties due to the textural differences(Tables 1 and 2). Both soils were acidic throughout the profile except for the bottom(deeper than 65cm) of the clayey site which was calcareous. The sandy site was somewhat excessively drained while the clayey site was poorly drained. The greater CEC and calcareous subsoil have resulted in a higher site index for aspen at the clayey site(23.1m, at 50 years) than at the sandy site (21.4m).

Treatment Applications

Twenty five 400m^2 plots were nested within each site with a 5 or 10m width buffer area. Five treatments – three levels of organic matter removal and two levels of compaction – were applied by a completely randomized design with five replications. After initial inventory of vegetation and soils, the stands were commercially whole-tree harvested (CWH) during dormant season(January and February, 1991).

All merchantable stems and non-merchantable trees taller than 3m were removed from the study areas, but relatively large amounts of logging slash remained after the logging operations. From the CWH area, logging slash was removed as a medium-intensity of organic matter removal(LSR), and forest floor was removed in addition to LSR as a high-intensity of organic matter removal(FFR) during early May of 1991. The area used for logging trail during winter was considered as a low intensity of compaction(WLT), and an artificial compaction over FFR(CMP) was applied during spring to simulate a high-intensity compaction. Forest floor was removed prior to the CMP treatment because it would have precluded compaction. The logging slash included all stems and branches greater than 2.5cm in diameter or longer than 50cm in length. Forest floor was removed by raking, which removed most of the forest floor but did not disturb the underlying mineral soil.

A dozer(JD 450C, 0.43kg/cm^2) was used to compact treated plots. The sandy site received 1.72kg/cm^2, and the clayey site received 0.86kg/cm^2 static pressure. The sandy site needed more pressure than the clayey site to make visible depression of surface soil in comparison to the non-compacted area.

Soil Sampling and Microbial Assay

Before and after the treatment applications, soil samples were collected from the upper 20cm layer using an oakfield soil corer. The samples were collected twice a year during 1990 and 1991(summer and fall), and three times a year druing 1992(spring, summer and fall). Ten soil cores were collected from each plot and the cores were composited prior to assay. The soil samples were kept below 4℃ in an ice box and transported to the laboratory for microbial assay. The samples were stored at 4℃ in a refrigerator and the microbial assay was performed within a week of sample collection. A modified Owen's buffer solution was used for the dilution of soil samples(Owens and Keddie, 1969). Ten grams of the fresh soil samples were added to a 125ml Erlenmeyer flask which contained 95ml of buffer solution. The soil suspension was diluted by ten-fold series of dilution down to 10^{-8}g/ml and the soil fungal and bacterial populations were determined by plate-dilution frequency(PDF) technique(Harris and Sommers, 1968). Martin's rose bengal/streptomycin agar(MRB) medium was used for soil fungus culture (Martin, 1950), and the diuted nutrient broth(DNB) medium for soil bacterium.

Total Soil Respiration Rate

Total soil respiration rate was measured at the same time as soil sampling by collecting evolved CO_2 in 20ml of 1M NaOH solution *in situ*(Anderson, 1982). The height and diameter of the incubation chamber were 30cm and 25cm, respectively, and the diameter of collecting bottle was 6.5cm(6.76% of the chamber diameter). After 24-hour incubation, the solution was transported to the laboratory, and titrated against a standard acid(1M HCl) in a supersaturated 1.5M $BaCl_2$ solution.

RESULTS

Dry Matter and Nutrient Export by the Treatment Applications

Whereas the aboveground woody biomass contained the largest proportion of organic matter at the clayey site(56%), the mineral soil made up the largest fraction at the sandy site(56%)(Fig. 1). Commercial whole-tree harvesting removed 47% of the total ecosystem organic matter at the clayey site (83% of dry matter in living aboveground biomass) and 23% at the sandy site(67% of aboveground biomass). Logging slash contained approximately 10% of the total ecosystem organic matter at each site. The forest floor contained 5% and 10% of the total ecosystem organic matter at the clayey and sandy sites, respectively. Therefore, the LSR treatment removed 56% and 34% of dry matter and the FFR 61% and 44% of the organic matter at the clayey and sandy sites, respectively.

