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The Development of Forest Practice and Management in Western Australia

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THE DEVELOPMENT OF FOREST PRACTICE AND MANAGEMENT IN WESTERN AUSTRALIA.

The timber industry has played an important part in the industrial life and development of Western Australia. Trial shipments in the very early days of the colony established the excellent quality of local hardwoods, and an appreciable demand from overseas buyers has shown a steady increase since 1850. By 1913 the export trade had reached an annual value of £1,089,500, and no effort had been made to regenerate or protect cut-over areas. During the period 1850 to 1920 the total declared value of timber exports amounted to £16,200,000. In addition the increasing population had resulted in a greater demand for timber for local consumption. To build up this trade considerable capital has been invested in the industry, and a comparatively large population has become dependent on the preparation of indigenous timbers for the home and overseas market as a source of livelihood. As early as 1904 a Parliamentary Commission reported among its findings that "in the interests of the State it would be a wise policy to discourage any increase in the rate of timber cutting till the consumption of scantling sizes is apace with the export of the larger sizes. State acquiescence in the destruction of good timber, only because the export trade demands it, is a crime against coming generations; and any attempts to increase the export in the interests of foreign companies or with the object of inducing more men to join in timber getting at the expense of posterity, needs wise resistance." Apparently the Government of the day was not prepared to face the problem of restricting a growing primary industry in a country then largely dependent on gold mining, and the Commission, unassisted in their deliberations by any forester, failed to view the problem in its widest aspect. The forest was a timber mine to be worked over and neglected. A better appreciation of the principles of forest economics might have led to a suggestion that "the crime against coming generations" referred to by the Commission was associated not only with the failure to restrict exports, but in the negligence to provide proper conditions for the protection and regeneration of "cut-over" forests.

By 1910 conditions had changed. Wheat and wool had supplanted gold mining as the principal primary industries of the State.

Timber continued as the principal product of the wet South-West, but the big reserves of untouched forests were no longer available. It was not until 1918 that a Forests Act, embodying the necessary provisions for the control of timber getting on Crown lands, and the protection and regeneration of timber trees on prime forest areas, was placed on the Statute Book. It has proved a fortunate thing for the State that early timber concessions and leases granted for long periods on easy terms made provision that the land should remain the property of the Crown. The last of these concessions expires in 1929, and the last of the leases in 1933, when the land with any timber remaining on it, reverts to the Crown.

With the support of the legislative provisions contained in the Forests Act, 1918, there has been a steady improvement in the position with regard to timber on Crown lands. The restriction of output and increased values have resulted in the exploitation of inferior forest types, which passed into private ownership as grazing country many years before the value of the timber carried was appreciated. The volume of timber on such land is limited, but it has proved sufficient to maintain the total output of timber from the State at its pre-war level. The tabulated statement hereunder indicates the extent to which conditions have changed in view of the fact that prior to 1918 the volume of timber obtained from private property was negligible, and the bulk of the output from Crown lands was hewn and sawn sleepers. The following figures are for the year 1926-27:—

Obtained from Private Property.		Obtained from Crown Land (including State Forests and Timber Reserves and land in the process of alienation).			Total.
Hewn Sleepers.	Sawn Timber, including Sleepers.	Hewn Sleepers.	Sawn Sleepers.	Other Sawn Timber.	
5,758,846 cubic feet valued at £719,856	850,694 cubic feet valued at £106,337	1,764,216 cubic feet valued at £220,527	1,583,368 cubic feet valued at £197,921	11,420,193 cubic feet valued at £1,427,524	21,377,317 cubic feet valued at £2,672,165
27 per cent.	4 per cent.	8 per cent.	7 per cent.	54 per cent.	100 per cent.

Of the total production of 21,377,317 cubic feet, the volume exported during the year amounted to 12,580,262 cubic feet, or 59 per cent., valued at £1,659,876. It is estimated that 8,000 men with their families are directly dependent on the industry. Several million pounds capital are invested in large mills with railway systems, town-

ships, and all the associated machinery and plant. Timber constitutes a big factor in railway revenue, returning 19.16 per cent. of the gross receipts of the Government railways, compared with 13.93 per cent. from wheat. The prosperity of the ports of Bunbury and Busselton, and, to a less extent, Fremantle, depends on the timber trade.

Among the most difficult problems of forest management under Western Australian conditions is the need for decision concerning the extent to which the combination of economic factors, briefly indicated above, may be allowed legitimately to influence the application of rules and formulæ for the determination of the annual yield to be extracted, as sawn or hewn timber, from each permit area. With heavy capital investments in large sawmilling plants in certain districts, and reserves of untapped forests in other districts, it is evident that purely local Working Plans cannot alone meet the position. The two main forest types in Western Australia (Jarrah and Karri) may be described as comparatively pure compact forest areas, and in considering questions of sustained yield must be envisaged as single units.

Among the clauses of the Forests Act, 1918, provision was made for a joint classification of timber country to be carried out by the Lands Department, representing agricultural interests, and the Forests Department, representing timber interests, so that an early and precise determination should be made of the lands which are suitable to be (a) permanently dedicated as State Forests, or (b) reserved from sale as Timber Reserves (Forests Act, 1918, Section 19).

