Effects of Spring Burning on a Mountain Range

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Highlight: The physical, biological, and chemical consequences of burning mountain range were monitored the year of a spring burn on the Gallatin National Forest, Montana. Two sites within the burn were intensively studied. Burning did not cause any major changes in soil chemical or physical properties. Significant soil chemical changes occurred regardless of the fire influence. Burning resulted in early reduction of basal cover of vegetation. This effect was decreased as the season advanced. A listing of species damaged by burning and favored by burning is provided.

Because of the concern over the use of herbicides in the environment, there has been increasing interest in burning as a means of reducing big sagebrush (*Artemisia tridentata* Nutt.) to improve herbaceous production. Burning in the spring has been considered desirable in the northern Rocky Mountains because (1) fire control is much easier and (2) it is assumed that the detrimental effects of very hot fires are largely avoided due to less heat and moist soils. This study evaluates the first-year results of a spring burn in southwestern Montana. About 140 acres were burned on May 30, 1973.

Daubenmire (1968), Vallentine (1971), and Wright (1974) provide a fairly complete review of the literature relating to the use and effects of fire.

Rain storms beating on the surface of burned soils may reduce infiltration rates, thus sometimes reducing soil moisture (Hanks and Anderson 1957; Anderson 1965). In some instances higher infiltration rates are reported on burned sites than on unburned sites (Scott and Burgy 1956; Beaton 1959). Torrant (1956) explained that light surface burns may increase the macroscopic pores and percolation rate through burning individual dead shrub and grass roots for several inches into the soil.

The oxidation of organic materials and production of ash by fire are accompanied by a release of bases, resulting in slight increases of pH (Lloyd 1971). This author concluded that the effects of fire in terms of plant nutrition are unimportant in the ecology of grassland relative to damage caused to the plants and alteration in the physical environment.

Blaisdell (1953), in a study in the upper Snake River Plains, stated that all plants are damaged by fire, but if given complete protection from grazing for one season, most recover. He found that Idaho fescue (*Festuca idahoensis*) was slower to recover than other species. It is generally accepted that the effect of burning on forage plants varies according to species, location, condition of range, season of burning, stage of growth, and many other characteristics of the range as well as the characteristics of the burn (McMurphy and Anderson 1965; Hadley and Kieckhefer 1963).

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Study Area

The study area is in the Gallatin National Forest, located on Taylor Fork of the Gallatin River, immediately southwest of the Taylor Fork and Wapiti Creek junction.

The pasture is in a grazing system in a horse allotment. The range was rested 1 year prior to the burn and was classified as good condition.

Two experimental sites were chosen. The lower site (site 1) is at 6,900 ft elevation while the upper site (site 2) is at 7,200 ft. Both sites were divided into two blocks, one burned and the other protected from burning. Site 1 is gently sloping towards the east while site 2 is sloping towards the northeast. Site 1 is more exposed than site 2, which is surrounded by timber and topographical barriers. The snow melted from site 1 almost two weeks earlier than from site 2.

The burn was not complete, leaving some areas completely unburned, some partially burned, and others completely burned. Of the two sites studied, site 1 had the most complete burn. The fire was much less intense in site 2.

The soils of site 1 are well drained. The profile has about 15 cm of very dark brown loam surface layer, a grayish brown blocky structured clay loam subsoil, and a calcareous loam substratum that rests on partially weathered sandstone. The soils of site 2 are excessively drained. The profile has a thin dark grayish brown loam surface layer, a weak blocky structured grayish brown gravelly loam subsoil, and a calcareous gravelly loam substratum. Fractured hard bedrock occurs at about 20 cm.

The dominant shrubs in both sites are big sagebrush (*Artemisia tridentata*) and silver sagebrush (*Artemisia cana*). Shrubby cinquefoil (*Potentilla fruticosa*) occurred in site 1 only. One spike danthonia (*Danthonia unispicata*) is the dominant grass in site 1. Mountain brome (*Bromus marginatus*) is the dominant grass in site 2. Both species occur in the two sites with Idaho fescue, slender wheatgrass (*Agropyron trachycaulum*), alpine bluegrass (*Poa alpina*), and green needlegrass (*Stipa viridula*). Sedges (*Carex* spp.) occur in both sites. The common forbs are common avens (*Geum triflorum*), northwest cinquefoil (*Potentilla gracilis*), common dandelion (*Taraxacum officinale*), sticky geranium (*Geranium viscosissimum*), crag aster (*Aster scopulorum*), velvet lupine (*Lupinus leucophyllus*), rose pussytoes (*Antennaria rosea*), virginia strawberry (*Fragaria virginiana*), false dandelion (*Agoseris glauca*), common yarrow (*Achillea millefolium*), tufted phlox (*Phlox caespitosa*), and forget-me-not (*Myosotis sylvatica*).

