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Slash and duff reduction by burning on clear-cut jack pine sites in southeastern Manitoba



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**SLASH AND DUFF REDUCTION BY BURNING
ON CLEAR-CUT JACK PINE SITES IN SOUTHEASTERN MANITOBA**

BY

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ABSTRACT

Seventeen burns were carried out on dry to moist, clear-cut jack pine (*Pinus banksiana* Lamb.) sites in southeastern Manitoba. The burns were conducted over a range of Duff Moisture Codes that were then statistically correlated with the postburn duff depth and the postburn duff cover by groups of similar sites. Slash burned well under all conditions tested, but the reductions of duff depth and duff cover varied directly with the Duff Moisture Codes. The resulting straight-line regressions are suitable for predicting the duff reductions in future burning operations.

RESUME

Dix-sept brûlages ont été effectués en des stations de Pin gris (*Pinus banksiana* Lamb.) variant de sèches à humides, coupées à blanc, dans le sud-est du Manitoba. Les brûlages furent menés en couvrant un éventail d'Indices de l'humus qui furent ensuite statistiquement mis en corrélation avec l'épaisseur de l'humus brut après brûlage et avec la couverture (ou le couvert) d'humus brut après brûlage (par groupes de stations semblables). Les rémanents ont bien brûlé dans toutes les conditions expérimentées mais les réductions dans l'épaisseur de l'humus brut et la couverture d'humus brut varièrent en relation directe avec les Indices de l'humus. Les régressions en ligne droite résultant de cette expérience conviennent pour prévoir les réductions de l'humus brut lors de futurs brûlages.

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INTRODUCTION

Jack pine (*Pinus banksiana* Lamb)¹ does not regenerate adequately after harvest cutting in southeastern Manitoba, mainly because most of the surface duff, or raw humus, remains undisturbed. The moisture loss from the loose, upper portions of the duff is usually very high under normal drying regimes, and this alone creates poor conditions for seed germination and seedling survival. The situation, however, is further exacerbated by postcut accumulation of logging slash, which if excessive, may hinder pine regeneration through overshadowing. Moreover, a dense, tall, and robust postcut vegetation on some of the moister sites can suppress and eventually smother pine regeneration even if germination occurs.

Ongoing field studies in Ontario (Chrosiewicz 1959, 1967, 1968, 1970, 1974) and Minnesota (Ahlgren 1970) have shown that the postcut conditions can be effectively rectified and pine re-established through a rational use of burning either in the presence of seed trees or followed by direct seeding. In 1964, a program was initiated to test the various uses of burning under the climate and soil conditions prevalent on jack pine cutovers in southeastern Manitoba (Adams 1966; Cayford 1966). Since then, several burns in different combinations with mechanical scarification, seed-tree systems, direct seeding, and planting were tried, and evaluations are continuing.² Adjunct to the program were postburn studies of soil nutrients, vegetation, and microclimates (Sims 1976).

On the whole, the results of these early Manitoba trials were highly variable and failed to elucidate the specific conditions under which the right quantities of slash and duff could be burned to produce consistently favourable environments for pine regeneration. Therefore, additional burning tests were conducted in 1968 and 1969 to obtain this essential information. They were done on dry to moist sites at latitudes 49° 37'–49° 39' N and longitudes 96° 01'–96°

04' W, some 73 km by road east-southeast of Winnipeg, Manitoba. The results, as well as the guidelines for future use of burning on similar sites elsewhere in southeastern Manitoba, are presented in this report.

THE SITES

Physiography

The tests were carried out on three flat, clear-cut jack pine sites, each at a different elevation. The mineral soil materials were deep, podzolized fine sands on all three sites. The depths to ground water averaged by sites more than 2.4 m, 1.8 m, and 0.9 m, and the soil moisture regimes (Hills 1955) were 1, 2, and 4, respectively. In general, the sites matched Mueller-Dombois's (1964) habitat descriptions as "oligotrophic (nutritionally poor), dry, fresh, and moist types."

Slash and Duff

The original stands were 70–80 years old, with basal areas of about 18, 20, and 34 m²/ha on the dry, fresh, and moist sites, respectively. They were pure jack pine on the dry and fresh sites, and jack pine with a black spruce (*Picea mariana* (Mill.) BSP.) understory on the moist site. The stands were clear-cut in the spring of 1968, and only stumps and logging slash remained by the start of burning later in that year. The slash averaged in depth 0.3 m on the dry and fresh sites, and 0.5 m on the moist site. It was randomly distributed and provided an intermittent ground cover totalling about 60% on all three sites.