Because the extractable soil nutrient pools were large, the various organic matter removal treatments removed less than 15% of the total ecosystem macronutrient pools except in the case of P at the clayey site. Of the three levels of organic matter removal, commercial whole-tree harvesting(CWH) removed the largest proportion of nutrients at the clayey site, while nearly equivalent amounts of

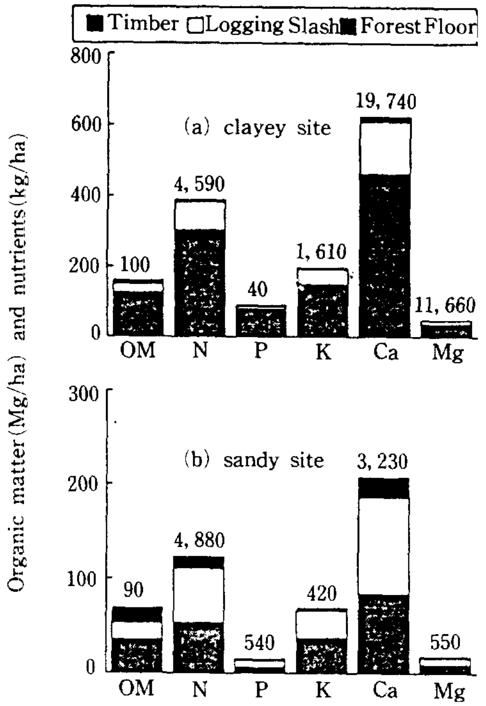

Fig. 1. Organic matter and nutrients removed from each site by treatment applications. CWH removed timber only, LSR removed timber and logging slash, and FFR removed all three of the compartments. The numbers on top of each bar indicate soil pool(A and B horizon ; 66cm at the clayed site and 87 cm at the sandy site) of each element.

nutrients were removed in logging slash as with CWH from the sandy site. Less than 1% of the labile nutrients were contained in the forest floor at either site. Because of the initially low extractable P concentration in the Ontonagon clay soil, which might be fixed by clay and/or CaCO3, nearly 60% of the ecosystem P was removed from the clayey site by the CWH. However, there was no observable P deficiency in foliage of aspen suckers despite the large proportion of P removed by the various treatments at the clayey site(Park and Bockheim, 1993). Since the soil samples were extracted by Bray-I solution instead of weak acid, the extractable P in soil possibly was underestimated.

Microbial Populations and Soil Respiration Rate

Although there were no significant differences among the treatment applications, populations of soil fungi and bacteria increased immediately following treatment applications and persisted during the first two years after timber harvesting. At the sandy site, the soil fungal population increased ten-to hundred-fold during 1992 compared to the populations in 1990(Fig. 2). During 1990(pre-harvest), the fungal populations were constant or decreased slightly in October compared to July at both sites. During the post-harvest years(1991 and 1992), however, the clayey site showed similar fungal populations in October than in August. Soil bacterial populations showed a similar pattern of change as soil fungal populations(Fig. 3), but the comparison of the bacterial populations to the pre-harvesting populations was impossible since I did not assay the bacterial populations before the treatmet applications.

Despite the increased microbial populations, however, there was a significant decrease in total soil

