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Title INFLUENCE OF SLASH BURNING ON MICROBIAL POPULATION AND ACTIVITIES IN A DOUGLAS-FIR FOREST SOIL

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Slash burns of three different intensities were made on north and south slopes of a logged-off area on Astoria silt loam south of Burnt Woods, Oregon. Records were made of heat penetration during burning, and of precipitation, air temperature and soil temperature during the ensuing year. Soil samples were collected two days after burning and at seasonal intervals thereafter. For each intensity of burn, hard, medium, and light, composite samples were taken to a depth at which the temperature from burning reached 150° F. Samples were brought to the laboratory and promptly subjected to physical, chemical and microbial analysis.

The principal results are as follows: As with many previous investigations, in which the long continued effects of burning were not determined, the short-time influences on a number of soil properties were largely stimulative and beneficial. However, after

three months, many depressive effects were observed. Water-holding capacity of the soil was decreased in direct relation to intensity of burn. Burned soils subsequently heated more rapidly and cooled more slowly as air temperature changed. Soil pH was increased by burning; after three months, so also was ammonium nitrogen, especially under hard burns. Total nitrogen temporarily increased, but averaged slightly less one year after burning; the decreases were attributed to leaching of nitrate. Total carbon was one to two percent higher in burned soil, due probably to residues of finely divided char.

Bacteria were generally more numerous in burned soil, but molds were decreased. The percentage of *Streptomyces* was affected little. Ammonifying power increased in burned soils at the three-month sampling, but declined thereafter. Nitrification, always low, decreased during the year.

Carbon dioxide evolution from added dextrose and from litter was less in burned than unburned soils. Decomposition of litter was markedly slow, particularly in burned soils, but was at a rate about two times that of the soil's native organic matter.

It is concluded, that from the standpoint of soil fertility, the effects of slash burning on the soil properties investigated are more undesirable than desirable for a period of at least one year. This condition could well improve over a longer time, and it seems desirable to continue the study with more samples to be collected at a later date.

INFLUENCE OF SLASH BURNING ON MICROBIAL POPULATION AND ACTIVITIES IN A DOUGLAS-FIR FOREST SOIL

by

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INFLUENCE OF SLASH BURNING ON MICROBIAL POPULATION AND ACTIVITIES IN A DOUGLAS-FIR FOREST SOIL

INTRODUCTION

Thousands of acres of logging slash are burned annually in the Douglas-fir region of the Pacific Northwest to reduce the hazard of accidental fire. In addition to being a potential fire hazard, the limbs, tops of trees, and residues left on the ground following logging, referred to as slash, may hamper the regeneration of the forest.

The manner of conducting controlled slash-burning varies with the nature of the area, but the basic principles involved are similar for all areas. Burnings usually are made during the time of year when air temperature is low and the humidity is higher than usual, often following a fall rain when the soil is wet or damp. Many theories have been advanced as to whether burning of the soil is harmful or beneficial and most investigations have approached the effect of burning from a physical or chemical point of view rather than from a microbiological standpoint. Effects on the forest soil microflora and their physiological activities, and on other changes that take place following logging and subsequent removal of the slash by burning have not been investigated extensively.

A project was undertaken in the fall of 1960 to study the influence of slash-burning on the microflora of forest soils on both north and south slopes of a recently logged hill. The project was established in order to obtain basic information for a better understanding of part of the broad problem of natural reforestation in the Douglas-fir region of the Pacific Northwest.

Three intensities of slash-burns were simulated on north and south slopes of recently logged land near Burnt Woods, Oregon. The intensity of burn was controlled by size and amount of slash, which influenced the duration of heat generated during burning. The intensity of burn was measured by thermocouples and thermometers placed in the soil at various depths.

Samples of soil, burned and unburned, were collected 48 hours after burning and at three month intervals for a period of one year. Bacteria, Steptomyces, and soil mold populations were estimated by plating methods at each sampling interval. Physiological activities of the soil microflora as indicated by ammonification, nitrification, and carbon dioxide evolution were determined for each set of samples. In addition to the microbial population and their physiological activities, the relevant physical properities of the soil, including moisture, moisture-holding capacity, and maximum and minimum soil and air temperatures, were measured. Chemical analyses included pH, total carbon and ammonium, nitrite, nitrate and Kjeldahl nitrogen.

Changes in chemical and physical properties of the forest soil attributed to slash burning are discussed in relation to the observed physiological activites and population changes of the soil microflora that occurred during the sampling period of one year.

LITERATURE REVIEW

The action of heated soils upon plant growth was observed long before extensive scientific investigation was begun. According to Johnson (20, p. 1-104) Sir Humphrey Davy stated the improvement of "sterile" soils by burning was known to the ancient Romans, the custom having been mentioned by Virgil in his Book of the Georgics. The burning of soil became quite general in Europe during the eighteenth century (20, p. 1-104) and many theories were advanced as to why soils were often more productive after burning.

Johnson (20, p. 1-104) in 1919, conducted an extensive study of the influence of heated soils on the germination of seeds and the growth of plants. Included in his report is an investigation of the effect of applied heat upon microbial activity in the soil. Johnson found the growth of fungi on a variety of soils were best after previous heating at a temperature of about 250° C.; at higher or lower temperatures the growth either occurred later or was less profuse or entirely absent. He attributed this to the formation of toxic compounds in the soil caused by certain degrees of heat. Johnson also noted that heating soils by steam increased nitrification and nitrogen-fixation.

Corbet (14, p. 407-416), while investigating the influence of burning upon the soil microflora of virgin forests in the Malay peninsula observed that the bacterial and mold populations increased in burned-over soils as compared to non-burned soils. His results further indicated the pH of the soil increased and the base exchange capacity was altered. He attributed these effects to the abrupt changes in soil temperature and moisture.

Fowells and Stephenson (15, p. 175-181) studied the effect of burning on forest soils in the Oregon coast range. They reported that burning liberated basic ash materials and soluble phosphate and stimulated nitrification, but destroyed organic matter on the soil and possibly also in the immediate surface soil.

Isaac and Hopkins (18, p. 264-279), when investigating the changes brought about by slash-burning in forest soil of the Douglas-fir region, found that although the organic matter and total nitrogen decreased, the carbon-to-nitrogen ratio was narrowed. An observed decrease in the moisture-holding capacity of the soil was attributed to the decreased organic matter content. Following burning of the soil, the reaction became slightly alkaline and soluble salts were increased in the surface layer.

Most of the reports appearing in the literature following Isaac and Hopkins investigation were concerned with seedling survival on burned soils. Not until 1952 did investigations appear dealing with chemical changes related to the microbial populations.

Burns (12, p. 1-43) discussed the effect of fire on forest soils in his doctoral dissertation and concluded from his experiments that annual burning produce favorable effects, which included increases in soil pH, organic matter, total nitrogen, and exchangable calcium and potassium. He indicated that controlled burning had little effect from the standpoint of physical changes in the mineral soil, and that intermittent or moderate burning produced beneficial chemical effects.

Fuller, Shannon and Burgess (16, p. 44-50), investigating the effect of burning on soils of northern Arizona, reported that pH, CO_2-soluble phosphate, and exchangeable bases were increased by burning. The degree of dispersion was increased and the permeability of the soil to water was decreased. Microbial activity as measured by CO_2 evolution was found to be lower in burned soil than in soil from unburned areas, except with a slash-burn that, due to high underlying moisture, did not decrease the soil organic matter. Burned soils were found to be significantly higher in numbers of bacteria and lower in fungi as compared to adjacent non-burned soils.

Meikeljohn (24, p. 317-319) reported that the numbers of bacteria and fungi in some Kenya soils were diminished by bush burning; nitrogen-fixing bacteria and nitrifying bacteria also were decreased.

Tarrant (29, p. 1-5; 30, p. 1-5; 31, p. 439-441; 32, p. 408-411; 33, p. 18-22), in a series of investigations of slash-burning on

Douglas-fir soils in Oregon found the pH increased, the increase being proportional to the severity of the burn. The pH increase, however, was temporary and was only slightly evident one year after burning. Severe burning decreased percolation rate and cation-exchange capacity, increased soluble phosphate and exchangeable potassium, and strongly reduced the soil nitrogen content.

Miller, Stout, and Lee (26, p. 290-313), investigating the chemical and biological changes following scrub burning on a New Zealand hill soil, reported that immediately after burning, changes occurred in pH, total phosphate, ammonium and nitrate nitrogen, and exchangeable bases. Bacterial populations were reduced at first, but quickly recovered and markedly increased in numbers as compared to soil samples collected before burning. Miller and Fitzpatrick (25, p. 171-181), investigated the effect of scrub burning on a similar New Zealand hill soil and noted a pH increase immediately after burning; during the following year the pH decreased to approximately the value before burning.

Beaton (5, p. 6-11) found that controlled burning increased the soil pH, total phosphorus, and CO_2-soluble calcium in the surface organic layer of soils in British Columbia. Increases in available potassium, phosphorus, calcium, magnesium, and pH following slash-burning were observed by Applequist (3, p. 899-900) in a Louisiana soil catena consisting of Lintoia, Oliver, and Calhoun soil types.

Wright and Tarrant (37, p. 1-5) studied microbial properties of soil after logging and slash-burning and reported that the upper 0-1.5 inches of soil became less acid as the severity of the burn increased. Soil bacteria and Actinomycetes were found to be little affected in numbers by light slash-burning, but severely burned soils showed a definite increase in these microbes. The number of fungi were reduced in proportion to the intensity of the burn. The greatest effect on microbial numbers appeared in the uppermost part of the surface soil.

Wright and Bollen (38, p. 825-828), investigated microflora changes at monthly intervals in severely slash-burned soil and unburned soil of the Douglas-fir region. Their summary is the following:

> On a seasonal basis, the greatest number of microorganisms found in soil from a young-growth Douglas-fir stand occurred from Feburary to April. Generally, the highest percentage of molds occurred when bacteria and actinomycetes were low, and conversely. Soil from an adjacent burned area showed the same trend in micropopulation; however, it was much reduced immediately after burning and did not begin to approach normality until 14 months later.
>
> Fusarium spp. appeared numerous in late spring, and Phythium spp. were most common in summer and fall. Additional observation of many molds, especially Phytophthora spp. still are required.
>
> Hard-burned soil acquired complex microflora about a year after being burned and in the second year began to exhibit a population characteristic of unburned soil.

> The microflora of forest soils greatly increased in numbers during rainy periods and decreased during times of drought. This variation emphasized the importance of standardizing microbial studies with season of year, type of soil, and method of sampling.
>
> The pH of soil appeared to vary inversely with rainfall; it was slightly lower during summer months, when precipitation is lowest, than during winter, when soils are wettest. This trend was exhibited by both burned and unburned soils.

Kucera and Ehrenreich (23, p. 334-336), studying the effects of annual burning of Missouri prairies, found soil temperature to be higher in the burned-over soils during the spring months. No significant differences were noted in total ash or mineral composition of dry matter from burned and non-burned areas.

Prescribed burning of forest litter was found by Klemmedson, Schultz, Jenny, and Biswell (22, p. 200-202) to increase total nitrogen in the first inch of soils, although the combined effects of light and intense burning decreased nitrogen on the forest floor by 124 pounds per acre per year due chiefly to litter destruction.

Although exceptions occur, these results of previous investigations thus indicate that as a general rule the burning of soils tends to (1) temporarily increase the subsequent microbial populations, (2) increase the pH, (3) liberate basic ash constituents and soluble phosphate, (4) increase exchangeable cations but decrease cation exchange capacity, (5) decrease soil organic matter and total nitrogen, and (6) decrease moisture-holding capacity.

Information on intensity of burn, temperature penetration, and subsequent changes with extended time is limited or lacking.

EXPERIMENTAL METHODS AND MATERIALS

An area in a logged Douglas-fir forest on Astoria silt loam soil, 20 miles west of Corvallis and two miles southwest of Burnt Woods, Oregon, was chosen for study. The site is located in the coast range at an elevation of 800 feet above sea level.

Three piles of logging slash, ten feet square by approximately five feet in height, were erected on north and south slopes of the recently logged hill. For the heavy burn, slash 5 to 12 inches in diameter was included; for the medium burn most of the material ranged from three to six inches in diameter; for the light burn, no limbs exceeding a diameter of three inches were included.

The sites for burning were selected randomly, but within about ten feet of each other. The slash was burned October 24, 1960, after the first heavy fall rains. Thermocouples, thermometers, and transite stakes covered with heat sensitive paint were placed in the soil under each pile at various depths to measure temperatures during and after burning. Because of limited equipment, temperatures during burning on the north slope were measured only by painted stakes and thermometers.

A temperature of 150^{o} F. was the minimum considered as a burn. Samples for chemical, physical, and microbial analyses were taken to depths to which this temperature was recorded.

Samples for analyses were composites of 30 to 60 subsamples taken in a random manner with a one-inch soil sampling tube. For every soil sample collected from the burned areas a sample of approximately the same volume and depth was collected from the unburned perimeter of the burned areas.

Collections were made two days after burning, and thereafter at three month intervals for a period of one year. Additional soil samples were collected to a depth of two inches from each burned area beginning at the three month sampling interval. Samples were stored at 34° F as soon as they could be transported to the laboratory. These were screened through a 10-mesh sieve and analyses were started within three days after collection. After chemical, physical, and microbial analyses were made, the remainders of samples were air dried, sieved again through a 10-mesh screen, and stored in screw capped gallon glass jars.

Methods of Physical Analysis

The percentage of detritus was determined on a dry weight basis and characterized according to amount of gravel, roots, small twigs, and other debris present.

Soil moisture was determined by drying triplicate samples to a constant weight at 105° C; from the loss in weight, moisture percentage on the oven-dry basis was calculated.

Moisture-holding capacity was calculated from samples in Gooch crucibles wetted from below by immersion in water, drained to constant weight in a moisture saturated atmosphere, and then dried to a constant weight at 105^{o} C.

Maximum and minimum air temperatures were determined at weekly intervals by maximum-minimum thermometers on both slopes. The thermometers were shielded from the sun by well ventilated rectangular wooden boxes, two by three feet square.

Maximum and minimum soil temperatures in the heavy slash-burned and non-burned areas on both slopes were recorded by a Burroughs seven-day recorder attached to thermocouples buried to a depth of two inches.

The amount of precipitation was measured at weekly intervals on each slope. The method involved collecting the rainfall in No. 10 cans covered with aluminum foil shaped like a cone with a one-fourth inch diameter hole at the vertex. The foil reduced evaporation of collected rain water. The water that had accumulated in each can was measured in a precalibrated plastic tube and recorded as inches of rainfall (6, p. 1-4).

Methods of Chemical Analysis

Active Acidity

For active acidity or pH, a one to five soil-to-water ratio was used. Twenty grams of moist soil samples, oven-dry basis, plus distilled water to give 100 grams total water, were stirred in a 200 ml. beaker. After coarse particles had settled for five minutes, readings were made with a Model N Beckman pH meter using a glass electrode.

Ammonium, Nitrite, and Nitrate Nitrogen

Ammonium nitrogen was determined by the method used by the Oregon State University soil testing laboratory (21, p. 7-8) which employs displacement of the ammonium ion on the soil micell by potassium chloride extracting solution and subsequent nesslerization. Concentrations in ppm (parts per million) were estimated from a standard curve, using a Bausch and Lomb spectrophotometer with transmittance at 420 millimicrons.

Nitrates were determined on a one to five soil-water extract by Harper's phenoldisulfonic acid method (17, p. 180-183). The method was modified by use of ammonium carbonate to remove excess calcium after clarification with cupric acetate and calcium hydroxide.

Aliquots of the same extract were used for determination of nitrites by the diazotization method with sulfanilic acid, 1-naphthylamine hydrochloride, and sodium acetate buffer (2, p. 246-247). Nitrite and nitrate nitrogen values were obtained from standard cruves, using a Bausch and Lomb spectrophotometer with transmittance at 420 millicrons and 520 millimicrons respectively. The results are reported as ppm nitrogen.

Total Nitrogen

Total nitrogen was determined by a semi-micro adaptation of the Kjeldahl method with salicylic acid to include nitrates (19, p. 188). Triplicate 1.0000 gram sub-samples, ground to pass a 60-mesh screen, were transferred to 100 ml. Kjeldahl flasks. Two grams of Hibbard's mixture plus a Hengar selenized granule, and four ml. of concentrated sulfuric acid containing three percent salicylic acid were added to each flask. After standing for 30 minutes digestion by heat was started and was continued for ten minutes after clearing. When cool, the digest was diluted with 30 ml. of distilled water, made alkaline by addition of 15 ml. of 70 percent sodium hydroxide, and steam-distilled into eight ml. of saturated boric acid solution. The absorbed ammonium was titrated with N/70 sulfuric acid after adding bromcresol green-methyl red indicator.

