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SOME ASPECTS OF REGENERATION SILVICULTURE IN SPRUCE-ASPEN STANDS IN ALBERTA

by

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IN SPRUCE-ASPEN STANDS IN ALBERTA

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INTRODUCTION

Surveys of spruce-aspen stands in northern Alberta have shown that natural regeneration of white spruce is generally a failure on areas which have been logged but not burned (Candy 1951). The possibility that scarification might improve spruce regeneration in such areas has been investigated and the results strongly indicate that with an adequate seed supply and favourable climatic conditions, scarification would result in adequate stocking (Quaite 1956). The following investigation was initiated by Quaite[2] in 1952 in a 110-year-old spruce-aspen stand near Smith, Alberta, to determine:

(a) Whether to scarify before or after logging,

(b) The duration of improved seedbed conditions after scarification,

(c) The effect of residual stand density on the germination and survival of spruce seedlings.

METHODS

The Study Area

The treated stand is in the B-18 section of the Boreal Forest (Halliday 1937). The local topography consists of a series of prominent but gently rolling ridges with muskegs and grassy sloughs occurring in the depressions and low-lying areas.

The soil, representative of the grey wooded type is predominantly fine sandy-loam in texture. Clay loam appears in the depressions and muskegs. In general, the soil profiles are characterized by a leached A_2 horizon and a dark brown-grey crumbly B_2 horizon over a calcareous parent material. The thickness of the duff varies from three inches on the ridges to one foot in the low-lying areas.

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C O N T E N T S

The Stand

The stand is typical of the mixedwood association in this section of Alberta. White spruce and aspen, with the aspen predominating, are the main species, with black spruce and larch occupying the wet lowlands and muskegs. Other species such as black poplar and jack pine are relatively scarce.

The stand age averages 110 years for the spruce and slightly more than 110 years for the aspen. In general the main stand of spruce is sound though diameter increment has decreased. Most of the aspen is decadent and the younger spruce, which became established following ground fires 48 years ago, is suppressed.

Ground cover on portions of the stand supporting pure spruce consists mainly of feather mosses and scattered herbs. Where aspen occupies the largest portion of the stand, tall shrubs such as rose and highbush cranberry are dominant.

Experimental Treatments and Design

The experimental design of this project includes three treatments: residual stand density (four levels), time of scarification (two levels), seedbed condition (three levels).

The details of these treatments are as follows:

A. Residual Stand Density

(1) Uncut - No logging disturbance,

(2) Heavy residual stand - Selectively logged leaving 8,000 f.b.m. per acre,

(3) Medium residual stand - Selectively logged leaving 5,000 f.b.m. per acre,

(4) Light residual stand - Selectively logged leaving 2,000 f.b.m. per acre.

In this logging operation, only merchantable white spruce seven inches and over in diameter at breast height were felled. The lack of a market for aspen prevented its utilization. The board foot volumes per acre before and after logging are shown in Tables 1 and 2.

B. Time of Scarification

(1) Before logging - June and July 1952.

(2) After logging - September 1952.

Scarification both before and after logging was done with a T-D9 Caterpillar tractor equipped with a nine-foot dozer blade. Scarified spots were created by repeatedly lowering and raising the blade as the bulldozer moved through the stand. A series of patches of scarified soil were located in parallel strips. The size of each patch was roughly eight feet by five feet and the distance between patches on a strip was roughly 15 feet. Generally only one run with the tractor was necessary to provide a mineral soil seedbed; however, where the duff was one or more feet in thickness, two and sometimes three passes had to be made to expose mineral soil.

TABLE 1

BOARD FOOT VOLUMES PER ACRE BEFORE LOGGING FOR WHITE SPRUCE AND HARDWOODS

RESIDUAL STAND	DIVISION OF TREATED STANDS									
	BLOCK 1		BLOCK 2		BLOCK 3		BLOCK 4		BLOCK 5	
	W.S.	HDWD.	W.S.	HDWD.	W.S.	HDWD.	W.S.	HDWD.	W.S.	HDWD.
UNCUT	12,973	5,473	10,028	6,642	14,027	7,785	15,347	8,744	9,985	8,314
HEAVY	13,731	3,129	9,094	11,814	17,880	4,380	13,966	8,604	11,756	6,736
MEDIUM	6,159	7,198	7,442	9,320	9,908	8,243	11,199	6,790	10,119	5,213
LIGHT	6,512	11,729	6,336	10,018	13,037	2,269	2,411	8,841	6,497	8,609

