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SILVICULTURAL SYSTEMS AS APPLIED TO JARRAH AND KARRI FORESTS

Introduction:

A silvicultural system may be broadly defined as 'the process by which forest crops are tended, removed and replaced by new crops' (Troup) or, in more detail, 'as a planned method of forest management in which the protection, regeneration, tending and utilisation of the crop are incorporated into the objects of management' (Jacobs).

Most silvicultural systems have been developed in Europe and adopted extensively, in whole or in part, in the younger countries of the world, including Australia. These systems, evolved over a long period of time and representing the contributions of numerous workers, provide an invaluable background to present day silviculture. However, their application in Australia requires careful evaluation and a cautious approach. The Forester's art rests largely in manipulation of forest canopy within the limits of the environment, and care is necessary in our climate in assessing any form of silviculture which entails severe reduction of canopy. Many countries can point to areas where this has resulted in serious deterioration of soil structure and fertility and to loss of soil itself.

Choice of System

Choice of a suitable silvicultural technique involves consideration of the objects of management, of forest condition and composition, and of the silvicultural requirements of species, at the same time keeping in mind the limitations imposed by markets, conversion costs, and other factors of an economic nature.

Object of Management

The commercial forests of Western Australia are comprised of relatively fire resistant eucalypts which are managed mainly for the production of sawlogs with the aim of achieving a regular periodic yield which approaches the maximum the site can produce. The sustained yield concept is basic to considerations of yield calculation and regulation in Western Australia.

Forest Composition and Condition

Virgin jarrah and karri forest is far removed from the ideal of the 'normal' forest, which is comprised of a regular and complete succession of age classes in such correct proportion, density and distribution, that as each age class matures, it may be cut and regenerated in its proper sequence, giving each year an equal yield of timber for industry.

Our forests have been subject to repeated fires of varying intensity, even the mildest of which has burned down some trees. Regeneration developed in the gaps thus created, and over a long period of years resulted in the presence of a considerable range of size classes. However, as is commonly the case in virgin forest, there was a preponderance of volume in the mature and overmature classes.

Protection, the first essential to sound forest management, is now such that fire and other destructive agencies are unlikely to degrade extensive areas of forest in the future.

In the early days of exploitation, unregulated selection of the best and largest trees prevailed, and the smaller, weaker and more defective trees remained. This resulted in a grossly overworked forest in poor condition, and such operations could not be permitted to continue.

Fire and cutting history, particularly in the northern jarrah belt, resulted in a forest which is largely comprised of groups which are more or less even aged within themselves, but uneven aged with respect to other groups. Even age, however, is not synonymous with even size, for expression of dominance has led to substantial size variation between stems of the same age. In certain areas, particularly in parts of the karri region, the 'group' nature of the forest is less marked and a good range of size classes is present.

Neither the jarrah nor karri forests occur in pure formation over more than limited areas. Present in varying degree throughout, is marri (E. calophylla) which tolerates a much wider range of soil and climatic conditions than either of these species. It is at present not favoured by the industry due to the presence of gum veins and loose rings. However, it is recognised

that probably 20 per cent of it is of good saw log quality and in hardwood Working Plans, provision is made for its future use. As an indication of the quantities involved, a survey for pulpwood disclosed that upwards of 30 million tons of marri lies within 35 miles of Pemberton. The heaviest volume and best quality occur in the karri forest where extensive areas carry an average volume of 1400 cubic feet per acre.

Adoption of any system of clear cutting, then, would involve the felling to waste not only of saplings, poles and piles in jarrah and karri forest, but of considerable volumes of marri. Such sacrifice could not be contemplated. Clear cutting would also delay for long periods the extension of development and protection to the remaining areas of virgin forest, particularly those areas which are vulnerable to fire or severely degraded by fire.

Silvicultural Requirements of Species

The silvicultural characteristics of jarrah and karri are listed as appendices. It will suffice to mention here that differences in seed resource and seedling development involve some divergence in regeneration practice. (See under 'Regeneration').