The average yearly precipitation of the study area is about 40–50 cm—most of it in the form of snow. The monthly average maximum temperatures during the summer range between 60 and 80°F. The monthly average minimum temperatures during the summer range between 26 and 39°F.

Methods

Soil Physical Properties

Mulch collections were made before burning on ten 1-dm plots located at random in each site. Samples were oven dried and weighed.

Three different mulch destruction classes were recognized: Class 1, 25% of the mulch changed to ash; class 2, from 25 to 75% of the mulch changed to ash; and class 3, more than 75% of the mulch changed to ash. The amount of each burn class was measured along two 15-meter randomly located lines.

Soil temperatures during the burn were determined using Tempil Sticks. Tempil Sticks are hard waxes mixed with different chemicals having different melting points. The sets of Tempil Sticks used for the surface temperatures had melting points ranging from 120°C to 425°C and the sets used from the temperatures at the depth of the 1 cm had melting points ranging from 65°C to 175°C. The Tempil Stick waxes were broken in small crumbles and folded in aluminum foils made in rectangular shapes about 2.5 × 1.75 cm. Four replicates of Tempil Stick sets were placed in each site before burning.

Measurements of soil temperature were taken weekly in the top 4 cm by a soil thermometer with a metallic probe. Measurements were taken about 3:00 p.m.

A pocket penetrometer was used to measure soil penetration indices biweekly.

Two concentric rings having 10-inch and 6-inch diameters and 1 ft high were used to measure infiltration rates. Both were firmly fixed into the ground and water was applied simultaneously in both rings. The time required to complete the absorption of a certain level of water from the inner ring was recorded.

Moisture in the top 20 cm of the soil was determined by taking ten soil samples from each block and drying them at 105°C until they lost no more water. The samples were taken once in late August.

Soil Chemical Properties

A circle with 3.9 m radius was used on each block to collect soil samples. Cores of soil were collected every two steps along the circumference of the circle. The cores were divided into 0–2 cm, 8–10 cm, and 18–20 cm depths. About 15 cores were taken around the circumference with the soil from each depth being composited, thus providing a composite sample for each depth in one traverse of the circle. Three traverses were made to provide three replications. Before-burning samples were collected in mid-May. After-burning samples were collected in mid-June.

In addition to the above, 20 soil cores from completely burned surfaces and 20 soil cores from the completely unburned surfaces within the burned blocks were collected. The soil samples from 0–2 cm and 8–10 cm were separated from each core.

The soil samples were analyzed for pH, oxidizable organic matter, exchangeable potassium, calcium and magnesium, available phosphorus, and nitrate-nitrogen.

Vegetational Analyses

Basal vegetational cover was estimated weekly on a total of twenty 4 × 5 dm plots located at 1.5-m intervals on two 15-m transects in each block.

Vegetational development was measured weekly on ten 4 × 5 dm plots located at random on each block. Culm heights of dominant grasses and sedges and leaf height of dominant forbs were measured. Floral development was recorded.

Observations were made of the "recolonization" of some of the completely burned areas and the vegetational development in them.

Productivity was obtained during the last week of August by clipping ten 4 × 5 dm plots located at random on a transect on each block. The plots were clipped at ground level. A species was segregated whenever it was present in reasonable quantities. The samples were oven dried and weighed.

Results and Discussion

Soil Physical Properties

The measurements of the mulch and the measurements of the estimated burn classes indicate major differences between the nature of burns in the two experimental sites. In site 1, although the mulch was very limited (2.8 g/sq dm), the fire was severe and consumed most of the available mulch. The volume of mulch in site 2 (10.8 g/sq dm) was considerably greater than in site 1, but the fire was very light and resulted in very few severely burned surfaces. This was probably due to the fact that site 2 was more moist than site 1.