The duff consisted of moss and litter materials in varying states of decomposition, from the mostly unaltered state right at the surface down to, and including, the semifermented state with traces of true, well-decomposed humus just above the mineral soil. In terms of total stratum, the duff ranged in depth from 1 to 8 cm on the dry and fresh sites, and from 2 to 22 cm on the moist site. It was classified as "thin

¹ Species' nomenclature follows Scoggan (1957) for vascular plants, Crum *et al.* (1973) for mosses, and Hale *et al.* (1970) for lichens.

² Unpublished reports, N.R. Walker.

duff" and "thick duff", respectively. Some mineral soil was exposed during logging operations, but about 88 to nearly 100% of the original duff cover remained undisturbed.

Vegetation

Schreber's moss (*Pleurozium schreberi* (Brid.) Mitt.), strawberry (*Fragaria virginiana* Duchesne), low sweet blueberry (*Vaccinium angustifolium* Ait.), and rose (*Rosa acicularis* Lindl.) were among the main species growing on all three sites. Common bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.), mountain rice (*Oryzopsis pungens* (Torr.) Hitchc.), choke cherry (*Prunus virginiana* L.), and serviceberry (*Amelanchier alnifolia* Nutt.) occurred in large numbers on the dry and fresh sites, while twinflower (*Linnaea borealis* L. var. *americana* (Forbes) Rehd.) and raspberry (*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.) grew rather well on the fresh and moist sites. Reindeer moss (*Cladina rangiferina* (L.) Harm.), Canada everlasting (*Antennaria canadensis* Greene), and redroot (*Ceanothus ovatus* Desf.) were found almost exclusively on the dry site, whereas bunchberry (*Cornus canadensis* L.), sweet coltsfoot (*Petasites palmatus* (Ait.) Gray), blue joint (*Calamagrostis canadensis* (Michx.) Nutt.), bracken (*Pteridium aquilinum* (L.) Kuhn var. *latiusculum* (Desv.) Underw.), Labrador tea (*Ledum groenlandicum* Oeder), aspen (*Populus tremuloides* Michx.), and alders (*Alnus crispa* (Ait.) Pursh and *A. rugosa* (Du Roi) Spreng. var. *americana* (Regel) Fern.) grew in profusion on the moist site.

The vegetation averaged 0.3, 0.4, and 0.6 m in height on the dry, fresh, and moist sites, respectively, with some of the shrub heights ranging up to 1.8 m. The total moss cover was 20% on the dry and fresh sites, and 90% on the moist site. The herbs, grasses, and shrubs provided a combined cover of about 80% on all three sites.

METHODS

Experimental Layout

Seventeen 0.16-ha plots were involved in the burning tests, seven on the dry site and five each on the fresh and moist sites. The plots were 40 by 40 m, most situated in gridlike formations, and all individually enclosed by 6-m-wide bulldozed fire guards.

Ten uniformly spaced transects were established on each of the plots. The individual transects consisted of 20 sample quadrats, each 4 m² in area. The resulting 200 quadrats per plot provided for a 50% areal sampling.

Fuel Assessments

Most of the assessments on each plot were done by means of the 10 transects. They included determination of slash depths and cover before and after burning on 200 quadrats, and measurement of duff depths before and after burning at 200 randomly spaced steel observations pins. A dot-grid method was subsequently used in converting the mapped duff-cover information to numerical values. Changes in vegetative cover due to burning were, in each case, estimated for the entire plot area.

To determine their moisture contents, the slash and duff materials were sampled on each plot just before burning. The per-plot slash sample consisted of 30 sheared branch segments from exposed locations at 0.6 m above the ground, all 2.5 cm long, and replicating by groups of 10 the thicker-end diameters of 0.5, 1.3, and 2.0 cm. The per-plot duff sample consisted of 20 vertical cores, all taken with a 3.8-cm-across tubular auger to the depth of 2.5 cm, 10 from exposed locations outside slash and 10 from shaded locations under slash. These duff cores included surface moss and leaf litter. The sampled materials were subsequently transported in airtight containers to a field laboratory where they were weighed, dried at 100°C, and then weighed again when completely dry. The resulting differences were expressed as moisture contents in percentage of net oven-dry weights.