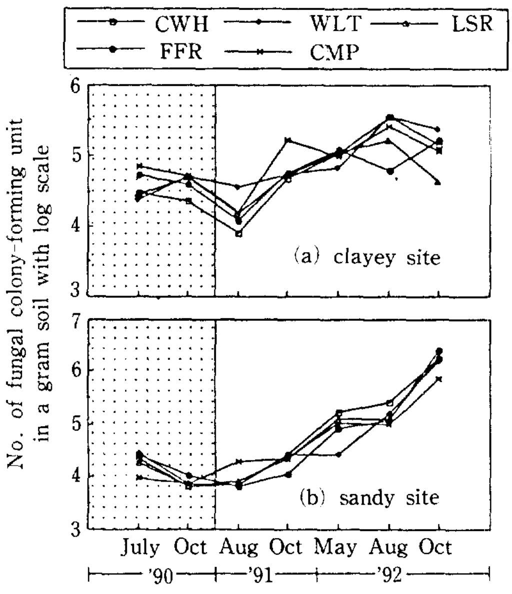

Fig. 2. Soil fungal populations during 1990 through 1992 at the two aspen stands(upper 20cm). The dotted area indicates pre-harvest period. CWH : commercial whole-tree harvest, WLT : CWH+winter logging trail, LSR : CWH+logging slash removal, FFR : LSR+forest floor removal, and CMP : FFR+spring compaction. There were no significant differences among the treatment applications.

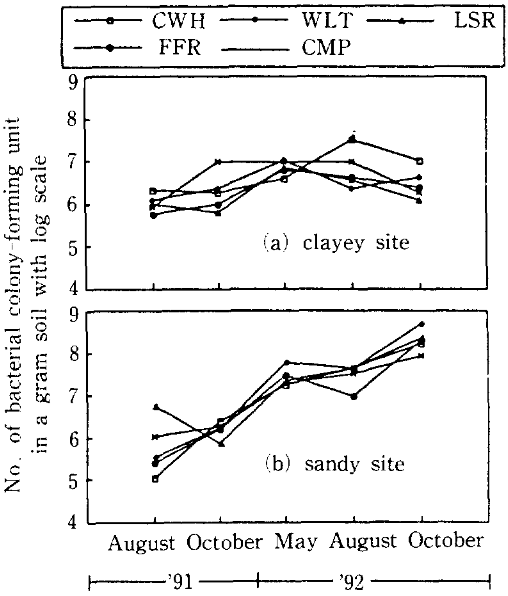

Fig. 3. Soil bacterial populations during 1991 and 1992 at the two aspen stands(upper 20cm). CWH : commercial whole-tree harvest, WLT : CWH+winter logging trail, LSR : CWH+logging slash removal, FFR : LSR+forest floor removal, and CMP : FFR+spring compaction. There were no significant differences among the treatment applications.

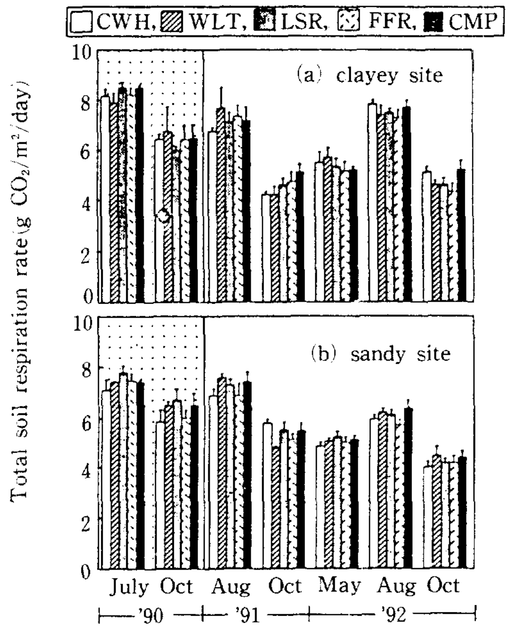

Fig. 4. Total soil respiration rates during 1990 through 1992 at the two aspen stands. Bars indicate standard errors of each value and the dotted area indicates the pre-harvest period. CWH : commercial whole-tree harvest, WLT : CWH+winter logging trail, LSR : CWH+logging slash removal, FFR : LSR+forest floor removal, and CMP : FFR+spring compaction. There were no significant differences among the treatment applications.

respiration during the first year following timber harvesting(Fig. 4).

