
U.S. DEPARTMENT OF AGRICULTURE
NATIONAL AGRICULTURAL LIBRARY

STATION PAPER NO. 1 APRIL 1949

ALTERNATE CLEAR-STRIP CUTTING
in the Lodgepole Pine Type

Richard
Bert Lexen 19

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FORT COLLINS, COLORADO
W. G. MC GINNIES, DIRECTOR

U.S. Department of Agriculture, Forest Service
Rocky Mountain Forest and Range Experiment Station*

Station Paper No. 1 April 1949

ALTERNATE CLEAR STRIP CUTTING
in the Lodgepole Pine Type

*Maintained at Fort Collins, Colorado, in cooperation with Colorado A & M College

ALTERNATE CLEAR-STRIP CUTTING IN THE LODGEPOLE PINE TYPE

By

Bert Lexen 1/

- - - - -

THE ALTERNATE CLEAR-STRIP SYSTEM

Strip cutting is subject to many variations, but perhaps the simplest and best known of the strip systems, and the one from which the many variations stem, is the alternate clear-strip system. By this method of cutting, trees are harvested in alternate, parallel strips. Both the cut and uncut strips are made from 120 to 180 feet wide. Strip length is governed largely by topography and the transportation system, and is seldom a fixed distance. Modifications of the system are often desirable to meet local requirements. For example, not all trees in the clear-strip need to be cut. If the stand to be harvested contains some thrifty young growth, it may well be left in the clear strip for some future harvest. If wind is not a serious hazard, strip width can be increased to a point where the system approaches present-day "block-cutting." In most instances, however, very wide strips will defeat the purpose of alternate clear-strip system of cutting. Still other modifications are possible, such as making the uncut strip twice the width of the clear-strip, but permitting a salvage cut in the uncut strip or making the clear-strip wider than the uncut strip in order to make a heavier cut possible. But regardless of the modifications, the principal purpose of the alternate clear-strip system of cutting is to create a condition conducive to the rapid regeneration of an intolerant species and, at the same time, reduce as much as possible the ever-present hazard of wind.

Alternate clear-strip cutting has never found a secure place in European silviculture. Its failure to do so is attributed to several shortcomings. The first is the failure of seedlings to become established adjacent to the uncut strips, which leaves considerable space unproductive. The second is the difficulty of controlling it. Retracing old strips in stands of Scotch pine has proven very difficult. And lastly, all the advantages that go with a short cutting cycle are lost because alternate clear-strip cutting imposes upon management a cutting cycle equal to one-half of the rotation.

In the lodgepole pine type of Colorado and Wyoming the objections to the alternate clear-strip cutting system are not so pronounced. Lodgepole

---

1/ In Charge, Forest Management Research, Rocky Mountain Forest and Range Experiment Station.

pine is an extremely aggressive species and on all experimental strip cuttings has regenerated uniformly throughout the clear-strip and along the edges of the uncut strips as well. The density and over-all uniformity of reproduction on clear-strips should ultimately make the retracing of strips rather simple. The objection to the system because a long time must elapse between harvests in the same locality holds as well for lodgepole pine as it does for European species of pine. Alternate clear-strip cutting is, nevertheless, one step better in this respect than the present system of complete clear-cutting which makes the period between harvests equal to the rotation. Moreover, as will be shown later, the system can be modified to shorten still further the time when cutting operations can be again resumed on previously cut-over areas.

The alternate clear-strip system offers the solutions to many of the problems confronted in the successful management of the lodgepole pine type. The advantages of the system are not restricted to silviculture and to forest management alone, but to the watershed management and wildlife management as well. In watershed management, for example, the clear-strips create a condition conducive to maximum snow storage and the uncut strip reduces the movement of wind at snow level and, as a consequence, decreases evaporation. The shade cast by the uncut strip also tends to prolong the period of snowmelt. The danger of erosion is reduced by frequently breaking strips in steep mountain terrain and is easily subject to further control with the slash left on each strip after logging.

Wildlife management stands to gain also by the use of the alternate clear-strip system. The habitat created by clear-strips lying adjacent to uncut or lightly cut strips is considered more to the liking of large game animals than extensive areas clear-cut or cut heavily by selective logging. Uncut strips provide protection and later a source of forage after the clear-strips have become completely regenerated. Extensive clear-cut areas which inevitably result in dense sapling stands, curtails, on the other hand, the production of forage and provides wildlife little more than a place for protection. The alternate clear-strip system seems, in short, to be well adapted to the multiple-use forests of the Rocky Mountains.

SOME CHARACTERISTICS OF THE LODGEPOLE PINE TYPE

The lodgepole pine type is most often pictured as a vast even-aged forest, varying in age from locality to locality, but uniform in age within any given stand. This conception of the type is correct on those areas where favorable fire, seed, and climatic conditions once combined to produce a heavy and almost instantaneous catch of seedlings. Many other instances occur, however, where the origin of the stand can be traced to scattered, isolated trees which produced the seed for the subsequent development of the forest. Under these conditions the forest is not even-aged, although from casual observation it may appear so. The illusion of even-age is made still more real when sufficient time has elapsed to permit the younger trees to reach or approximately reach their maximum height growth. Crowns of all stems then occupy the same general level, giving the forest its false appearance of even-age. But, since the range in age of individual

trees may vary from 100 years to 250 years, such stands are more truly broad-aged than even-aged. For silvicultural purposes this distinction is important.

On rarer occasions the occurrence of a light mixture of young trees with an overmature age class is the result of the gradual deterioration of the old stand. On sites where lodgepole pine is the climax species[2/], the young stand is lodgepole pine, as in the broad-age stand; where lodgepole pine has invaded sites normally occupied by spruce and fir, the young age class is largely, although not entirely, alpine fir and spruce.

Evidence is present in many commercial stands of lodgepole pine which makes it clear that their early development took place under an overstory of aspen. Remnants of dead aspen may still be found on the ground, and in stands less completely developed, a few live but badly suppressed aspen trees now occur as an understory. The effect of the aspen overstory has been to prolong the period of restocking to lodgepole pine and to produce a forest more broad-aged than even-aged.

It is impossible to be completely familiar with all the factors which have had play in the development of each even- or broad-age stand of lodgepole pine. And, for practical purposes, this is unnecessary. The important thing is to be able to recognize each age class on the ground so that the stand can be given the most appropriate silvicultural treatment.