TABLE 2

BOARD FOOT VOLUMES PER ACRE AFTER LOGGING FOR WHITE SPRUCE AND HARDWOODS

RESIDUAL STAND	DIVISION OF TREATED STANDS									
	BLOCK 1		BLOCK 2		BLOCK 3		BLOCK 4		BLOCK 5	
	W.S.	HDWD.	W.S.	HDWD.	W.S.	HDWD.	W.S.	HDWD.	W.S.	HDWD.
UNCUT	12,973	5,473	10,028	6,642	14,027	7,785	15,347	8,744	9,985	8,314
HEAVY	7,884	3,129	7,717	11,814	7,845	4,380	8,5[illegible]5	8,604	7,368	6,736
MEDIUM	4,718	7,198	4,253	9,320	4,959	8,243	5,650	6,790	5,388	5,213
LIGHT	2,138	11,729	2,238	10,018	2,471	2,269	2,411	8,841	2,097	8,609

C. Seedbed Condition

(1) Scarified - the litter and humus were removed and mineral soil exposed.

(2) Mounded - areas of mixed litter, humus and mineral soil, deposited by the bulldozer blade at the end of a scarified patch.

(3) Undisturbed - no disturbance of litter or humus.

The design of the experiment called for five replications of each treatment. The residual stand density treatments were laid out on the ground in a replicated randomized block design. Scarification and seedbed treatments were added to the design on a non-random split plot basis.

In the field a total of 40 one-half-acre plots were located. These were combined on a basis of physiographic site condition into five comparable blocks. In each block two plots were assigned at random to a residual stand density treatment, (Figure 1). Average board foot volumes of these blocks and residual stand density levels are shown in Tables 1 and 2.

The two other treatments, time of scarification and seedbed condition, were then located by dividing each ½-acre plot into 4 equal strips in a north-south direction. Strips 1 and 3 were scarified before logging and strips 2 and 4 after logging. In each scarification strip, 10 ¼-milacre sample units of the scarified seedbed condition and 10 samples of the mounded condition, were selected. The third seedbed condition was sampled by selecting 20 ¼-milacre units on each plot from the undisturbed area between the scarification strips (Figure 2).

This design provided a total of 100 ¼-milacre quadrats per ½-acre treatment plot or a total of 4000 quadrats. The disposition of these quadrats by stand treatment and seedbed condition classes is shown in Table 3.

TABLE 3

DISTRIBUTION OF THE 4,000 ¼-MILACRE QUADRATS ACCORDING TO TREATMENT

RESIDUAL STAND TREATMENT	SEEDBED TREATMENT		
	SCARIFIED	MOUNDED	UNDISTURBED
Uncut Residual Stand	400	400	200
Heavy " "	"	"	"
Medium " "	"	"	"
Light " "	"	"	"
TOTAL	1600	1600	800

The first tally of germination was made in June 1956 following a moderate spruce seed crop of the previous year[3].

Remeasurement of Regeneration

For the first three years following treatment the spruce seed crops were either very low, or as in the case of the moderate 1954 crop, infected with a cone rust which destroyed the viability of the seed. Observation indicated that while some regeneration was becoming established, it was insufficient to justify a major remeasurement of results. However, following the moderate seed crop of 1955, this investigation was initiated by carrying out bi-weekly tallies of germination and survival of spruce seedlings during the 1956 field season. The tally was carried out on a subsample of 500 of the marked quadrats; which constituted a stratified random sample of the initial 4000 quadrats, and which were distributed as shown in Table 4. In 1957 survival tallies in the spring and fall were carried out to assess overwinter and second season mortality.

In addition to the germination and survival tally a stocking survey based on the 4000 ¼-milacre quadrats was undertaken in September of 1956. Each quadrat that supported one or more spruce seedlings, which had become established since 1952, was classed as stocked.

TABLE 4

DISTRIBUTION OF THE 500 ¼-MILACRE QUADRATS USED IN 1956 SPRUCE GERMINATE STUDY

RESIDUAL STAND TREATMENT	SEEDBED TREATMENT		
	SCARIFIED	MOUNDED	UNDISTURBED
Uncut Residual Stand	50	50	25
Heavy " "	"	"	"
Medium " "	"	"	"
Light " "	"	"	"
TOTAL	200	200	100

RESULTS

Table 5 provides a summary of the number of spruce seedlings, resulting from the 1955 seed crop, which had germinated on the 500 ¼-milacre subsamples by June 30 of 1956. The figures in brackets in Table 5 indicate the average number of seedlings per stocked quadrat. Table 6 shows the per cent stocking by ¼-milacre quadrats for the various treatments included in the study.

