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Western Australia.

The Damage caused by Creeping Fires in the Forest.

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FOREWORD.

A Forests Department operating in a new country has many and varied problems of silviculture to solve. Experiments in problems of silviculture take many years to work out, and do not lend themselves to precise results on account of the numerous inter-acting factors involved. A forester is often in a position to apply in a modified form the experience gained in other countries where forestry has been practised over a long period of years. It is seldom, however, that he has the good fortune to find that problems which are practically similar to his own, have been investigated by a representative body of sawmillers and foresters in another country. The reprint from the July, 1923, issue of "The Timberman," published at Portland, Oregon, U.S.A., which forms the subject of this publication, shows that other countries are faced with vital problems of forest protection and silviculture almost identical with those which present themselves to the forester who seeks to secure regeneration in the cut-over Jarrah bush.

The keen local controversy on the subject of creeping fires *versus* complete fire prevention, renders this evidence, which is the result of careful investigation, of particular value and interest at the beginning of a fire season. It may be held that conditions where the experiments were carried out, differ from Western Australian conditions in many respects. After a careful study of the whole problem, however, I feel convinced that such differences are not vital to the issues involved, nor do they affect the conclusions arrived at.

The main variations are set out and commented upon hereunder:—

1. *Burning.*—The visible damage by light burning to mature trees in the Jarrah bush may be less apparent than the damage caused to pine trees in regions where the experiments were carried out. Eucalypt species are not easily killed by mal-treatment, but, to the forester, it is evident that "no burning yet critically studied failed to show damage caused to mature timber which was considerably larger than would be apparent to the casual observer."

2. The casual observer in the Jarrah bush has less chance of forming true conclusions concerning the damage done by insects after fires than he has in most other forests. The pin-hole borers of Western Australian forests, which only attack trees where the bark has been removed or scorched off, destroy the value of timber, although they do not kill the tree. In other countries insect attack usually results in dead foliage, and dead or partially dead trees strike the eye of the casual observer, whereas the less apparent damage evidenced by the fine dust of the pinhole borer is often overlooked.

3. Since the timber trade started to exploit the Jarrah bush, and settlement extended into some of the fertile valleys which occur throughout the forest, the Jarrah bush has been burned over so frequently that the parched, sterile iron-stone gravel of the present day has come to be regarded as the natural soil condition of the Jarrah country. This impoverishment of the soil results in a slowing up of the rate of growth of timber trees, which can only be demonstrated by making a series of measurements extending over a period of years. Although comparative results are lacking, there is sufficient evidence to warrant the forester believing that fire control will result in a greatly increased annual volume increment.

4. In a forest being worked on the selection principle, under minimum girth restriction, the most serious damage of all is done to regrowth, and, strangely enough, it is the faulty regrowth which has survived the frequent fires, which is triumphantly pointed out by the advocates of light burning as proof that there is no need to worry about complete fire control in the Jarrah bush. Collectively, this regrowth appears to indicate that a satisfactory new crop is developing, but if the component saplings are examined individually, it is difficult to find a sound one which gives any indication of developing into a useful mill log. The number of fires of which saplings have been the victims, can be traced by the occurrence of burnt leaders to be seen at intervals up the stems.

The Jarrah bush near centres of population has been burnt over as frequently as it is possible to set the bush on fire. The resulting regeneration might appear satisfactory to the layman, but to the forester it presents a most difficult problem. It is useless if left, but if cut down coppice forest, instead of sapling forest, will be the result.

It has been demonstrated now in two districts that fire control is economically possible under conditions obtaining in this State, and the principle of complete fire control has been definitely adopted by the Western Australian Forests Department as the first step towards re-stocking cut-over bush.

Complete fire prevention is impossible in practice, and controlled fires play an important part in silvicultural operations. Consequently to cover the protection of the forest from fire, the term "Fire Control" has been adopted locally rather than the term "Fire Prevention."

S. L. KESSELL,

Conservator of Forests.

Perth, 21st December, 1923.

Light Burning as a Method of Forest Protection.

REPORT OF FORESTRY OFFICIALS AFTER EXTENDED STUDY.