Identification of Even-aged and Broad-aged Stands

Both even- and broad-age classes are rather easily identified. A true even-aged stand contains many clear, cylindrical-boled trees, and there is almost a complete absence of coarse-limbed wolf trees. All thrifty surviving trees have pushed their crowns into the upper crown canopy, and there is no understory present except occasional specimens of the tolerant species, spruce or alpine fir, and some badly suppressed, ill-formed lodgepole pine seedlings and saplings.

Since broad-age stands of lodgepole pine may differ in their origin from one locality to another, they are not so easily recognized as the true even-aged stands. If a broad-aged stand is the result of the gradual establishment of reproduction between scattered seed trees, it can be recognized by the original seed trees which are still present, but are now large-sized and coarse-limbed. Trees growing between seed trees are usually better formed and finer limbed. Cases occur, of course, where so many trees were present originally that the "filling-in" process has been limited and the variation in appearance between the old and the new stand is practically indiscernible.

2/ Some authorities do not agree that lodgepole pine can be a climax species, but there is strong evidence that under certain conditions it can remain the dominant species indefinitely.

If the broad-age stand has resulted from the deterioration of an even-aged stand, it can be identified by younger trees growing in openings. Remnants of old trees which have fallen to produce these openings are still on the ground in varying stages of decay. The merchantable portion of such stands is very often so decadent that there is no alternative left but to cut every tree of saw-log size. Practically all of the healthy and potentially fast-growing trees are in the submerchantable class; that is, below 10 inches d.b.h.

If the broad-aged stand has developed under a canopy of aspen, it can be identified by the presence of a thin, residual stand of severely suppressed aspen or from the remnants of dead aspen on the ground. It is possible for an even-aged stand to become established under aspen, but this condition more frequently leads to broad-aged rather than even-aged stands.

If, after casual examination, some question remains whether a given saw-log stand of lodgepole pine is even- or broad-aged, it can be settled by a study of the trees on the ground. To do this, it is advisable to tally all trees over 4.0 inches d.b.h. on a representative strip 1 chain wide and 10 or more chains long according to Taylor's tree classification system. If only an occasional A and B tree is recorded on the strip, there is sufficient evidence to believe that the stand is even-aged. On the other hand, if 30 or more A and B trees are recorded per acre it is almost certain that the stand is broad-aged. In other words, the tendency of even-aged lodgepole pine to develop into uniformly dense stands precludes the development of long crowned trees. Both trees of large and small diameters are short crowned in even-aged stands.

SOME CONDITIONS FOR WHICH ALTERNATE CLEAR-STRIP CUTTING IS SUITABLE

Strip cutting is not the complete answer to the silviculture of lodgepole pine. It is, nevertheless, particularly well suited to certain conditions encountered in virgin stands, and to satisfy some demands placed upon timber harvesting by other forest uses and fire control. Some of the more important applications are discussed below.

Protection of Young Stand in Clear-strip from Wind

One of the most useful applications of alternate clear-strip cutting is to broad-aged class stands of lodgepole pine. Under this system of cutting the young-age class can be brought to maturity without serious danger of extensive windfall.

If large-scale, commercial clear-cutting is practiced, much of this thrifty young material will be windthrown after logging. And, if absolute clear-cutting is adapted, that is, if the trees below 10 inches d.b.h. are harvested for mine props and fence posts, many trees will be cut at an age when they are capable of putting on maximum growth.

Experimental work has demonstrated that only by leaving a buffer or protective uncut strip to the windward can the young submerchantable trees be saved. Under protection and maximum release which heavy cutting in the clear-strip provides, these trees may contribute from 4 to 6 M board feet per acre to the harvest at the end of the first cutting cycle. Moreover, they may some day produce the volume necessary to make a return harvest and thinning in the clear-strip economically feasible.

Reduction of After-cutting Fire Hazard in Even-aged Stands

Since the advanced reproduction on the ground, together with the seed recently fallen before cutting and the seed released from persistent cones is always ample to restock medium to good sites, alternate uncut strips are not needed as a seed source. The main purpose of the uncut strip is to protect the widely spaced young trees in the clear-strip from wind. In even-aged stands the young-age class is absent. Nothing then remains to be protected so that strip cutting can be abandoned, and simple clear-cutting adopted instead. However, if this is done, it will often prove advantageous to proceed progressively toward the windward over the area to be harvested. The purpose of moving toward the windward is to keep the cutting edge free from heavy winds. In other words, it is better to have the damaging winds blowing over rather than into the edge of any cutting.

In areas of serious fire hazard it is often desirable to avoid the accumulation of large, contiguous bodies of slash after logging. Alternate clear-strip cutting offers one means of achieving this end.[3/] In this respect strip-cutting is equally as effective in broad-aged as it is in even-aged stands, but in even-aged stands the system is more flexible. Greater flexibility is possible in even-aged stands because the uncut strip is not needed to reduce wind movement in the cut strip. With this restriction removed, strips can be made wide enough to permit cheaper logging or to provide enough logs for at least one portable mill set in each strip.

Retardation of Spruce-fir Climax

Lodgepole pine in Colorado and Wyoming occurs both as a climax and subclimax species. On north and northeast exposures, toward the upper limits of the lodgepole pine type, and on limited areas within the type where the soil is more or less moist because of some peculiarity of drainage, lodgepole pine is subclimax. On many of such areas forest conditions can be changed to favor lodgepole pine by alternate clear-strip cutting. Intensive studies of the behavior of lodgepole pine, Engelmann spruce, and alpine fir under various degrees of sunlight have proven quite conclusively that full sunlight greatly hinders the germination of Engelmann spruce and alpine fir seed. Subsequent survival of seedlings is also adversely affected by full sunlight. While lodgepole pine, on the other hand, is also affected by the lack of shade during early development, it can, nevertheless, withstand full sunlight with less harm than Engelmann spruce or

3/A. L. Nelson, Timber Management Division, U. S. Forest Service, Denver, Colorado, has long advocated green strips as a means of reducing fire hazard in cut-over lodgepole pine.

alpine fir. Any form of clear-cutting will, therefore, retard the trend toward the spruce-fir climax, and prolong the subclimax stage.

Wherever a well-established stand of alpine fir and spruce advanced reproduction occurs under lodgepole pine, the problem of maintaining the subclimax species is difficult but not hopeless. By adopting some form of destructive logging such as tree-length logging with heavy, dozer-fitted tractors, and by windrowing and burning all logging slash, at least a portion of the area can be placed in a condition which will permit rapid regeneration to lodgepole pine.