This joint classification disclosed the satisfactory position that the bulk of the finest timber was not growing on arable land, but despite this fact it has remained for the present administration, ten years after the passing of the Act, to make the first serious attempt to give effect to the intention of Parliament concerning the permanent reservations of prime forest areas.

This classification served to show that early estimates of the area of prime timber country of each species had been greatly in excess of the actual area. The result of the classification may be summarised as follows:—

Prime Jarrah forest (*Eucalyptus marginata*)—2,330,000 acres.

Prime Karri forest (*Eucalyptus diversicolor*)—75,000 acres.

Prime Tuart forest (*Eucalyptus gomphocephala*)—5,289 acres.

Prime Tingle forest { *Eucalyptus Jacksoni* / *Eucalyptus Guilfoylei* }—8,662 acres.

Practically the whole of which are now being dedicated as State forest.

In comparison with the total area of the State (624,588,800 acres) these areas are small, and represent a very low percentage of the total wooded area. A large proportion of the State is carrying a low volume per acre of hard and heavy Eucalypt timber which cannot be marketed at a profit at the present time. Large tracts are being cleared annually for the growth of cereals, but extensive areas of poor land bordering on the prime forest belt will be retained under timber, and will help to increase the total volume available for trade purposes in the future, with higher values and more economical methods of exploitation.

Sandalwood (*Santalum spicatum* syns. *Santalum cygnorum, Fusanus spicatus*) and Mallet Bark (*Eucalyptus astringens*) are species of considerable economic importance, but do not occur in extensive pure forest formation, and were not dealt with in the first classification. Considerable attention has been devoted to these two species during the past three years, and comprehensive Working Plan reports prepared, which will allow extensive reforestation measures to proceed as soon as initial experimental work in methods of establishment by artificial sowings has been brought to a satisfactory conclusion.

A classification of Crown lands in the habitat of each species has been made with the object of reserving sufficient area for reforestation operations, and the following areas have been set aside for the purpose:—

Sandalwood reserves—205,176 acres.

Mallet reserves—45,716 acres.

Sandalwood.—The artificial regeneration of Sandalwood presents a number of unusual botanical and silvicultural problems. In 1920 it was definitely established that Sandalwood was a root parasite, but it was not known to what extent this root parasitism was obligatory, at what stage in its life history the first connection was established, or the plants suitable for hosts. Early attempts at reforestation were abortive, and after publication of Herbert's work on root parasitism of the species this was attributed to local destruction of host plants prior to planting operations. The problem was reconsidered in 1920, and the conclusion reached that for the successful establishment of Sandalwood plantations, work would need to be confined to country within the 18-inch to 20-inch rainfall belt, carrying a crop of *Acacia acuminata*, which was the only recognised host plant at that time. Two reasons were given for this conclusion: firstly, the difficulty of carrying over young seedlings after germin-

ation in lower rainfall areas, except in very exceptional seasons, and, secondly, the slow rate of growth to be expected in such areas. Careful search had failed to reveal any extensive areas of Crown lands considered suitable for the purpose. About 1921 attention was drawn to the importance of the physical properties of the oil distilled from *Santalum spicatum*. The optical rotation of the oil, which is of some importance in enabling it to conform with B.P. standards, was found to vary with the district of origin of the wood, and wood from the low rainfall areas of the Eastern Goldfields proved most satisfactory to distillers. Attention was thus drawn to the problem of reforestation in these districts where extensive areas of land were available, free from conflict with agricultural or pastoral interests. A careful study of immature Sandalwood to be found in all stages led to the unexpected conclusion that natural regeneration was reasonably plentiful in regions of 8-inch to 10-inch rainfall. The numerous flowering shrubs such as Acacias and Eremophilas occurring in the country around Kalgoorlie were found to be satisfactory host plants, and subsequent investigations have traced 77 distinct species of host plant in this region. Following the removal of the Eucalypts over large areas for mining timber and fuel these shrubs have taken possession and regenerated freely, and where this condition of plentiful vigorous growing host plants is associated with satisfactory conditions of soil and contour, large scale plantation experiments are now being carried out.

Without attempting to trace the history of sowing operations over a period of four years, during which 1,850 acres have been sown, the present state of our knowledge may be summarised as follows:—(a) In low rainfall areas parasitising of the Sandalwood seedling on the host plant within a few weeks of germination is essential; (b) the most important factor in selecting an area to be planted is a satisfactory stocking of host plants in a condition of vigorous development; (c) soil texture and contour are of importance, and early results indicate that, even on slopes, sandy loams appear to hold the moisture near the surface for a longer period following heavy downpours than heavier soil on wide flats; (d) sandalwood "nuts" buried for several years in the ground will retain their germinating capacity despite infrequent light rains and germinate after heavy rains; (e) soil cultivation at time of sowing, depth of sowing, and size of nuts are all factors of considerable importance in connection with which the series of experiments on various soil types are proceeding; (f) in rabbit-infested districts young Sandalwood are freely attacked during the summer months. Attacks are continued until the young plant is killed, partly by destruction of foliage and partly by bark damage.

Mallet.—Mallet (*Eucalyptus astringens*) presents an interesting problem as a Eucalypt occurring in comparatively small colonies scattered through forests of Wandoo (the vernacular name of two associated species (*Eucalyptus redunca, var. elata,* and *Eucalyptus accedens*). The colonies of Mallet are usually found clustered on ridges where a peculiar conglomerate type of laterite occurs in the form of large deposits, or on slopes covered with gravel formed by the decomposition of this laterite. This rock formation has not been fully investigated by either chemist or geologist, and except for the ease with which large boulders may be broken into component gravel, might be taken for the ordinary ferruginous laterite so common in the South-West of Western Australia.