[3]Field measurements were carried out by G. Ontkean, Former Forestry Officer, Forestry Branch, Calgary.

Tables 5 and 6 were prepared following an analysis of variance which showed that there was no significant difference in either number of seedlings or per cent stocking between blocks or between times of scarification. The results in Tables 5 and 6 therefore combine the figures for all blocks and both times of scarification.

It is apparent from Table 5 that the scarified seedbeds produced 14 times as many seedlings as the mounded conditions and 60 times the number produced on the undisturbed condition. A comparison of these results in terms of residual stand density indicate no appreciable difference in germination as a result of density of overstorey. The bracketed figures in Table 5 represent average number of seedlings per stocked quadrat. It may be noted that these figures are quite low and do not differ greatly as a result of either stand treatment or seedbed condition. In Table 6 the per cent stocking figures for spruce seedlings also show that while there are only minor differences between residual stand density treatments, the scarified condition is a consistently better seedbed than either the mounded or undisturbed conditions.

TABLE 5

NUMBER OF SPRUCE GERMINATES AND AVERAGE NUMBER PER STOCKED QUADRAT JUNE 1956

RESIDUAL STAND TREATMENT	SEEDBED CONDITION		
	SCARIFIED	MOUNDED	UNDISTURBED
Uncut Residual Stand	52 (2.9)	2 (1)	0 0
Heavy " "	25 (2.0)	0 0	0 0
Medium " "	19 (1.7)	4 (1.3)	2 (2.0)
Light " "	29 (1.8)	3 (1.5)	0 0
Total Seedlings - Total No. of Quadrats	125 200	9 200	2 100

TABLE 6

PER CENT STOCKING OF SPRUCE GERMINATES JUNE 1956

RESIDUAL STAND TREATMENT	SEEDBED CONDITION		
	SCARIFIED	MOUNDED	UNDISTURBED
Uncut Residual Stand	[1]36 (83)[2]	4 (15)	0 (0)
Heavy " "	26 (70)	0 (0)	0 (0)
Medium " "	22 (63)	6 (22)	8 (28)
Light " "	32 (79)	4 (15)	0 (0)
Average	29.0	3.5	2.0

[1]Stocking based on ¼-milacre quadrats.
[2]Estimate of 1 milacre quadrat stocking.

In Table 7, the first year mortality figures from June to September, 1956 for the various treatments have been expressed as percentages. Little reliance can be placed on the figures for mounded and undisturbed seedbeds since the number of seedlings is very low. More detailed examination of mortality on scarified seedbeds did not indicate any significance to the apparent trend of reduced mortality under lighter overstorey conditions.

In Table 8 survival data and per cent mortality figures are shown for the scarified quadrats during the first two seasons following germination. While the first growing season mortality has been slightly lower than that of other studies under similar conditions (Ackerman 1956 and 1957), the overwinter and second season mortality has been far below normal.

TABLE 7

FIRST YEAR MORTALITY OF SPRUCE SEEDLINGS
JUNE 1956 - SEPT. 1956

RESIDUAL STAND TREATMENT	PER CENT MORTALITY JUNE TO SEPT. 1956		
	SCARIFIED	MOUNDED	UNDISTURBED
Uncut Residual Stand	46	50	-
Heavy " "	41	-	-
Medium " "	24	75	50
Light " "	26	33	-

TABLE 8

NUMBER OF SEEDLINGS AND MORTALITY
ON SCARIFIED SEEDBEDS 1956-1957

RESIDUAL STAND TREATMENT	NUMBER OF SEEDLINGS						
	June 1956	Mort.	Sept. 1956	Mort.	June 1957	Mort.	Sept. 1957
Uncut Residual Stand	52	24	28	1	27	0	27
Heavy " "	29	12	17	1	16	1	15
Medium " "	25	6	19	1	18	0	18
Light " "	19	5	14	3	11	0	11
Total	125	47	78	6	72	1	71
Cumulative Mortality in Per cent		38		42		43	

This level of mortality, however, does not appear to have reduced the per cent stocking below an acceptable level. In Table 9 the per cent stocking figures for June and September of 1956 and 1957 are presented on a ¼-milacre quadrat basis together with estimated figures on a one milacre basis (after Grant 1951). The data for scarified quadrats only are presented since Tables 5 and 6 have already indicated the almost complete failure of germination on mounded and undisturbed seedbeds. Table 9 shows that the reduction in stocking over the two-year period of study has not been excessive and that the greatest reductions in percentage stocking have taken place during the first summer following germination. Both overwinter and second growing season mortality have been relatively light. The estimated milacre stocking figures indicate that stocking would vary from well-stocked to acceptable on scarified ground.