In those instances where logging damage has been made intentionally severe in the clear-strip, and when windrowing or piling of slash has been done before the seed in persistent cones have been adequately released, it is well to safeguard the regeneration of clear-strips by keeping them narrow. The uncut strip, under these circumstances, may be needed as a source of seed. Wider strips are permissible when there is an abundance of lodgepole pine cones in the slash and ample time has been permitted for them to open before windrowing or piling is done.

The use of destructive logging to maintain lodgepole pine as the dominant species in mixture with spruce and fir should always be considered carefully before it is adopted. Ordinarily, it will require definite and clear-cut objectives in the management plan to justify the destruction of 10 to 30 years of advanced growth of a less desirable species in order to regenerate a more valuable one. It is conceivable, nevertheless, that the location and the economics of a working circle may be such that only by growing lodgepole pine can satisfactory returns be sustained and a high level of economy be maintained within the working circle.

Regeneration of Poor Sites

As a general rule, lodgepole pine regenerates quickly from seed that has fallen prior to logging and from seed released from persistent cones in logging slash. Its rapid juvenile growth and ability to bear seed at an early age further assures successful regeneration except on the poor sites.

Poor sites in the lodgepole pine type are commonly associated with south exposures where high temperatures make a normal amount of rainfall less effective in establishing reproduction than elsewhere. The stand per acre is also lighter on south exposures, which means fewer trees and, therefore, less seed to be released from persistent cones. If rainfall for 2 or 3 years after logging is insufficient to germinate seed or to assure seedling survival, the seed supply from logging slash soon deteriorates with age or becomes exhausted from germination and the subsequent death of seedlings. Successful regeneration under such circumstances must depend upon another source of seed. The uncut strip under the alternate clear-strip system of cutting will effectively furnish this seed if the clear-strip is not made too wide. To avoid failures, strip width should be kept under 180 feet on south exposures.

Protection of Residual Stand after Heavy Thinning

Not all stands of lodgepole pine that need attention are mature or overmature. There occurs within the type extensive areas of seedlings, saplings, and poles. These stands are usually the result of past fires and are invariably even-aged and dense. Almost all are in need of thinning; but thinning heavily enough to stimulate diameter growth often introduces the danger of heavy windfall.

Sapling stands can be thinned satisfactorily and on an extensive scale without too much regard to wind. Pole stands thinned heavily enough to stimulate diameter growth must, on the other hand, be given some protection from wind or serious blow-down is likely to occur. The protection necessary to avoid excessive windfall in pole stands can be provided by the unthinned strips when alternate strip-thinning is practiced. Lying always to the windward, the unthinned strip acts as a buffer against strong prevailing winds. It must not be thinned. Any thinning in it must be deferred until the trees in the thinned strip have developed windfirmness.

CONDITIONS FOR WHICH ALTERNATE CLEAR-STRIP CUTTING IS UNSUITABLE

Alternate clear-strip cutting is adaptable to many situations, but there are conditions for which it is unsuitable. To avoid misuse, attention is called to certain stand conditions for which it is unsuitable or is undesirable for at least the first harvest.

Overmature Insect-infested Stands

Overmature and decadent stands of lodgepole pine that are heavily infested with bark beetles should be clear-cut. Despite the fact that these stands may be broad-aged and therefore contain young trees which need protection from wind, it is wise to harvest all merchantable trees as rapidly as possible. If alternate clear-strip cutting is practiced in such stands, the loss of volume in the uncut strip to insects will, in all likelihood, far exceed the potential growth of the young trees lost by wind.

The mere evidence of some insect damage in an old stand of lodgepole pine should not be accepted as an excuse to adopt wide-scale clear-cutting. If the infestation is endemic, regular control measures should be applied to the infested trees regardless of whether they occur in the cut or uncut strips. If the attack is epidemic but localized, such areas should be cleaned up by clear-cutting the areas infested. Only when there is little hope of controlling an epidemic by spot clean-ups, or when the cutting plan for removing infested trees becomes too cumbersome should over-all clear-cutting be adopted.

Mistletoe-infected Stands

Very few extensive stands of lodgepole pine are completely free from mistletoe. Infected areas are usually large and may be either lightly or heavily infected. If they are heavily infected no form of strip-cutting is advisable because uncut strips will quickly re-infect the regenerated clear-strips. Lightly infected areas can be cleaned up by either cutting individual trees or groups of trees, but heavily infected areas are best treated by complete clear-cutting.

Where strip-cutting is to be applied to lightly infected areas, it is a good policy to cut all infected trees in the "uncut strip." The purpose of so doing is twofold: first, it reduces the spread of mistletoe to other trees in the strip as well as to new seedlings as they become established in the clear strip; and second, it provides a more thorough check of the degree of infection and thereby insures the correct treatment of each infected area. For example, if marking of infected trees indicates the need of removing so many trees that the protective influence of the strip is nullified, clear-cutting becomes mandatory. On the other hand, if light cutting will remove all seriously infected trees, the strip will be made more productive as a result of cutting and will also retain, to a large extent, its effectiveness as a barrier to wind.

Pre-sale planning should include the delineation of all mistletoe-infected areas. If examination proves that these areas must be clear-cut, cutting should be complete, that is, the submerchantable stand must also be removed and sold for small products such as fence posts or mine props. Lacking a market for these products, the submerchantable stand must be cut as a stand-improvement measure in order to remove all sources of re-infection. Clear-cutting only the merchantable portion of the stand (trees 10 inches d.b.h. and larger) will do little toward the eradication of mistletoe.

Stands with Aspen Understory

It is unwise to practice any form of clear-cutting, strip or otherwise, in stands with an extensive understory of aspen. Even though the aspen has been severely suppressed for many years by an overstory of lodgepole pine, clear-cutting is still likely to yield poor results.

The effect of clear-cutting such stands is to release aspen and to greatly retard the development of lodgepole pine regeneration. Although the juvenile growth of lodgepole pine is rapid, it does not equal that of aspen which has been completely released. Once aspen has recovered from suppression, it will take over the site for 30 to 50 years. If there is a ready market for aspen, and the site is good enough to grow trees of commercial size, not much will be lost by the temporary change of type; but if the objective of management is to grow only lodgepole pine, the production of products from this species will be greatly decreased.