Considered as a problem of ecology one would be led to suggest that the Mallet has been caused to retreat to the poorer hill tops by the advancing Wandoo type of forest. The latter possess two very great advantages over the Mallet. Both species of Wandoo, owing to their thick smooth barks, are exceptionally resistant to damage by fire, and have very strong power of reproduction by coppice shoots. Mallet is thin barked, easily killed by even radiant heat from a fire, and coppices weakly.

Recent unpublished work by Mr. W. M. Carne, Economic Botanist and Plant Pathologist, Department of Agriculture, Western Australia, undertaken in connection with consistently unsatisfactory results from cereal crops sown on cleared Mallet country, has led to the suggestion that the so-called laterite of the Mallet hills gives rise, on decomposition, to certain peculiar soil conditions. Whether this is due to the presence of certain definite metallic salts liberated in the soil, or the effect of these salts on soil acidity, has not been definitely determined, but remarkable variation has been shown to exist between winter and summer p^{H} values of Mallet soils.

How far the Mallet habitat is determined by dependence on these soil conditions remains to be shown, but it is evident from a study of the natural occurrence of the respective species that Wandoo can grow on practically all types of Mallet soil, but Mallet is not likely to grow on certain wide-spread types of Wandoo country. Pending more careful field examination of the chemical characteristics of Mallet soils, artificial regeneration by spot sowing of seed is being undertaken only on land where small colonies of Mallet are plentiful.

There is nothing novel in the method of sowing a small pinch of seed in cultivated spots regularly spaced at intervals of 6 feet by 6 feet. Best results are obtained from seed sown on ash beds where the tops of large trees have been burnt, but it is not known how far

this result is due to the fertilising value of the ash, or to the elimination of competition by the destruction of woody shrubs. It is probable that both factors assist in promoting rapid growth after germination.

The encouraging results obtained from sowings on the Lol Gray Working Circle, where approximately 500 acres have now been established, has led to proposals to establish a number of new Working Circles on which the first work to be undertaken will be the protection and thinning of existing regrowth. On the first two groups of reserves dealt with the Working Plan reports show that in each case, within a radius of five miles of the proposed site of overseer's house, the following areas are available:—

Montague Working Circle—

Area of Mallet regrowth fully stocked—317 acres.
Area of scattered Mallet regrowth—1,049 acres.
Area of country suitable for sowing of Mallet—2,847 acres.

Lol Gray Working Circle—

Area of Mallet regrowth fully stocked—345 acres.
Area of scattered Mallet regrowth—1,052 acres.
Area of country suitable for sowing of Mallet—2,831 acres.

Jarrah.—Jarrah (*Eucalyptus marginata*) is the principal timber species of the State. Jarrah is also the most valuable of timbers owing to its wide range of uses. Its unusual durability renders it useful for all underground work, and the export of railway sleepers forms a large part of the overseas trade at the present time. It is equally well suited to cabinet work, and is being used for flooring, interior wood work and furniture in increasing quantities. When dressed, it works up to a fine finish, takes an excellent polish, and resembles Honduras mahogany.

Jarrah is found in practically pure forest formation, and the area of 2,330,000 acres of prime forest occurs as an almost continuous belt, some 20 miles wide and 200 miles long, extending from Mundaring in the north to Manjimup in the south. It is a rough-barked Eucalypt, developing under optimum conditions into a tree 150 feet in height with a girth (b.h.) of 16 feet, and a clear bole of 60 feet. According to European standards, it may be described as a light demanding species with a fair spread of crown. The virgin forest is usually open, having a ground cover of woody shrubs about one to two feet in height. When the canopy is broken and the vitality of remaining trees affected by frequent fires, a thicker and taller understorey develops. The geological formation throughout the Jarrah belt

is granite, and the surface of the ground is practically covered with a ferruginous laterite either in the form of broken capping or gravel.

The rainfall varies from 35 to 45 inches, practically the whole of which falls during the winter months. From December to March high temperatures and absence of rain intensify the problem of the survival of natural regeneration, particularly where such regeneration is endeavouring to develop in competition with seed trees and woody undergrowth. It is apparent that, unlike European conditions, the intense competition and struggle for existence between the components of the forest floor takes place not for light, but below ground level in the attempt to secure sufficient moisture.

Jarrah coppices freely, particularly in early life. Extensive areas of first quality Jarrah forest have been worked through under minimum girth restrictions by sawmillers or hewers, and in many cases by both. Regulations have existed for many years prohibiting the cutting of any tree under 90 inches girth measured at 4 feet 3 inches above ground level, with the result that the canopy of the comparatively even aged mature virgin forest has been opened up, and natural regeneration from seed has resulted in the "blanks" so formed and occasionally under the remaining crop. This regeneration has received no care or protection, with the result that, while certain groups of pole and pile growth have developed, a very great deal of it represents faulty advance growth. In dealing with species which coppice freely it is desirable both from an economic and silvicultural point of view that use be made of this advance growth. Careful observations have shown that if cut back to ground level, small Jarrah saplings may be expected to produce shoots which will develop more rapidly than seedling growth of the same age, and grow into satisfactory mill logs.