In order to provide a more intensive sample of the results of this investigation, a stocked quadrat survey was undertaken in September of 1956 on the 4000 one-quarter milacre quadrats located on the area. Any quadrat having one or more spruce seedlings which had resulted from germination since 1952 was classed as stocked. The results have been expressed in terms of estimated milacre stocking for the various cutting and seedbed treatments (Table 10). These data confirm the results of the smaller sample. While there is no marked difference in seedling establishment as a result of the overstorey density, it is apparent that only the scarified seedbed has produced an acceptable stocking.

TABLE 9

THE EFFECT OF MORTALITY ON STOCKING PER CENT OF THE SCARIFIED ¼-MILACRE QUADRATS

RESIDUAL STAND TREATMENT	STOCKING PER CENT			
	June 1956	Sept. 1956	June 1957	Nov. 1957
Uncut Residual Stand	36 (83)[1]	26 (70)	24 (67)	22 (63)
Heavy " "	26 (70)	18 (54)	16 (50)	16 (50)
Medium " "	22 (63)	18 (54)	16 (50)	16 (50)
Light " "	32 (79)	26 (70)	26 (70)	20 (59)

[1]Estimated one milacre stocking.

TABLE 10

NUMBER OF ¼-MILACRE QUADRATS STOCKED AND THE PREDICTED RANGE OF STOCKING ON A MILACRE BASIS FOR 4000 ¼-MILACRE QUADRATS, SEPTEMBER 1956

RESIDUAL STAND	SEEDBED TREATMENT								
	SCARIFIED			MOUNDED			UNDISTURBED		
	Number of ¼-Milacre Quadrats		Predicted Milacre Stocking	Number of ¼-Milacre Quadrats		Predicted Milacre Stocking	Number of ¼-Milacre Quadrats		Predicted Milacre Stocking
	Examined	Stocked		Examined	Stocked		Examined	Stocked	
UNCUT	400	125	77%	400	14	Below 10%	200	3	Below 10%
HEAVY	400	75	54%	400	9	" "	200	1	" "
MEDIUM	400	93	64%	400	3	" "	200	4	" "
LIGHT	400	89	63%	400	9	" "	200	11	" "

DISCUSSION

While the results of this experiment cannot be accepted as a large-scale practical trial of scarification in partially cut mixedwood stands, they illustrate the behaviour of some of the factors involved in scarification and cutting method. The treatments were carried out over the typical range of site conditions encountered in mixedwood stands in the B-18 section of Alberta (Halliday 1937). The soil textures in the study area varied from fine sandy loams to clay loams. In general the lighter soils occurred on the ridges and higher ground, while heavier textures predominated in the moist depressions. Moisture conditions on these sites varied from somewhat dry on the exposed ridges and knolls to somewhat wet in the depressions. In terms of moisture regime (after Hills) the conditions would include the 1-6 moisture regimes.

While the study was not specifically designed to investigate the effects of site condition upon reproduction of spruce, observation did not indicate any obvious relationship between the site and seedling establishment on scarified ground. On unscarified ground the regeneration success was so poor that no site preference could be distinguished.

Initial investigation showed no difference in seedling success on areas scarified before and after logging. This, however, was to be expected since little or no seed was available until after both treatments had been completed.

Because of the similarity between some aspects of this experiment and work carried out at the Riding Mountain Forest Experiment Station, Manitoba, brief comparisons of the results of these two studies are in order.