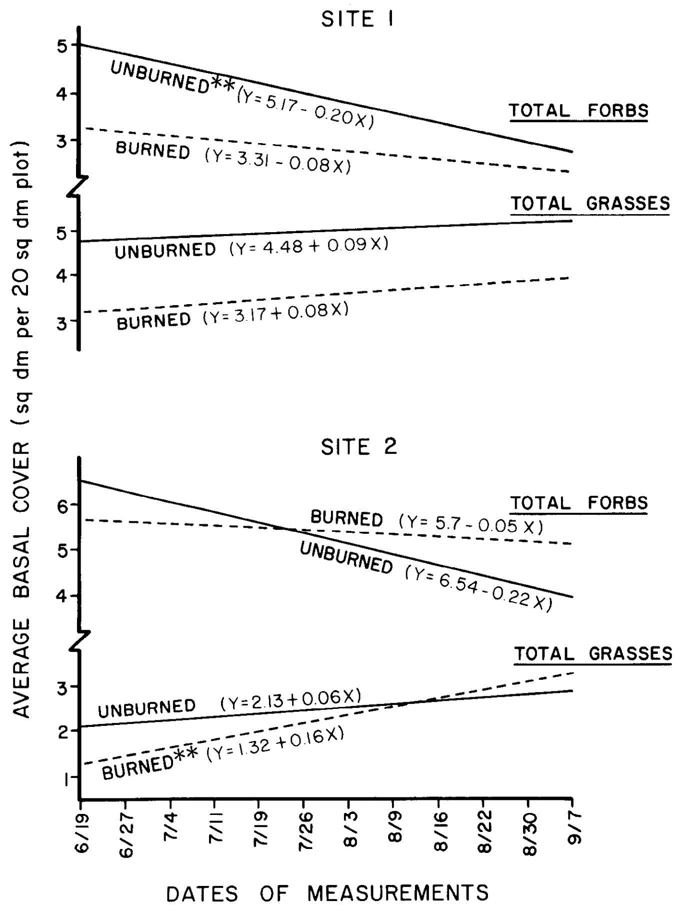

Fig. 1. *Regression lines for changes in basal cover of vegetation through the growing season (**highly significant variation due to regression).*

The maximum Tempil Stick temperatures reached during the burn were between 175 and 205°C at the soil surface and between 65 and 80°C at the depth of 1 cm. This compares with temperatures of 600°C to 720°C reported by Daubenmire (1968) in his summary of fire literature.

Soil temperatures for the 3-month period following burning were generally higher on the burned surfaces (Table 1). Complete combustion of the mulch cover probably would have resulted in greater differences. Sweeney (1956) concluded that blackened ash was an important factor determining soil temperatures of burned areas.

The soil penetration indices were slightly higher in the burned than the unburned blocks but the differences were not statistically significant.

Soil Chemical Properties

The chemical properties of the soils of the burned and unburned blocks before and after burning are shown in Tables 2 and 3 for site 1 and site 2, respectively.

At site 1, higher pH values occurred in the 0–2 and 8–10 cm soil depths in the burned block than in the unburned block. This

Table 1. Temperature (°C) at the top 4 cm of soil on burned and unburned blocks at intervals of 1 to 2 weeks through the summer, taken at 3 p.m. Values are averages of ten measurements.

Date	Unburned	Burned
	Site 1	
6/23	22.8	26.2**
6/28	23.5	28.4**
7/5	29.7	28.3
7/11	17.5	17.7
7/22	26.0	29.2**
7/28	30.2	31.8**
8/16	27.3	30.6**
8/30	23.8	26.0**
Averages	25.1	27.2
	Site 2	
6/21	21.4	23.3*
6/27	23.6	22.3*
7/4	23.6	27.7**
7/13	25.1	27.1**
7/21	23.0	26.9**
7/28	23.3	24.0
8/5	22.4	22.2
8/17	25.7	28.3
8/29	20.8	21.3
Averages	23.3	24.1

* Significant differences at the 0.05 probability level.
** Significant differences at the 0.01 probability level.

can be attributed to release of bases from the burned ash. At site 2, where the intensity of the burn was much lower, pH did not differ between burned and unburned blocks.

Phosphorus increased markedly through the summer at site 2, but did not change significantly at site 1 except for a reduction in one case. Burning apparently had no effect on phosphorus. Site 2, being more moist and with more organic matter, likely has a higher chelation rate than site 1.

Potassium decreased in the unburned and increased in the burned blocks at the 0–2 cm soil depth. Changes were not consistent at deeper levels.