Light-burning agitation has thus far been centred largely in California. However, the timber owners of Oregon and Washington have watched with interest the gradual development in the light-burning controversy in California, because the conditions under which light-burning was advocated in California are duplicated in the pine forests of the Pacific North-West. The Forest Service has been committed to a policy of absolute forest protection ever since it was charged with the administration of the national forests, but it has always been interested in any impartial and careful study of the light-burning theory and all aspects of its application. Three years ago the California forestry committee was formed and it included representatives of the Forest Service, the California White and Sugar Pine Manufacturers' Association, the Southern Pacific Railroad Company, and the University of California. The committee gave open-minded attention to the light-burning methods of forest production and, after three years of attention to the problem, it issued a final report **which in effect discards light burning and advocates the so-called absolute fire-prevention plan** in use on all forests protected by the government and in vogue on by far the larger proportion of the privately-owned timber.

OREGON GIVES BASIS FOR CALCULATION.

The fire which covered a part of the Fort Rock area on the Deschutes several years ago have served as a basis to indicate what timber and reproduction losses can be expected for a number of years following hotb light and severe fires in yellow pine. As early as 1911, Messrs. T. T. Munger and E. H. MacDaniels prepared two reports on their observations. One report was entitled "Fallacies of the Light-Burning Method of Forest Protection," and included data on timber losses in light fires in yellow pine forests of Eastern Oregon. The other report was called "The Effect of Surface Fires in Preventing Subsequent Fires," and dealt with fire and forest conditions comparable to what is found in the "west side" forests of the district.

Light-burning is by no means a dead issue because of the verdict of the California forestry committee. Forest officers will, undoubtedly, be called on even more frequently in the future than in the past to defend the absolute protection against fire which the Forest Service is trying to render on the national forests, and which most of the private protective agencies are agreed best serves the interests of the timber owner. The findings of the California committee unquestionably greatly strengthen the case against light-burning.

TWO METHODS OF FOREST PROTECTION.

In general it may be said that there are two radically different theories of forest protection. The first of these is what may be called the fire-prevention theory, and it is based on the assumption that fire is absolutely harmful to the establishment of the reproduction which is needed for the perpetuation of the

forests; that it causes considerable damage to merchantable timber and that the prevention of fires is possible at a lower cost than any plan of controlled or light-burning which will accomplish the ends sought. This is the plan now in use in all government forests and on most privately-owned timber.

The other plan, variously called "light-burning" and "controlled-burning," is designed primarily to protect the merchantable timber, although in its later phases of development its advocates have claimed that it results not only in the protection of existing reproduction, but it is an essential aid in the establishment of new reproduction. This theory is based fundamentally on the assumption that fire prevention in the long run is an impossibility; that controlled-burning does protect the merchantable stands of timber and that controlled-burning is cheaper than the attempt to maintain absolute fire protection.

The theory of light-burning is based, according to the California forestry committee, on three postulates: (1) That under favourable circumstances, fire will run through the forest, consuming dead needles and branches, but with little or no damage to living trees. (2) That the intensity of a given fire depends largely on the amount of inflammable debris which has accumulated on the ground since the preceding fire on the same area. (3) That complete prevention of fire is impracticable.

THE CASE FOR LIGHT-BURNING.

Specifically the supporters of light-burning or controlled-burning base their attitude on part or all of these assumptions:

1. That before the advent of absolute fire protection, fires caused no great damage to timber because the fires ran over the forests at intervals and prevented the accumulation of much inflammable debris.

2. That light-burning is practicable in all pine forests, and will prevent damaging fires.

3. That as a result of the practice of fire prevention, great amounts of litter have accumulated, which result occasionally in very damaging fires.

4. That the fire-prevention policy was introduced from Europe, and that since there the inflammable material is removed by hand, the fire-prevention policy is not applicable in this country.

5. That the damage to mature timber by the practice of light-burning is negligible.

6. That fires do not fire-scar living trees.

7. That the clear trunks of much of our virgin timber is due to the occurrence of fires.

8. That fires kill the destructive bark beetles in standing trees and that, therefore, fires control epidemic infestations and prevent their recurrence.