In this experiment the number of seedlings germinating on 200 one-quarter milacre scarified plots was 125, or an equivalent of 2500 seedlings per acre. In contrast, Rowe (1955) in Manitoba records that 9317 seedlings germinated in 1949 on 900 one-eighth milacres, an equivalent of 82,930 seedlings per acre. Germination in 1948, 1950 and 1951 was, respectively, 7000, 120 and 350 seedlings per acre. It is apparent that wide fluctations in germination can be expected from year to year as a result of variations in seed supply. The exceptional success of the 1949 germination probably relates to an exceptionally heavy spruce seed crop in 1948. Certainly, in Alberta, many observers noted the abundance of this seed crop. Based on this comparison, it may be inferred that the 1955 seed crop in Alberta was only moderately heavy.

Percentage mortality figures from this experiment have been substantially lower than those of other experiments involving spruce reproduction on scarified ground. This result is particularly evident in the case of the overwinter and second year's survival. These results can, however, be explained by the favourable weather conditions of 1957. A heavy blanket of snow reduced frost penetration which may have minimized frost heaving damage to seedlings, while the abnormally wet summer of 1957 undoubtedly increased survival during the growing season. Comparative survival results from Manitoba (Rowe 1955) indicated 80 per cent mortality on scarified ground during the first three years. Such figures are in agreement with the results of other survival studies of spruce seedlings in Alberta (Ackerman 1956 and 1957). It must therefore be inferred that the favourable weather conditions may greatly influence early survival of spruce seedlings and that considerable variation in mortality may be expected from year to year. While Rowe notes that the main cause of mortality in his studies was smothering by aspen leaves, this factor had only a minor influence on survival in this study. The Manitoba scarification took the form of plowed furrows while the Alberta treatment consisted of smooth scarified depressions; presumably the ridges and hollows of the furrows formed a natural trap for wind-blown leaves which subsequently increased mortality.

The results of this study have demonstrated the relative success of germination on various seedbed media. Scarified ground provided an excellent seedbed while neither mounded or undisturbed conditions were satisfactory. The failure of the mounded seedbed, which consisted of accumulations of broken slash, mineral soil, litter and duff, suggests that the availability of moisture is one of the determining factors in successful germination and establishment of spruce seedlings. In spite of its mineral soil component, the mounded condition was not sufficiently compacted to form a moisture-retentive seedbed.

The amount of spruce left in the overstorey (2000 to 14,000 f.b.m. per acre) did not materially influence the success of regeneration on the scarified seedbeds, and it can be assumed that the seed supply was not a limiting factor in the treatments. Except in the case of the uncut stands, differences in the density of the total overstorey (both spruce and aspen) were not sufficiently consistent between treatments to draw definite conclusions as to the influence of the overstorey on the regeneration. However, it would seem that at this stage of development, competition from the overstorey is not a limiting factor, especially since the best regeneration generally occurs in the uncut stands. For the regeneration to develop in a satisfactory manner, reduced overstorey densities will, of course, be required. Information on this point will be available from later work on this project and from others now in progress.

In view of the periodicity of heavy white spruce seed crops, the duration of receptivity of a scarified seedbed becomes important. In this study, receptivity is gradually being reduced by the invasion of lesser vegetation and the accumulation of aspen litter; the former being the more important factor. The scarified seedbeds are, however, still receptive 5 years after treatment and observation suggests that they will continue to be so for an additional 2 years.

Sucker reproduction of aspen following the treatment did not represent a serious problem in this experiment, but the aspen suckers were most frequent on the heavily cut areas. This situation might become more serious with an attempt to secure a higher percentage of scarified seedbed. Surprisingly, aspen suckers occurred with greater frequency on undisturbed conditions than on scarified locations.

The adequacy of spruce stocking on the scarified areas of this study is open to question. Mortality was subnormal and if the trends suggested by Rowe (1955) are accepted; i.e. 80 per cent reduction in number of stems during the first three years, it may be concluded that milacre stocking will drop to 35-40 per cent. However, if it is considered desirable to maintain the mixed character of these stands by fostering some aspen suckering, then in all probability 40 per cent milacre stocking with 4-year-old white spruce would be acceptable.

While this study has provided information on some of the factors involved in the regeneration of spruce-aspen stands in Alberta, nevertheless further investigations are urgently required. More information is needed about such factors as; the influence of site quality, method of scarification, and control of species composition. At the same time, the most logical methods should be tested on a practical scale.

At the present stage of development, two distinct methods of regeneration silviculture could be considered for spruce-aspen stands in Alberta. One of these should be adapted to the production of pulpwood while the other should aim at production of spruce sawlogs.