Total Carbon

Total carbon of each soil sample was determined by dry combustion using the Association of Official Agricultural Chemists procedure (4, p. 30-31) as modified by Bollen (10). The method consisted of grinding soil samples to pass a 60-mesh screen and burning triplicate 1.0000 gram sub-samples at 1400^{o} C in a Linberg high-temperature resistance furnace. The samples were burned in a stream of oxygen, purified by passage through a train of concentrated sulfuric acid, Ascarite, and anhydrous $Mg(ClO_4)_2$. The effluent gas stream was passed through a dust trap, activated MnO_2, a Leco low-temperature catalytic furnace, and concentrated sulfuric acid to ensure (1) a gas stream free from particulate matter, (2) complete oxidation of any CO, and (3) absorption of most of the water vapor. The effluent CO_2, dried further by passage through anhydrous $Mg(ClO_4)_2$, was absorbed by Ascarite in absorption bulbs backed by anhydrous $Mg(ClO_4)_2$ and weighed. The results are reported as percent carbon.

Microbial Analyses

Microbial Populations

Numbers of microorganisms were estimated by plating procedures, using triplicate plates of appropriate dilutions. Peptone glucose agar (34, p. 339-341), acidified to pH 4.0, was used for molds; sodium albuminate agar (35, p. 283-298) was employed for bacteria and Streptomyces. The plates were incubated at 28° C; molds were counted after four days incubation, bacteria after seven days, Streptomyces after 12 days. Colonies of Streptomyces were enumerated after total counts were made on sodium albuminate agar, and reported as percentage of total bacteria.

Ammonification

Four 50-gram portions of each soil sample, oven-dry basis, were placed into half-pint milk bottles. Two were treated at rates of 1000 ppm nitrogen as peptone, and two served as controls. Soil moisture was adjusted to 60 percent of the moisture-holding capacity, after which the bottles were loosely capped and incubated for five days at 28° C. Moisture loss by evaporation during incubation was restored at two day intervals. After incubation, aliquots were taken from each bottle and analyzed for ammonium, nitrite, and nitrate nitrogen as described under methods of chemical analysis. The results are reported on the percentage basis of peptone nitrogen transformed to ammonia.

Nitrification

Four 50-gram portions of each soil sample, oven-dry basis, were weighed and placed into half-pint milk bottles. Two were treated with ammonium sulfate in solution at rates of 300 ppm nitrogen, and two served as controls. Calcium carbonate was added to each bottle as recommended by Waksman (36, p. 697) to neutralize the acidity produced during nitrification. The dry carbonate was mixed with the soil prior to addition of water and ammonium sulfate solution. Water content was adjusted to 60 percent moisture capacity. Subsequent water losses were restored at two day intervals. The bottles were loosely capped and incubated 30 days at 28° C.

Analyses for nitrate nitrogen were made at the end of the incubation period as described under chemical methods. The results are reported as percentage ammonium nitrogen nitrified.

Soil Respiration Studies

Fifty-gram portions, oven-dry basis, of each soil sample in half-pint milk bottles were treated with dextrose and with forest litter at 2000 ppm carbon. The air-dried litter was previously ground to pass a 60-mesh screen by means of a Weber hammer mill. Each treatment was duplicated. Moisture at 60 percent moisture capacity was maintained throughout the experiment by frequent addition of distilled water when shown to be necessary by weight loss. The experiment was set up in a 28° C incubator and connected to a modified Potter and Snyder (27, p. 76-94) respiration apparatus designed by Bollen (7, p. 353-374). The carbon dioxide evolved was absorbed in tubes containing 1N sodium hydroxide. At intervals of 2, 5, 10, 25, 35 and 45 days, the tubes were removed for titration and replaced with tubes of fresh 1N sodium hydroxide. The final determination was made at 55 days. The absorbed carbon dioxide was determined by differential titration with a Beckman automatic titrator. The end points used were those recommended by Cooper (13, p. 466-470). Results are expressed on a cumulative basis as milligrams of carbon dioxide carbon evolved.

The percentage decomposition of added dextrose and litter was calculated from the totals at 55 days; thus, compared to untreated soil, the net increase in mg. carbon evolved as CO_2 with organic addition, divided by mg. carbon added, multiplied by 100, gave the percentage of apparent decomposition.

All data except pH are expressed on the oven-dry basis.

RESULTS AND DISCUSSION

The temperatures measured by thermocouples, thermometers and painted stakes are shown in Figure 1. Maximum temperatures of 1000° F and over were registered in the lightly burned areas at the surface of the soil. As depth progressed, however, temperature during burning of the soil decreased rapidly. A similar pattern was followed in medium-burned areas, but higher temperatures occurred in the soil at greater depths as compared to the light-burned soil. The heavy slash-burned soil did not attain as high a surface temperature as did the light slash-burn, but a temperature of 150° F was shown at a depth of about five inches (Table 1). This temperature was attained at a depth of approximately two inches in the lightly burned soil, and three inches in the medium-burned area. It is of interest that medium slash-burned soil did not heat as quickly as the light and heavy slash-burned soil, requiring about 2.5 hours to reach a maximum temperature. The heavy slash burn area maintained the highest temperature for the longest period of time, thus probably having the greatest effect upon the microbial population, especially in the upper portion of the soil. There was a difference of about three hours between light and medium slash-burned soil for the time required to cool to 150° F; the difference was about 15 hours between medium and heavy slash-burned soil.

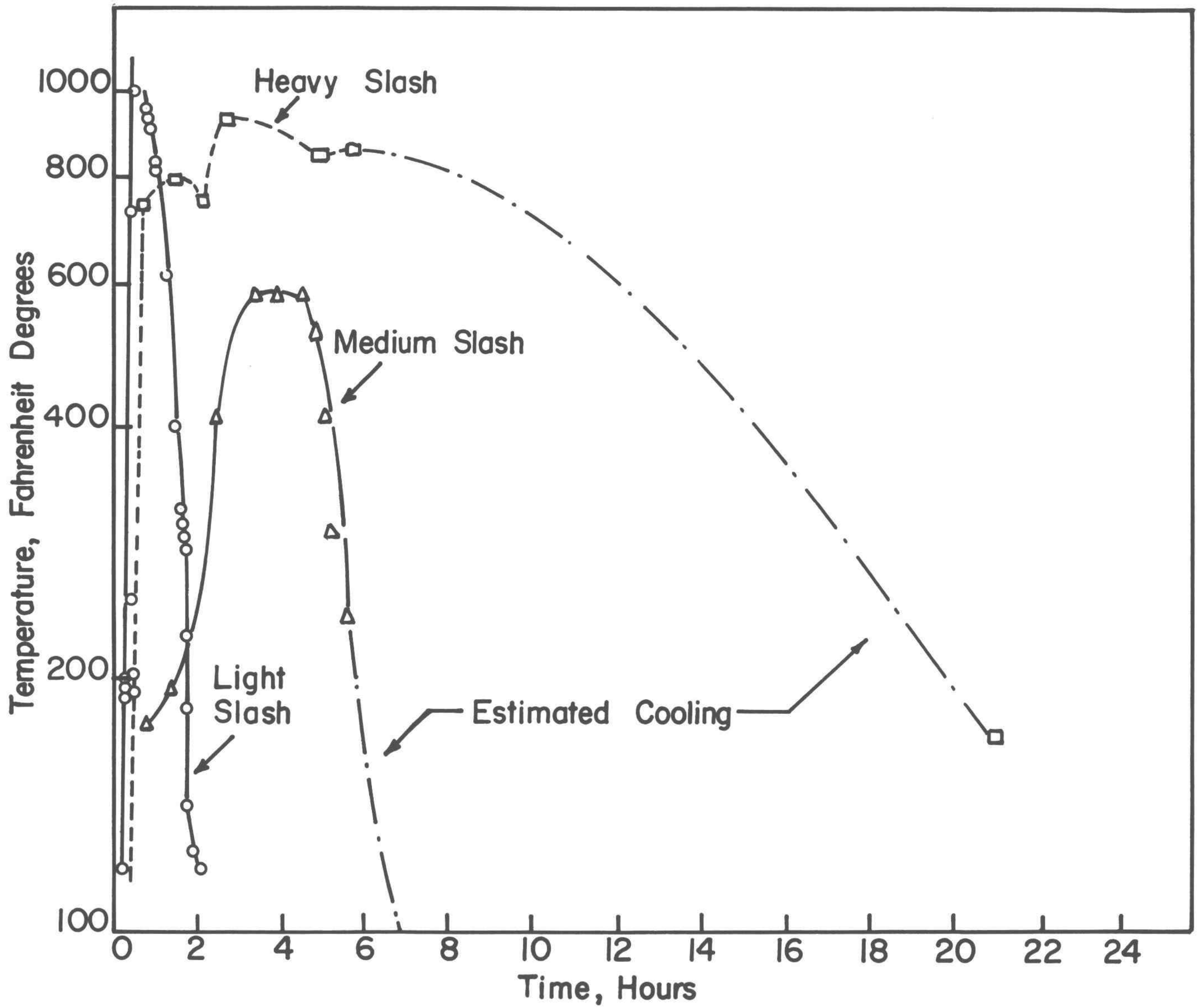


Figure 1. Relationship of amount of slash burned to rate of cooling on the south slope. Temperatures were recorded at a depth of 1/4 inch by thermocouples.

Table 1. Maximum temperatures attained at various depths under burning slash.

Slash Concentration	Depth*	Maximum Temperature**
	Inches	Deg. F.
South Slope		
Heavy	0. 25	810
Heavy	1. 0	360
Heavy	3. 0	182
Heavy	5. 0	143
Medium	0. 25	650
Medium	1. 0	179
Medium	3. 0	158
Medium	5. 0	116
Light	0. 25	>1000
Light	3. 0	94
Light	4. 0	< 80
North Slope		
Heavy	1. 2	644
Heavy	3. 0	193
Heavy	5. 0	156
Medium	0. 1	644
Medium	0. 45	347
Medium	1. 25	293
Medium	1. 3	149
Medium	3. 0	94
Light	0. 55	>644
Light	1. 3	347
Light	1. 8	293
Light	3. 0	164

* Sample taken from soil surface to depth indicated.

** As measured by thermocouples, maximum thermometers, and stakes coated with heat-sensitive paint.

Physical Analyses

Detritus of samples, passed through a 10-mesh sieve, averaged about 25 percent by weight for non-burned soils. Burned samples averaged about eight percent less; the percentage probably was slightly low, due to powdery carbonaceous material which could pass the sieve. The detritus consisted of about 90 percent coarse gravel plus ten percent roots, small twigs and other debris. No appreciable difference was noted between the burned and non-burned samples of both slopes, as is evident from Table 2.

Soil moisture content was found not to be lowered appreciably immediately after burning as compared to adjacent non-burned soil. Soil moisture, however, was lower by as much as ten percent in the burned areas at the winter and spring sampling periods, three and six months after burning. In summer, little or no rain fell, and a drop in soil moisture was found in all cases. Burned soils showed the greatest decrease in moisture, which ranged four to eight percent lower than in adjacent non-burned soil. Soil samples from the south slope were found to contain less moisture during the dry summer as compared to north slope samples. The decrease in soil moisture in the burned areas may have been due to decreased permeability (32, p. 408-411) or organic matter content (18, p. 264-279). After the period of summer drought, moisture was replenished by

Table 2. Effect of slash-burning on the percentage of detritus.

Treatment	Depth*	2 days Fall	3 months Winter	6 months Spring	9 months Summer	12 months Fall
		Sampling Interval				
	Inches	%	%	%	%	%
South Slope						
Light burn	2	18	17	17	17	16
Medium burn	2	--	15	15	15	14
Medium burn	3	15	16	16	16	16
Hard burn	2	--	14	15	16	16
Hard burn	5	22	22	25	23	23
No burn	2	27	25	28	28	27
No burn	3	25	22	25	25	26
No burn	5	23	28	32	31	30
North Slope						
Light burn	2	21	21	20	21	20
Medium burn	2	--	18	17	18	18
Medium burn	3	18	18	17	17	18
Hard burn	2	--	12	12	11	12
Hard burn	5	11	11	12	12	13
No burn	2	24	25	28	28	28
No burn	3	26	27	30	31	30
No burn	5	20	22	30	31	31

* Sample taken from soil surface to depth indicated.

moderate rainfall during the fall months. Noticable differences were found between burned and non-burned soils at this time (Table 3); the non-burned soils contained about 25 percent water while the burned soils showed only 10 to 16 percent. The reduction of the capacity to retain moisture after burning may well affect microbial activity, especially during the periods of low rainfall.

Water-holding capacity, influenced by micro and macropore space and organic matter content, was decreased throughout the sampling period of one year following burning, as shown in Table 4. The reduction of moisture-holding capacity was proportional to the intensity of the burn, the greatest reduction occurring in the first two inches of soil. The hard burn soil samples showed the greatest reduction. Reduction of water-holding capacity affects the amount of reserve moisture during periods of low rainfall, and thus influences available water upon which plants and microbes depend for growth.

Average maximum and minimum air temperatures were found to be slightly higher on the south slope, although the difference was often only one degree. The greatest difference in temperature occurred during the spring growing season, as illustrated in Figure 2, when the sun was in a southerly direction.

Appreciable differences in soil temperatures at the two-inch depth were found between burned and non-burned areas. During the hot summer months, the burned soils reached temperatures of 20° F

Table 3. Moisture content of slash-burned and non-burned soil.

Treatment	Depth*	Sampling Interval				
		2 days Fall	3 months Winter	6 months Spring	9 months Summer	12 months Fall
	Inches	%	%	%	%	%
South Slope						
Light burn	2	17	53	48	8	11
Medium burn	2	--	50	46	8	11
Medium burn	3	20	57	46	9	12
Hard burn	2	--	49	44	7	10
Hard burn	5	13	52	45	11	12
No burn	2	20	62	54	16	22
No burn	3	23	62	55	13	24
No burn	5	21	66	55	15	25
North Slope						
Light burn	2	14	62	53	12	15
Medium burn	2	--	60	52	11	15
Medium burn	3	10	54	52	12	16
Hard burn	2	--	50	50	10	13
Hard burn	5	12	57	51	13	18
No burn	2	16	65	60	16	26
No burn	3	18	66	58	19	28
No burn	5	20	69	56	20	28

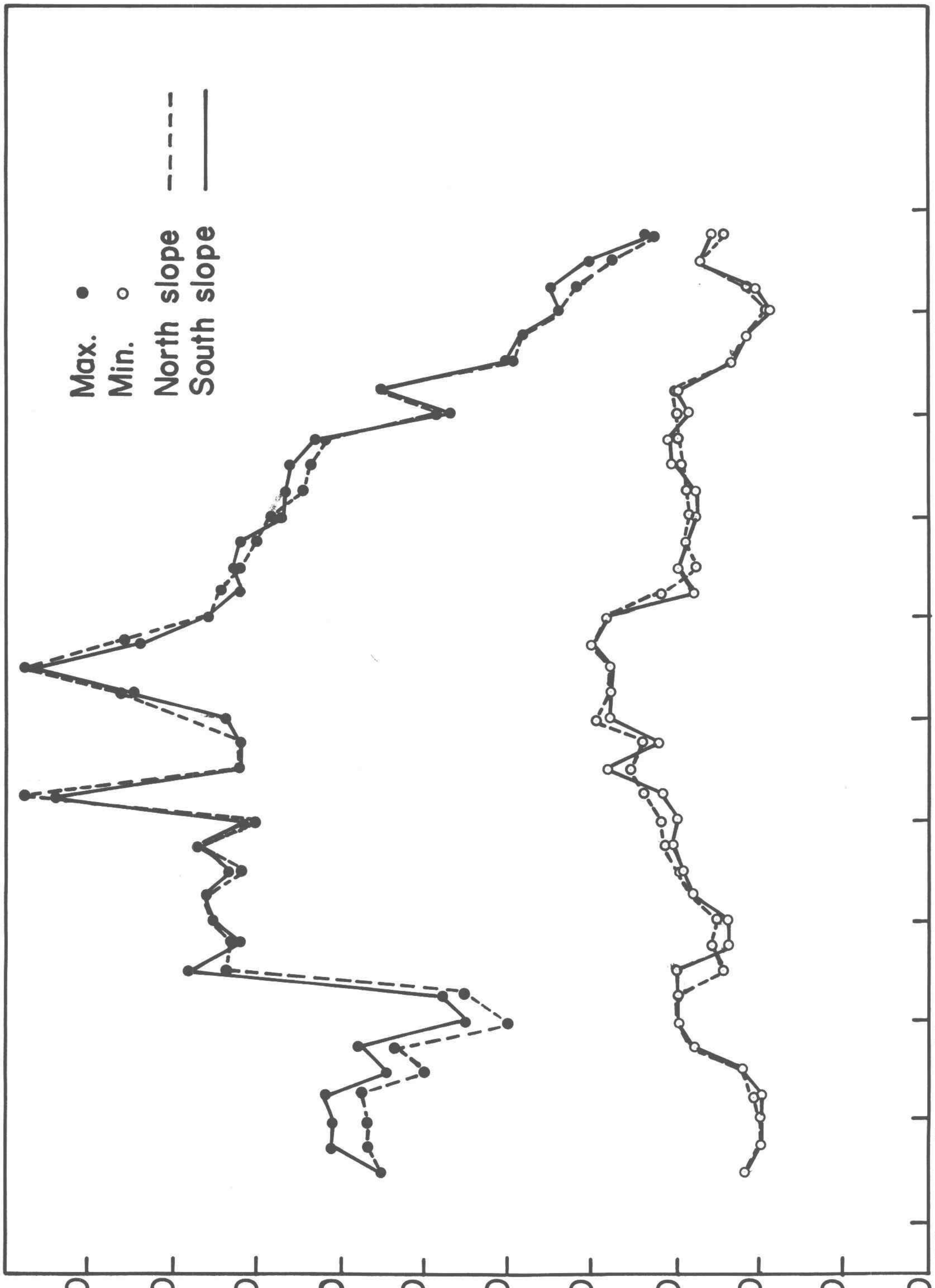
* Sample taken from soil surface to depth indicated.