9. That the smoking and charring of the bark of living trees by fire prevents the entrance of insects into such trees.

10. That fire is a cleansing agent and fills the same function in the forest that disposal of refuse does in the cities.

11. That reproduction is undesirable in the virgin forest, because it hinders the growth of mature trees.

12. That fire has a beneficial, selective action in dense stands of reproduction by thinning out the weaklings, and bringing the stand to the desired density without entirely obliterating it.

13. That brush fields within the timber belt are not the result of fire, but are natural phenomena.

14. That light-burning prevents serious fires, and that disastrous and uncontrollable fires will result from the accumulation of litter brought on by complete fire protection.

ALL ARE NOT AGREED.

It must not be thought that the light burners are all agreed as to the best way to burn, nor are they all of one mind as to what light-burning does in the forests. There are a number of differences in the way in which light-burning is used. One class of light burners believe that even light fires may do damage to merchantable timber, and to prevent such damage the litter is scraped away from around the base of the trees. In addition, the reproduction and brush close to the trees is cut down and the fire scars are filled in with dirt or rocks. A second class of light burners have only one thought in mind in using fires, namely, to control bark beetle infestations and prevent their return. These burners are of the opinion that light fires do not damage merchantable timber, and, therefore, the bug-cleansing fires are permitted to run over the areas without any efforts to protect the timber. A third class of light burners goes further than the other two in that it is admitted that some damage is done to both merchanable timber and reproduction unless special precautions are taken. To prevent such damage, the standing snags are burned in winter, then the windfalls and debris are burned at a time when the fires will not spread and the last step is the burning over of the areas in such a way that they will be entirely covered every five years.

Aside from the damage which is done to merchantable timber and reproduction by all three of these varieties of light-burning, the actual carrying out of the burning is full of practical difficulties and the cost is excessively high in comparison with the results secured. These are matters which will be discussed later in the report.

THE CASE AGAINST LIGHT BURNING.

Those who oppose light burning and are in favour of the plan of fire prevention in use on all national forests and most private timber maintain that the following are the effects of light burning:

1. The losses to merchantable timber by light burning are considerable; by burning down of previously fire-scarred trees or fire scarring uninjured trees to the extent that they are subsequently blown down by wind and storm; by actually killing trees due to heat of the fire; by cull and reduction in the grade of lumber due to fire scars and more rapid action of wood-destroying fungi; by greatly increasing the activity of tree-killing beetles; and by the reduction of growth of thrifty merchantable trees.

2. The damage to reproduction by repeated light fires is sufficient to make impossible the permanent production of timber.

3. Light burning results often in the enlargement of brush fields and the crowding out of the forest where it once grew satisfactorily.

4. The grazing resources of areas which are light burned are gradually reduced in value because of the practice.

5. The difficulties of actually carrying out light-burning operations are tremendous, and cannot be overcome at a cost many times in excess of the cost of systematic fire protection.

6. The use of even regulated fires in the forests results in an attitude toward fire protection on the part of the public which is hurtful to forest protection in general. It develops the feeling that special precautions to prevent fires are not

needed since fires often do not result in much damage to merchantable timber anyway. Even the most enthusiastic supporters of light burning are anxious that those who use the forests exercise all possible care to prevent and suppress fires.

MERCHANTABLE TIMBER AND LIGHT BURNING.

What damage does light burning do to merchantable timber? It is over the answer to this question that most of the controversy between the light burners and what might be called the absolute protectionists has been centred. The matter has several more or less distinct aspects. In the first place, there is the killing of trees by the heat of the fire as one type of damage. Then there is the burning down of trees which have been fire-scarred by previous fires or deepening old fire-scars or making such severe new ones that the trees are later blown down by wind. Another type of damage is that caused by wood-destroying fungi which enter the wood of living trees through the fire-scars. Fire-scars in the butt logs result in decreasing the amount of lumber which can be secured from them. Frequently even light fires damage the crowns of the trees. This results in slowing down the rate of growth, a condition which is really of economic importance when timbered areas contain any considerable volume of thrifty timber. Then the increase of bark beetles because of light burning is another important consideration.