For pulpwood purposes it would appear that some form of clear cutting in either small patches or alternate narrow strips not exceeding five chains in width will be advisable. A uniform scarification of the area with a toothed blade should follow the cut. Slash should not be windrowed and heavy slash accumulations should be avoided. The improved seedbed condition will undoubtedly last long enough to take advantage of a heavy spruce seed crop from the marginal stand.

In contrast, the production of spruce sawtimber calls for a two-stage shelterwood cutting in either patches or strips. The first cut should be followed by an intermittent patch scarification. Logging slash should be lopped and scattered. Poisoning of a proportion of the standing aspen will provide release for residual spruce and will limit aspen suckering to a desirable level. It is suggested that not more than 40 per cent of milacre quadrats should be stocked to either residual or sucker aspen. If a moderate to heavy spruce seed crop fails to occur within four years after the initial cut, the scarified spots should be seeded with pelleted spruce seed. The final removal cutting of spruce should occur at roughly ten years after the establishment of spruce regeneration. Both of these methods are already, or will, in the near future, be tested on a practical basis.

SUMMARY

An investigation into mechanical scarification before and after logging to induce spruce regeneration in mixedwood stands marked for partial cutting was initiated in 1952 in a 110-year-old spruce-aspen stand near Smith, Alberta in the B-18 region.

In each of the four residual stand densities; (a) uncut, (b) heavy, (c) medium, and (d) light, mechanical scarification using T-D9 Caterpillar tractor was carried out creating three seedbed types:- (a) Scarified, (b) Mounded, and (c) Undisturbed. Regeneration and survival of the spruce seedlings germinating in 1956 was studied on 4000 ¼-milacre quadrats between June 1956 and November 1957.

It was found that:

(a) The time of scarification, i.e. before or after logging, did not significantly affect the amount of regeneration.

(b) The scarified seedbeds remained receptive to regeneration throughout the five-year study period and are still partially receptive.

(c) Residual stand density of the spruce component, within the limits of the experiment, did not significantly affect the germination and survival of the spruce.

(d) The scarified seedbed condition was the only one which permitted satisfactory establishment of spruce regeneration.

It is recommended that further study be carried out to determine the practical applicability of scarification in commercial logging operations in this forest region.