Table 4. Water holding capacity of the soil as influenced by slash burning.

Treatment	Depth*	Sampling Interval				
		2 days Fall	3 months Winter	6 months Spring	9 months Summer	12 months Fall
	Inches	%	%	%	%	%
South Slope						
Light burn	2	76	73	73	73	72
Medium burn	2	--	68	67	67	66
Medium burn	3	64	65	65	65	66
Hard burn	2	--	60	60	61	59
Hard burn	5	61	61	62	62	61
No burn	2	86	90	89	88	90
No burn	3	90	88	88	90	89
No burn	5	86	90	88	87	87
North Slope						
Light burn	2	75	74	75	73	74
Medium burn	2	--	70	70	69	69
Medium burn	3	80	75	75	74	74
Hard burn	2	--	65	66	65	66
Hard burn	5	65	70	71	72	68
No burn	2	80	83	84	86	86
No burn	3	80	83	84	86	86
No burn	5	70	74	74	75	76

* Sample taken from soil surface to depth indicated.

Figure 2. Weekly averages of maximum and minimum air temperatures as measured by maximum-minimum thermometers on north and south slopes.



higher than the non-burned soils at the same depth, as illustrated in Figures 3 and 4. Soil temperature differences were found to be less during the cool winter and late fall months. Minimum temperatures were higher in the burned soils than in the non-burned soils, the difference being more pronounced during the late spring, summer, and early fall months. The results indicate that burned soil heats faster and cools slower than non-burned soil. South slope soil temperatures were found to be higher than on the north slope, the effect being greater during the summer months. The higher soil temperatures characterizing the burned areas are of importance because of the general rule that chemical reactions increase with an increase in temperature. Chemical weathering processes therefore could be expected to proceed at a more rapid rate in the burned areas, and also on the south slope. For the same reason biological activity would be correspondingly increased when soil moisture is plentiful.

The amount of precipitation was found to be higher on the south slope than on the north slope, the greatest difference occurring during the early spring months (Figure 5) when active vegetative growth begins. The increase in precipitation, coupled with higher temperatures, could well influence the growth and physiological activities of microorganisms and the resultant effects on plant growth.

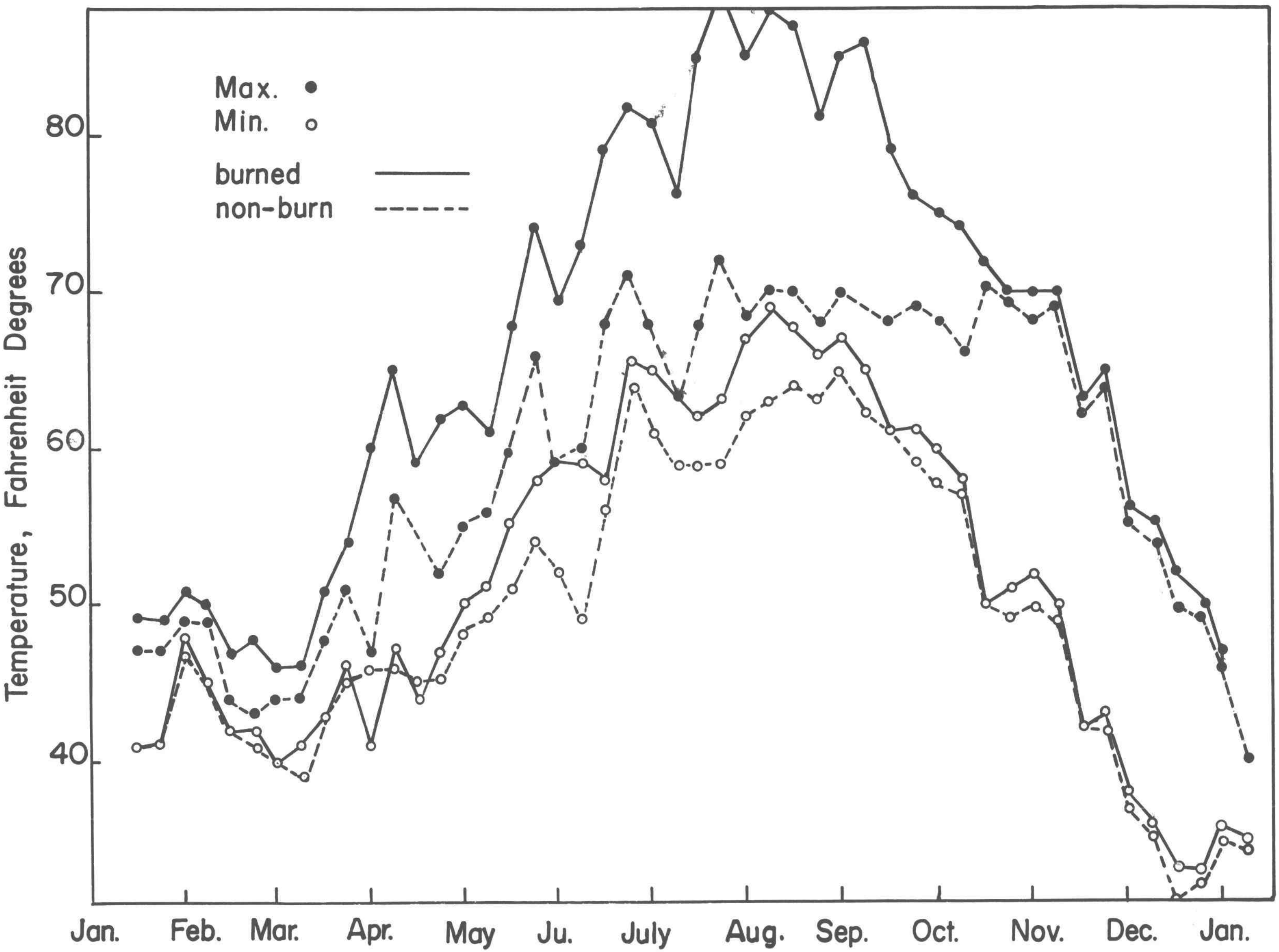


Figure 3. Weekly soil temperature averages of slash-burned and non-burned soil on the south slope. Temperatures were recorded at a depth of two inches by thermocouples.

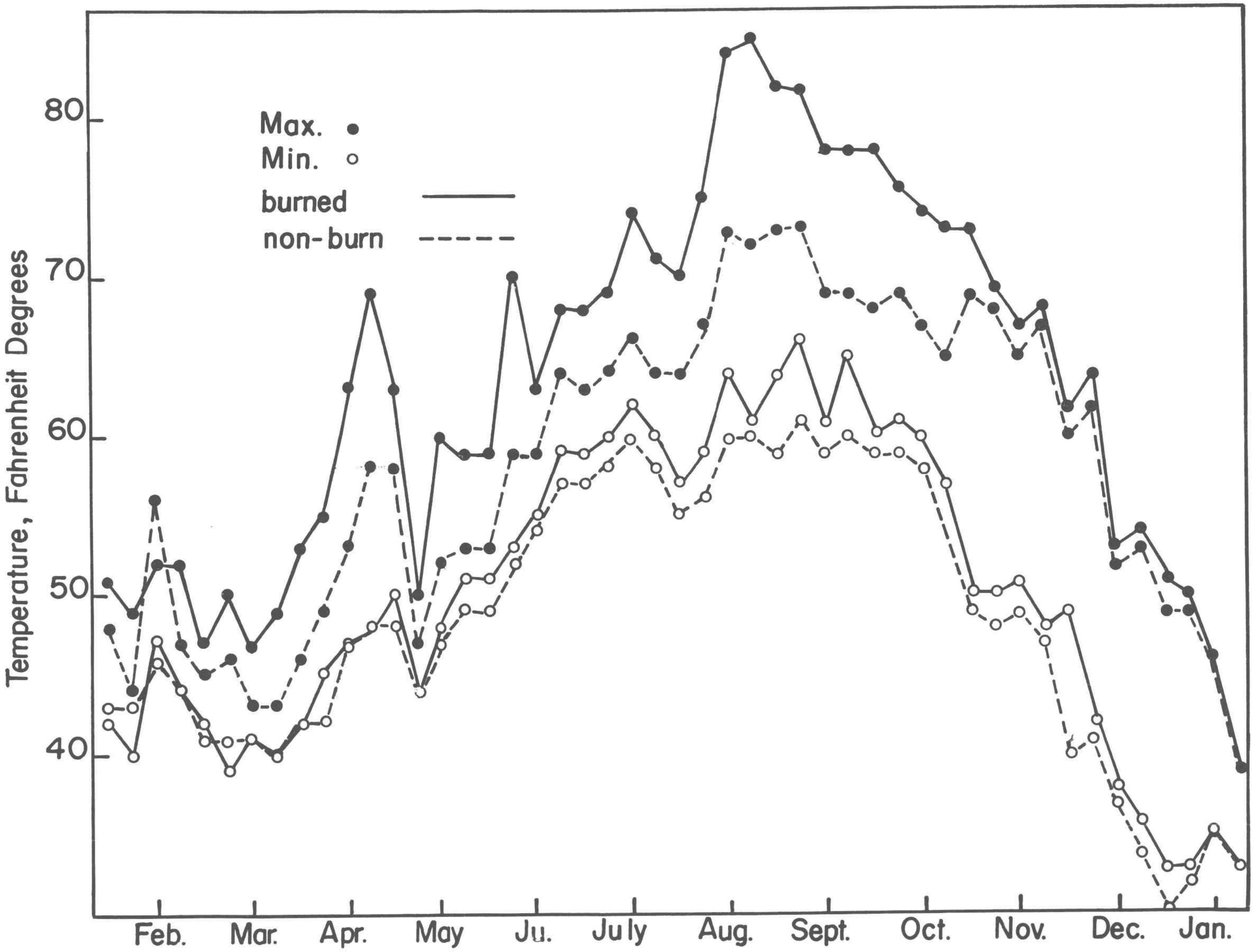


Figure 4. Weekly soil temperature averages of slash-burned and non-burned soil on the north slope. Temperatures were measured at a two inch depth by thermocouples.

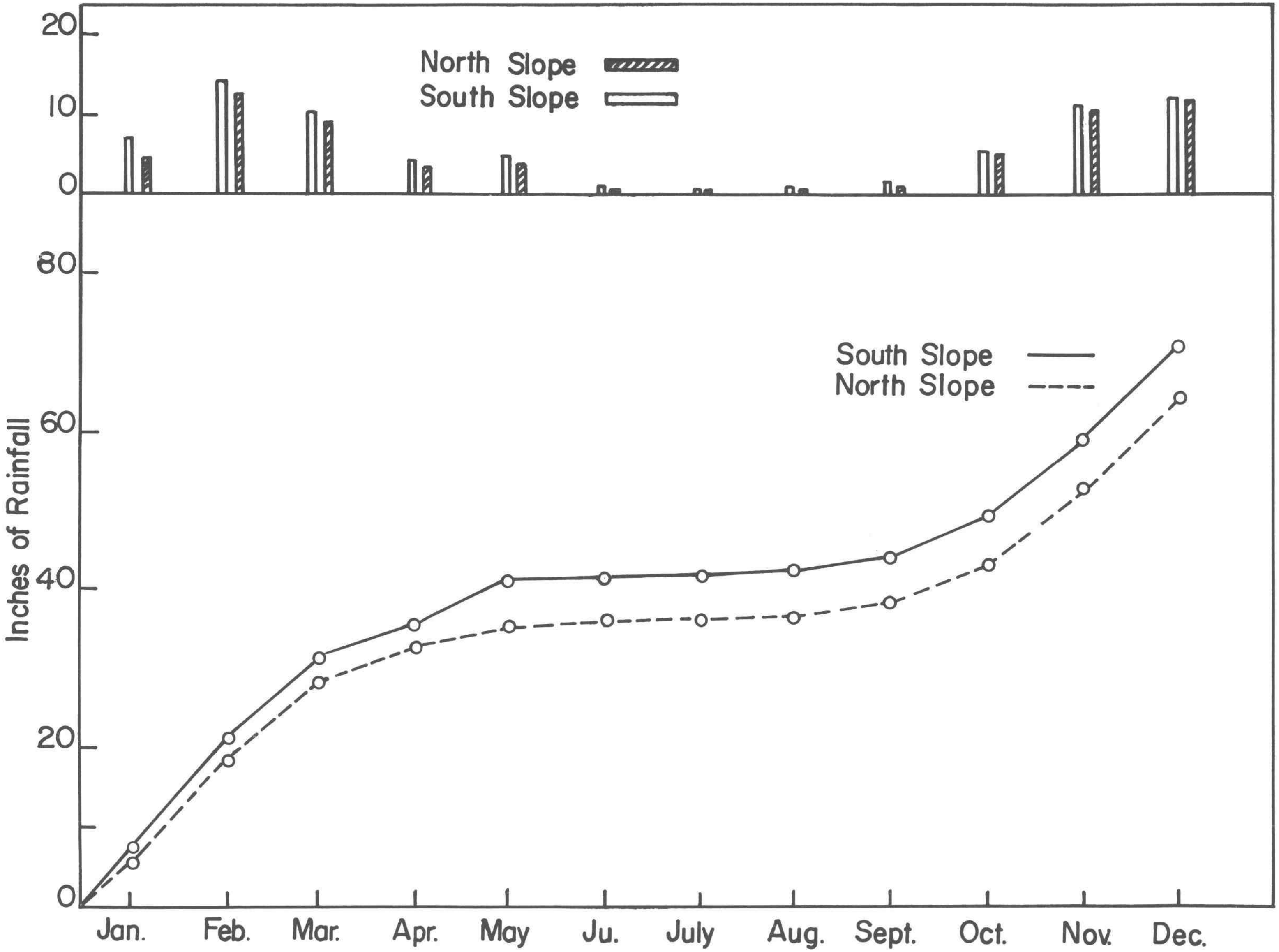


Figure 5. Monthly and accumulative average rainfall occurring on north and south slopes.

Chemical Analysis

Soil pH

Original pH of the soil was not immediately altered by slash-burning, as shown in Table 5. Increases from 0.3 to 1.2 pH units in the burned soils were found after three months and appeared to be related to the intensity of the burn. These increases were still prevalent, and in some cases greater, at 12 months. Adjacent non-burned soil showed little change in pH with time. The effect of severity of burn was more pronounced in the upper two inches of soil. Soil pH also fluctuated with soil moisture; the wetter the soil, the lower the pH, and the drier the soil, the higher the pH. This is in agreement with the observations of Wright and Bollen (38, p. 825-828). Samples from the south slope were slightly more acid than those from the north slope.

Because the optimum pH for many soil bacteria and molds is near neutrality or pH 7.0, the neutralizing effect of slash-burning could increase soil microbial activity and its desirable influences on soil fertility.