Selection System

The considerations outlined above have led to the continuation in a regulated form of the early system of selection cutting. Control is exercised by means of 'treemarking' for silvicultural advantage. The variable nature of the forests suggest a flexible approach and, in fact, the tree marker is trained to treat each area and each group according to its composition and condition. Treatment ranges from selection of single trees (thinning of groups, for instance) to what amounts to clear felling by groups in some of the grossly overmature sections of the karri forest where younger age classes are deficient. Jacobs has termed this versatile approach the 'Australian Group Selection System'.

Ideally, the aim in marking for removal by the industry is the stimulation of the elite trees in all size classes by removal of the relatively static component of the crop. In fact, it is one of the advantages of selection felling, that elite trees can be retained in all the size classes present.

It is considered that the group selection system approaches most nearly the natural establishment and development of our indigenous forest.

The question of whether the irregular forest managed under the selection system results in a greater or lesser yield than more even-aged systems has long been debated. There has been little comparative data to prove the relative production merits of the two types of forest. However, plots established in recent years are expected to furnish an answer with respect to karri, in which the only notable departure from the group selection system was applied some 30 to 40 years ago in prime forest west of Pemberton. Here, following a heavy exploitation cut and a hot regeneration burn, dense regeneration from seed trees (which were later ringbarked) may be seen today as a fine stand of even-aged poles. A disadvantage of the treatment has been the lack of a market for the large volume of small sized trees removed in the essential operation of thinning the second growth forest. However, the expected advent of a pulping industry in the karri forest could lead to the introduction of clear felling with retention of seed trees in relatively pure stands of karri.

Current Practice

Virgin forest can be regarded as a static reserve of wood volume. Its net increment is nil as growth is balanced by death and decay. In fact, where exposed to frequent uncontrolled firing, the net increment can well be negative, with losses exceeding growth of useful timber. In order to achieve protection and a productive forest condition, the ideal treatment for remaining virgin forest would be a felling to remove only the overmature and damaged trees together with useless culls. For economic reasons this is not usually practicable and a higher volume is marked to enable the industry to meet commitments such as roading.

Current practice involves the following sequence of operations -

(a) Protection of cutting section (by a broadcast advance burn in jarrah or a peripheral burn in karri). Provision of access.
(b) Prescription for treemarking and regeneration.
(c) Treemarking.
(d) Trade cutting; cull felling (karri).

(e) Top disposal.
(f) Regeneration burn.
(g) Assessment.
(h) Regeneration appraisal.
(i) Compartment subdivision and record.
(j) Fire protection.

The general aim in treemarking is to -

(a) Remove static volume - mature, overmature, and defective trees plus millable suppressed stems down to the smallest size the industry can handle.
(b) Preserve dynamic volume - vigorous trees of all sizes.
(c) Avoid damage to growing stock (by specifying direction of fall).
(d) Create openings adequately served with seed trees for generation of the new crop.
(e) Remove cull trees (standard practice in karri forest, but not in jarrah).

Vigorous trees reserved in the top canopy are not only the most productive component of the crop, but are also the best seed resource for the new forest. Increasing emphasis is being placed throughout the world on the use of genetically superior stock. This may involve considerable research, the painstaking selection of superior trees and the development of seed orchards. It certainly does not make sense to rely on inferior crop trees as a seed source for the forests of the future.

It need hardly be stressed that the prime objective of the forester is to achieve for the future an improved forest estate.

The treemarker's brand, then, is a tool of considerable importance in determining the composition and condition of the cut over forest, particularly when it is remembered that the presently accepted cycle of cutting is 30 years, and that a non-productive stem which is by-passed today may occupy good growing space for that period of years. It is anticipated that something approaching a fully productive condition will be secured after the second cut. We are all familiar with areas close to key markets where pressure

of population has enabled a progressive reduction in the standard of acceptable log, so that certain trees rejected today may be felled in 30 years time along with prime growing stock reserved by the treemarker.

The cutting cycle, in the faster growing karri forest at least, is likely to be reduced in time to15 or 20 years to enable thinning to favour selected stems and maintain production at a high rate.