Weather Measurements

A master weather station was established in a large forest clearing near the plots on the dry and fresh sites, and some 4-5 km away from the plots on the moist site. Using standard methods of instrumentation, the factors measured at the station included rainfall, cloud cover, air temperature, relative humidity, and two concurrent wind speeds, one at the 1.2-m level and one at the 10.0-m level. Moreover, rainfall was measured at a number of substations next to

the plots on all three sites.

The weather measurements were taken daily at 12:00 Central Standard Time (CST), starting each year after a substantial rainfall at least 10 days prior to the first burn and ending with the last burn. The daily noon data for the preceding periods were obtained from the nearest provincial weather stations at Hadashville (rainfall) and East Braintree (cloud cover, air temperature, relative humidity, and wind speed) 8-12 km and 27-31 km away from the plots, respectively. Using these data, various fuel moisture codes and fire behavior indices were determined directly from appropriate tables (Anonymous 1976). The weather was also measured right on location before, during, and after each burn by portable instruments.

Burning and Fire Control

All burning was done between 13:30 and 17:30 CST on clear to partially cloudy, warm and dry days with low to moderate wind speeds (Table 1). Spring burning was tested on two plots, and summer burning on fifteen plots. By design, the burns were conducted over the range of Duff Moisture Codes (DMC's)³ 13-44 so that, in terms of duff consumption, different degrees of burn were obtained (Table 2). The codes were originally based on-duff materials similar to the ones in this experiment and, as such, they were considered suitable for rating the preburn moisture conditions. Moreover, the consistently high Fine Fuel Moisture Codes (FFMC's) of 86-92 on the days of burning ensured that the fine, dead aerial and surface fuels were sufficiently dry for easy ignition. Other associated ratings included the Buildup Indices (BUI's) of 22-63, the Initial Spread Indices (ISI's) of 4-15, and the Fire Weather Indices (FWI's) of 11-26. The selection of conditions for burning slash posed no problem because, as shown by other experiments (Chrosiewicz 1959, 1967; Van Wagner 1966), any fire for duff reduction automatically consumed all, or most, of the finer slash materials.

Each burn began as a U-shaped backfire and was completed by a headfire. At wind speeds of 8 km/h or less, about 10-20% of the plot area was burned over by the

backfire before the headfire was started. At wind speeds exceeding 8 km/h, the ignition of fuels for the headfire was usually delayed until 30-40% of the plot area was burned over by the backfire. The flames averaged 1.0-1.8 m in height for the backfires, and 1.5-2.6 m for the headfires, with occasional ones reaching as high as 7.6 m. However, the protection crew had no difficulty in confining the burns within the plots.

Data Analysis

Burning of slash and vegetation was effective for all conditions tested (Fig. 1) and it required no further analysis. Similarly, there were no discernible differences in duff consumption between backfires and headfires, so that corresponding distinctions were not maintained when the data were analyzed. However, preliminary summations and plotting of the results in terms of duff-depth and duff-cover reductions by the different DMC's showed a number of variation trends. This, in turn, provided a basis for analyzing the duff-reduction data in two distinctive groups, one containing the results of ten summer burns on the dry and fresh sites, and one containing the results of five summer burns on the moist site. The duff-reduction data from the two spring burns did not fit any of the variation patterns and, because of this, they were excluded from grouping with the other data.

The mean duff depths before burn (Table 2) varied considerably, owing to a chance distribution of the individual preburn duff-depth values on the different sites. Moreover, the total areas burned (Table 2) showed substantial variations, and many of the observation pins were found within the unburned patches. To overcome this lack of standardization all duff-depth measurements within the unburned patches were excluded from further analysis, and for the remaining data, common preburn duff-depth ranges were established by groups of burns to be compared. These ranges were 1.1-6.0 cm for the ten burns on the dry and fresh sites, and 5.1-15.0 cm for the five burns on the moist site. Subsequently, only the preburn duff-depth values together with their postburn counterparts within the predetermined ranges were used in computing the new means. The mean duff-depth values

³ For definitions of the codes and indices as used in this report see Van Wagner (1974) and Anonymous (1976).