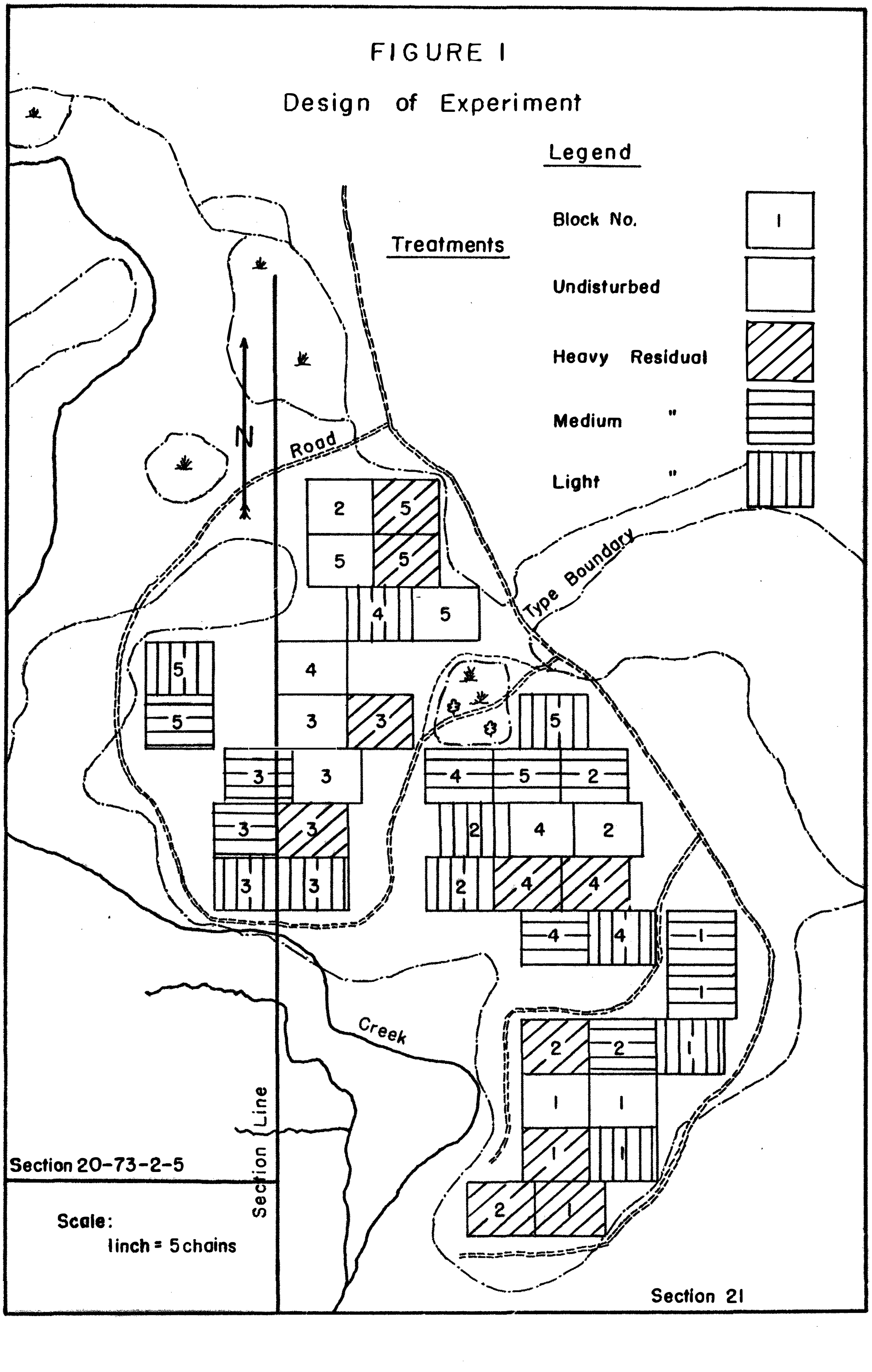
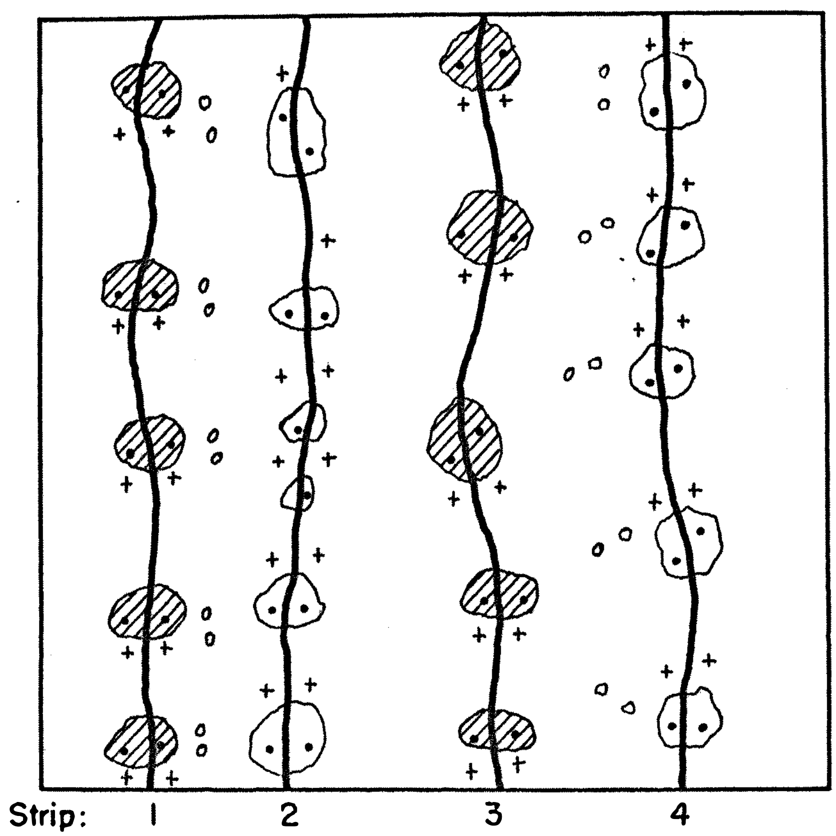


FIGURE I

Design of Experiment

Figure 2

The Layout of Scarification Strips and the one hundred 1/4 mil/acre Regeneration Quadrats on the 1/2 acre Plots



Legend

Scarified 1/4 mil/acre reg. quadrat .... •
Mounded " " " " .... +
Undisturbed" " " " .... o
Area scarified before logging .... (hatched)
" " after " .... (open)

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