Soil Nitrogen and Carbon

Results presented in Table 6 indicate that the ammonium

Table 5. Effect of slash-burning on active acidity (pH) of the soil. *

Treatment	Depth**	Sampling Interval: 2 days Fall	3 months Winter	6 months Spring	9 months Summer	12 months Fall
	Inches	pH	pH	pH	pH	pH
South Slope						
Light burn	2	5.9	6.2	6.2	6.6	6.5
Medium burn	2	---	6.3	6.6	6.7	6.5
Medium burn	3	5.9	5.8	6.4	6.6	6.5
Hard burn	2	---	6.4	6.5	6.8	6.8
Hard burn	5	5.2	6.2	6.2	6.5	6.4
No burn	2	5.9	5.2	5.6	5.8	5.6
No burn	3	5.9	5.4	5.6	5.8	5.5
No burn	5	5.6	5.5	5.6	5.6	5.6
North Slope						
Light burn	2	5.8	6.2	6.3	6.4	6.3
Medium burn	2	---	6.2	6.3	6.6	6.5
Medium burn	3	5.4	6.2	6.2	6.3	6.4
Hard burn	2	---	6.3	6.5	6.6	6.5
Hard burn	5	5.3	5.6	5.9	6.1	6.1
No burn	2	5.6	5.8	5.7	5.8	5.6
No burn	3	5.8	5.8	5.8	5.9	5.7
No burn	5	5.6	5.6	5.8	5.9	5.6

* Each value is the mean of two replicates.

** Sample taken from soil surface to depth indicated.

Table 6. Ammonium and nitrate nitrogen in slash-burned and non-burned soils.*

		Sampling Interval									
		2 days Fall		3 months Winter		6 months Spring		9 months Summer		12 months Fall	
Treatment	Depth**	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^--N	NO_3^--N	NH_4^+-N	NO_3^--N
	Inches	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
South Slope											
Light burn	2	54	5	60	6	25	5	11	3	3	2
Medium burn	2	--	--	42	7	26	4	10	2	4	2
Medium burn	3	21	1	40	5	25	3	8	3	3	0
Hard burn	2	--	--	44	4	20	2	5	3	3	2
Hard burn	5	39	4	40	4	20	3	6	3	4	1
No burn	2	5	1	10	2	28	2	5	4	5	3
No burn	3	4	1	8	2	26	3	3	3	6	2
No burn	5	2	0.4	12	2	26	4	3	2	6	1
North Slope											
Light burn	2	35	2	48	4	28	2	11	2	6	0
Medium burn	2	--	--	48	3	30	1	10	3	5	1
Medium burn	3	52	3	52	3	32	2	10	2	7	3
Hard burn	2	--	--	75	2	25	3	11	4	5	1
Hard burn	5	76	8	76	4	25	4	12	4	6	0
No burn	2	7	3	11	4	20	4	7	3	9	1
No burn	3	12	6	13	6	22	2	12	4	11	3
No burn	5	13	4	15	3	21	2	13	2	12	2

* Each value is the mean of three replicates.

** Sample taken from soil surface to depth indicated.

nitrogen in the soil was increased by slash-burning, the effect being noticable immediately and continuing for six months until the following spring. The influence of intensity of burn was not the same on each slope; for the south slope, light burning gave the greatest increase in ammonium, while on the north slope, the hard burn produced the greatest increase. During the spring and summer, decreases in ammonium nitrogen occurred on both slopes.

Nitrates were relatively low in all samples and the minor differences found are considered of little significance in relation to intensity of burning. It is probable that low temperature retarded nitrification in the fall and winter, while during spring and early fall nitrates were lost by leaching. Deficiency of moisture would limit nitrification in the summer. The slight but consistent decrease in Kjeldahl nitrogen, which included nitrates, in all cases attest to these conclusions.

Concentrations of nitrite nitrogen were never above 0.5 ppm; the data, regarded as irrevelant, are not presented.

Increases in ammonium nitrogen in the burned soils may be attributed to thermal degradation of nitrogeneous organic compounds not completely decomposed by burning, and in part to subsequent stimulation of ammonification (20, p. 1-104).

Total nitrogen content of the soil appeared to be increased in a few instances by burning, as indicated in Table 7. Increases and

Table 7. Total carbon and Kjeldahl nitrogen in soil as influenced by slash-burning.* (Part I)

Treatment	Depth**	Sampling Interval: 2 days Fall Carbon	Nitrogen	C/N	3 months Winter Carbon	Nitrogen	C/N
	Inches	%	%	%	%	%	%
South Slope							
Light burn	2	7.01	.30	24	6.91	.29	24
Medium burn	2	----	---	--	6.75	.28	24
Medium burn	3	6.51	.28	23	6.50	.28	23
Hard burn	2	----	---	--	7.16	.28	26
Hard burn	5	4.96	.23	22	5.06	.20	25
No burn	2	5.13	.26	20	5.15	.26	20
No burn	3	5.01	.25	20	5.20	.25	21
No burn	5	4.75	.24	20	5.01	.25	20
North Slope							
Light burn	2	6.23	.24	26	6.25	.24	26
Medium burn	2	----	---	--	6.30	.25	25
Medium burn	3	6.24	.28	25	6.24	.25	25
Hard burn	2	----	---	--	6.90	.26	27
Hard burn	5	4.74	.20	24	4.81	.20	24
No burn	2	5.56	.24	23	5.54	.24	23
No burn	3	5.42	.24	23	5.30	.23	23
No burn	5	5.58	.24	23	5.61	.24	23

* Each value is the mean of three replicates.

** Sample taken from soil surface to depth indicated.

Table 7 (Part II)

		Sampling Interval					
		6 months Spring			9 months Summer		
Treatment	Depth**	Carbon	Nitrogen	C/N	Carbon	Nitrogen	C/N
	Inches	%	%	%	%	%	%
South Slope							
Light burn	2	6.93	.28	25	6.98	.27	26
Medium burn	2	6.80	.27	25	6.67	.25	27
Medium burn	3	6.42	.27	24	6.50	.26	25
Hard burn	2	7.01	.25	28	6.95	.25	28
Hard burn	5	5.01	.20	25	4.96	.19	26
No burn	2	5.05	.24	21	5.12	.24	21
No burn	3	5.22	.26	20	5.15	.26	20
No burn	5	5.11	.26	20	5.03	.25	20
North Slope							
Light burn	2	6.01	.22	27	6.05	.22	27
Medium burn	2	6.25	.24	26	6.18	.24	26
Medium burn	3	6.10	.24	25	6.15	.25	25
Hard burn	2	6.80	.24	28	6.90	.25	28
Hard burn	5	5.00	.20	25	4.90	.20	25
No burn	2	5.40	.25	22	5.48	.25	22
No burn	3	5.26	.25	21	5.34	.25	21
No burn	5	5.51	.26	21	5.57	.27	21

* Each value is the mean of three replicates.

** Sample taken from soil surface to depth indicated.

Table 7 (Part III)

Treatment	Depth**	Sampling Interval 12 months Fall Carbon	 Nitrogen	 C/N
	Inches	%	%	%
South Slope				
Light burn	2	6.95	.26	27
Medium burn	2	6.63	.24	28
Medium burn	3	6.38	.24	27
Hard burn	2	6.40	.21	30
Hard burn	5	5.13	.19	27
No burn	2	5.16	.26	20
No burn	3	5.05	.25	20
No burn	5	5.09	.26	20
North Slope				
Light burn	2	6.16	.22	28
Medium burn	2	6.15	.22	28
Medium burn	3	6.20	.23	27
Hard burn	2	6.75	.23	29
Hard burn	5	5.01	.18	28
No burn	2	5.39	.26	21
No burn	3	5.69	.28	20
No burn	5	5.52	.28	20

* Each value is the mean of three replicates.

** Sample taken from soil surface to depth indicated.

decreases of more than 0.02 percent are beyond experimental error of the micro-Kjeldahl method, but may involve sampling variability. However, the increases with south slope samples generally carried over consistently for each sampling period. The gradual decline in nitrogen of the burned soils can be attributed to loss of nitrates by leaching as previously mentioned, and possibly also to some denitrification.

Total carbon (Table 7) increased by one to two percent in the burned soils, with the exception of hard burned soil sampled to a depth of five inches. The increase could be expected because the burning of slash leaves some char and incompletely burned organic residues, parts of which would pass through a 10-mesh sieve. The percentages of carbon remained relatively constant for each treatment throughout the sampling period of one year. Carbon in unburned soil from the south slope was slightly lower than in soil from the north slope.

The ratio of carbon-to-nitrogen was slightly wider in burned soils than in non-burned soils, and also in burned and non-burned soils of the north slope. For each slope the ratios were wider in the slash-burned soils one year after burning, while in the non-burned soils, the ratio changed little.

Because carbon and nitrogen are major food elements in microbial nutrition, even small changes in the C:N ratio resulting from physical, chemical, or microbial changes can affect soil microbial activities. Organic matter decomposition is generally most favorable when the C:N ratio is near 20:1 (8, p. 13). Decomposition of native or added organic matter by soil microbes is active only as long as nitrogen is present in an available form, which except for nitrogen fixing organisms, may be ammonium, nitrate, or organic nitrogen compounds. As the supply becomes depleted, microbial activity slows down to an equilibrium minimum because the nitrogen becomes extensively immobilized in microbial protein. Although the protein of dead fungi is readily decomposable by a variety of microbes, a large proportion of bacterial protein is susceptible to attack only by specialized bacteria, and Streptomyces (8, p. 11). The liberation of ammonium becomes slow at this point. If available nitrogen is not added, decomposition will continue only at a very slow rate dependent upon release and repartition of the original nitrogen supply. The supply of available nitrogen to plants under natural conditions is dependent upon ammonification, and in some cases, nitrification (1, p. 248). Decomposition of organic matter results in a narrowing of the C:N ratio. This did not occur in the slash-burned soil as would be expected because burning leaves some finally divided char and highly carbonaceous residues on the soil surface. The physical and chemical effects of fall slash burning on forest soil are summarized in Table 11.

Microbial Analyses

Microbial Populations

Enumeration of bacteria and molds in the soil by dilution and plating procedures is at best only an estimation of total numbers and is restricted by the type of medium and conditions of incubation. Diverse nutritional requirements of bacteria as well as mechanical difficulties in preparing adequate suspensions for dilution are limiting factors. No single method will yield a complete selection of the total population. For similar reasons it is difficult to estimate numbers of soil molds accurately; in addition, mycelia of molds tend to break up into viable fragments and each individual may produce many spores, thus contributing to an over-estimation of the population. In most cases, however, results from replicated samples tend to agree within random sampling expectation. The counts indicate potentialities if not actual numbers. It is possible then to compare results obtained by a given technique from a number of soil samples taken at different locations, or at different times, or from samples receiving different treatments. The importance of the plate count is that it provides a basis for comparison.

Total bacteria. Figures 6 and 7 illustrate the changes in numbers of bacteria occurring in slash-burned and non-burned soil

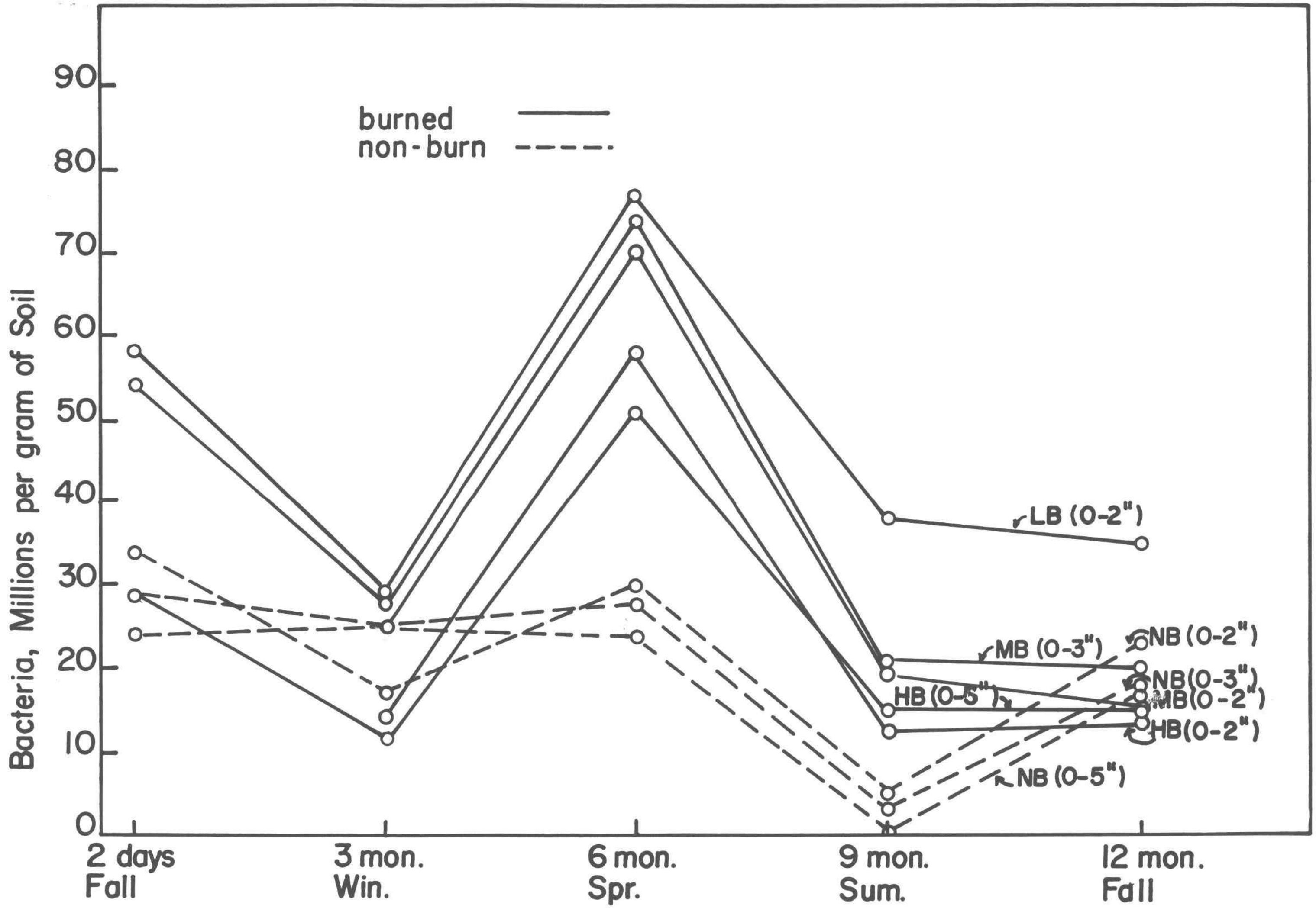


Figure 6. Populations of bacteria and *Streptomyces* as estimated by plating procedures for slash-burned and non-burned soils from the south slope.

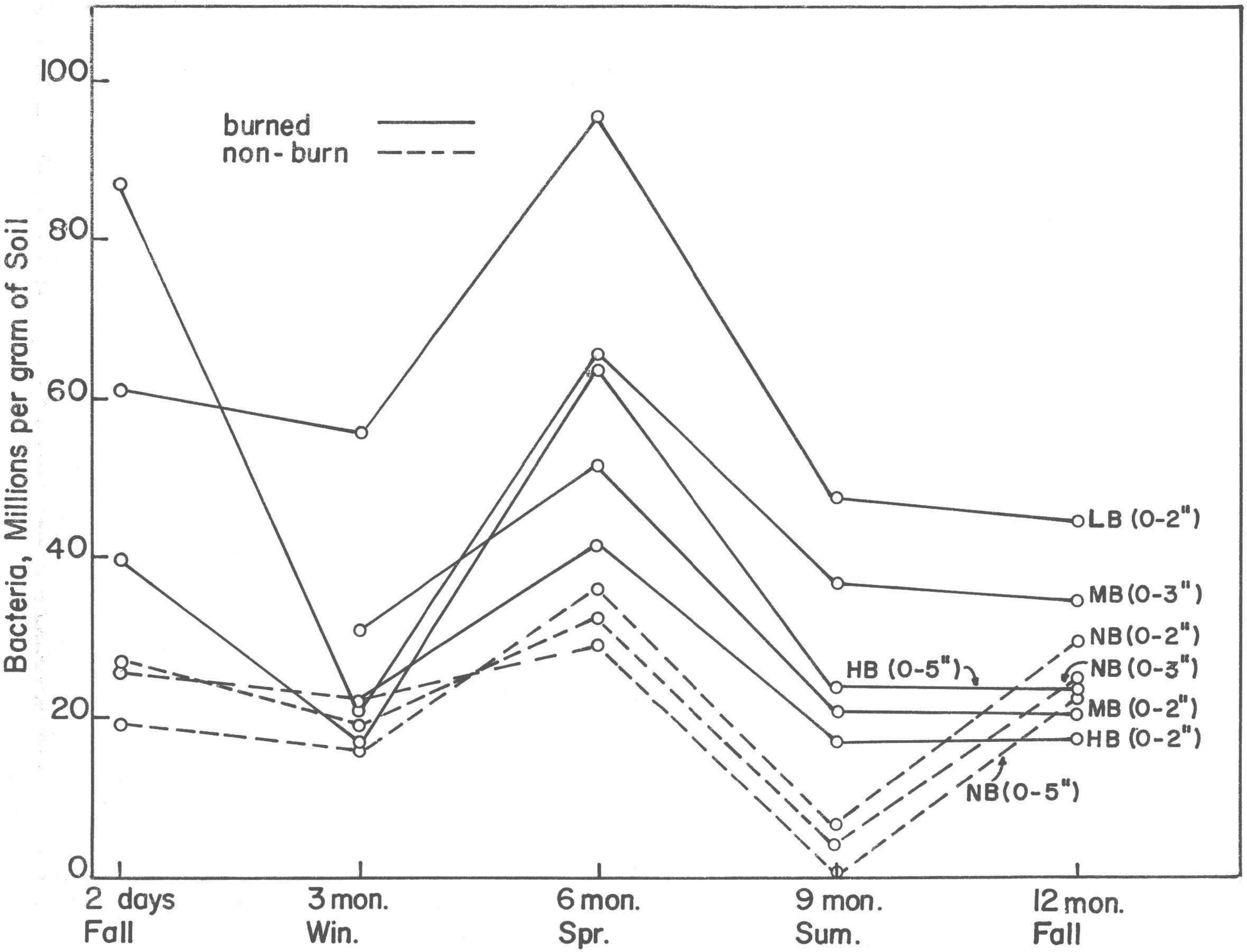


Figure 7. Populations of bacteria and *Streptomyces* as estimated by plating procedures for slash-burned and non-burned soils from the north slope.

samples collected from the south and north slopes. The same general pattern was observed to occur on each slope. Two days after burning, the population of bacteria in the burned areas were found to be higher than in samples from adjacent non-burned areas. Three months after burning, decreases to approximately the same numbers found in unburned soil occurred, excepting the light burn on the south slope, where the count remained high. By this time winter rains had increased soil moisture, but temperatures were still low.