Wherever aspen is likely to constitute a serious menace to successful regeneration of lodgepole pine, the two-cut system is probably more appropriate than any strip system. If the overstory of lodgepole pine left after the first cutting by the two-cut system is spared from wind, it will tend to hold aspen in check while an adequate stand of lodgepole pine saplings becomes established. Occasional scattered clumps of aspen in commercial stands of lodgepole pine need not, however, require the adoption of the two-cut system. If aspen is not too abundant, it can be kept under control by some stand-improvement measure.

Stands of Mixed Patches of Age Classes

In some instances, frequent fires in the past have left a few stands composed of several age classes. When these age classes occupy relatively small areas, there is considerable question as to the advisability of superimposing a systematic pattern of strips upon them. This is particularly true when there are several age groups present that do not contain merchantable timber. It is possible to gradually convert such stands to a forest where age-class differences are confined to strips, but it may be awkward and costly to do so. The transportation system, for example, would at the beginning traverse considerable terrain from which little merchantable timber would be available. In the few instances where a mixture of age classes is encountered, the best procedure for the present is to harvest the groups of mature trees and plan the transportation system for the harvest of them only. This will result in clear-cutting in groups, although the groups will often be larger than specified under the formal system of group selection.

THE APPLICATION OF THE ALTERNATE CLEAR-STRIP SYSTEM OF CUTTING

The application of alternate clear-strip system of cutting to virgin stands of lodgepole pine requires careful preliminary planning. Strips must be arranged to assure maximum protection from wind, to simplify logging as much as possible, and to minimize damage to the regenerated strip when the next strip is cut.

Strip Width

As the width of the clear-strip increases, the danger of windfall toward the windward of the next uncut strip increases. Strips wider than 150 to 180 feet permit heavy, overhead winds to descend into the crowns of the reserve stand where extensive damage is likely to occur. The objective should be to hold the heavy winds above the crowns of the reserve stand where they can cause little damage. This is best accomplished by narrow strips. Wide clear-strips are particularly dangerous if a salvage or light cut has been made in the uncut strip.

Strip width need not always be hard and fast. If it is desirable to sacrifice some protection to the reserve stand from wind for cheaper and

perhaps more convenient logging, strip width can be increased to any standard desired. In so doing, it should be remembered that not only will this result in more windfall, but that wind movement will be increased at the ground level in the slash-filled clear-strip. From the standpoint of fire control this is obviously undesirable.

Strip Length

Strips do not need to be any fixed length; they should, instead, be made to fit into the logging plan for the area and any topographic feature which would make a break desirable. The purpose of breaking a strip occasionally so that the end of a clear-strip adjoins the end of an uncut strip is twofold: first, it reduces the fire hazard after logging, and second, it decreases the danger of snow slides on long, steep mountain slopes.

Because of the tendency for fires to move "up-slope" it is particularly desirable to break strips as frequently as possible when strip-cutting is used in mountain terrain. On level to rolling ground, strips can be longer since they are then always laid out at right angles to the prevailing wind. The movement of any fire in such cases would be across the strip rather than lengthwise. Perhaps the only need for breaking strips in level country other than for convenience is protection from unusual winds that might blow parallel to the strip and make fire suppression difficult.

Studies of wind damage in the lodgepole pine type of Colorado and Wyoming have proved that the damaging winds are from the southwest. In mountainous areas wind direction is modified greatly by topography, but, regardless of the direction of the drainage, wind movement is always at right angles to the slope. Trees uprooted by wind almost invariably fall along the slope, only seldom up- or down-slope. To secure maximum protection from wind, strips should then always be laid out at right angles to the drainage, and in level to rolling country in a northwesterly to southeasterly direction.

Theoretically, east and west strips are the best for prolonging snowmelt. Tests have not been made to prove their effectiveness in this respect, but it appears logical that snowmelt would be retarded on the south edge of clear strips which remain shaded the entire day. In north and south drainages strips will fall naturally in this direction, but in east and west drainages, strips will fall north and south. Because clear-strips that lie in the latter direction are exposed at least a portion of each day to direct sunlight, this arrangement is likely to be the poorest for prolonging the period of snowmelt.

Other Considerations

Strips laid out parallel rather than perpendicular to the drainage have, in some instances, the advantage of hiding a cutting area from the view of a main highway. They are, nevertheless, generally undesirable,

because the trees in the uncut strip must at sometime be felled into the regenerated strip, where considerable damage is bound to occur. Skidding must also be done, on many occasions, through one or more regenerated strips, which further increases the amount of logging damage.

Unless recreational or esthetic values are extremely high, there should be no compromise with good silviculture. The disturbing thing to the passerby on cut-over areas is poor utilization and the accumulation of large quantities of logging debris. Wherever these conditions are encountered adjacent to main highways, special improvement measures should be enforced. The rapid regeneration of clear-cut areas in the lodgepole pine type will quickly heal over the scars of logging. This is particularly true on areas where slash has been piled and burned.

MODIFICATIONS OF ALTERNATE CLEAR-STRIP CUTTING

Where intensive management is possible, it is desirable to modify the alternate clear-strip system in order to shorten the cutting cycle. To avoid loss of timber between cutting cycles it is also desirable to cut the so-called uncut strips lightly when the clear-strips are harvested.

The three-strip system (even-aged stands)

The three-strip system is essentially an alternate clear-strip system of cutting but differs in that the clear strips are alternated with two uncut strips or two lightly cut strips. The cutting cycle in place of being $\frac{\text{rotation}}{2}$, as it is for the formal alternate clear-strip system, is instead $\frac{\text{rotation}}{3}$. For a 120-year rotation the cutting cycle is reduced from $\frac{120}{2}$ = 60 years to $\frac{120}{3}$ = 40 years. Short cutting cycles are advantageous because intermediate harvest can be planned simultaneously with the major harvest. Small material which under normal conditions cannot be handled economically alone, can be moved when enough large-sized trees are available for harvest.

The application of the three-strip system to an even-aged stand of mature lodgepole pine is illustrated in figure 1. All strips are the same width (not exceeding 180 feet) and cutting proceeds from the northeast to the southwest except as modified to meet the topographic changes of wind direction. The first harvest consists of clear-cutting all No. 1 strips and cutting lightly strips No. 2 and No. 3. The entire working circle is cut-over in this manner in 40 years. If cutting begins in 1950, the first cutting will appear 40 years later as shown in figure 1 for year 1990.