TABLE 1. Duff moisture codes and weather on days of burn

Duff Moisture Code	Plot No.	Mean weather during burn				Date of burn —	Time of burn C S T
		Cloud cover ^a %	Air temperature ^b °C	Relative humidity ^b %	Wind speed ^b km/h		
Spring burning, thin duff over fine sand, soil moisture regime 1							
36	1	0	19	20	13	22 May '69	13:30-14:30
44	2	80	19	29	14	25 May '69	"
Summer burning, thin duff over fine sand, soil moisture regime 1							
16	6	10	30	29	10	10 Aug. '69	13:30-14:30
20	9	0	27	46	10	13 Sep. '68	"
31	7	0	32	46	10	22 Aug. '69	"
34	5	65	21	50	10	25 Jul. '69	"
41	8	50	31	46	10	25 Aug. '69	"
Summer burning, thin duff over fine sand, soil moisture regime 2							
13	12	0	24	39	10	10 Sep. '68	14:30-15:30
16	14	5	31	30	10	10 Aug. '69	"
31	15	0	32	40	10	22 Aug. '69	"
34	13	55	21	48	10	25 Jul. '69	"
41	16	45	30	48	8	25 Aug. '69	"
Summer burning, thick duff over fine sand, soil moisture regime 4							
16	28	5	30	32	2	10 Aug. '69	16:30-17:30
24	30	45	22	47	3	19 Aug. '69	"
33	29	30	18	48	3	25 Jul. '69	"
33	31	0	32	38	5	22 Aug. '69	"
43	32	20	28	48	2	25 Aug. '69	"

^a Ocularly estimated.

^b Measured at 1.2 m above ground.