Jarrah seedlings are slow to develop after the first leaves replace the cotyledons. After two or even three years they are frequently only a few inches high, with half a dozen tough leathery leaves, but a much greater development of tap root takes place under ground. After the first year a pair of very pronounced woody nodules are formed at ground level, of the type characteristic in Eucalypts having the power of coppicing vigorously.

The operations of mill fallers and hewers during a period of 50 years, working under this faulty selection system of depending entirely on minimum girth restrictions, have resulted in the cut-over Jarrah forest containing an unduly high percentage of malformed, over-mature and damaged trees, and the removal of these trees and their replacement by a new crop represent the main silvicultural problem. Before endeavouring to secure more complete utilisation,

some reasonable assurance that a new crop can be obtained economically and expeditiously is needed. The popular idea among bush workers of long experience in the Jarrah forest was that a fire after falling operations was inevitably associated with plentiful natural regeneration, resulting from seed in the ground being baked and rendered fertile by the fire. Careful observation and germination experiments disproved this theory, and showed the importance of seed years in securing adequate regeneration by natural means. After several years of careful study the factors controlling successful natural regeneration of Jarrah may be summarised as follows:—

(1) Seed years occur every three to four years, but not uniformly over the 2,330,000 acres. Practically every tree in one district will be heavily laden with seed, while there is little or no seed to be found on trees in a district 50 miles distant.

(2) A strong surface fire destroys practically all seed in and on the ground, and natural regeneration is dependent on seed dropped from the trees standing on the area at the time of the fire.

(3) Owing to the weight and size of seed, distribution is poor, and numerous seed trees are necessary to secure an even stocking by natural means. On a well-grown tree with a large top, 10 ounces of seed may ripen in a favourable season, made up of 10,000 to 20,000 fertile seed, but this will seldom be distributed by natural means much further from the bole than a distance equal to the height of the tree.

(4) Natural regeneration is uniformly good in open spaces immediately adjacent to and under the canopy of trees bearing seed where a ground fire has been put through the forest during January, February or March following the ripening of the seed. During a year when climatic conditions are normal, the seedlings survive only in the open or when the mother trees are killed before the summer following germination.

(5) Germination will take place without the summer ground fire, but is not so uniformly good owing to a large quantity of the seed remaining on the tree until the second year, and the young seedlings suffer to a great extent from the ravages of insects while in the cotyledonary stages. Another important consideration in practice is the greater fire risk to which the young crop is exposed, owing to the accumulation of debris on the ground.

(6) An ordinary surface fire does not kill advance growth on the area, even when present as seedlings only a few years of age, and in practically every compartment a full stocking may be expected from such advance growth which, if above 6 to 10 feet in height and malformed, is cut down before the fire. Owing to the general occurrence of this advance growth, areas where the retention of seed trees is necessary, are the exception rather than the rule.

With regeneration operations proceeding in 30 centres in the Jarrah forest, and very limited professional staff, it has proved necessary to standardise silvicultural practice and adopt certain arbitrary standards, which longer experience in dealing with the species and results from sample plots may show need modification. The silvicultural system followed is most nearly described as "selection by groups," and regeneration operations are divided into the removal of marked trees by permit holders, generally referred to as trade cutting, followed by regeneration cleaning by departmental employees. The term "regeneration cleaning" has been adopted to express the completion of the regeneration work which is started by the fallers who extract the mature merchantable timber. Another point worthy of explanation is the purpose of any valueless, over-mature trees which may be retained as "seed" trees. Under local conditions these trees have no function as a shelterwood but are retained for seed only, and must be destroyed by ring-barking (girdling) before the summer following seed fall, otherwise they may enter into moisture competition with the seedling and cause total loss of the seedling crop which germinated in the previous winter. The ring-barked trees remaining in this way may constitute a fire menace, but have never been found to prove a menace by breeding insect or fungus diseases. The disposal or utilisation of the tremendous volume of dead timber remaining on a compartment after regeneration operations is a serious economic problem which it seems will not be solved until the local population is many times the present figure. Its removal, apart from the damage which may result to immature trees around, is an economic impossibility under existing conditions.

Existing practice may be briefly summarised as follows:—

(1) Advance burning.—The area to be worked over during the ensuing twelve months is burnt over by a slow ground fire in spring or autumn. The object of this fire is to facilitate timber getting and reduce fire hazards resulting from lop and top after falling operations.

(2) Tree marking.—An officer who is an experienced bush worker, with a knowledge of timber values and some training in the elements of silviculture, brands the base of every tree which may be taken out. No attention is paid to the improvement by thinning of existing stands of immature timber in the pole stage during this marking, but all marketable over-mature timber is removed as far as economically possible, thereby opening up "blanks" on which regeneration may be secured.

(3) Trade cutting operations are then carried out by falling for milling or hewing, and provision is made that coupes are worked through in regular order. This work is performed by private companies operating under a permit to cut on the particular area on a royalty basis.

(4) Regeneration cleaning.—This operation is confined to work on the blanks left by trade cutting, and comprises all operations up to the time of the final burn. Advance growth is cut back level with the ground; Xanthorrhoea, Banksia, and other useless species are cut down; debris is cleared away from around good groups and promising individual trees. In the exceptional cases where there is insufficient advance growth already on the ground, useless Jarrah trees remaining are partially ringbarked, a strip of bark about one foot wide being left intact so that these trees may serve as seed trees and be easily and expeditiously destroyed when they have served this purpose.