But is light burning guilty of all or part of these things? Let us analyse some of the data. The death of merchantable timber by light burning is due to two things, namely, by the fire itself and by the insects which come afterward.

DESTRUCTION OF MERCHANTABLE TIMBER.

Even under the best possible conditions, the heat of the fires will frequently kill mature timber in considerable quantities. Heat killing of large timber depends, of course, on the intensity of the fire which in turn is dependent on the amount of inflammable material, the topography, weather conditions, etc. Even in the early spring, on steep south and west exposures, where the litter has dried most rapidly, or at the heads of draws where air currents are stronger, a light fire may flare up and destroy large trees.

Munger has shown in typical yellow pine stands in Oregon, burned over by frequent light, surface fires, five per cent. of the merchantable trees may be burned to death by a single fire. Four fires were studied.

Up to 1919, Show had studied the results of five fires in California in sugar-pine-yellow pine forests, which occurred under conditions like those which light burners have to contend with. He found that on a total burned-over acreage of about 12,000 acres over one per cent. of the timber was killed by fire. The conditions were similar to those in Southern Oregon.

EFFECTS OF FIRE IN YELLOW PINE.

For several years, M. L. Merritt, of the Forest Service, studied the effects of fire in a yellow pine stand in the Fort Rock district on the Deschutes National Forest. The merchantable timber, which died immediately because of heat-killing, even where the fire was of the lightest severity, amounted to more than two per cent. But the losses which followed for four years after the fire among merchantable trees which had been making a struggle to recover from the effects of the fire, were even greater than the volume of trees killed immediately by the fire. Merritt's findings have been found to apply also to fires in the Blue Mountains of North-Eastern Oregon.

In 1921, Show studied areas in Northern California which were under the light-burning plan of protection, and found that the killing of merchantable tim-

ber by the heat of the fire was sufficiently great to make the plan an undesirable one from this standpoint alone.

After three years of study, the California forestry committee came to the following conclusion on this phase of the problem:

"No burning yet critically studied failed to cause damage to mature timber, which was considerably larger than would be apparent to the casual observer."

KILLING OF TIMBER BY HEAT.

Thus far we have discussed only the killing of merchantable timber by the heat of the burn. Much merchantable timber is lost because it is burned down by further eating out of fire-scars brought on by previous fires. Or the fire-scars are deepened to such a degree that the trees are later blown down by the wind.

On one fire in North-Eastern Oregon, Munger found that one per cent. of the number of trees on the area were felled by the fire, and on another area over two per cent. were burned down by the fire.

Five typical fires in Northern California were studied by Show in 1918, and he found that five per cent. of the volume of yellow pine was burned down. Large trees are rarely burned down by a single fire, but a single fire may start a fire-scar which is constantly deepened by the fires which follow later. This deepening process goes on even during very light fires, for it is only necessary for the flames to reach the scar to ignite it. This is especially true of the pines, since their scars are usually quite pitchy and easily ignited.

Another burn studied by Show in Northern California in 1921 in a pure stand of yellow pine was covered by light burning under fairly favourable conditions. Over two per cent. of the timber volume was burned down. These results are similar to those which can be expected in the yellow pine forests of Oregon and Washington.

Investigations show that, in addition to the trees which are burned down, there is an additional loss of timber through the wind throwing of trees which have had their fire-scars deepened to such an extent that they cannot resist storms.

DESTRUCTION BY INSECTS FOLLOWING FIRE.

Some of those in favour of light burning have been of the opinion that light burning results in a decrease of the bark beetles, and that by light burning at the necessary intervals it is possible to prevent tree-killing bark beetles from getting a foothold on the areas which have this type of protection. The Bureau of Entomology and the Forest Service have given considerable attention to the relationship between fires and the character of the bark-beetle infestations which follow them. The conclusions which have been reached on this matter may be briefly stated as follows:

1. That fires, whether severe or light, often increase the annual beetle damage in yellow pine by several hundred per cent. over that which occurred before the fire.