At the six-month sampling interval, an appreciable increase in the bacterial population occurred, the effect being much more pronounced in the soil from the slash-burned areas. The increases over non-burned soil were related to the intensity of burning; lightly burned soil showed the highest numbers, followed by the medium- and hard-burned soils. Increases were less pronounced in the first two inches of surface soil in the medium- and hard-burned areas, but remained related to the intensity of the burn. These stimulating effects of burning are probably due to a combination of several factors, including the observed increases in pH, soil temperature, and ammonium and nitrate nitrogen. In addition, any partial sterilization of the soil temporarily retards or eliminates certain competitors and antagonists and thus permits an upsurge of the general microbial population. Marked decreases in numbers of bacteria were found in all samples collected at the end of summer, nine months after burning. The slash-burned soils, however, still showed higher numbers, and again the same relation to intensity of burn existed. Although summer temperatures were more favorable for microbial development, moisture and available nitrogen had decreased. These deficiencies could well account for the general decrease in bacterial numbers in both the burned and non-burned soils. Moisture depletion due to lack of rainfall was probably the most important contributing factor. Bollen (8, p. 6) enumerates seven factors of environment influencing the growth of microorganisms in the soil; these are (1) moisture, (2) temperature and other forms of radiant energy, (3) aeration, including O_2, N_2 and CO_2, (4) pH, (5) food supply, (6) biotic factors, and (7) inhibiting factors, which may be positive or negative extremes of any of the others. If any one of these becomes limiting, microbial activity and growth would in turn be limited.

For the soil samples collected in the fall, 12 months after burning, increases in the numbers of bacteria were found in all the control samples from each slope, while in the slash-burned soils the population remained essentially unchanged from the summer values. Although fall rains had increased soil moisture and the soil temperature was favorable, available nitrogen was low in the burned soils, as indicated in Table 6, and may not have been sufficient to induce increased bacterial development.

The pattern of changes of bacterial numbers with time in all the plots was similar for each slope, but the numbers were lower on the north slope, as was the soil temperature.

The percentage of Streptomyces (Table 8) in the bacterial population remained relatively constant for all samples, ranging from 35 to 45 percent. Little difference was noted between slash-burned soils and unburned soils, although the higher percentages were characteristic of the latter; similarly, no appreciable differences were found between samples from the different slopes. Streptomyces in the soil fluctuate less than do the bacteria because they are not as greatly influenced by decreased moisture and they develop slowly, but continuously, on the more resistant organic residues (1, p. 53, 58).

Molds. Plate counts of molds, shown in Figures 8 and 9, revealed that burning reduced their numbers in most cases. Except for marked reduction at six months, in spring-collected samples, the numbers in burned and unburned soil were similar in order, especially on the south slope. Increased moisture and temperature during the spring was accompanied by an extensive rise in numbers in all cases, except on the south slope where all the burned soils showed a decline. For burned soils on the north slope, numbers increased through the spring, changed little in summer, and approached values for the controls one year after burning. Lowest counts

Table 8. Streptomyces, percentage of total bacteria, in burned and unburned soils.

Treatment	Depth*	Sampling Interval: 2 days Fall	3 months Winter	6 months Spring	9 months Summer	12 months Fall
	Inches	%	%	%	%	%
South Slope						
Light burn	2	37	39	36	35	37
Medium burn	2	38	40	37	38	39
Medium burn	3	35	43	43	36	37
Hard burn	2	39	39	41	37	38
Hard burn	5	40	40	42	36	37
No burn	2	40	43	43	38	39
No burn	3	42	42	44	41	41
No burn	5	41	40	42	40	40
North Slope						
Light burn	2	40	39	40	36	38
Medium burn	2	38	41	42	41	40
Medium burn	3	36	41	42	40	40
Hard burn	2	39	40	40	39	37
Hard burn	5	41	42	44	35	40
No burn	2	40	41	44	40	39
No burn	3	38	40	43	41	39
No burn	5	39	42	45	39	38

* Sample taken from soil surface to depth indicated.

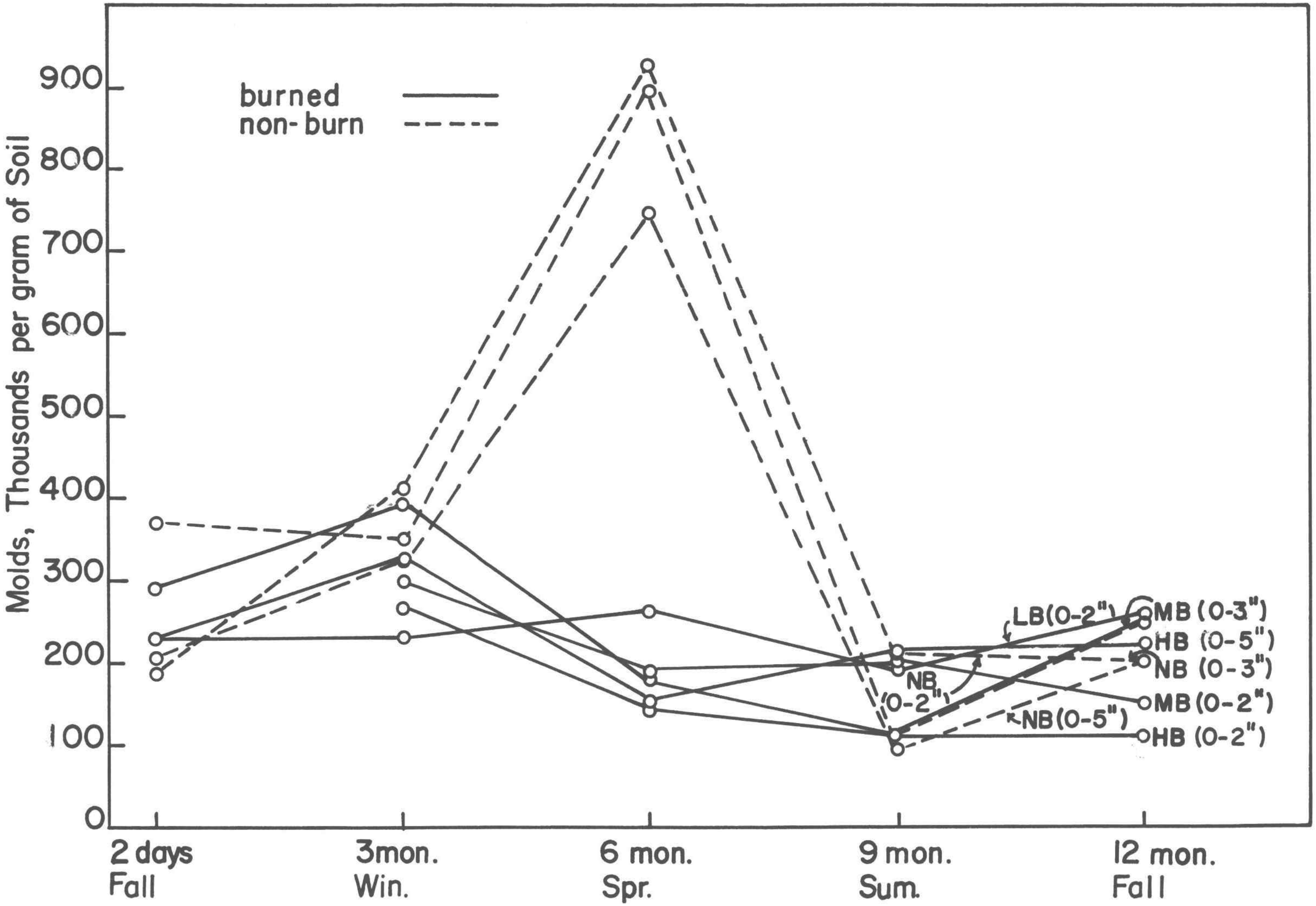


Figure 8. Population of soil molds as estimated by plating procedures from slash-burned and non-burned soils from the south slope.

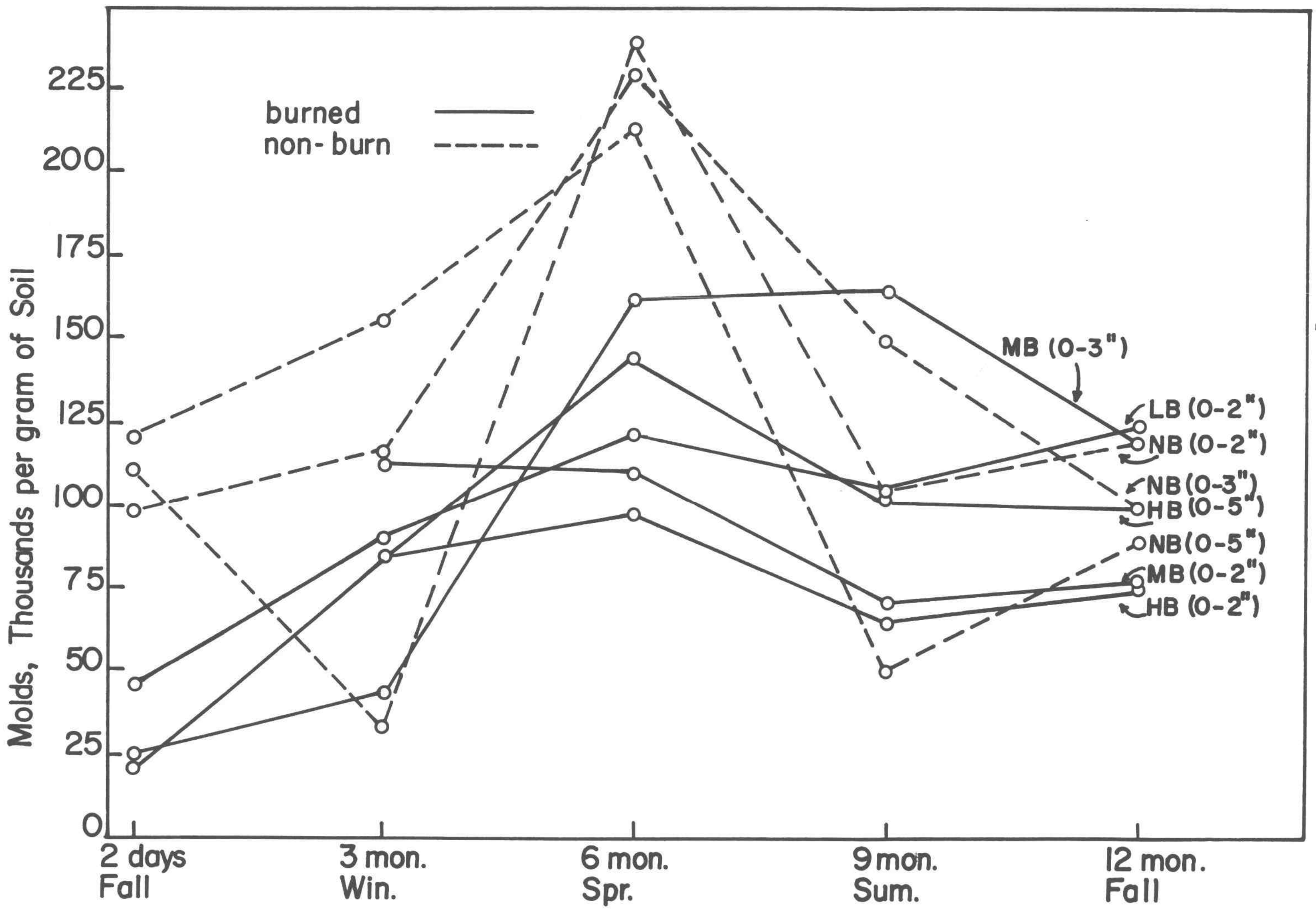


Figure 9. Populations of soil molds as estimated by plating procedures from slash-burned and non-burned soils from the north slope.

were obtained with hard-burned soils, while medium burns generally showed intermediate populations. As with the bacteria, the general decrease in the soil mold population noted nine months after burning could be attributed to decreased soil moisture.

Representatives of the genus <u>Penicillium</u> were dominant in the mold population, and although their proportion varied, the percentage was always high.

The general trend of changes in the mold population on both the south slope and the north slope were similar, but the fluctuations were more pronounced on the south slope and the numbers were higher.

In general, the results show that light and medium slash-burns increased numbers of bacteria. Seasonal fluctuations were greater in burned soils than in unburned soil, until one year later, when the effect of burning became less pronounced. Except for some small increases when soil moisture and temperature were most favorable, hard burns tended to decrease the bacterial population. With few minor exceptions, molds were reduced by slash-burning, the decrease being most noticable in the spring, six months after burning. One year after burning, their numbers were found to be nearly the same as in the non-burned soils.

While similar effects could be expected to occur when slash is burned on similar types of soil under similar conditions, any extended response of the microbial populations in different soils, or under different environments, or at different seasons of burning, could be entirely different.

Ammonification

The soil nutrient required by plants in the greatest quantity is nitrogen in available form. Nitrogen serves as the keystone of the proteinaceous matter of living tissue (1, p. 240). Despite its critical role in plant nutrition, nitrogen is assimilated almost entirely in the inorganic state, as ammonium or nitrate. Most of the soil's nitrogen is derived from organic matter in or added to the soil as residues of plants and animals (8, p. 14). A variety of bacteria and molds are capable of rapidly transforming protein material and liberating the nitrogen as ammonium which is then assimilated by microorganisms, and in many cases by plants. Any excess over immediate requirements is stored on the cation exchange complex (8, p. 14) and in turn may be subject to nitrification. Many molds and higher fungi readily decompose proteins, amino acids, and other nitrogenous compounds with the liberation of considerable quantities of ammonium. Molds frequently release less ammonium than bacteria because, being more efficient in utilizing carbon sources, they assimilate more of the nitrogen for cell synthesis (1, p. 253). However, they may occupy a dominant position in the process of ammonification in acid soil because they are more tolerant of acidic environments. Like microbial process in general, ammonification is influenced by pH, temperature, aeration, moisture, and inhibitory factors.

The ammonifying power of a soil is quite difficult to measure and interpret in field experiments. The potential for ammonification of a particular soil is therefore usually measured in the laboratory where environmental conditions and organic nitrogen source may be controlled.

Table 9 shows the influence of slash-burning on the ammonifying power of the soil. Two days after burning, soil samples from the south slope showed essentially no difference in ammonification of peptone. Medium-burned soil sampled to a depth of three inches showed considerable increase. In samples taken three months later, substantial increases in ammonification were found in all burned soils. Subsequently, at six months after burning, decreased ammonification in the burned soils occurred, but non-burned soil showed increases. The decreases were slightly more pronounced on the south slope in the first two inches of medium- and hard-burned soils. Although a rapid increase in the bacterial populations were noted at six months in the burned areas, a decrease in molds occurred. This change could account for lessened ammonifying power. An appreciable drop in the ammonifying potential occurred in all the burned

Table 9. Effect of slash-burning on ammonification of peptone. *

Treatment	Depth**	2 days Fall	3 months Winter	6 months Spring	9 months Summer	12 months Fall
		Sampling Interval				
	Inches	%	%	%	%	%
South Slope						
Light burn	2	31	52	33	16	22
Medium burn	2	--	50	31	16	20
Medium burn	3	27	48	42	18	21
Hard burn	2	--	48	30	15	18
Hard burn	5	29	50	36	17	17
No burn	2	36	33	45	26	45
No burn	3	23	39	43	27	33
No burn	5	29	39	40	27	30
North Slope						
Light burn	2	38	56	30	20	26
Medium burn	2	--	55	31	19	24
Medium burn	3	65	57	32	19	25
Hard burn	2	--	50	28	15	20
Hard burn	5	22	45	30	19	22
No burn	2	39	35	40	39	43
No burn	3	38	36	40	36	38
No burn	5	27	32	38	30	36

* Based on percentage increase in NH_4^+-N with added peptone equivalent to 1000 ppm N; each value is the mean of three replicates.