The second harvest, which begins in 1990, removes all the volume from the No. 2 strips and again lightly cuts strips No. 3. Thinnings (40-year-old) are available at this time from strips No. 1. By the beginning of the

STRIP CUTTING IN LODGEPOLE PINE

Cutting cycle 40 years - Rotation 120 years

Compiled by Bert Lexen

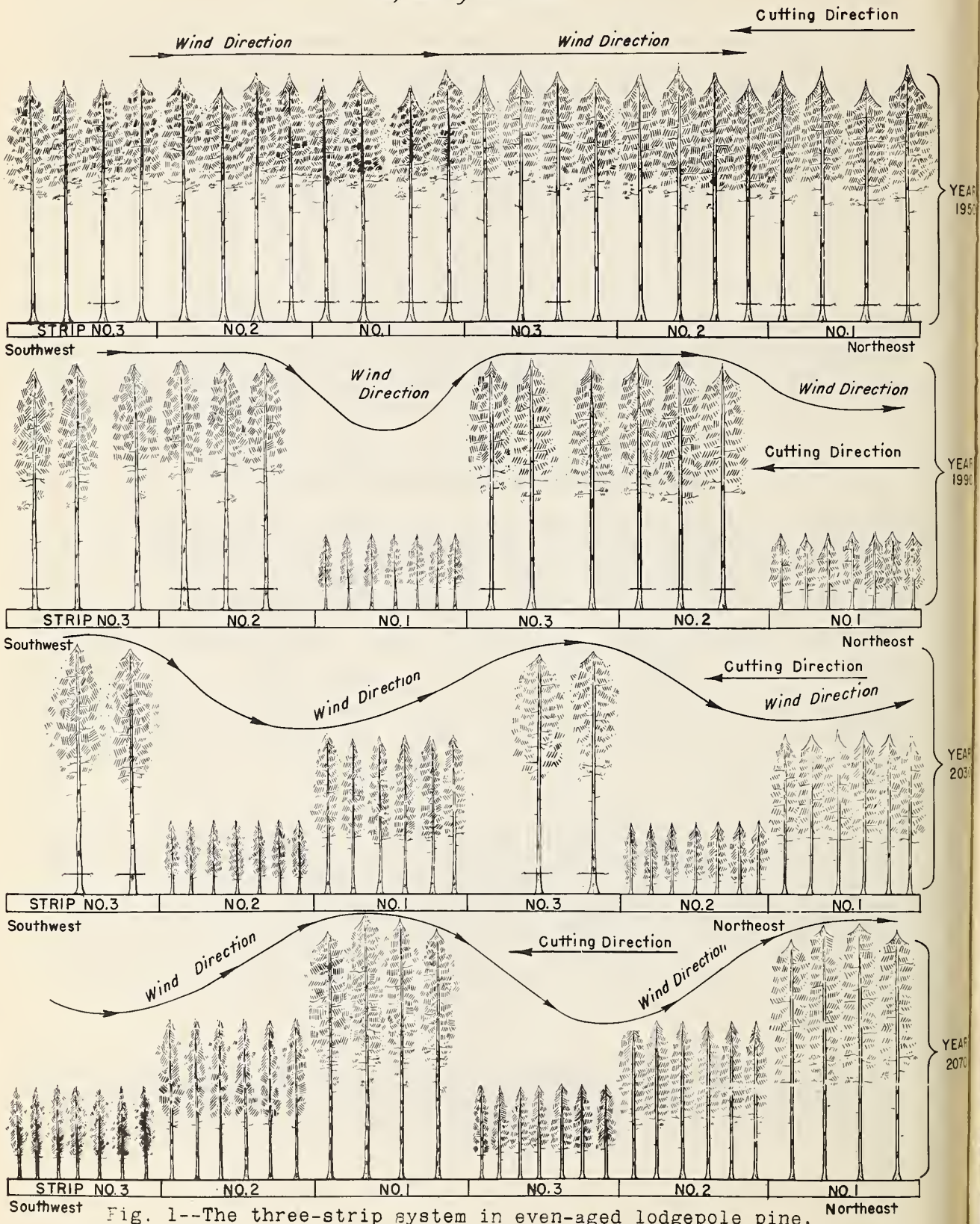

Fig. 1--The three-strip system in even-aged lodgepole pine.

third cutting cycle, the first cutting in the second cutting cycle appears as is shown in figure 1 for year 2030.

In the third cutting cycle, the last of the original growing stock is removed. Eighty years will have elapsed since cutting began, and 120 years will elapse before the last of the No. 3 strips are cut. This means that cutting must be directed from the beginning to those compartments where the deterioration of the original growing stock is going on most rapidly, if mortality losses are to be minimized.

The volume in board feet and the smaller products to be cut in each successive cutting cycle is summarized below for a hypothetical example where the original growing stock is assumed to be 12 M board feet per acre and of an age which will permit the successful application of the three-strip system. The stand is also assumed to be strictly even-aged.

First Cutting Cycle

Clear-cut strip 1 =	1/3(12,000 bd.ft.) =	4,000 bd.ft.
Light-selection strips 2 & 3 =	1/4(8,000 bd.ft.) =	2,000 bd.ft.
T.S.I. strip 1 =	Poles,posts,props	
		6,000 bd.ft.

Second Cutting Cycle

Clear-cut strip 2 =	1/3(12,000 bd.ft.) =	4,000 bd.ft.
Light-selection strip 3 =	1/4(4,000 bd.ft.) =	1,000 bd.ft.
T.S.I. strip 2 =	Poles,posts,props	
Thinning strip 1(40yrs.old) =	Posts	
		5,000 bd.ft.

Third Cutting Cycle

Clear-cut strip 3 =	1/3(12,000 bd.ft.) =	4,000 bd.ft.
Light selection =	None	
Thinning strip 1 (80yrs.old) =	Poles,posts,props	
Thinning strip 2 (40yrs.old) =	Posts,props	
T.S.I. strip 3 =	Poles,posts,props	
		4,000 bd.ft.