(5) Final burn.—Where there is sufficient advance growth to supply a reasonably full stocking, a ground fire is run through the treated compartment in the summer following treatment. The principal object is the reduction of fire hazards in subsequent years. Where regeneration from seed is desired, the compartment is protected from fire until a satisfactory seed year occurs, when it is burnt in the summer following the maturing of the seed vessels. This fire causes a simultaneous fall of all seed on the trees, and provides that the seed falls on a satisfactory germinating bed of ash or mineral soil, from which it starts in the next winter on more or less equal terms with the competing undergrowth.

(6) Final ringbarking.—As soon as possible after the final burn the ringbarking of seed trees partially done during regeneration cleaning is completed.

During the past five years 24,000 acres of Jarrah forest have been treated for regeneration in this manner, and provision is being made to extend this work as rapidly as men can be trained and houses built.

Reference has been made to the fact that no improvement work in existing groups is associated with regeneration cleaning. In training staff to actually carry out the work without interference with groups or unnecessary clearing of second-storey species under the groups, this has been found necessary. As overseers become more experienced, the removal by ring-barking of useless trees over-topping promising trees in a group is frequently authorised. Improvement work, principally thinning in groups which have reached the pole and pile stage, is not justified until such time as a market can be established for the poles, and this has not proved practicable to date. Younger stands still in the sapling stage have been treated in certain centres, where they occur over extensive areas following heavy trade cutting 15 to 20 years ago. This work is of a particularly urgent nature, as the saplings have not yet suffered from the dominance of faulty mature timber left after the falling, although frequently the dominants among the saplings themselves are bad forms resulting from successive fires. Jarrah thins itself comparatively satisfactorily, and it is a moot point whether thinning will be justified as sound economic practice in a treated forest which has received reasonable protection from fire damage following silvicultural treatment, but it is certainly necessary if the natural regeneration, referred to above as still in the sapling stage, is to be converted into a forest in which the dominants are trees with the best form.

Eleven hundred acres of young Jarrah have been improved by the removal of dominants of the previous crop and crown thinning during the last twelve months, and the work is being extended as suitable areas of natural regrowth are located.

Karri.—The Karri forest is restricted to the higher rainfall regions of the extreme South-West (40 to 60 inches). It is the only forest in the State which approaches the temperate rain forest type, in that the undergrowth and trees of the lower storey have a softer foliage. The Karri trees tower to a height of 200 to 250 feet, with a girth of 120 to 200 inches, and although larger specimens are frequently found, it is questionable whether any trees over 300 feet in height exist to-day. The timber resembles Jarrah in general appearance, but is stronger. It is not durable in the ground unless treated, and does not work to a satisfactory finish as readily as Jarrah, but these characteristics do not affect its value for superstructional work, wagon building, etc.

The tree has a clean light-coloured bark, and in pure forest formation is most impressive. The areas of pure forest are restricted to belts and patches of a few thousand acres, but it occurs as the predominating species mixed with Marri (*Euc. calophylla*) and Jarrah over 240,000 acres in sufficient quantities to render milling payable even under present conditions. In pure forest, yields of up to 20,000 cubic feet of merchantable log timber per acre have been recorded.

The soil of the mixed Karri and Marri and, to a less extent the pure Karri, has attracted considerable attention during recent years for intense culture, with the result that areas cut out by big sawmills have been subdivided for settlement, but the work of dedicating pure Karri country as State forest is now proceeding. Within the first area dedicated, 7,500 acres of country which have been milled over have received silvicultural treatment. The removal of the large trees and heavy loadage results in the destruction or damage of nearly all the immature trees which may exist in the virgin forest. Sufficient damaged smaller trees and faulty over-mature trees remain after sawmilling operations to provide seed, so that the subsequent regeneration operations amount to "clear felling," with the retention of odd immature trees or groups of immature trees from the original crop. The procedure adopted has been to fall the understorey of *Casuarina decussata* and other species; hold pending a seed year; burn in midsummer and immediately ringbark the worthless seed trees, as even in the Karri forest the competition for moisture in summer may prove sufficient to cause the death of the seedlings. Five hundred acres of treated country were completed by a "final burn" last year, so that by the end of next summer our knowledge of the species will be considerably increased.

Tuart.—Tuart (*Eucalyptus gomphocephala*) is a Eucalypt of restricted habitat, providing a timber specially valued for railway wagon construction. Problems of natural regeneration referred to in connection with Jarrah occur in an exaggerated form, and in consequence have been the subject of special investigation. Tuart grows on a sandy soil, having a depth of usually 10 to 20 feet over limestone. It is one of the few forests in Western Australia which carries a crop of grass, and this fact, resulting in heavy grazing and annual grass fires, has been responsible for the absence of natural regeneration during the last 30 or 40 years. With fencing and fire prevention it was anticipated that a crop of Tuart would rapidly re-establish itself on many of the extensive blanks. Seed years were found to be infrequent, but, following a heavy seeding and treatment under the Group Selection System on lines indicated for Jarrah, a carpet of seedlings was noted in the following winter. By