** Sample taken from soil surface to depth indicated.

soils nine months after burning, those from the south slope showing the greatest decreases. At the same time, lesser decreases were found with the unburned soils, the values being comparable to those shown at two days after burning. All these low ammonification percentages could be related to low moisture conditions during the summer, when the samples were taken. The order of ammonification percentages were similar in non-burned soils sampled at 12 months, but the values were higher in most cases. The burned soils, however, showed definite decreases in ammonification at this time.

Ammonifying power was similar in both north and south slope samples throughout the year. Differences occurred between soils receiving different intensities of burn, but these differences appeared unrelated to burning intensity.

From these results it is evident that fall slash-burning stimulates the ammonifying power of the surface soil through the following winter. After this six month period, differences between burned and unburned soil became negligible.

Nitrification

Any ammonium in the soil, free or held on the cation exchange complex, is available to plants, and to nitrifying bacteria which oxidize it to nitrite and nitrate to obtain energy for autotrophic reduction of carbon dioxide (8, p. 14). Nitrification takes place in two successive steps; the oxidation of ammonium to nitrite, and usually immediately following, the oxidation of the nitrite to nitrate (1, p. 413). Nitrifying organisms are favored by good aeration and available calcium and phosphate, and are retarded by extremes of pH and by free ammonia (11, p. 138, 415). Nitrifiers are retarded by high or low extremes of soil moisture, and by temperatures below 5^{o} C or above 40^{o} C (11, p. 415-416). Nitrification can lead to more or less loss by leaching and by denitrification (8, p. 14; 11, p. 417), depending upon environmental conditions. Inasmuch as many kinds of plants can assimilate ammonium nitrogen at least as well as nitrate under certain conditions, nitrification is not necessarily an indespensible function in soil fertility (28, p. 7-11).

As in the experiments to determine ammonification potential of burned and non-burned soils, experiments were conducted in the laboratory under controlled conditions.

The results of the nitrification experiments are given in Table 10. Nitrification by samples taken two days after slash-burning was similar in burned and unburned soils. Three months after burning, decreases in the nitrifying power was apparent in all burned soils, the effect being slightly stronger for the south slope. Results with the six month samples were quite similar. At nine months, the summer samples all showed marked decreases, attributable to limited moisture; the greatest reductions, however, were

Table 10. Effect of slash-burning on nitrification of ammonium sulfate. *

Treatment	Depth**	Sampling Interval				
		2 days Fall	3 months Winter	6 months Spring	9 months Summer	12 months Fall
	Inches	%	%	%	%	%
South Slope						
Light burn	2	25	20	20	5	20
Medium burn	2	--	19	20	5	18
Medium burn	3	22	18	21	6	16
Hard burn	2	--	17	20	4	10
Hard burn	5	20	19	22	4	10
No burn	2	28	40	43	10	29
No burn	3	29	40	45	12	30
No burn	5	30	42	48	20	34
North Slope						
Light burn	2	28	25	24	7	22
Medium burn	2	--	23	22	7	20
Medium burn	3	24	22	20	8	22
Hard burn	2	--	20	19	9	13
Hard burn	5	26	20	20	10	16
No burn	2	30	38	38	15	32
No burn	3	32	40	40	18	35
No burn	5	35	45	46	22	36

* Based on percentage increase in NO_3^--N with added ammonium sulfate equivalent to 300 ppm; each value is the mean of three replicates.

** Sample taken from soil surface to depth indicated.

in the burned soils. After one year, all values approached those found two days after burning. Neither the direction of the slopes nor the intensity of burn had appreciable influence on the results.

Liming soils, thus increasing the pH toward neutrality, enhances nitrification. This, however, is attributed to increases in exchangable calcium and not primarily to the effect of increased pH. Although burning increased the soil pH, which would generally increase microbial activity, this alone did not enhance nitrification.

As indicated by the experimental results, slash-burning reduced nitrification within three months after burning and thereafter throughout the sampling period. Because nitrification is dependent upon ammonification to supply the energy substrate, the transformation is sensitive to competition for the ammonium ion by other microbes and usually is decreased in soil when active microbial growth takes place (11, p. 138). Accordingly, the numbers of nitrifying bacteria would decrease because of the competition for the ammonium as a nitrogen source by the increased microbial population found in the burned soils. This could thus possibly account for the decreased nitrifying power observed.

Soil Respiration Studies

Decomposition of organic matter from which energy is obtained by microbes in the soil is often measured by rate and extent of the evolution of carbon dioxide. Although this may serve as an index of metabolic activity and as an index of organic matter decomposition, exceptions may occur. Carbon dioxide may be formed without the liberation of energy by microorganisms, as in the decomposition of pyruvic acid, or energy may be liberated without the formation of carbon dioxide during anaerobic fermentation of sugar (36, p. 607). However, in the soil where a great variety of microorganisms with diverse nutritional requirements are present, the metabolic organic end product of one group of microorganisms often serves as a substrate for another group, eventual metabolic end products being carbon dioxide and water. For this reason, carbon dioxide production can serve as an index of general microbial decomposition of organic matter in the soil.

Decomposition of added dextrose. Because dextrose is readily utilized by most heterotrophic bacteria and molds, it is useful in determining maximum respiratory activity in soils. The results presented in Figures 10, 11 and 12 and summarized in Table 12 illustrate the influence of burning on this capacity. With samples collected on the south slope two days after burning, decomposition of added dextrose was more extensive in burned soils, except for the light burn, than in the corresponding controls. Greatest carbon dioxide evolution was shown in the medium burned soil; at 55 days the apparent decomposition was 120 percent. The excess over 100

Figure 10. Carbon dioxide evolution from 50 g. of slash-burned and non-burned soil treated with 2000 ppm carbon as dextrose. Samples were collected two days after burning.

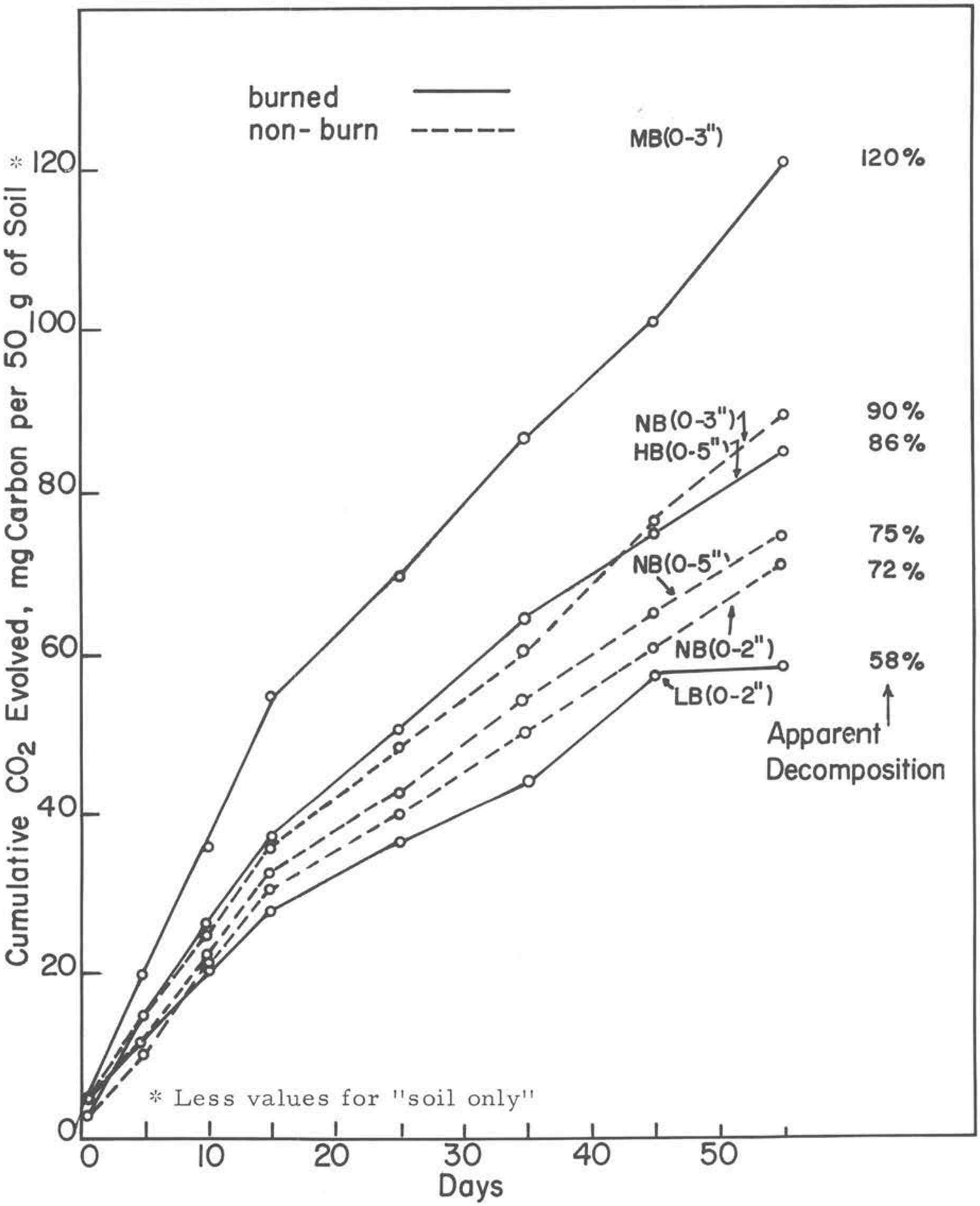


Figure 11. Carbon dioxide evolution from 50 g. of slash-burned and non-burned soil treated with 2000 ppm carbon as dextrose. Samples were collected six months after burning.

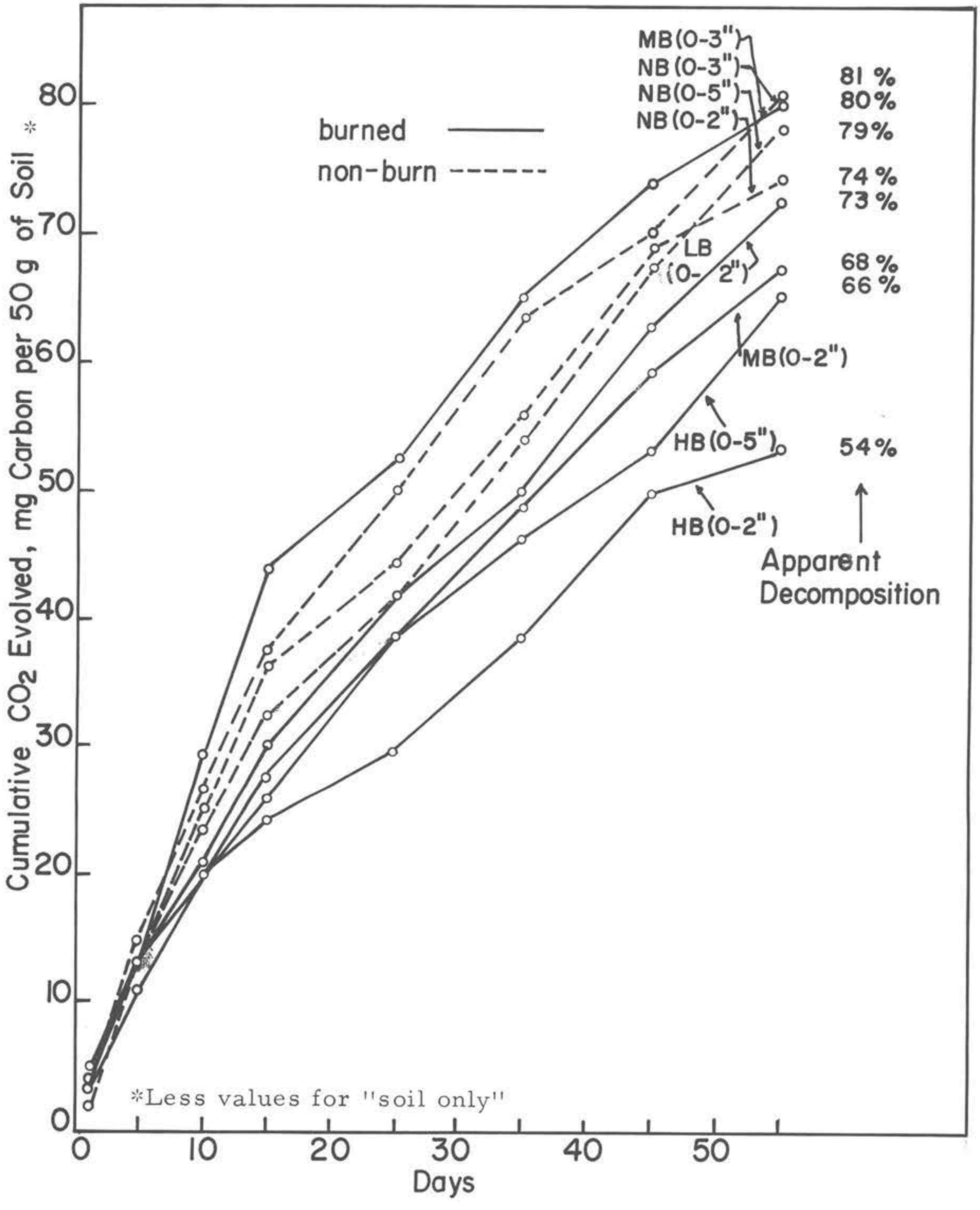
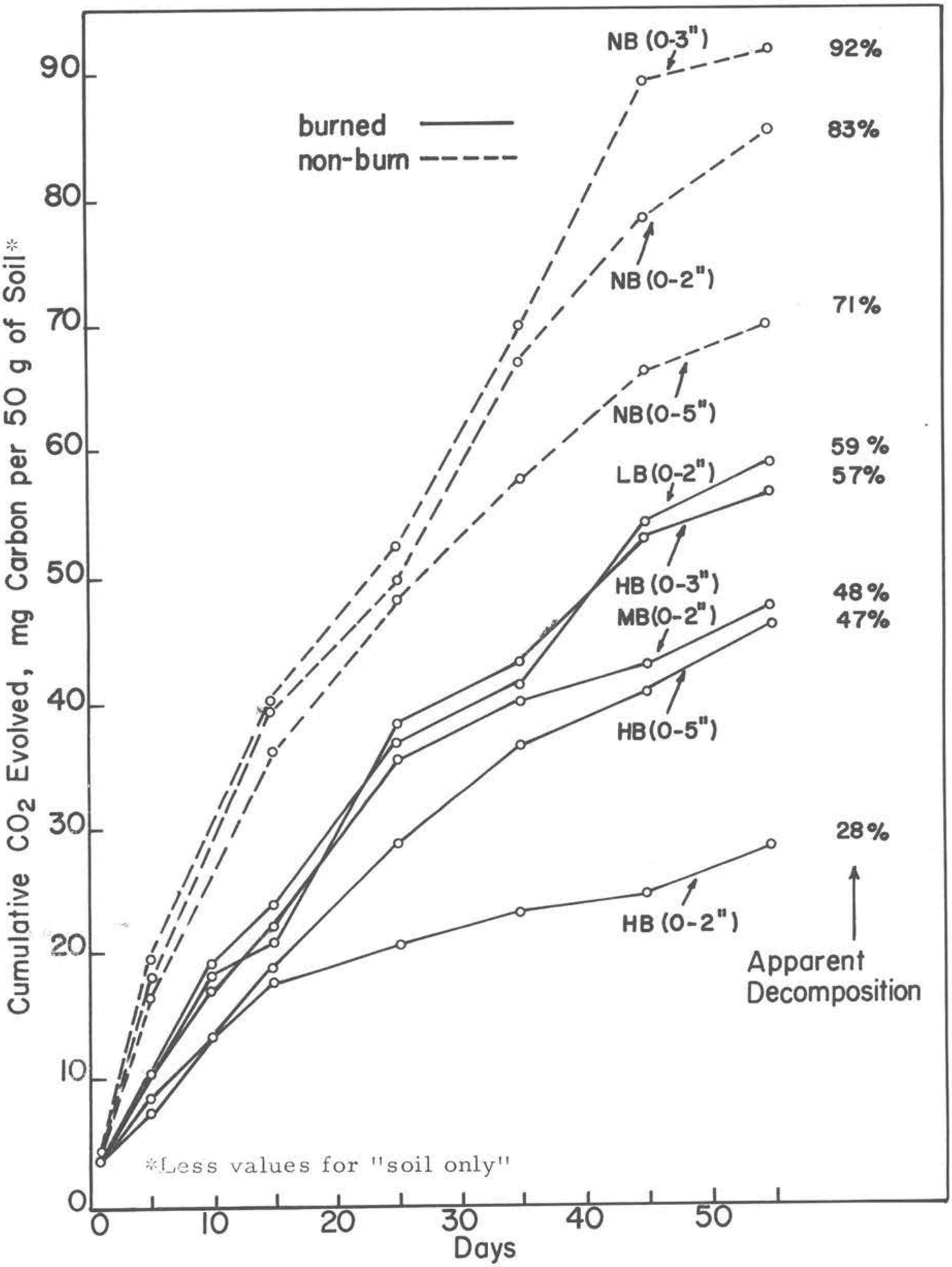


Figure 12. Carbon dioxide evolution from 50 g. of slash-burned and non-burned soil treated with 2000 ppm carbon as dextrose. Samples were collected 12 months after burning.



percent is attributable to a stimulated decomposition of the native soil organic matter by increased microbial development, greater than in the control, from added sugar (9, p. 35-41). By the same token, part of the carbon dioxide evolved from the other treated soils could also be due to this phenomenon; hence the use of "apparent decomposition." However, it is evident that the medium-burned soil initially produced more favorable conditions for general microbial activity as indicated by carbon dioxide evolution. Although a temporary increase took place with the light burned soil, a depression followed after five days of respiration. The reason for this is not clear; possibly it is related to inclusion of only the first two inches of soil in these samples. That this may be true is supported by the results obtained with burned and unburned soil collected at subsequent intervals, when 0-2 inch, as well as deeper samples were taken from the medium and hard burned areas. At three months and six months, 0-2 inch samples of all the burned soils gave less carbon dioxide than the unburned soils. A possible explanation is that the 0-2 inch horizons before burning contained higher microbial populations than did the 0-3 and 0-5 inch layers. Figures 5 through 8 and Table 4 show this to be true in several instances. Hence the effect of heat penetration to a depth attaining 150° F could be quantitatively more destructive or inhibiting in the shallower layer, more microbes per gram of soil being affected.