Since the stand is even-aged and the submerchantable trees are of no value as growing stock, T.S.I. consists of cutting all the trees below 10.0 inches d.b.h. for whatever product there is currently a market. Lacking a market, they are felled in order to restock the clear strip as completely and as quickly as possible. In the second cutting cycle, the cut in strip 2 and the light cut in strip 3 assumes that growth in 40 years will bring the volume on these strips back to the original volume at the beginning of the first cutting cycle. From existing after-cutting yield studies, this is a conservative estimate of growth.

The T.S.I. operation in the second cutting cycle is the same as in the first cutting cycle, but coming 40 years later a more ready market may be available for the small material. A good market for small material

is important at this time because thinning must be done in the 40-year-old stand in strip 1. If thinning is not done at this time, a 120-year rotation will be too short. Without thinning, at least 200 years must elapse before saw-log material is again available in satisfactory quantities.

In the third cutting cycle, growth in the preceding 40 years is considered sufficient on strip 3 to provide a cut of 4,000 board feet. This is an increase of 3,000 to 4,000 board feet, which should be obtained without difficulty. After the third strip has been clear-cut, the light-selection cuttings made during the first and second cutting cycles are no longer possible because the working circle is now completely clear-cut. Additional medium-sized material will be available, however, from strip 1, which is now stocked with 80-year-old trees. Small material (40 years old) will also be available from strip 2, together with the regular submerchantable trees from the T.S.I. operation in strip 3.

While the board-foot volume available for cutting drops progressively with each cutting cycle, the amount of cubic-foot volume ready for harvest increases enough simultaneously to offset this loss. New markets must be found for this small material, but that should not be difficult 40 to 80 years hence.

Even though the annual cut is not kept perfectly constant from cutting cycle to cutting cycle, the original forest with a surplus of growing stock is converted by the first cutting cycle in the second rotation to one that is approximately normal. The ease with which lodgepole pine regenerates should result in the complete and immediate restocking of each strip as it is clear-cut. The growing stock at the beginning of the first cutting cycle in the second rotation will, therefore, deviate from ideal only insofar as thinning or intermediate cuttings have not been made correctly.

Three-strip System (Broad-aged Stands)

The three-strip system differs in broad-aged stands only in that a light reserve stand of young submerchantable trees is brought to maturity in the clear-strips. The light reserve stand will seldom consist of more than 30 to 60 submerchantable trees per acre so that ample space is available for the simultaneous development of a reasonably dense understory of reproduction.

The three-strip system is particularly effective in broad-aged stands because the lightly cut strips to the windward provide the protection from wind that is needed to bring the light reserve stand in the clear-strip to maturity (see figure 2). Without this protection, windfall, as experience has shown, will be extremely heavy.

The conversion of the original stand to a three-age stand with a normal growing stock is not completed under broad-age conditions until the end of the second cutting cycle in the second rotation (see figure 2). The steps to be followed and the volume in both large and small material available each cutting cycle is summarized below.

STRIP CUTTING IN A BROAD AGE STAND OF LODGEPOLE PINE

CUTTING CYCLE 40 YEARS- ROTATION 120 YEARS

Compiled by Bert Lexen

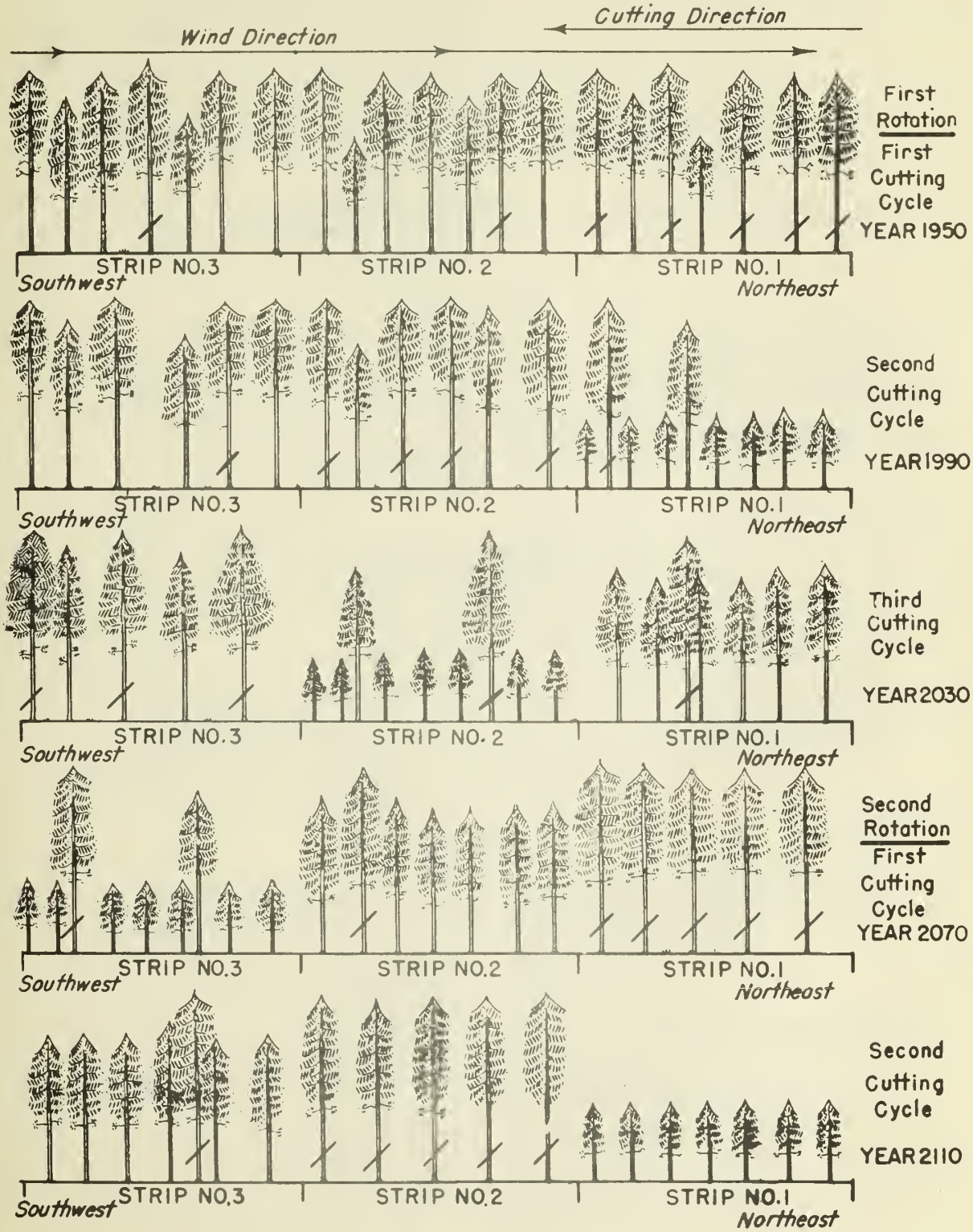

Fig. 2--The three-strip system in broad-aged lodgepole pine.