A rotation of 120 years is envisaged for karri, producing a tree of 10-12 feet in girth (B.H.). The second growth forest should be of consistently good form, as the less desirable trees are gradually eliminated by progressive thinning. Log uniformity could enable wide use of gang saw conversion. The rotation for jarrah and marri will be in the vicinity of 180 years. The rotation can be regarded as elastic enough to provide for the retention of vigorous trees beyond rotation age should industry then require a proportion of larger sizes.

An important aspect of the silvicultural approach is that regeneration should occur as a result of the fellings. The second growth forest at rotation age will consist, then, of four or more age strata, each containing a substantial size distribution. Parts of the karri forest may approach the normal sequence of size classes.

One of the stated disadvantages of the selection system in high forest is that damage may be caused to the younger trees and saplings during the felling and extraction of the overstory. This could be more serious in karri than in jarrah forest, hence operations involving the felling of karri veterans into pole stands have been carefully observed. Some damage is unavoidable, however in each case it has been regarded as being within acceptable limits. A pulping industry could enable pre-logging of pole growth or salvage of damaged stems, with virtually no loss to waste.

The cull felling project recently applied in the karri forest was designed to secure a simple and workable means by which the industry, as part of the normal trade operation, would fell marked useless and doubtful trees and effectively prove the latter. Recovery of millable wood from doubtful trees is an

essential feature of the project. The Forests Department recoups the faller in respect of the cutting of useless trees and of doubtful trees proved unacceptable, but accepts no commitment in respect of a tree which yields an acceptable log.

The cull tree is one which has no millable potential but has sufficient crown vigour to occupy useful growing space. Thirty per cent of normal crown is used as the criterion for culling. Cull trees with small or decadent crowns do not seriously compete and are therefore not removed. 'Culling' extends the growing space which results from normal trade cutting by approximately ten per cent.

Regeneration

It is general practice to burn jarrah cutting sections in advance of felling operations to reduce fire hazard and to improve access and visibility. Advance burning was attempted with varying degrees of success in karri forest until it was realised that its merits were outweighed by the following disadvantages -

1. The difficulty of securing a uniform burn without undue scorching of crowns and damage to buds and blossom.
2. Premature release and germination of seed with subsequent loss in logging and in regeneration burning.
3. Burning in other than seed years results in dense establishment of competing species which inhibit establishment of karri.
4. Advance burning prejudiced effective regeneration burning.

Advance burning in karri forest has now been largely discontinued and karri cutting sections are now protected, in units not exceeding 1,000 acres, by burning of the surrounding and intervening jarrah and marri forest types and of non-timbered flats.

Trade cutting is followed by a cleaning or top disposal operation which entails removal of logging debris where it has been heaped against growing stock. After a period of curing, the debris is reduced by a regeneration burn carried out under mild conditions in autumn or spring.

The regeneration of each species is briefly as

(a) Jarrah - Seed supply is not limiting for jarrah and much of the jarrah regrowth derives from 'advance growth' which is present as semi-prostrate stems (2-3 feet high) arising from lignotubers. These woody reserves of food material develop over a period of 10-15 years or more until they reach a diameter of approximately 4 inches, at which stage they are capable of producing one or more dynamic saplings which develop to become normal components of the crop.

The lignotuber renders the jarrah 'seedling' virtually indestructible for it rapidly produces new growth if the aerial portion is removed or damaged. The regeneration burn can trigger dynamic development of some of the advance growth where it occurs in openings created by logging.

(b) Karri - Karri is not a lignotuberous species, but it develops rapidly from seed. However, in approximately two years in four the seed resource may be limited or lacking. Careful appraisal of the seed reserve is essential before burning for regeneration. Ideally the burn should release adequate seed to fall on a cleanly burned seed bed. Dense karri seedling growth successfully competes with such acacias as may germinate on even terms, but any advantage conferred on weed species by faulty regeneration technique may seriously inhibit karri development.