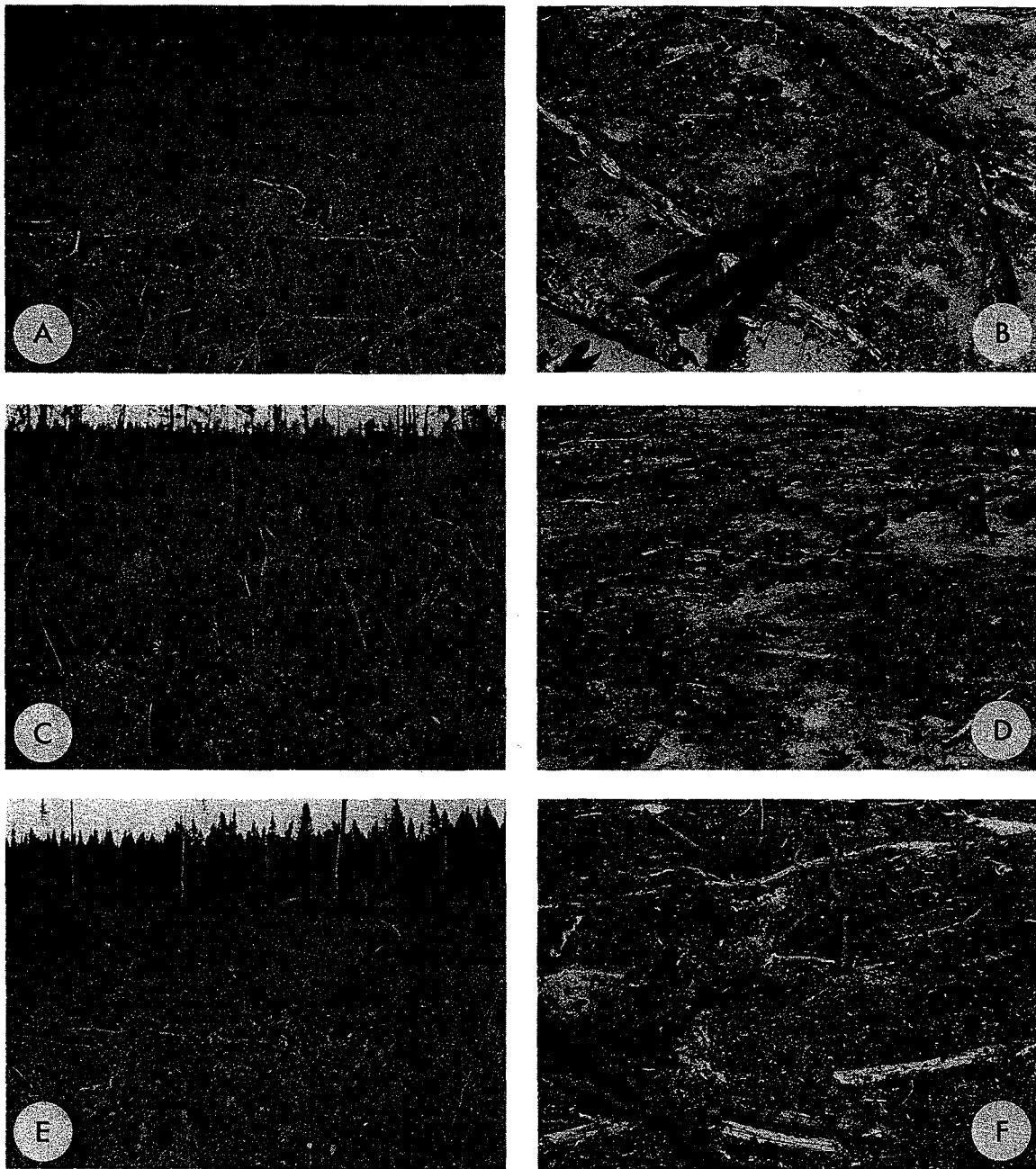


Figure 1. Typical examples of slash conditions before and after burning on dry site (A, B), fresh site (C, D), and moist site (E, F). Note differences in postburn exposure of mineral soil.

TABLE 2. Duff conditions before and after burn

Duff Moisture Code	Plot No.	Preburn duff moisture ^a %	Mean duff depth		Total duff cover		Total area burned ^c %
			Before burn ^b cm	After burn ^b cm	Before burn ^c %	After burn ^c %	
Spring burning, thin duff over fine sand, soil moisture regime 1							
36	1	48	2.6	0.6	97.4	44.5	97.4
44	2	23	1.6	0.3	94.0	35.7	93.7
Summer burning, thin duff over fine sand, soil moisture regime 1							
16	6	75	2.3	1.8	90.4	80.3	69.1
20	9	59	2.6	1.4	96.1	74.8	95.9
31	7	27	3.1	1.3	97.4	67.8	76.9
34	5	24	3.2	0.8	93.7	55.1	89.1
41	8	14	3.1	1.4	93.4	62.9	73.3
Summer burning, thin duff over fine sand, soil moisture regime 2							
13	12	139	2.6	1.9	98.5	92.1	77.4
16	14	58	1.6	1.2	96.3	87.6	74.9
31	15	42	3.4	1.8	88.1	67.7	64.3
34	13	29	2.9	1.2	95.7	62.2	78.4
41	16	19	3.2	1.3	98.7	70.3	85.0
Summer burning, thick duff over fine sand, soil moisture regime 4							
16	28	127	9.0	8.4	99.7	96.2	70.5
24	30	110	8.2	6.5	99.7	94.2	71.0
33	29	105	9.8	8.2	99.4	96.6	59.9
33	31	78	12.4	10.3	99.9	90.9	50.6
43	32	93	10.8	7.8	99.8	88.7	81.9

^a Each value based on 20 duff samples, 10 outside slash and 10 under slash
- all taken to a depth of 2.5 cm.

^b Each value based on 200 direct duff measurements.

^c Each value based on mapping to scale duff areas - sampling 50%.

before and after burn so computed were then adjusted to the representative constant duff depths before burn, 3.0 cm on the dry and fresh sites, and 9.0 cm on the moist site. Similarly, the corresponding total duff-cover values after burn (Table 2) were adjusted to the constant 100% duff cover before burn.

Using the adjusted mean duff-depth and total duff-cover values after burn as variables Y and DMC's as variables X, linear regressions, correlation coefficients (r), and standard errors of estimate ($s_{y.x}$) (Snedecor 1956) were calculated and shown in relation to the constants (Figs. 2 and 3). No substantially better regressions were obtained when the BUI's were substituted as variables X. In fact, the correlation coefficients (r) for both these types of X differed little and were significant, if at all, at identical probability levels. There was, moreover, no evidence that fire behavior, as rated by the ISI's and FWI's, had a differential effect on the reductions of duff depth and duff cover. The moisture content of duff was obviously the controlling factor, with fire behavior assuming a subordinate position. Similar conclusions were drawn from other experiments (Chrosiewicz 1959, 1967, 1978; Van Wagner 1966).