2. That the trees which are attacked and killed after the fire are just as apt to be those which are slightly scorched as those which are not injured by fire. In other words, the beetles are not attracted by any weakening effect of the fires on the trees.

3. This great increase in beetle activity on the burn does not bring about any corresponding decrease in the beetle damage on the areas surrounding the burns.

4. That this large increase in damage does not usually continue for more than three or four years.

The above conclusions are based on careful observations, especially in the yellow pine and sugar pine forests of Oregon and Washington, and are apparently applicable to the pine stands everywhere in district six.

INCREASE IN KILLING BY BEETLES.

The increases in killing of merchantable timber by beetles after fires ordinarily varies from three to ten times what it was before the fires. Special attention to this situation has been given in or near the Shasta, Sierra and Plumas National forests in California and the Crater and Whitman National forests. The data bear out the fact that large increases in killing of merchantable timber by beetles after fires can be expected. The severity of the fires does not appear to have any influence on the degree of these increases.

On the Sierra National Forest, Ralph Hopping, formerly of the Forest Service, watched the progress of the infestation on a burned and an adjacent unburned area for four years. On the burned area the pine beetle loss for the four years following the fire amounted to about 350,000 board feet per section, while the four-year beetle loss per section immediately adjoining the burn totalled less than 50,000 board feet per section. In other words, the beetle loss on the burn was seven times as severe for a four-year period after the fire as it was on the adjoining unburned area for the same period. The timber was largely yellow pine.

1,200 PER CENT. INCREASE.

J. E. Patterson, of the Bureau of Entomology, has given this phase of the light-burning problem a good deal of time in Southern Oregon. On what is known as the Mistletoe burn of abont 800 acres, a comparison of the beetle damage done immediately before the fire and that which appeared immediately afterward showed an increase of about 1,200 per cent. On another burn, the Chinquapen burn in Southern Oregon, the fire was followed by an increase in beetle damage amounting to over 400 per cent. On a third burn in the region, the Siskiyou burn of 200 acres, the beetle damage after the fire also showed a large increase over that of the year before. The timber involved in this beetle destruction was yellow pine.

Show studied two fires in 1921, which were light burned under special precautions and conditions. These fires were located in Northern California and in the yellow pine forests. The pine beetle losses on these areas, before and after the fires, were estimated. The figures show marked increases in beetle activity after the fires. Show's findings are undoubtedly applicable to burns in the yellow pine forests of Oregon and Washington. They show increases of several hundred per cent. in the pine beetle damage after the fires. Show's data indicate also that there is no reslationship hetween the degree of beetle damage increase and the severity of the fires.

INJURY OF TIMBER BY FIRE.

It has already been pointed out that light burning kills merchantable timber by the direct effect of heat, by burning down fire-scarred timber, by so deepening the fire-scars that the trees are subsequently blown down, and by bringing about a greatly increased amount of hark beetle activity. But in addition to acutally killing merchantable timher, light hurning injures merchantable timber in several different ways.

In the first place, light burning causes the formation of fire-scars on a considerable percentage of trees on the hurns. These fire-scars may he gradually deepened and enlarged by later fires until the trees are finally burned down or

blown down. How general these fire-scars are on areas which have been purposely light burned or which have been covered by fires of low severity, is indicated by data from several different sources. These data are believed to be generally applicable to at least the east side forests of the district. Munger studied four fresh burns in North-Eastern Oregon. The per cents. of the trees scarred by the fires on these four burns were found to be 32 per cent., 43 per cent., 47 per cent. and 45 per cent. Munger found further that yellow pine in Eastern Oregon was very much more susceptible to fire-scarring than Douglas fir. In Northern California, in a yellow pine forest, Show tagged 321 trees, both with and without fire-scars, prior to light burning of the area. Of these trees, 120 had fire-scars on them, and the light burning enlarged and deepened over 85 per cent. of these fire-scars. Of the 201 trees without scars, 22 developed scars as a result of the light burning. The striking thing brought about by Show's data is that once the fire-scars are formed, a subsequent fire enlarges the far greater proportion of them.