DISCUSSION

Microbial Populations on Two Contrasting Soils

Regardless of soil type and treatment applications, soil fungal population increased progressively during the first two years following harvesting(Fig. 2). These increases likely were due to the increased organic matter in the upper 20cm on all plots regardless of treatment applications. The microbial populations increased more rapidly and constantly at the sandy site than at the clayey site, which may indicate that the soil physical and chemical conditions changed more drastically for microbial activity following timber harvesting at the sandy site than at the clayey site. Since the sandy soil had a smaller amount of organic matter than the clayey soil, the added organic matter from harvesting by increased root decomposition may have caused the increase in microbial populations. The same amount of organic matter input could not accelerate microbial population increase at the clayey site because the continuously wet soil condition even after timber harvesting could have restricted microbial activity.

The fungus/bacteria(F/B) ratio fluctuated at around 0.1(ranged from 0.02 to 0.24 at the clayey site and from 0.01 to 0.17 at the sandy site) during the two post-haravest years. Differences in organic matter input often result in F/B ratio changes(Entry *et al.*, 1986), but the ratio was not significantly different among the treatment applications at either site. No difference in F/B ratio among the treatment applications supports that there were no significant differences in organic matter input among the three different levels of organic matter removal. As illustrated by previous report(Park and Bockheim, 1993), the organic matter input from root-decomposition was possibly far larger than from aboveground by timber harvesting.

Although the spring compaction was expected to retard decomposition of soil organic matter as soil physical property changes regulate aeration-dependent microbial activities(Skopp *et al*., 1990), there were no significant differences in microbial populations among treatment applications during the two post-harvest years. It indicated that the compaction I applied did not affect severely on soil physical environment which may affect microbial activity while the compaction might influence on root activity in long-term perspective. Therefore, the treatment effects on soil microbial activity might appear during the fourth or fifth years after timber harvesting as the role of root-decomposition reduce with the role of organic matter input from aboveground get larger.

Total Soil Respiration Rate as an Index of Soil Microbial Activity

In view of the fact that microbial populations increased during the post-harvesting period(Fig. 2), decreased total soil respiration rate would imply a temporary reduction in autotrophic root respiration. Although the activity of heterotrophic organisms were not measured separately, the activity usually been reported as being increased after timber harvesting(Jurgensen *et al*., 1979). Thus, reduced total soil respiration rate possibly reflect the decreased root respiration instead of decreased microbial respiration.

Soil respiration rate is largely dependent on soil temperature and moisture(Webber, 1990 ; Jurik *et al*., 1991 ; Raich and Schlesinger, 1992). Temperature influences soil respiration by controlling enzymatic processes in living cells ; thus, the influences on root and microbial respiration are expected to be similar. However, total soil respiration(root respiration + microbial respiration) is less sensitive to soil temperature variation than root respiration (Chapman, 1979). Total soil respiration and microbial populations showed poor relations at both sites in this study($r=-0.14$ for fungus and $r=-0.16$ for bacterium with total soil respiration, $p=0.05$). Since the microbial populations were larger during mid-summer than during fall, the increased soil respiration during mid-summer were possibly due to increased root respiration.

Total soil respiration appeared to be dependent primarily on root respiration during the two post-harvest years at the aspen stands in this study. Weber(1990) reported that various clearcut and burned aspen sites showed temporary declines in total soil respiration rate for the first two post-treatment years but recovered within three years of the treatment applications. Jurik *et al*.(1991) also found no differences in total soil respiration rates in five aspen stands ranging from 11 to 70 years in age in northern lower Michigan, USA. These studies imply that total soil respiration is stabilized during early development of aspen suckers. Although the root system of aspen continues to function in support of the next generation of vegetatively produced stems(Schier *et al*., 1985), fine-root activity can be affected by aboveground conditions, especially for the first two or three years after timber harvesting. This may explain why total soil respiration rates declined during the first two post-harvest years in this study. Thus, total soil respiration is not recommended as an index of microbial activity in the study of below-ground metabolism with the stand of heavy root-system containing species like trembling aspen.