the middle of summer practically every seedling, except those on "ash beds," where debris such as the tops of fallen trees had been burnt, were dead. Results in subsequent years confirmed the conclusion that satisfactory natural regeneration could only be expected on ash beds. A study of "ash bed" conditions suggested that survival was due principally to the fertilising value of the ash, but it has not proved possible to develop a technique of sowing on more restricted and better distributed spots giving similar results. Transplanting of seedlings from ash beds to surrounding blanks during the winter following germination has proved reasonably successful, and planting in bamboo tubes and from trays has shown that artificial regeneration is feasible, but the form of the single-planted specimens in their early years, following the attacks of bark and leaf-eating insects, is not promising. A further problem is introduced by excessive regeneration of peppermint (*Agonis flexuosa*), a second-storey species which has regenerated and coppiced to such an extent, following repeated fires and over-grazing, that it has rendered the prospect of successful regeneration of Tuart being established on certain compartments, at reasonable cost, unlikely. At the present time consideration is being given to a proposal to introduce a rotation of *Pinus pinaster*, retaining only vigorously growing young Tuart as standards, with the object of restoring satisfactory forest conditions for the future regeneration of Tuart.

Fire Protection.—Reference has already been made to the part played by fire in the regeneration of the forest. One of the greatest problems is the protection of the young crop from fire after establishment. It may be accepted as a literally correct statement that prior to 1920 the whole Jarrah forest was burnt over by surface fires every three years. Only the great resistance of Jarrah bark and timber to fire, and the power to coppice freely, have saved the species from extinction. Frequent bush fires were looked upon as inevitable and rather to be encouraged, in that a fire every two or three years was much less of a menace than a raging conflagration in a forest which had escaped burning for a long period of years. Large scale operations during the past five years have shown that with proper organisation, fire protection is economically possible in Jarrah forest. Permanent look-outs are necessary during the five dry summer months, so that outbreaks of fire may be detected early. Rapid communication by telephone or heliograph between look-out and workmen engaged in the forest on effective work is essential, and finally it is necessary that the workmen themselves shall have some training in fire-fighting methods.

At the same time it should be realised that for many years controlled burning will play a large part in forest protection, as well

as in silvicultural practice, and that very often in dealing with hardwood forests it will prove safer and more economical to run a slow controlled fire through a sapling or pole forest than run the risk of a serious fire at the height of summer.

Any attempt to analyse the effects of surface fires on a growing stand of a fire-resistant Eucalypt such as Jarrah after it has reached the pole stage further illustrates the urgent need for research into fundamental problems of Australian silviculture. Moisture competition in surface layers of a Eucalypt forest in areas of low summer rainfall has already been discussed in connection with natural regeneration. The light penetrating the canopy of a Jarrah forest is sufficient to support a ground cover of woody shrubs. Jarrah does not form a floor covering of forest humus in the sense the term is used in European forest practice. Jarrah certainly casts a considerable volume of debris in the form of dead branches, twigs and leaves, but this is not gradually decomposed in such a manner as "to form, in mixture with the upper layer of mineral substances, the mould or black earth of the forest." Decomposition is fairly rapid; the line between leaf litter and mineral soil is sharply defined. It is open to question how far such rapidly decomposing vegetable matter can serve the recognised function of humus, and as a source of soluble salts of use as plant food, other than nitrogen which is apparently present in sufficient quantities in local soils, its value may be increased by burning. Other factors to be considered are the effects of burning on shallow root systems, soil organisms, the trunk of the growing tree and canopy. Consideration of these factors shows the importance of the intensity of the fire. A slow burn on a cool day has little apparent effect, but a stronger fire on a hot day will prove a setback to the younger trees even if no permanent injury results. Pending the establishment of a research station equipped to study such problems, a series of sample plots for measurement of the rate of growth under various methods of treatment have been established in several districts.

Forest Management.—The Forests Act, 1918, provides a satisfactory basis on which it has been possible to build a system providing for the continuity of policy and management. Legislative provision is made for—

(1) A properly constituted Department of the Government Service, having a professional staff of fully qualified men.

(2) A trust fund into which is paid three-fifths of the net revenue from the forests for expenditure on reforestation measures.

(3) The permanent reservation of prime forest areas.

(4) The preparation and enforcement of Forest Working Plans, which may specify—

(a) the maximum area from which forest produce may be taken annually;

(b) the maximum quantity of forest produce that may be disposed of annually;

(c) the silvicultural operations necessary to assure the regeneration of the best species of forest produce on areas which have been cut over; and

(d) such other matters as the Conservator may think fit.

Since 1921 700,000 acres have been brought under more intensive management, requiring the preparation of 36 Working Plan documents.

For reasons discussed in paragraphs dealing with the history of the sawmilling industry, local Working Plans restricted to areas where reforestation operations can be undertaken forthwith will not meet the urgent need for control of the output of timber of each species, particularly Jarrah and Karri. In some centres the need for extensive improvement fellings, and in others economic factors, limit the application of sustained yield principles, so that correlation between the provisions of numerous Working Plans relating to annual output becomes necessary. To meet this need General Working Plans for Jarrah and Karri are nearing completion.

The assessment which has preceded the preparation of these plans shows that the present stand of mature milling timber is in the case of Jarrah 1,125.7 million cubic feet, which will provide supplies for existing sawmills on present output for 28 years, and in the case of Karri 301.65 million cubic feet, having a life of 66 years.