HEARTWOOD DESTROYING FUNGI.

In the second place, fire injury makes it possible for heartwood-destroying fungi to gain entrance. Dr. E. P. Meinecke and Dr. J. S. Boyce, forest pathologists of the Bureau of Plant Industry, have shown that, through the fire-scars, wood-destroying fungi very commonly enter the heartwood of living trees. Carefully collected data are available on this point. In some species of trees, the amount of wood deterioration brought on by heartwood-destroying fungi, which secure their entrance through fire-scars, is very much greater than the other losses for which fire-scars are responsible, such as, for instance, lowering the value of the butt-logs for lumber, hastening the burning down, or blowing down, of merchantable timber.

In the third place, light burning often injures the crowns of trees by killing a part of the foliage. This brings about a decrease in the rate of growth for a number of years or even permanently. When the light-burned area contains a considerable portion of thrifty timber, this loss in growth is a real matter of dollars and cents to the owner, even for such short periods as five or ten years. This matter has been studied in several places in Oregon and California, but one specific instance will serve to bring out the point. On the Klamath National Forest in Northern California, a fire, in 1910, ran through a forest of yellow pine, sugar pine, and Douglas fir. The fire was one of average severity. In 1915, five years later, a study of the growth of the timber showed that there had been a reduction of 25 per cent. in the volume growth for the five years following the fire. On this particular area, this loss in growth is equivalent to 100 board feet per acre annually, which, at a stumpage rate of $2 per thousand board feet, would amount to 20 cents per acre. Weather conditions and other factors influencing growth, except the fire, were essentially the same during the two periods.

Until recently, the greater majority of timber owners have been interested only in the protection of merchantable timber. To them, reproduction usually increased logging costs and greater fire hazard. That is why many timber owners have been interested in a plan of light burning which would result in the destruction of the so-called "brush" and in the safeguarding of the merchantable timber against fire. There is, however, a certain school of light burners who are convinced that light burning leaves uninjured a sufficient proportion of the reproduction to enable the forest to perpetuate itself. It is the purpose of this section of the report to attempt to show that nothing short of absolute fire prevention is for the best interests of the future of the forest. From the Forest Service standpoint, it is just as important in the national forests to protect the reproduction as to protect the merchantable timber. Any plan of protection which does not in-

clude, therefore, both reproduction and timber cannot be considered to be applicable whenever continuous forest production is the one big aim of forest management.

CONDITIONS SIMILAR IN SEVERAL STATES.

The position is sometimes taken that light burning does not kill sufficient reproduction to prevent the new forest from coming on. The studies on this phase of the light-burning problems have nearly all been made in California, but the results of the studies are thought to be applicable with equal force to conditions in Oregon and Washington.

A few specific cases will be cited to show that light burning cannot be practised where permanent timber production is planned.

State Forester M. B. Pratt, of California, studied an area near Nevada City, California, which was "light burned" in the early spring of 1911. He found that over one-half of the reproduction from five to 40 years old had been killed.

Show studied an area in Plumas County, California, in 1915, three years after it had been light burned. On most of the area there had been a stand of reproduction less than six feet high and averaging 600 seedlings to the acre. Practically all of these were killed. Further, 80 per cent. of the saplings and small poles between two and eight inches in diameter were also killed.

In 1911, Show studied an area near Castle Rock, California, which had been light burned under the most favourable conditions. Practically all the seedlings less than 15 years of age were killed, and 60 per cent. of the young trees between 15 and 25 years of age were destroyed.

An area burned over in 1910 under the best possible conditions, located near Westwood, California, was examined by Show in 1915. He found that a single fire had killed 74 per cent. of the yellow pine reproduction and 83 per cent. of the white fir reproduction. Later fires such as are contemplated in a light-burning programme would undoubtedly make further inroads on the remaining young growth.

A light-burned area, studied by Show in Northern California in 1921, showed that 64 per cent. of the reproduction was killed by the fire.

HEAVY PERCENTAGE OF REPRODUCTION KILLED.