Nitrate nitrogen increased at all soil depths in both unburned and burned areas. In the 0–2 cm depth, the increases were greater in the burned areas than in the unburned areas.

Salts were consistently lower at the after-burning date in site 1, while little change took place at site 2. Burning did not influence salt content.

Organic matter content of the soil was consistently lower at all depths on both burned and unburned soils at the after-burning date. It is apparent that fire was not the causative agent in organic matter reduction at either site.

Calcium tended to increase regardless of burning treatment, although the trend was not consistent. Magnesium decreased consistently regardless of burning treatment. Sodium increased consistently and significantly regardless of treatment at site 1. No trend was evident at site 2.

In summary, it appears that the short-term effects of burning are most noticeable in the 0–2 cm soil depth. There were increases related to burning in pH, potassium and nitrate nitrogen levels.

Changes not related to burning but rather to normal seasonal changes were increases in nitrate nitrogen, phosphorus, calcium, and sodium and decreases in magnesium, salts, and organic matter.

As has been pointed out, the above sampling was from a random sampling procedure on block areas protected from fire and available to fire. The fire missed some spots in the "burned" block at site 1 and a much larger part of the "burned" range at site 2. The random sampling included some of these unburned spots. A very limited soil sampling (not subject to statistical analysis) of spots with mulch totally consumed and spots with mulch completely unburned was done and the same chemical analyses made. Nearly all characteristics had higher values in the burned than unburned spots. Those characteristics that increased in the random sampling procedure showed similar increases in this test. The increases in those characteristics that decreased in the random sampling were very minor. It appears that further studies of soil chemical changes would be useful.

Table 2. Soil chemical properties of the burned and unburned blocks before and after burning, site 1, at the 0–2 cm, 8–10 cm, and 18–20 cm depths (values are averages of three replicates).

Depth			PPM.			Mmhos/cm	%	Milliequivalent/100g		
(cm)		pH	P	K	NO3-N	Salts	O.M.	Ca	Mg	Na
0–2										
Unb.[1]	Before[1]	6.00	56	812	0.8	1.9	11.75	22.3	3.99	0.50
	After	6.03	56	715*	1.8**	0.7**	5.80**	19.7*	3.24	0.83*
B	Before	6.07	43	838	0.8	1.7	8.48	19.5	4.29	0.56
	After	6.37*	49	848	2.8**	0.9**	5.97	21.9	4.05	0.89**
8–10										
Unb.	Before	6.20	40	635	0.0	0.9	4.87	13.1	2.57	0.50
	After	6.23	32	615	0.5	0.5**	4.47	15.0*	1.94*	0.82**
B	Before	6.26	21	661	0.0	0.8	4.57	13.4	3.48	0.69
	After	6.37*	11*	575	0.5	0.5**	4.40	15.4**	3.31*	0.88**
18–20										
Unb.	Before	6.40	31	585	0.0	0.8	4.20	12.3	2.65	0.56
	After	6.33	34	502*	1.4**	0.4**	3.33**	14.1**	2.54	0.84**
B	Before	6.37	07	532	0.0	0.7	3.27	12.3	4.04	0.71
	After	6.47	06	442	0.5	0.3**	2.40**	14.5**	3.63	0.96*

[1] Unb.: Unburned plot.
B: Burned plot.
Before: Before burning (mid-May).
After: After burning (mid-June).
* Significant differences at the 0.05 probability level.
** Significant differences at the 0.01 probability level.

Table 3. Soil chemical properties of the burned and unburned blocks before and after burning, site 2, at the 0–2 cm, 8–10 cm, and 18–20 cm depths (values are averages of three replicates).

Depth (cm)		pH	PPM. P	PPM. K	PPM. NO3-N	Mmhos/cm Salts	% O.M.	Milliequivalent/100g Ca	Milliequivalent/100g Mg	Milliequivalent/100g Na
0–2 Unb.[1]	Before[1]	6.17	50	1002	0.5	0.7	6.06	21.1	4.73	0.49
	After	6.17	66*	914	1.7	0.9	5.87*	25.1	4.69	0.55
B	Before	6.30	66	655	0.2	0.7	6.00	19.8	4.51	0.55
	After	6.33	89**	980**	2.2**	0.7	5.83*	18.9	3.24**	0.63
8–10 Unb.	Before	6.10	28	690	0.0	0.4	5.80	15.2	3.49	0.51
	After	6.00	38	682	1.3**	0.4	5.60	15.1	2.54**	0.49
B	Before	6.17	41	962	0.0	0.4	5.46	14.7	3.31	0.55
	After	6.07	54*	932	1.3	0.5	5.36*	15.3	2.54**	0.69
18–20 Unb.	Before	6.10	29	525	0.0	0.4	4.0	13.7	3.23	0.51
	After	6.00	37*	508	1.8**	0.3	3.7	11.8	2.19*	0.50
B	Before	6.10	37	815	0.0	0.5	5.0	13.4	3.26	0.51
	After	5.93	58	852	0.8**	0.4	3.96*	13.3	2.13**	0.75**