Decomposition in 0-2 inch samples collected at six, nine, and 12 months after burning was greatest in light-burned soil and least in hard burned soil. At all times, except for the two-day and three-month samples from the medium burn at 0-3 inches and hard burn at 0-5 inches, dextrose decomposition was most extensive with the unburned 0-3 inch soil samples.

Results obtained for dextrose decomposition in all samples taken from the north slope were similar to those shown for the south slope and gave the same general pattern. An exception worthy of mention is the greater decomposition shown at all times in the 0-2 inch layer from the north slope. This correlates with the higher total carbon in these samples than in those from the south slope.

Decomposition of added litter. Figures 13, 14 and 15 show the course of carbon dioxide evolution from added litter; the extent of decomposition at 55 days for each set of samples is given in Table 11.

Because litter in the experimental area consisted largely of dead braken fern (*Pteridium aquilinum* var. *pubescens*) and a small proportion of Douglas-fir needles, the material was probably high in ligno-celluloses. An analysis of a composite sample gave 20.95 percent carbon, 0.45 percent nitrogen, and 18.20 percent ash. That the litter had a high resistance to decomposition is shown by the respiration data. Although carbon dioxide production at 55 days was three

Table 11. Physical and chemical effects of fall slash-burning on forest soil (Part I).

Treatment	Water					Water Capacity				
Time after burn	2 days	3 months	6 months	9 months	12 months	2 days	3 months	6 months	9 months	12 months
	%	%	%	%	%	%	%	%	%	%
South Slope										
Unburned										
0-2 inches	20	62	54	16	22	86	90	89	88	90
0-3 inches	23	62	55	13	24	86	90	88	87	87
0-5 inches	21	66	55	15	25	86	90	88	87	87
Light burn										
0-2 inches	17	53	48	8	11	76	73	73	73	72
Medium burn										
0-2 inches	--	50	46	8	11	--	68	67	67	66
0-3 inches	20	57	46	9	12	64	65	65	65	66
Hard burn										
0-2 inches	--	49	44	7	10	--	60	60	61	59
0-5 inches	13	52	45	11	12	61	61	62	62	61
North Slope										
Unburned										
0-2 inches	16	65	60	16	26	80	83	84	86	86
0-3 inches	18	66	58	19	28	84	84	83	86	84
0-5 inches	20	69	56	20	28	70	74	74	75	76
Light burn										
0-2 inches	14	62	53	12	15	75	74	75	73	74
Medium burn										
0-2 inches	--	60	52	11	15	--	70	70	69	69
0-3 inches	10	54	52	12	16	80	75	75	74	74
Hard burn										
0-2 inches	--	50	50	10	13	--	65	66	65	66
0-5 inches	12	57	51	13	18	65	70	71	72	68

Table 11 (Part II)

Treatment	pH					Total Nitrogen				
Time after burn	2 days	3 months	6 months	9 months	12 months	2 days	3 months	6 months	9 months	12 months
						%	%	%	%	%
South Slope										
Unburned										
0-2 inches	5.9	5.2	5.6	5.8	5.6	0.26	0.26	0.24	0.24	0.26
0-3 inches	5.9	5.4	5.6	5.8	5.5	0.25	0.25	0.26	0.26	0.25
0-5 inches	5.6	5.5	5.6	5.6	5.6	0.24	0.25	0.26	0.25	0.26
Light burn										
0-2 inches	5.9	6.2	6.2	6.6	6.5	0.30	0.29	0.28	0.27	0.26
Medium burn										
0-2 inches	---	6.3	6.6	6.7	6.5	---	0.28	0.27	0.25	0.24
0-3 inches	5.9	5.8	6.4	6.6	6.5	0.28	0.28	0.27	0.26	0.24
Hard burn										
0-2 inches	---	6.4	0.5	6.8	6.8	---	0.28	0.25	0.25	0.21
0-5 inches	5.2	6.2	6.2	6.5	6.4	0.24	0.25	0.26	0.25	0.26
North Slope										
Unburned										
0-2 inches	5.6	5.8	5.7	5.8	5.6	0.24	0.24	0.25	0.25	0.26
0-3 inches	5.8	5.8	5.8	5.9	5.7	0.24	0.23	0.25	0.25	0.28
0-5 inches	5.6	5.6	5.8	5.9	5.6	0.24	0.24	0.26	0.27	0.28
Light burn										
0-2 inches	5.8	6.2	6.3	6.4	6.3	0.24	0.24	0.22	0.22	0.22
Medium burn										
0-2 inches	---	6.2	6.3	6.6	6.5	---	0.25	0.24	0.24	0.22
0-3 inches	5.4	6.2	6.2	6.3	6.4	0.28	0.25	0.24	0.25	0.23
Hard burn										
0-2 inches	---	6.3	6.5	6.6	6.5	---	0.26	0.24	0.25	0.23
0-5 inches	5.3	5.6	5.9	6.1	6.1	0.20	0.20	0.20	0.20	0.18

Table 11 (Part III)

Treatment	Total Carbon					NH_4^+-N				
Time after burn	2 days	3 months	6 months	9 months	12 months	2 days	3 months	6 months	9 months	12 months
	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
South Slope										
Unburned										
0-2 inches	5.13	5.15	5.05	5.12	5.16	5	10	28	5	5
0-3 inches	5.01	5.20	5.22	5.15	5.05	4	8	26	3	6
0-5 inches	4.75	5.01	5.11	5.03	5.09	2	12	26	3	6
Light burn										
0-2 inches	7.01	6.91	6.93	6.98	6.95	54	60	25	11	3
Medium burn										
0-2 inches	----	6.75	6.80	6.67	6.63	--	42	26	10	4
0-3 inches	6.51	6.50	6.42	6.50	6.38	21	40	25	8	3
Hard burn										
0-2 inches	----	7.16	7.01	6.95	6.40	--	44	20	5	3
0-5 inches	4.75	5.01	5.11	5.03	5.09	39	40	20	6	4
North Slope										
Unburned										
0-2 inches	5.56	5.54	5.40	5.48	5.39	7	11	20	7	9
0-3 inches	5.42	5.30	5.26	5.34	5.69	12	13	22	12	11
0-5 inches	5.58	5.61	5.51	5.57	5.52	13	15	21	13	12
Light burn										
0-2 inches	6.23	6.25	6.01	6.05	6.16	35	48	28	11	6
Medium burn										
0-2 inches	----	6.30	6.25	6.18	6.15	--	48	30	10	5
0-3 inches	6.24	6.24	6.10	6.16	6.20	52	52	32	10	7
Hard burn										
0-2 inches	----	6.90	6.80	6.90	6.75	--	75	25	11	5
0-5 inches	4.74	4.31	5.00	4.90	5.01	76	76	25	12	4

Table 11 (Part IV)

Treatment Time after burn	NO_3^--N				
	2 days	3 months	6 months	9 months	12 months
	ppm	ppm	ppm	ppm	ppm
South Slope					
Unburned					
0-2 inches	1	2	2	4	3
0-3 inches	1	2	3	3	2
0-5 inches	0.4	2	4	2	1
Light burn					
0-2 inches	5	6	5	3	2
Medium burn					
0-2 inches	-	7	4	2	2
0-3 inches	1	5	3	3	0
Hard burn					
0-2 inches	-	4	2	3	2
0-5 inches	4	4	3	3	1
North Slope					
Unburned					
0-2 inches	3	4	4	3	1
0-3 inches	6	6	2	4	3
0-5 inches	4	3	2	2	2
Light burn					
0-2 inches	2	4	2	2	0
Medium burn					
0-2 inches	-	3	1	3	1
0-3 inches	2	3	2	2	3
Hard burn					
0-2 inches	-	2	3	4	1
0-5 inches	8	4	4	6	0

Table 12. Microbial effects of fall slash-burning on forest soil (Part I).

Treatment	PLATE COUNTS									
	Molds, thousands per gram					Bacteria, millions per gram				
Time after burn	2 days	3 months	6 months	9 months	12 months	2 days	3 months	6 months	9 months	12 months
South Slope										
Unburned										
0-2 inches	370	350	900	104	275	19	16	36	6	30
0-3 inches	185	416	933	202	200	27	19	33	4	25
0-5 inches	202	320	750	100	201	26	22	29	1	23
Light burn										
0-2 inches	225	230	155	195	260	61	56	96	48	45
Medium burn										
0-2 inches	---	300	190	200	150	--	31	52	21	21
0-3 inches	293	390	179	115	250	87	21	66	37	35
Hard burn										
0-2 inches	---	275	120	110	112	--	22	42	17	18
0-5 inches	225	325	265	208	225	40	17	64	24	24
North Slope										
Unburned										
0-2 inches	112	34	240	105	120	34	17	30	5	23
0-3 inches	98	115	230	130	100	24	25	28	3	18
0-5 inches	121	155	214	50	90	29	25	24	1	17
Light burn										
0-2 inches	46	90	122	105	125	58	29	77	38	35
Medium burn										
0-2 inches	--	112	110	73	78	--	25	70	19	16
0-3 inches	25	44	162	165	120	54	28	74	21	20
Hard burn										
0-2 inches	--	85	98	65	76	--	14	58	12	13
0-5 inches	22	105	145	104	100	29	12	51	15	15

Table 12 (Part II)

Treatment / Time after burn	Ammonification* 2 days	3 months	6 months	9 months	12 months	Nitrification** 2 days	3 months	6 months	9 months	12 months
	%	%	%	%	%	%	%	%	%	%
South Slope										
Unburned										
0-2 inches	36	33	45	26	45	28	40	43	10	29
0-3 inches	23	39	43	27	33	29	40	45	12	30
0-5 inches	29	39	40	27	30	30	42	48	20	34
Light burn										
0-2 inches	31	52	33	16	22	25	20	20	5	20
Medium burn										
0-2 inches	--	50	31	16	20	--	19	20	5	18
0-3 inches	27	48	42	18	21	22	18	21	6	16
Hard burn										
0-2 inches	--	48	30	15	18	--	17	20	4	10
0-5 inches	29	50	36	17	17	20	19	22	4	10
North Slope										
Unburned										
0-2 inches	39	35	40	39	43	30	38	38	15	32
0-3 inches	38	36	40	36	38	32	40	40	18	35
0-5 inches	27	32	38	30	36	35	45	46	22	36
Light burn										
0-2 inches	39	56	30	20	26	28	25	24	7	22
Medium burn										
0-2 inches	--	55	31	19	24	--	23	22	7	20
0-3 inches	65	57	32	19	25	24	22	20	8	22
Hard burn										
0-2 inches	--	50	28	15	20	--	20	19	9	13
0-5 inches	22	45	30	19	22	26	20	20	10	16

* of 1000 ppm peptone N

** of 300 ppm $NH_4/_2SO_4$

Table 12 (Part III)

Treatment	Decomposition of added organic matter at 55 days*									
	Dextrose					Litter				
Time after burn	2 days	3 months	6 months	9 months	12 months	2 days	3 months	6 months	9 months	12 months
	%	%	%	%	%	%	%	%	%	%
South Slope										
Unburned										
0-2 inches	72	69	74	76	83	7	11	13	15	17
0-3 inches	90	89	81	90	92	8	12	15	20	20
0-5 inches	75	70	79	73	71	7	11	14	18	19
Light burn										
0-2 inches	58	69	73	62	59	6	7	6	4	4
Medium burn										
0-2 inches	--	60	68	52	48	--	6	4	3	3
0-3 inches	120	92	80	62	57	5	9	5	5	4
Hard burn										
0-2 inches	--	54	54	49	28	--	3	4	3	3
0-5 inches	86	90	66	52	47	4	9	7	5	4
North Slope										
Unburned										
0-2 inches	98	90	87	94	88	8	9	11	9	12
0-3 inches	92	89	92	97	95	9	10	13	10	15
0-5 inches	73	87	90	90	82	7	9	12	9	11
Light burn										
0-2 inches	53	52	78	54	52	5	4	6	3	3
Medium burn										
0-2 inches	--	50	63	50	47	--	4	7	3	3
0-3 inches	109	97	95	54	50	4	3	7	3	3
Hard burn										
0-2 inches	--	46	47	42	39	--	3	4	3	3
0-5 inches	101	93	57	49	42	3	4	4	3	3

* Based on increase in CO_2 evolution from 2000 ppm added organic matter C.

Table 12 (Part IV)

Treatment	Soil Respiration. C as CO_2 Evolved from Soil Only in 55 Days.						
Time after burn	2 days	3 months	6 months	9 months	12 months	Average	Decomposition*
	ppm	ppm	ppm	ppm	ppm		%
South Slope							
Unburned							
0-2 inches	1460	1520	1610	1430	1440	1492	2.9
0-3 inches	1610	1670	1800	1590	1620	1636	3.2
0-5 inches	1500	1560	1710	1600	1490	1572	3.1
Light burn							
0-2 inches	1920	1800	1640	1360	1180	1594	2.3
Medium burn							
0-2 inches	----	1730	1580	1300	960	1393	2.1
0-3 inches	1910	1790	1660	1420	1190	1594	2.5
Hard burn							
0-2 inches	----	1610	1020	930	790	1088	1.6
0-5 inches	1720	1760	1580	1510	1030	1520	3.0
North Slope							
Unburned							
0-2 inches	1380	1420	1580	1300	1280	1392	2.5
0-3 inches	1520	1460	1640	1400	1420	1488	2.8
0-5 inches	1360	1380	1500	1280	1280	1360	2.4
Light burn							
0-2 inches	1900	1800	1040	1060	1060	1372	2.2
Medium burn							
0-2 inches	----	1720	1020	880	900	1130	1.8
0-3 inches	1740	1780	1020	940	920	1280	2.0
Hard burn							
0-2 inches	----	1580	880	720	700	970	1.4
0-5 inches	1640	1660	960	800	720	1156	2.4

* Decomposition of natural organic matter as indicated by total C (Table 11) based on average CO_2 evolution at 55 days.

Figure 13. Carbon dioxide evolution from 50 g. of slash-burned and non-burned soil treated with 2000 ppm carbon as forest litter. Samples were collected two days after burning.