RESULTS

Consumption of Slash

The conditions for burning slash and other aerial fuels were generally favorable. Being in most cases inversely related to the FPMC's 86-92, the preburn moisture content of the finer <2.0-cm slash was consistently low, ranging for all seventeen plots from 11 to 15%. This resulted in a "clean" burn over a greater portion of each plot, where slash, aerial parts of vegetation, and surface litter were destroyed (Fig. 1). The remaining organic materials included surface-charred stumps and other large pieces of wood, partially burned duff with some unburned plant roots, and occasional patches of unburned litter and duff over which the plants became scorched. The unburned patches occurred mainly in those places where localized lack of slash, exposed mineral soil and seasonally lush vegetation in various combinations created substandard burning conditions. Reflecting these conditions, the total area burned (Table 2) varied by plots from 50.6 to 97.4%.

Reduction of Duff Depth and Cover

Burning under the DMC's 13-44 (Table 2) was associated with a highly variable moisture content in the upper 2.5 cm of duff. For all seventeen plots, this content ranged from 14 to 139%, showing mostly an inverse relation to the codes and generally increasing by sites with the soil moisture regime. The differentiation in the moisture content of duff by similar codes was considerably less pronounced between the dry and fresh sites (soil moisture regimes 1 and 2) than between the fresh and moist site (soil moisture regimes 2 and 4). However, under identical site conditions and roughly comparable codes, the moisture content of duff was substantially higher in the spring than in the summer.

All of these variations in the moisture content of duff had a strong effect on the reduction of duff depth and duff cover by burning. The mean duff depth (Table 2) ranged by plots from 1.6 to 12.4 cm before burn, and from 0.3 to 10.3 cm after burn. Similarly, the total duff cover (Table 2) ranged by plots from 88.1 to 99.9% before burn, and from 35.7 to 96.2% after burn. Figures 2 and 3 show the reductions for fifteen summer burns by means of calculated regressions of the postburn depths and covers over the corresponding moisture codes, all in relation to the preburn constants.

The regressions for the summer burning of thin duff on the dry and fresh sites (Fig. 2) revealed strong rectilinear relationships between the DMC's and both the postburn duff depth and the postburn duff cover. The r values of -0.93 and -0.91 were both highly significant (1% probability level). However, the regressions for the summer burning of thick duff on the moist site (Fig. 3) showed rectilinear relationships that were moderately strong between the DMC's and the postburn duff depth, and rather weak between the DMC's and the postburn duff cover. Here, the r values of -0.90 and -0.59 were significant (5% probability level) and not significant, respectively.

DISCUSSION

The experiment clearly demonstrates that the results of burning on clear-cut jack pine sites are predictable in southeastern Manitoba. Provided that the slash and the duff are similar, the regressions in Figs. 2 and 3 can be used as guides in future burning