It is sometimes agreed by the light burner that even if 80 per cent. of the reproduction is killed, there is enough left to fully restock the area anyway. The fallacy of this assumption is indicated by the fact that over large portions of an area the reproduction may be entirely wiped out by the fire even though perhaps the percentage of the reproduction killed on the entire burn may not be alarmingly great. For example, the study by Show in 1921 mentioned in the preceding paragraph, showed that 64 per cent. of the reproduction on the entire burn was killed by the fire. But unfortunately the reproduction still living is not distributed over the burn by any means. On this particular burn, two-thirds of the area was left absolutely devoid and any reproduction whatever as a result of this one fire. The fact that light fires do not uniformly thin out the reproduction on the burns, but entirely wipe it out in considerable parts of them is perhaps the most important point to remember in connection with the effect of light burning on reproduction.

OTHER EFFECTS OF LIGHT BURNING.

In the previous sections an attempt has been made to show that light burning brings about:

1. The injury and death of merchantable timber in considerable quantities.

2. The destruction of reproduction to an extent which endangers, or makes impossible, the future forests.

3. Damage to the grazing resources.

There are at least three other unfavourable effects of light burning which deserve, at least, brief mention. The increase of brush in the forests and the gradual change of forests into brush fields are problems which are vital in Southern Oregon and Northern California where fires have been set for one purpose or another on private and government lands. Light burning sometimes results in the gradual change of a forest of valuable tree species to a forest of inferior tree species. The third matter, entirely unrelated to the other two just mentioned, is the unfavourable effect which the practice of light-burning has on our efforts to educate the public to be careful with fire in the woods.

BRUSH AND LIGHT BURNING.

In regard to this matter, Show is quoted as follows:

"Probably most of the men who favour light burning make it a point of their creed that light fires keep the timber open and free from brush. Our own studies made over wide areas and for a considerable period of years show that what is now generally recognised, namely, that **fires may kill out timber but they do not kill out brush.** We find in many cases that certain brush species show remarkable vitality and vigor in coming back after fire. For example, in Southern Oregon and Northern California it has been found that the number of manzanita plants has sometimes been increased as much as 900 times following a fire. On specific light-burning areas where white-thorn, manzanita, and similar brush species occurred scatteringly before the fire, we found that the number of shoots from a given clump increased two or three times after the fire."

(From a report called "Forest Fire Protection in California" and dated November, 1919.)

BRUSH FIELDS REPLACE TIMBER.

Again and again brush fields are encountered where it is evident without question that trees of merchantable value once grew, and brush fields took their place as the result of repeated fires. These brush fields most frequently occur on steep south or west exposures, where conditions are especially favourable to destructive fires. Many brush areas stop sharply at the tops of ridges which are still covered with timber, and end abruptly at the bottom of slopes where the forest is still maintaining itself—a situation which in itself indicates that fire is responsible for the breaks in the forest. Charred snags and stumps furnish convincing evidence of a former forest. In very old brush fields, there may remain nothing but remnants of roots of trees or a shell of bark to prove that large trees once occupied the ground now covered by brush.

150,000 ACRES PRACTICALLY TREELESS.

The complete destruction of the forest and the formation of brush fields is a gradual process and results from the effect of many fires. The history of one brush field may help to illustrate this point. Show describes an area of 150,000 acres in the lower McCloud River and Squaw Creek watersheds which 50 years ago supported a forest of 15,000 board feet per acre composed of yellow pine, sugar pine, Douglas fir, and incense cedar. In 1875, a fire started near the lower limits of the area and burned from June until early October, a fire which resulted in the death of from 50 to 75 per cent. of the timber. In 1898, a second fire covered the same area and killed most of the remaining timber. Only a few scattered remnants of

living forest remained in such sheltered spots as creek bottoms and parts of north slopes. At present, the brush is so dense that travel through the area is difficult. The average stand of timber is now less than 1,000 board feet per acre. The reproduction is now slowly coming in.

Dr. J. V. Hofmann, of the Wind River Experiment Station, investigated the history of the brush fields in Southern Oregon, and found that all of them had their origin in repeated fires. He found, further, that fires merely served to make the brush gradually more vigorous and plentiful until unbroken brush fields were the final result.