There is a serious deficiency of older age classes of growing timber on country cut over for the past 50 years, owing to failure to provide conditions for regeneration and protection. Immature timber now developing will be insufficient to meet the need for the balance of a 90-year rotation, and a considerable reduction in output is proposed in the immediate future.

In the preparation of more detailed local Working Plans where it is not possible to provide adequately for sustained yield, it is nevertheless essential to provide for sustained work for staff em-

ployed on the forest and timber workers necessary for fire protection purposes, and this principle of sustained work becomes frequently a guiding factor in many provisions of the plan. The principles involved and the methods of organisation adopted in connection with local Working Plans will be illustrated by reference to the Jarrah forest only. Satisfactory maps on which to base subdivision into compartments for reference and working were found to be essential. At first it was considered that this subdivision should, as far as possible, be based on permanent topographical features, particularly watercourses. The Jarrah forest taken as a whole is an undulating plateau broken by occasional deep river beds. The peculiar laterite and laterite gravel formation serves to render tracks which have been used for heavy timber traffic remarkably free from undergrowth for many years. Experience in fire fighting showed the value of these tracks, and in consequence these old lines of transportation in cut-over bush have been surveyed, and are used as compartment boundaries in preference to shallow depressions carrying water for a month or two only each year. Where a high ridge impassable to hauling, or a deep creek bed occur, they are used, but such prominent natural features more usually form "Block" boundaries. Survey of internal lines has been carried out by prismatic compass, using a tripod and chaining. Provision is made for tying on to theodolite surveys every few miles, and reasonable accuracy is maintained. All reference marks at the intersection of tracks, old timber tramway formations, and branches of streams are cut on trees according to a system of squares which extends over the whole timber region. In this manner a system of forest maps is being built up which will ultimately extend over all timbered areas, and will have great utility, not only in the management of forests but in the extraction of timber by road and rail. This work has necessitated the running of 6,850 miles of traverse, covering an area of 918,000 acres.

Prior to 1920 the division of the forest into sawmilling permits was based on North, South, East and West lines, and the permit areas ranged from 10,000 acres to 250,000 acres. It was evident that such areas bore no relation to the contour of the country, and would have to be discarded as the old sawmilling rights lapsed. As a result of topographical surveys, new divisions, varying from 7,500 to 15,000 acres, were mapped out and designated "Blocks." An attempt has been made to confine each block to a natural logging section, so that it may be bounded by topographical features which may render hauling from adjoining blocks difficult or impossible, but within the block itself all timber may be hauled to one or more milling sites having a common outlet to main lines of transport.

It is intended that each Block shall ultimately carry a complete series of age classes making up a normal forest. Meantime every effort is being made to restrict the output to provide a sustained yield from the Block, and provision is made that regeneration operations shall form the source of permanent work for the resident overseer, who lives on the Block. The Block is further divided into a number of compartments approximately 500 acres in area.

A standard form of Working Plan headings and tabulations is in use so that all such documents shall conform to the same general pattern. The first section contains a summary of facts relating to the area; the second section deals with proposals for future management. The last chapter contains concise instructions concerning the actual operations to be carried out during the period of the plan, usually five years, at the end of which period provision is made for a revision to cover operations for a further period of probably ten years.

In practice, Minor Working Plans are usually prepared for each Block and serve to control the operations on such Block for the first four or five years, until the area treated for regeneration reaches about 2,000 acres. It is considered that to this stage the resident Overseer can be reasonably expected to protect the young crop from fire damage. Adjoining Blocks are then brought under a Major Working Plan and central fire control with look-out towers established.

Systems of accountancy, annual statements of work and costs, and progress plans have been evolved, so that provision is made for the proper observance of Working Plan conditions, and the collection of data on which the periodic revision of the Working Plan may be based. These systems involve features of interest to the practising forester as adaptations to meet special Australian conditions.

It may be claimed that Forest Management in Western Australia has emerged from the experimental stage. The lines of work are set out, and it now remains for a rational reduction in the rate of cutting to be effected with a view to eliminating the gap which otherwise will inevitably occur between the exhaustion of the virgin forests and the first yield from the regenerated forests.

Afforestation.—In the absence of indigenous softwood forests the people of Western Australia have learnt to use hardwoods for many purposes for which softwood timbers are used in other countries. Despite this fact the value of softwoods imported annually amounts to over £150,000. A modest pine-planting programme will meet local needs for some years to come, and until such time as experimental

work in determining species and methods best adapted to local conditions has progressed further, the establishment of 1,000 acres of new plantation per annum is proposed.

There has been some delay in reaching this figure owing to special problems arising largely out of the dry summer conditions experienced in the vicinity of Perth. The raising of satisfactory nursery stock in new nurseries was found to be the first difficulty, and after a lengthy series of experiments the trouble was traced to absence of necessary soil organisms. Recent work has shown that the factor missing in local soils is a mycorrhizal fungus. Without the plentiful association of the mycorrhiza with the roots of the pine in the nursery, satisfactory stock cannot be raised in average nursery sites, and the pine cannot stand up to field conditions when planted out. Soil inoculation in new nurseries is now a recognised practice, and is found necessary even in opening up new beds in a nursery established for some years.