(First Rotation)
First Cutting Cycle

Clear-cut strip 1 =	1/3(12,000 bd.ft.) =	4,000 bd.ft.
Light-selection strips 2 & 3 =	1/4(8,000 bd.ft.) =	2,000 bd.ft.
T.S.I. strip 1 =	Poles,props,posts,pulpwood	
		6,000 bd.ft.

Second Cutting Cycle

Clear-cut strip 2 =	1/3(12,000 bd.ft.) =	4,000 bd.ft.
Light-selection strip 3 =	1/4(4,000 bd.ft.) =	1,000 bd.ft.
Second cut strip 1 =	750 bd.ft.	750 bd.ft.
T.S.I. strip 2 =	Poles,posts,props,pulpwood	
Thinning strip 1 =	Posts,props,pulpwood	
		5,750 bd.ft.

Third Cutting Cycle

Clear-cut strip 3 =	1/3(12,000 bd.ft.) =	4,000 bd.ft.
Light selection =	None	
Third cut strip 1 =	750 bd.ft.	750 bd.ft.
Second cut strip 2 =	750 bd.ft.	750 bd.ft.
Thinning strip 1 (80yrs.old) =	Poles,posts,props,pulpwood	
Thinning strip 2 (40yrs.old) =	Posts,props,pulpwood	
T.S.I. strip 3 =	Poles,posts,props,pulpwood	
		5,500 bd.ft.

(Second Rotation)
First Cutting Cycle

Clear-cut strip 1 =	4,000 bd.ft.	4,000 bd.ft.
Third cut strip 2 =	750 bd.ft.	750 bd.ft.
Second cut strip 3 =	750 bd.ft.	750 bd.ft.
Thinning strip 2 =	Poles,posts,props,pulpwood	
Thinning strip 3 =	Poles,posts,props,pulpwood	
		5,500 bd.ft.

Second Cutting Cycle

Clear-cut strip 2 =	4,000 bd.ft.	4,000 bd.ft.
Third cut strip 3 =	750 bd.ft.	750 bd.ft.
Thinning strip 1 (40yrs.old) =	Posts,props,pulpwood	
Thinning strip 3 (80yrs.old) =	Poles, posts, props,pulpwood	
		4,750 bd.ft.

Third Cutting Cycle

Clear-cut strip 3 =	4,000 bd.ft.	4,000 bd.ft.
Thinning strip 1 (80yrs.old) =	Poles,posts,props,pulpwood	
Thinning strip 2 (40yrs.old) =	Posts,props,pulpwood	
		4,000 bd.ft.

Four-strip System

The four-strip system is merely an elaboration of the three-strip system. By introducing the fourth strip (figure 3) it is possible to reduce the cutting cycle from $\frac{120}{3}$ = 40 years to $\frac{120}{4}$ = 30 years. It also becomes possible to make three rather than two intermediate harvests simultaneously with the major harvest as soon as the original stand has been converted to one with a balanced growing stock (figure 1, year 2070). In the first cutting cycle of the second rotation (year 2070) the major harvest is made in strip 1 and the three intermediate harvests in strips 2, 3, and 4, or in stands 90, 60, and 30 years old, respectively. The next major harvest will come 30 years later and the intermediate harvest likewise.

The board-foot volume and the amount of small products available by cutting cycles is summarized below for an even-aged stand of lodgepole pine cut by the four-strip system.

First Cutting Cycle

Clear-cut strip 1 =	1/4(12,000 bd.ft.) =	3,000 bd.ft.
Light-selection strips 2,3,4 =	1/3(9,000 bd.ft.) =	3,000 bd.ft.
T.S.I. strip 1 =	Poles,posts,props	
		6,000 bd.ft.

Second Cutting Cycle

Clear-cut strip 2 =	1/4(12,000 bd.ft.) =	3,000 bd.ft.
Light-selection strips 3 & 4 =	1/3(6,000 bd.ft.) =	2,000 bd.ft.
T.S.I. strip 2 =	Poles,posts,props	
Thinning strip 1 (30yrs.old) =	Posts	
		5,000 bd.ft.

Third Cutting Cycle

Clear-cut strip 3 =	1/4(12,000 bd.ft.) =	3,000 bd.ft.
Light-selection strip 4 =	1/3(3,000 bd.ft.) =	1,000 bd.ft.
T.S.I. strip 3 (60yrs.old) =	Poles,posts,props	
Thinning strip 1 (60yrs.old) =	Posts,poles	
Thinning strip 2 (30yrs.old) =	Posts	
		4,000 bd.ft.

Fourth Cutting Cycle

Clear-cut strip 4 =	1/4(12,000 bd.ft.) =	3,000 bd.ft.
T.S.I. strip 4 =	Poles,posts,props	
Thinning strip 1 (90yrs.old) =	Poles,posts	
Thinning strip 2 (60yrs.old) =	Poles,posts	
Thinning strip 3 (30yrs.old) =	Posts	
		3,000 bd.ft.

Once the old growing stock has been converted to a new balanced growing stock, cutting by the four-strip system differs from the three-strip system primarily because less volume is cut each cutting cycle. The total cut for the rotation will probably be greater, however, by the four-strip system because the shorter cutting cycle of the four-strip system makes possible the salvage of dying or slow-growing