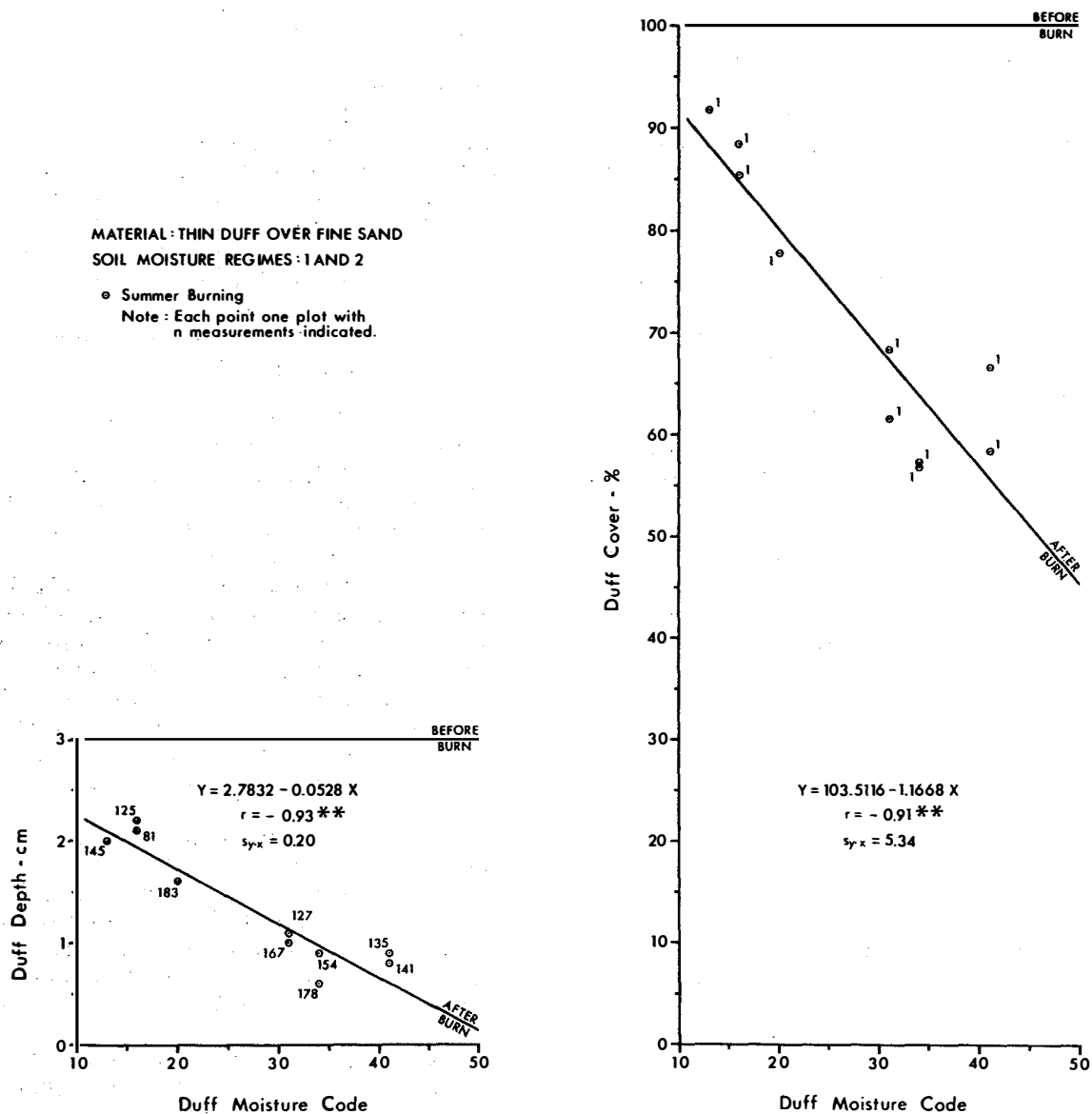


Figure 2. Reduction of duff depth (left) and duff cover (right) when burning thin duff on dry and fresh sites. Coefficients of correlation (r) with Duff Moisture Codes significant at 1% probability level ($**$) for both depth and cover.