[1] Unb.: Unburned plot.
B: Burned plot.
Before: Before burning (mid-May).
After: After burning (mid-June).
* Significant differences at the 0.05 probability level.
** Significant differences at the 0.01 probability level.

Vegetational Analyses

Basal Cover

The responses of individual species to burning is shown in Tables 4 and 5.

The effect of burning on the different grass species showed some similarities on the two sites. Significantly lower values were observed in the basal cover of Idaho fescue, sedges, and alpine bluegrass in the burned block in site 1. The three species also showed lower values in the burned block at site 2, but the values were not statistically significant. The significant differences in site 1 and the lack of significance in site 2 undoubtedly reflect the difference in fire intensity.

Slender wheatgrass showed significantly higher values in the burned blocks in both sites. This species did not appear in measurable quantities until mid-July. It not only escaped fire damage, but likely found the growing conditions more favorable in the burned than the unburned environments.

The effect of burning on forbs showed some variations. In site 1 the total forbs value was significantly lower in the burned

Table 4. Basal cover differences between the burned and unburned blocks, site 1, means of 12 weeks measurements (values are in sq dm/20 sq dm).

Species	Unburned	Burned	Differences
Agropyron trachycaulum	0.15	0.25	+0.10**
Carex spp.	0.49	0.31	−0.18**
Danthonia unispicata	2.49	2.70	+0.21
Festuca idahoensis	0.27	0.13	−0.14**
Poa alpina	0.40	0.10	−0.30*
Stipa viridula	0.16	0.15	−0.01
Total grasses and sedges	3.95	3.65	−0.30**
Achillea millefolium	0.00	0.01	+0.01
Agoseris glauca	0.09	0.04	−0.05
Atennaria rosea	0.37	0.30	−0.07
Dodecatheon pauciflorum	0.02	0.00	−0.02
Fragaria virginiana	0.13	0.20	+0.07
Geum triflorum	1.70	0.90	−0.80**
Lupinus leucophyllus	0.14	0.17	+0.03
Phlox caespitosa	0.42	0.21	−0.21**
Potentilla gracilis	0.15	0.19	+0.04
Taraxacum officinale	0.03	0.21	+0.18**
Miscellaneous forbs	0.84	0.54	−0.30**
Total forbs	3.90	2.78	−0.12**
Artemisia tridentata	2.05	0.29	−1.76**
Potentilla fruticosa	0.65	0.15	−0.50**
Dead *Artemisia tridentata*	1.28	1.94	+0.66**
Dead *Potentilla fruticosa*	0.01	0.07	+0.06
Ash	0.00	2.46	+2.46**
Bare soil	0.62	0.49	−0.13
Lichen	0.44	1.06	+0.62**
Litter	10.99	9.54	−1.45**
Rock	0.00	0.12	+0.12**

* Significant differences at the 0.05 probability level.
** Significant differences at the 0.01 probability level.

Table 5. Basal cover differences between the burned and unburned blocks, site 2, means of 12 weeks measurements (values are in sq dm/sq dm).