It is evident that these brush fields covering as many thousands of acres, represent an enormous loss in possible timber production. Not only are brush fields within the timber belt non-productive of timber, but they increase the danger from fire to surrounding timber.

INFERIOR SPECIES AND LIGHT BURNING.

It is well known that different species of trees vary in their ability to withstand heat. When fires are permitted to run through the forest repeatedly, those trees which are most sensitive to fire are killed out first, and the more fire-resistant tree species increase. In Eastern Oregon and Eastern Washington many stands of timber now consisting almost entirely of lodgepole, an inferior species, formerly contained a considerable volume of yellow pine. There are undoubtedly several different causes for this change, but unquestionably repeated fires have had much influence in bringing about such an undesirable change. Where complete protection against fire is given, the yellow pine will be encouraged to resume again its former abundance in these lodgepole-yellow pine forests.

There are other forests similarly affected by fires and in which the inferior species are encouraged at the expense of the better species, as a result of repeated fires.

PUBLIC SENTIMENT AND LIGHT BURNING.

For years, all those responsible for the protection of privately owned timber, as well as those charged with the safeguarding of the government's forests against fire, have used all possible means to impress upon the public the necessity for being careful with fire in the woods. The practice of light burning can only result in a feeling on the part of the forest-using public that fires are not such a serious menace after all and that, therefore, undue precautions to prevent them are more or less unnecessary. This is the experience of both government and private protective agencies in those portions of the Pacific Coast where light burning has been more or less prevalent in the past. This is by no means a fanciful effect of light-burning propaganda.

COST OF LIGHT BURNING.

In the early part of this report is was brought out that there is no uniform system of light burning. It is evident, therefore, that there must be a great variation in the costs of light burning. The cost of application of a certain kind of light burning would vary with the condition under which the light burning is attempted. As a consequence, the figures which are given are merely indications of the range of costs within which light burning has been done in the past. One light burning done on a large scale in yellow pine of Northern California which involved some scraping away of the litter from merchantable trees and filling some of the fire-scars with dirt or stones, cost 50 cents per acre. Under present conditions, this work would probably cost nearly $1 per acre. The burning resulted in practically no damage to the mature timber, but the burning was never repeated.

In 1921, another large light-burning operation in the yellow pine of Northern California was studied. In this burning, fire lines were built around each 160 acres. Standing snags near the fire lines were felled before the burning. The burning was done at night during the mid-summer. The operation cost $1 per acre. The same work in 1911 cost between 40 and 50 cents. per acre. The results were not satisfactory because of the quantity of merchantable timber injured and killed by fire, and by bark beetles which followed the fire.

In 1919, a 200-acre light burning was carried on in private lands within the Plumas National Forest in a mixed yellow pine, sugar pine, and Douglas fir forest. The building of a fire line around the area was the only preparation. The cost of the work was 34 cents per acre, and the results were of doubtful value.

DIFFICULTIES IN LIGHT BURNING.

The history of the attempts to light burn successfully shows repeatedly that it is extremely difficult to know just when to light burn without expensive watching of the areas which are to be burned. Often favourable conditions last but a few days or a week, and far too short a time to enable the burning of large areas. Conditions may be favourable on the south slopes, for example, and yet no burning at all be possible on the north slopes. The difficulties involved in deciding upon the right time to burn and the many mistakes which have been made in arriving at these decisions have perhaps been responsible, as much as any other thing, for the permanent abandonment of light burning by many of its advocates. The California forestry committee, after three years of work, was thoroughly convinced that the answer to the question of when to burn was one of the most intricate and puzzling matters involved in the whole light-burning problem.

THE EFFICACY OF THE FIRE-PREVENTION POLICY.

The costs of the present plan of protection in force on the national forests and most of the private holdings are too well known to warrant description, and the results of the fire-prevention policy need not be given here, for every ranger and every supervisor knows whether the present protection methods are effective and whether they can be made more effective. However, the forest officer must know what the costs and the results of the protection methods used by the Forest Service are if he is to be in a position to answer the arguments of the light burner.

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