LITERATURE CITED

1. Aber, J.D., D.B. Botkin, and J.M. Melillo. 1978. Predicting the effects of different harvesting regimes on forest floor dynamics in northern hardwoods. Can. J. For. Res. 8 : 306-315.
2. Alban, D.H. and D.A. Perala. 1990. Impact of aspen timber harvesting on soils. Pages 377-391. *In* S.P. Gessel, D.S. Lacate, G.F. Weetman, and R.F. Powers, eds. Sustained Productivity of Forest Soils. Proceedings of the 7th North American Forest Soils Conference. 1988 July. University of British Columbia, Vancouver, Canada.
3. Anderson, J.P.E. 1982. Soil respiration. Pages 831-871. *In* A.L. Page, R.H. Miller, and D.R.

Keeney, eds. Methods of Soil Analysis, Part 2. 2nd ed. Agronomy Monograph 9. ASA and SSSA, Madison, WI, USA.

4. Chapman, S.B. 1979. Some interrelationships between soil and root respiration in lowland *Calluna* heathland in southern England. J. Ecol. 67 : 1-20.

5. Covington, W.W. 1981. Changes in forest floor organic matter and nutrient content following clear cutting in northern hardwoods. Ecology 62 : 41-48.

6. Edwards, N.T. 1991. Root and soil respiration responses to ozone in *Pinus taeda* L. seedlings. New Phytologist 118 : 315-321.

7. Entry, J.A., N.M. Stark, and H. Lowenstein. 1986. Effect of timber harvesting on microbial biomass fluxes in a northern Rocky Mountain forest soil. Can. J. For. Res. 16 : 1076-1081.

8. Gordon, A.M., R.A. Schlentner, and K. Van-Cleve. 1987. Seasonal patterns of soil respiration and CO_2 evolution following harvesting in the white spruce forests of interior Alaska. Can. J. For. Res. 17 : 304-310.

9. Graham, S.R., R.P. Harrison, and C.E. Westell. 1963. Aspen, Phoenix Trees of the Great Lakes Region. Univ. of Michigan Press, Ann Arbor, MI., 272pp.

10. Harris, R.F. and L.E. Sommers. 1968. Plate-dilution frequency technique for the assay of microbial ecology. Appl. Microbiol. 2 : 330-334.

11. Jurgensen, M.F., M.J. Larsen, and A.E. Harvey. 1979. Forest soil biology-timber harvesting relationships. USDA For. Serv. GTR-INT-69, 12pp.

12. Jurik, T.W., G.M. Briggs, and D.M. Gates. 1991. Soil respiration of five aspen stands in northern lower Michigan. American Midland Naturalist 126 : 68-75.

13. Martin, J.P. 1950. Use of acid, rose bengal, and streptomycin in the plate method for estimating soil fungi. Soil Sci. 63 : 215-232.

14. Owens, J.D. and R.M. Keddie. 1969. The nitrogen nutrition of soil and herbage coryneform bacteria. J. Appl. Bact. 32 : 338-347.

15. Park, H. and J.G. Bockheim. 1993. Timber harveting impacts on aspen productivity on two contrasting soils in northwestern Wisconsin. Proceedings of the ASA Meetings, November 11-14, 1993. Cincinnati, OH, USA.

16. Raich, J.W. and W.H. Schlesinger. 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus 44B : 81-99.

17. Schier, G.A., J.R. Jones, and R.P. Winokur. 1985. Vegetative regeneration. Pages 29-33. In N.V. DeByle and R.P. Winokur, eds. Aspen : Ecology and Management in the Western United States. USDA For. Serv. RM-GTR-119.

18. Skopp, J., M.D. Jawson, and J.W. Doran. 1990. Steady-state aerobic microbial activity as a function of soil water content. Soil Sci. Soc. Am. J. 54 : 1619-1625.

19. Smith, C.T., Jr. 1985. Literature review and approaches to studying the impacts of forest harvesting and residue management practices on forest nutrient cycling. University of Maine Coop. For. Res. Unit Inf. Rep. 13. Orono, ME., 34pp.

20. Weber, M.G. 1990. Forest soil respiration after cutting and burning in immature aspen ecosystem. For. Ecol. Manage. 31 : 1-14.