Species	Unburned	Burned	Differences
Agropyron trachycaulum	0.11	0.19	+0.08*
Agrostis alba	0.18	0.08	−0.10
Bromus marginatus	0.72	0.55	−0.17*
Carex spp.	0.44	0.42	−0.02
Danthonia unispicata	0.03	0.05	+0.02
Festuca idahoensis	0.69	0.66	−0.03
Poa alpina	0.12	0.12	0.00
Stipa viridula	0.30	0.30	0.00
Total grasses and sedges	2.52	2.38	−0.14
Achillea millefolium	0.14	0.37	+0.23**
Agoseris glauca	0.32	0.34	+0.02
Antennaria rosea	0.07	0.15	+0.08
Aster scopulorum	0.24	0.43	+0.19**
Fragaria virginiana	0.01	0.04	+0.03
Geranium viscossissimum	0.62	0.49	−0.13
Geum triflorum	0.29	0.20	−0.09
Lupinus leucophyllus	0.32	0.34	+0.02
Myosotis sylvatica	0.28	0.26	−0.02
Potentilla gracilis	1.16	1.41	+0.25*
Taraxacum officinale	0.73	0.56	−0.17*
Miscellaneous forbs	0.84	0.74	−0.10
Total forbs	5.06	5.36	+0.30
Artemisia tridentata	1.46	0.08	−1.38**
Dead *Artemisia tridentata*	1.49	1.54	+0.05
Lichen	0.02	0.00	−0.02
Litter	10.63	8.61	−2.02**
Bare soil	1.54	3.56	+2.02**
Rock	0.08	0.03	−0.05

* Significant difference at the 0.05 probability level.
** Significant difference at the 0.01 probability level.

block than in the unburned block. In site 2 the total forbs value was nonsignificantly higher in the burned block.

Common yarrow and northwest cinquefoil showed higher basal cover in burned blocks than in unburned blocks in both sites. Common avens was reduced by burning at both sites. Tufted phlox, which occurred at site 1 only, was significantly reduced by burning. Crag aster, occurring only on site 2, increased significantly on the burned plots.

Big sagebrush was reduced significantly at both sites. Shrubby cinquefoil, occurring only at site 1, also was significantly reduced. Some resprouting of the latter species was noted.

The consistency of the pattern of changes of basal cover for most of the above species in both sites makes it possible to draw definite conclusions about the reaction of each species to fire as follows:

Species damaged by fire	**Species favored by fire**
Sedges	Slender wheatgrass
Idaho fescue	Common yarrow
Alpine bluegrass	Crag aster
Common avens	Northwest cinquefoil
Tufted phlox	
Big sagebrush	
Shrubby cinquefoil	

Interaction between burning effect and dates of observations was tested and found to be significant. Obviously these factors are not independent of each other. Regression lines were plotted for total grasses and total forbs of both sites to reflect the relationship between the basal cover measurement and dates of observations (Fig. 1). Forbs on the unburned blocks of both sites declined through the season from June 27 onward. The forb cover on the burned blocks was at lower levels at the beginning of the season but did not decrease as rapidly as on the unburned areas. Grasses increased through the season at both sites, but most rapidly on the burned block of site 2.

Vegetational Development

Most grasses and forbs showed slower vegetative growth in the burned blocks during the first few weeks of measurements. However, most species recovered in short time and the measurements were comparable after 5 or 6 weeks.

No clear differences were noticed in the rate of floral development between the burned and unburned blocks in the two sites; however there was less floral development in the burned areas. Most plant growth within these burned areas remained green while vegetational growth in surrounding unburned areas became quite dry.

Forage Production

Production 12 weeks following the burn tended to be lower on the burned than on the unburned range. The difference was statistically significant only for total grasses on site 2 with 490 kg/ha on the unburned block and 308 kg/ha on the burned range. Common avens was the only species showing a statistically significant response, this on site 1 with 294 kg/ha on the unburned block and 32 kg/ha on the burned block.

Conclusions

The most important factor affecting the results of this study was the nature of the burn. The burn was not a typical shrub-grassland burn in which all or most of the fuel caught fire and changed to ash, and hence contributed to the physical and chemical properties of the soil. The burn was started in unfavorable weather conditions and after considerable green growth, resulting in localized burned areas with surrounding areas not affected at all. The sampling procedures thus included both burned and unburned spots within the "burned blocks."

In addition to the natural differences between the two sites, the nature of the burn experienced in each site was quite different. In site 1, severe fire occurred resulting in many localized severely burned areas, while in site 2 the burn was light. These differences make it difficult to compare the effect of burning in the two sites.

The burn did not cause any major changes in soil physical properties.

Change in soil chemical properties were limited. The changes in the chemical properties tested appeared to be due more to normal changes in the ecosystem rather than to fire.

Burning resulted in a considerable reduction of basal cover of most of the vegetation. The reduction is mainly attributed to the direct damage caused by the fire. The differences between the burned and unburned blocks decreased as the season advanced.

Species respond differently to fire, some being damaged and others favored.

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