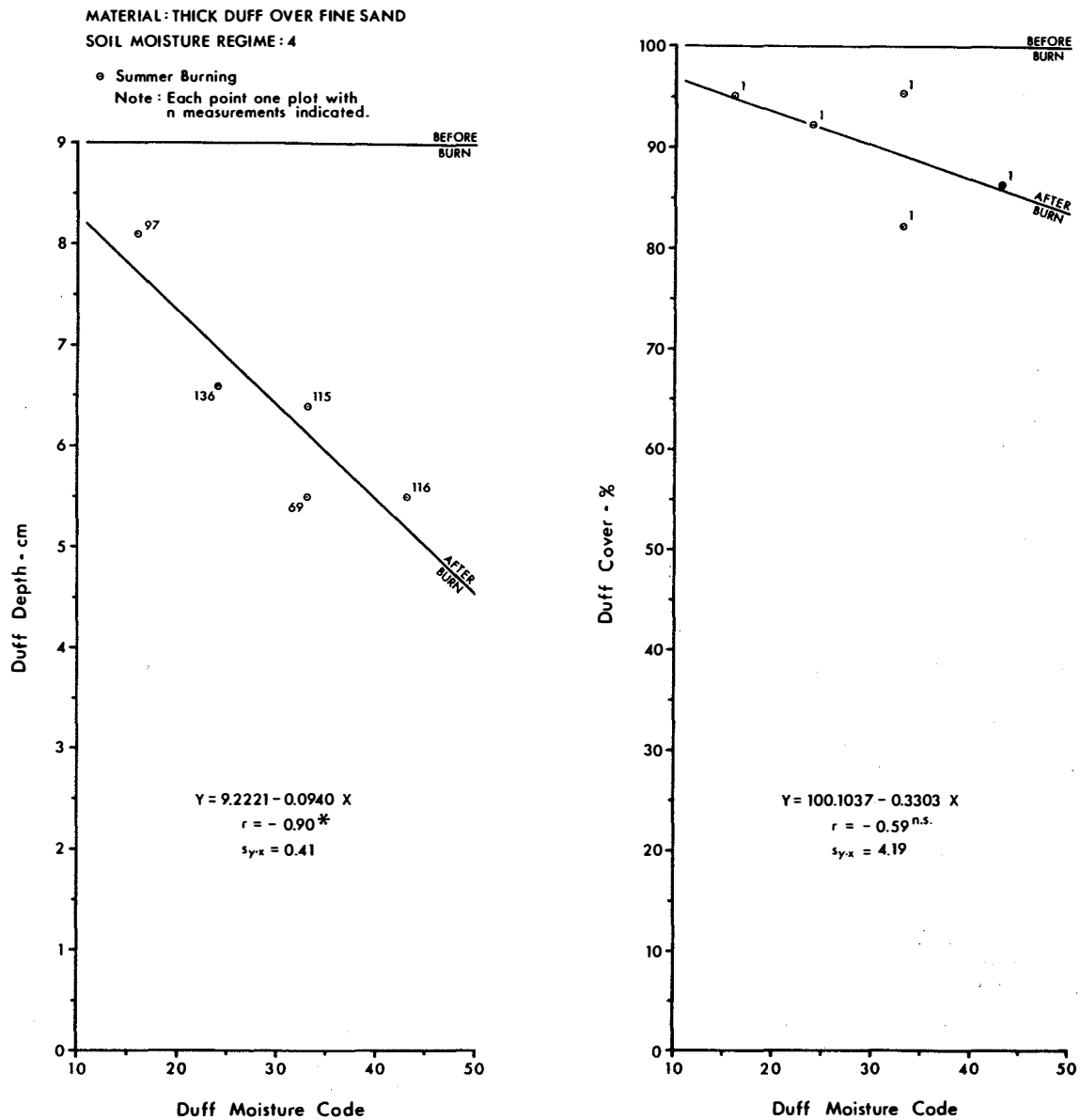


Figure 3. Reduction of duff depth (left) and duff cover (right) when burning thick duff on moist site. Coefficients of correlation (r) with Duff Moisture Codes significant at 5% probability level (*) for depth, and not significant (n.s.) for cover.

operations. Adequate measurements of local weather and daily determinations of moisture codes by a standard method (Anonymous 1976) are the preliminary requirements. Next, one should find out whether the fuels to be burned are on a dry to fresh upland site or whether they are on a moist lowland site. Knowing this, the burning operations may then be carried out on some summer afternoon with a preselected DMC best fitting the desired reduction of duff depth and cover. The selection can be made from Figs. 2 and 3 either directly by interpreting the regression lines, or better, by solving the regression equations for variables X.

The conditions for burning duff are usually more than adequate for burning slash (Chrosciewicz 1967). This experiment shows that satisfactory results are obtained when the slash is burned under the FPMC's 86-92. However, if the objective is to burn the fine components of slash and not much else, except perhaps a few plants and surface litter under the slash, then the required conditions will be less exacting. In fact, there are indications (Chrosciewicz 1978) that the slash will burn well under an FPMC as low as 81. The green slash, of course, must go through a certain period of curing before it can burn effectively. A complete browning of foliage on the slash itself will normally indicate readiness for burning. Surface wind speeds of about 8 km/h are sufficient to propagate the fire in dry slash.

Various techniques and other aspects of burning on jack pine cut-overs are described in the literature (Chrosciewicz 1959, 1967, 1968, 1970, 1974, 1978; Beaufait 1962; Adams 1966; Cayford 1966; Van Wagner 1966; Ahlgren 1970; Sando *et al.* 1970; Sims 1976), and they all warrant careful consideration. This report provides the much needed complementary information on the uses of fuel moisture codes (Van Wagner 1974; Anonymous 1976) in implementation of burning objectives.

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