The following species have been planted on an experimental scale in various districts within the 30 to 50-inch rainfall region of the South-West:—*Picea sitchensis, Pinus Banksiana, Pinus canariensis, Pinus Coulteri, Pinus caribea, Pinus densiflora, Pinus echinata, Pinus halepensis, Pinus insignis, Pinus laricio, Pinus Massoniana, Pinus muricata, Pinus palustris, Pinus patula, Pinus pinaster, Pinus pinea, Pinus ponderosa, Pinus Lambertiana, Pinus strobus, Pinus Jeffreyi, Pinus Torreyana, Pinus Thunbergii, Pseudotsuga taxifolia, Libocedrus decurrens, Larix epilopsis, Larix europea, Sequoia sempervirens, Taxodium distichum, Taxodium mucronatum.*

Pending the result of these experiments, *Pinus insignis* and *Pinus pinaster* will form the bulk of the planting stock.

The planting of *Pinus insignis* will be confined to the better soils of the Darling Ranges, where a system of pit planting, after clear felling and burning of indigenous forest of worthless species, is followed.

On the coastal sand-plain on which Perth is situated, *Pinus pinaster* has shown itself to be thoroughly at home, once established. Clearing of the stunted tree growth is easy, but a burn does not prove sufficient set back to the woody shrubs which form a dense low under-growth. The root competition for moisture during the summer months becomes too intense for survival of the pine unless the land is ploughed prior to planting. The following record of rainfall for the six months of last summer gives some idea of the

severity of summer conditions, which are associated with constant low humidities and absence of clouds:—

——	Nov.	Dec.	Jan.	Feb.	Mar.	April.	Total.	
							Inches.	Points.
Rainfall	0·43	0·19	0·85	0·01	0·10	0·89	2	47

The winter rains are regular, but dry spells even in midwinter are not infrequent. Frosts are rare and snow unknown.

——	May.	June.	July.	Aug.	Sept.	Oct.	Total	
							Inches.	Points.
Rainfall	4·85	7·98	6·23	6·49	3·03	2·67	32	15

The above figures give a total rainfall for the 1927-1928 period of 34 inches 62 points. The endurance shown by *Pinus pinaster* to summer drought on deep sand following thorough cultivation prior to planting, is remarkable; for example, losses last year on Collier plantation were 4.6 per cent. The seed was sown in August, lifted direct from the nursery lines for planting out in the following June; planted out on ploughed ground 6 feet x 6 feet, and given no further attention. The count referred to above was made over 50 acres in April, at the end of six months during which less than 2½ inches of rain fell. A well recently sunk on this plantation went down through sand 60 feet, at which depth permanent water was struck. A series of soil moisture determinations, carried out at weekly intervals last summer to ascertain the effect of different methods of soil cultivation prior to planting on coastal sand-plain country, would appear to indicate that moisture becomes a limiting factor in the growth of *Pinus pinaster* at 2.5 per cent., and death occurs rapidly in young pines when the moisture in the layer in which the roots are developing, drops below 1 per cent.

In higher rainfall areas nearer the South coast planting conditions are much less severe, and a number of experimental areas have been established with the object of testing the value for pine planting purposes of certain lands having no agricultural value. These may ultimately be used for large scale pine planting operations, but for the immediate future plantations in close vicinity of Perth, as the principal industrial centre in the State, will have a greater economic value. The area of effective plantation at the present time is 3,300 acres.

Conclusion.—During the ten years which have elapsed since the Forests Act, 1918, became law, the Forests Department has developed from a small policing and reveneue-collecting organisation to one of the more important branches of the Government Service, controlling wide-spread activities in many parts of the State. Among other important activities which form an integral part of the Department's work the following may be briefly mentioned:—A modest research programme has been carried out, covering problems of wood technology, seasoning, preservation and minor forest products. Results have emphasised the need for the early establishment of a fully-equipped Forest Products Laboratory in Australia. A herbarium collection of the woody plants of the State, including 2,000 specimens, has been established. A seed store for the collection, distribution and sale of indigenous seed, and the handling and testing of departmental seed requirements is attached to head office.

Sixty-five thousand trees are distributed annually at cost price to farmers and local authorities in country districts.

Ten million cubic feet of timber are inspected annually on behalf of local railways and overseas buyers.

Despite the inauguration of a vigorous programme of reforestation associated with limitation of output from prime forest regions, the increase in revenue during this 10-year period has more than kept pace with the expenditure, as indicated by the following statement of gross revenue and expenditure:—

Year.	Revenue. £	Expenditure. £	Balance of Revenue over Expenditure. £
1912–13	48,237	11,463	36,774
1919–20	59,220	27,632	31,588
1920–21	75,469	62,892	12,577
1921–22	88,530	47,886	40,644
1922–23	87,658	38,827	48,831
1923–24	127,253	48,333	78,920
1924–25	177,764	77,423	100,341
1925–26	227,061	101,321	125,740
1926–27	222,507	103,319	119,188
1927–28	228,615	125,745	102,870
Total	1,294,077	633,378	660,699

The next decade will be the most critical in the history of Western Australian forests. The framework of an organisation necessary for the establishment of Forestry as a permanent rural industry is set up, but a great deal remains to be done, and sacrifices in immediate gain for the future welfare must be faced. The goodwill which exists between the Department, the sawmiller and timber worker augers well for the completion of the task which the Government faced with the passing of the Forests Act in 1918.

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