STRIP CUTTING IN LODGEPOLE PINE

Cutting cycle 30 years - Rotation 120 years

Compiled by Bert Lexen

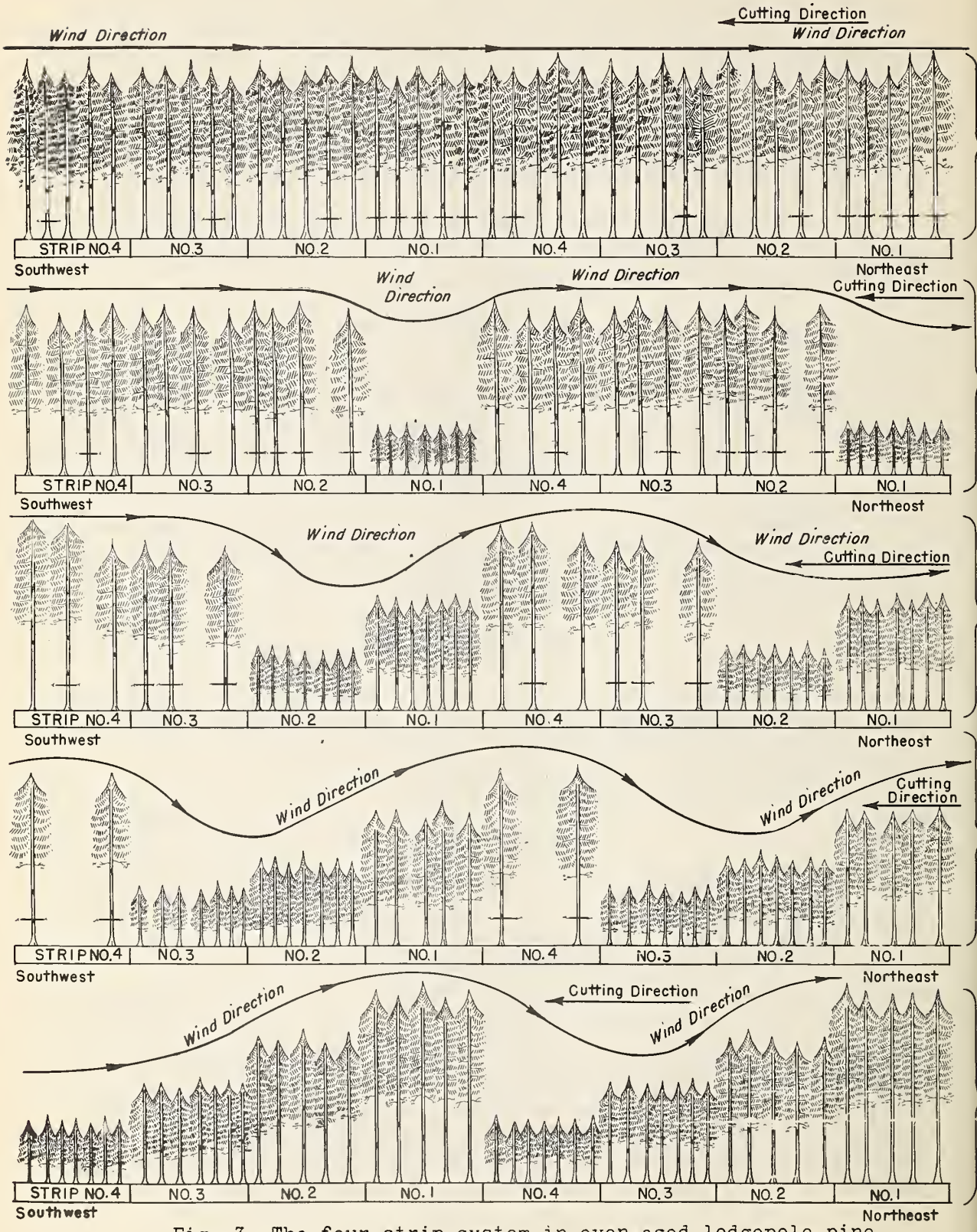

Fig. 3--The four-strip system in even-aged lodgepole pine.

trees more efficient. This advantage is offset, however, when intermediate harvests are scheduled more frequently than every 40 years under the three-strip system.

Rigidly adhering to the cutting schedule for the three-strip system necessitates holding a portion of the original growing stock for 80 to 120 years and, for the four-strip method, 90 to 120 years. Whether this can or cannot be done depends upon the general thriftiness of the original stand. If the stand lacks vigor, it may be necessary to shorten this period by 50 to 60 years. Whenever this step is taken the growing stock must be brought into balance during the second rotation. Provisions must also be made to provide additional timber from other sources until the oldest portion of the strip cutting is again ready to be harvested.

A Compromise System of Strip-cutting

The three-strip or four-strip systems of cutting are ideals or goals to be striven for. In much of the lodgepole pine type management is still too crude to warrant such refinement. Not until the transportation system is completed and is of high standard, and not until a firm market is available for the large quantity of small material cut during each intermediate harvest can either the three- or four-strip systems of cutting be satisfactorily applied.

The formal alternate clear-strip system of cutting offers a good compromise with the ideal systems, if the clear-strips and uncut strips are made equivalent to the sum of the three strips proposed in the three-strip system (fig. 1) or the sum of four strips in four-strip system (fig. 3). Strip width by the compromise system would then be either 150 x 3 = 450 feet, or 150 x 4 = 600 feet. The width of strip would be determined by the cutting system to which the compromise system is eventually to be converted. If the final objective is the three-strip system, strips should be approximately 450 feet wide; and if the four-strip system is the ultimate objective, the strips should be approximately 600 feet wide. Strip length and strip direction should, however, remain the same as proviously discussed for the formal alternate clear-strip system.

Whether or not light selective logging should be permitted in the wide uncut strip must be weighed against the damage such logging would do to the remaining stand. If the area is to be horse-logged, a light-selection cut would be permissible; but if logging is to be done with heavy tractors or by any other destructive method, it would be a better policy to confino cutting to the clear-strip only, or to wait until such a time when logging equipment is designed which can handle trees as a crop rather than as an ore.

As with all compromises something is gained and something is lost by sacrificing the ideal. The gain in this instance is cheaper and more convenient logging; and the loss is less effective protection from wind by the uncut strip and less orderliness in timber harvesting. Some of the advantage of narrow strips is also lost in fire control, but this is

probably not serious. The wide alternate strip of uncut green material is still helpful in controlling the spread of fire on cut-over areas. Narrower strips would result in less wind movement in the logging slash and would create smaller contiguous bodies of hazardous fuel than wide strips. However, whether this improvement is or is not important must still be demonstrated.

While the compromise system of strip-cutting is a crude beginning, it is, nevertheless, the first step toward the better management of lodgepole pine. To foresee the demands which will be placed upon this species a hundred years hence is, of course, impossible. But, regardless of whether the demand be great or small, or the demands for products be few or many, strip-cutting will convert our virgin lodgepole pine to an even-aged form of management to which it seems best adapted.