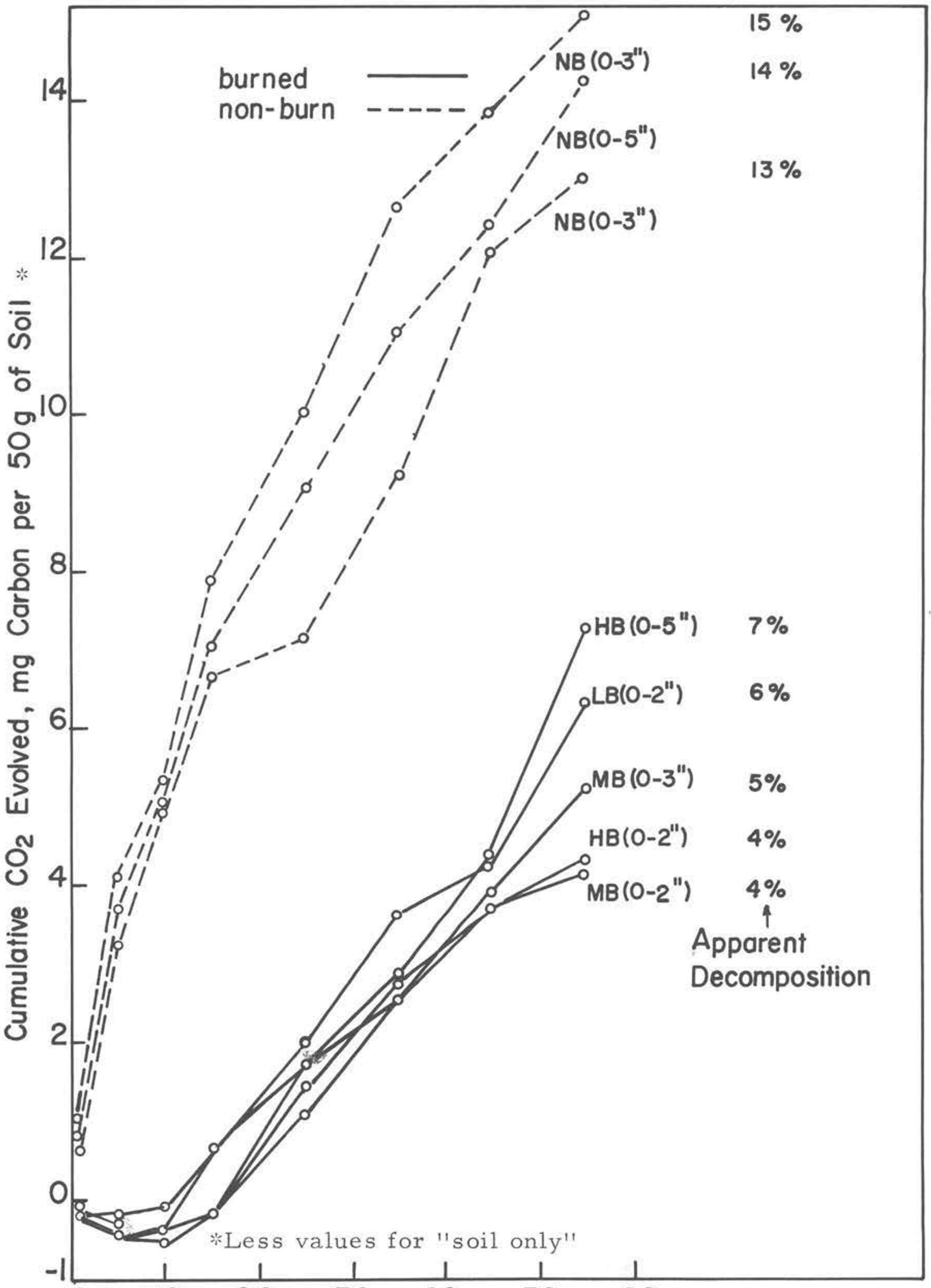

burned
non-burn
NB(0-3")
NB(0-5")
NB(0-3")
15 %
14 %
13 %
HB(0-5")
LB(0-2")
MB(0-3")
HB(0-2")
MB(0-2")
7%
6%
5%
4%
4%
Apparent
Decomposition
*Less values for "soil only"
Cumulative CO_2 Evolved, mg Carbon per 50 g of Soil *
Days
-1
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60

Figure 14. Carbon dioxide evolution from 50 g. of slash-burned and non-burned soil treated with 2000 ppm carbon as forest litter. Samples were collected six months after burning.

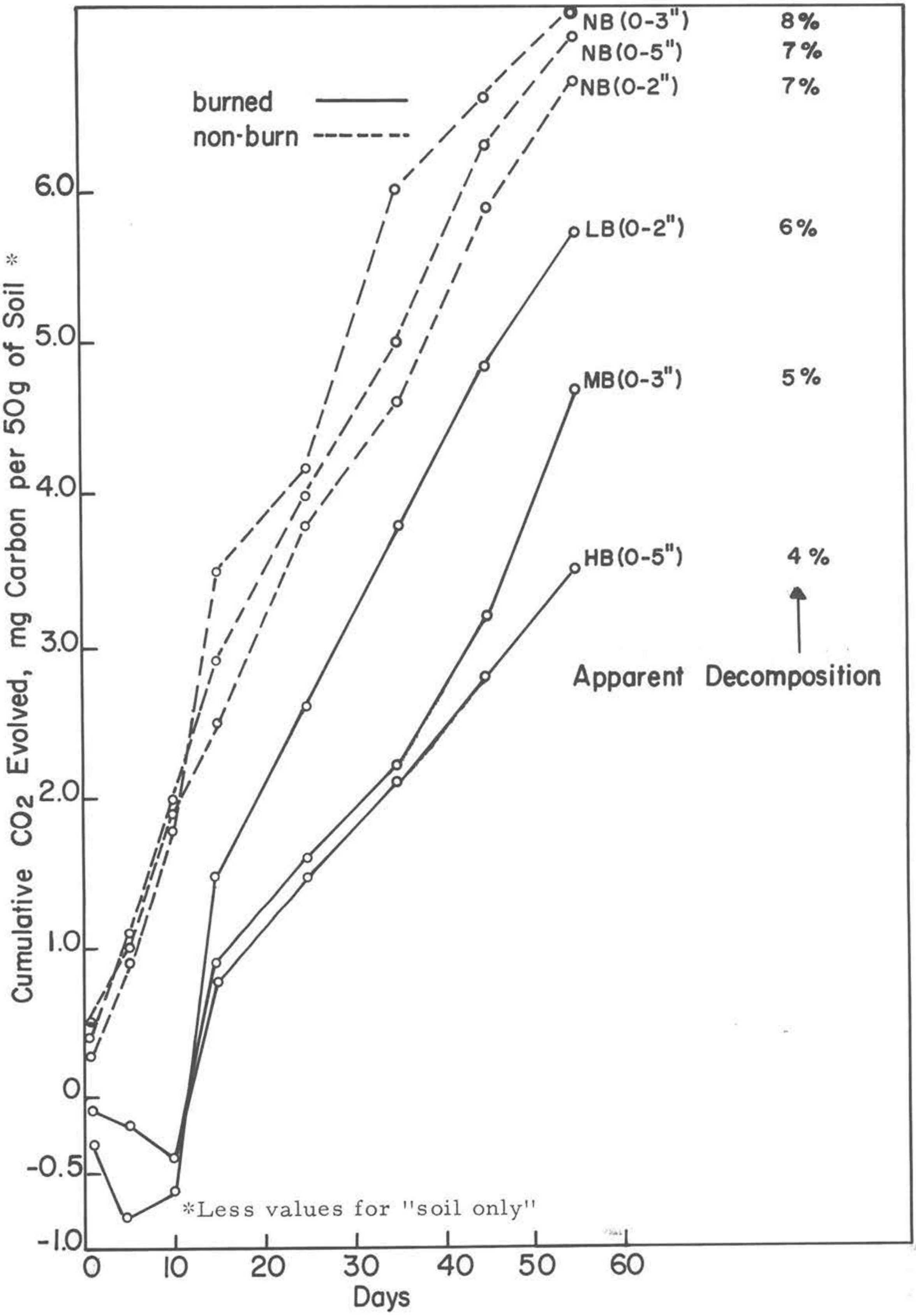
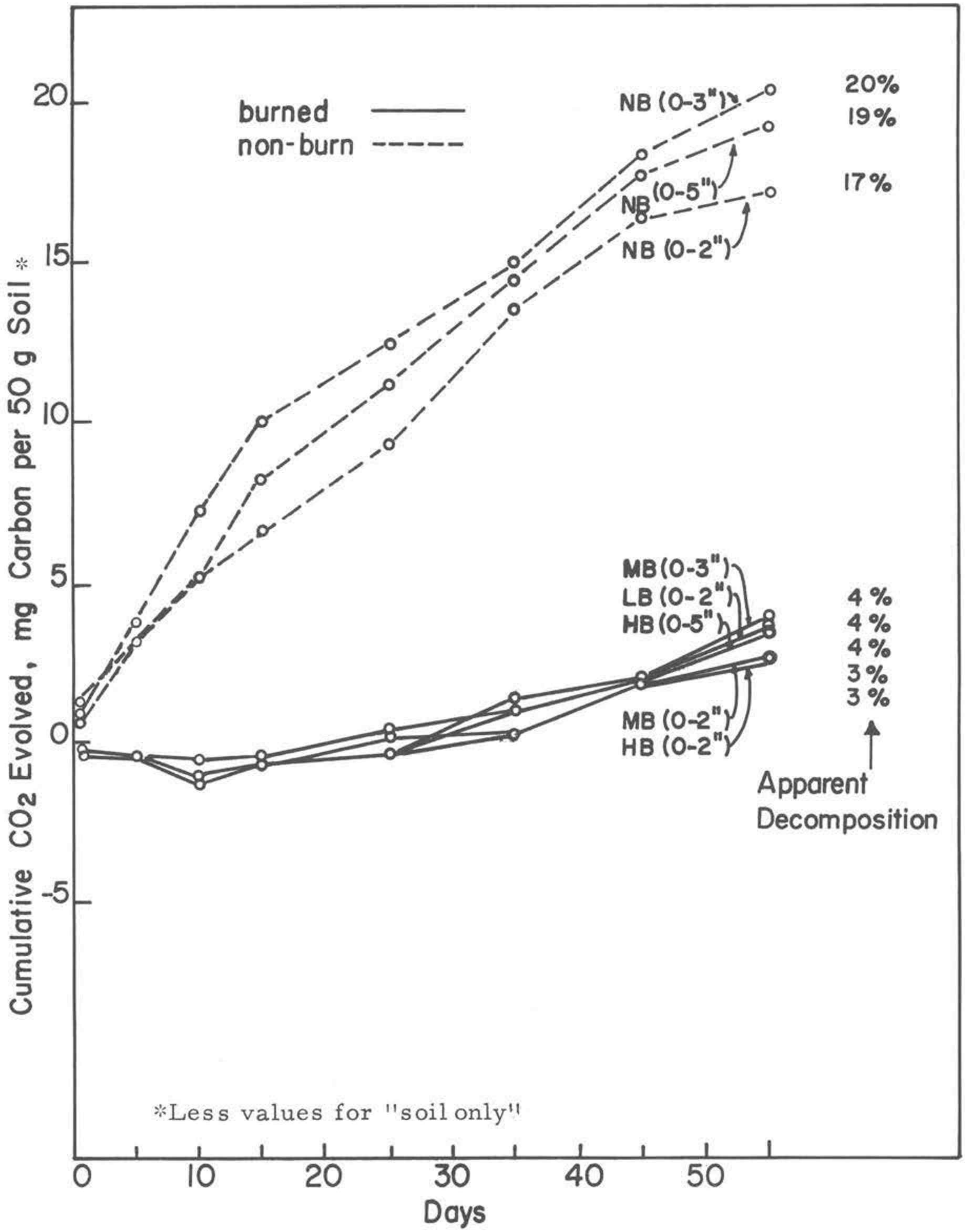

burned
non-burn
NB(0-3") 8%
NB(0-5") 7%
NB(0-2") 7%
LB(0-2") 6%
MB(0-3") 5%
HB(0-5") 4%
Apparent Decomposition
Cumulative CO_2 Evolved, mg Carbon per 50g of Soil *
6.0
5.0
4.0
3.0
2.0
1.0
0
-0.5
-1.0
0
10
20
30
40
50
60
Days
*Less values for "soil only"

Figure 15. Carbon dioxide evolution from 50 g. of slash-burned and non-burned soil treated with 2000 ppm carbon as forest litter. Samples were collected 12 months after burning.



to five times more extensive in the unburned soils, the maximum observed indicated only 20 percent decomposition. As with dextrose, the maximum decomposition was in the 0-3 inch layer of unburned soil. In burned soils, the most extensive decomposition took place in the earlier samples, attaining a maximum of only nine percent for the south slope and seven percent for the north.

Burning evidently destroyed some members of the microflora that could be effective in decomposing the litter, and reinfestation and development lagged. Most likely these organisms would be some members of Basidiomycetes and certain autochonous bacteria, including representatives of the genus Pseudomonas (8, p. 11). While Streptomyces, which can attack lignins and other resistant substances, were about as numerous in the burned as in the unburned soils, their action is notably slow.

Decomposition of native organic matter. The native organic matter of the soils ranged from 8 to 12 percent, calculated from total carbon values of 4.75 to 7.01 percent by employing the factor 1.724 (7, p. 353-374). As shown in Table 12, the average decomposition was relatively low, ranging from 1.6 percent for the hard-burned 0-2 inch layer on the south slope to 3.2 percent for unburned 0-3 inch samples. These values are similar to those obtained by Bollen (7, p. 353-374) for decomposition of native organic matter in a variety of Willamette Valley soils over a comparable period.

North slope soils gave similar values. On each slope, unburned soils showed the greatest respiration. As intensity of burn increased, carbon dioxide evolution from 0-2 inch samples decreased. In soil collected to depths of three and five inches, decomposition of native organic matter was more extensive. Depth had less influence on respiration of unburned soil. All these results are in an order of response to burning similar to that obtained with added dextrose, although dextrose was much more extensively decomposed.

SUMMARY AND CONCLUSIONS

Samples of slash-burned and unburned soil from logged-off plots on north and south slopes Astoria silt loam were collected to several depths two days after burning in the fall, and at seasonal intervals during the year following. The degree and extent of temperature penetration due to light, medium, and heavy burns were determined. All samples were subjected to physical, chemical and microbial analyses within two days after collection. Principal results were the following:

Soil moisture was not immediately influenced by burning. After spring and fall rains, non-burned soil held about ten percent more water than burned soils. This decrease in water-holding capacity was in proportion to the intensity of burning.

As air temperature changed, burned areas heated more rapidly and cooled more slowly than unburned soil.

Increases of 0.3 to 1.2 in soil pH followed burning; these increases were in order of intensity of the burn.

Burning increases ammonium nitrogen in the soil, the hard burn being the most effective. The concentration of nitrate nitrogen was low at all times and was little influenced by burning temperatures. Total nitrogen at first appeared to increase slightly in some instances but in general there was a general decline attributable to loss of nitrates. At the end of the year total nitrogen averaged about 0.05 percent less in burned than in unburned soil.

With one exception, total carbon was one to two percent higher in burned soils, probably due to finely divided charred residues left after burning. In all cases the carbon-to-nitrogen ratio was wider in burned soil.

Numbers of bacteria in burned soil at first increased over those in unburned soil. With subsequent seasonal declines and increases attributable to climate conditions, superiority in the burned areas was generally maintained. Differences in percentage of Streptomyces were not marked; for all samples the range was 35 to 45 percent, the higher values generally being for unburned soil. Molds, on the other hand, were generally less abundant in burned soil.

Slash-burning had little immediate influence on ammonification; three months later, after fall rains, ammonification was much greater in all burned soils. Subsequently this superiority over unburned soil declined. Differences existed between soils receiving different intensities of burn, but these differences appeared unrelated to burning intensity.

Slash-burning reduced nitrification within three months, and thereafter through the remainder of the year. Neither intensity of burn, despite effecting increases in pH, nor direction of slope had appreciable influence on nitrification.

In burned soil the decomposition of native organic matter and of added dextrose and litter was considerably retarded in most cases. Respiratory power tended to decrease with the successive soil samplings.

During the carbon dioxide evolution studies, dextrose was extensively decomposed, particularly in samples of unburned soil and in the first samples after burning of medium burn soils. Litter was less rapidly decomposed, and only very slowly in all burned soils. Decomposition of native organic matter was even slower, but at rates characteristic of many soils.

From the standpoint of soil fertility, slash-burning induced desirable as well as undesirable effects. Water-holding capacity, total nitrogen, ammonification, nitrification, and organic matter decomposition were decreased over a period of one year. Any of these decreases could retard plant growth and crop yield. Eventually these properties would return to the state existing before burning, but the time required is unknown and cannot be estimated from present information.

On the beneficial side, burning raised pH values, and temporarily increased microbial numbers and ammonification. This could be important to the nutrition of fall-planted tree seedlings.

Similar investigations with samples taken during several years following burning could provide more information concerning effects important to reforestation.

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