In common with most W.A. eucalypts, seedling vigour on ash bed is substantially greater than on exposed ash free soil which in turn gives much better results than unburnt and undisturbed soil. Under ideal conditions seedling numbers may approach 30,000 per acre at the end of the first summer.

Openings created for regeneration should not exceed six chains in width as karri seed is rarely dispersed beyond a distance equal to the height of the tree. Openings in general do not exceed 0.5 acre in extent. The dangers of excessive canopy removal and site exposure have already been mentioned. There is little doubt that heavy logging in the northern forest has, in affecting the critical relationship of jarrah to its environment, been a

prime factor in creating and aggravating the problem of jarrah 'dieback'.

It is seldom necessary to resort to artificial regeneration, but stocks of seed are held for spot sowing, where regeneration is regarded as inadequate, or where uncontrolled fire occurs and seed is lacking. The use of tubed or potted stock is not required.

Introduced Species

A wide range of Eastern States and Overseas species have been tried on a limited scale. Yellow Stringybark (E. muelleriana) is showing considerable promise in the karri zone and is now under large scale field trial. Trial of other species such as E. obliqua is continuing. The State is lacking in lightweight cabinet and veneer woods and Blackwood (Acacia melanoxylon) shows promise under karri and could find a useful place in lieu of the useless indigenous weed acacias.

APPENDIX A

KARRI (Euc. diversicolor) : Botanical and Silvicultural Characteristics

A. Site Requirements

Climate: Typically maritime - warm dry summers, cool wet winters.
Rainfall: 40-70 inches.
Temperature: Winter mean 51°F (Manjimup)
Summer mean 66°F (Manjimup)

Geology: Porent rock: granite gneiss with scattered basic intrusions.
Soils: chiefly red brown to yellow brown podsolic loam sands.

B. Silvicultural Requirements

Light: Full sunlight is necessary for optimum development.

Soil: See above. Good drainage is essential.

Moisture: See above. Best development where rainfall 50-60 inches. On marginal sites prefers sheltered aspects.

Temperature: Withstands extremes of natural habitat. Frost may cut back apical growth of seedlings.

Fire Protection:

Fuel Complex

Annual litter fall (leaves) = 1 ton per acre (oven dry weight)
" " " (total) = 2.25 " " "
Fireweed development = up to 20+ tons/acre

Rate of litter decay is slow and a high degree of hazard developes in summer in the full complex noted above.

Fire Damage is severe in many parts of the forest.
Fire control is secured by prescribed burning to reduce the fuel complex. Burning is concentrated in the more readily burnable and controllable jarrah and marri forest types and in non timbered flats.

C. Botanical Characteristics

Karri is a magnificient tree, typically reaching 170 to 240 feet in height, rarely to 270 feet. The tallest measured karri is 286 feet. Girths upwards of 20 feet are common and 38 feet has been measured.

The biggest tree milled at Pemberton was 265 feet high and 33 feet in girth. The top of the stump, 13 feet above the ground, was 28 feet in girth. At 113 feet from the ground, girth was 19 feet 3 inches. Log volume was 114 loads (68,590 super feet).

Crown

The crown is conical in the sapling and pole stages. In the lower crown from the pole stage onwards the branches tend to curve upwards at the ends. Leaves are borne on branch extremities as compact 'umbrellas' and tend to give an overall umbrella effect. Overmature crowns in horizontal view may appear stepped or tiered.

Root System

Upwards of 80 per cent of the karri root system feeds in the upper 4 feet of soil. Of large roots which penetrate below this depth, some penetrate deeply and play an important part in anchoring the tree and providing moisture during periods of relative drought.

Age

Most of the virgin forest is aged between 150 and 400 years. Physical maturity is considered to be approximately 250 years. Degrade is frequently rapid after age 400 years, although an occasional reasonably sound tree is considered to exceed 700 years (cf jarrah - 1,000 years).

Growth rings can be counted on selected stumps and butts with an accuracy of $\pm$ 5 per cent. In average forest a tree of 150 inches G.B.H. can be said to be roughly 150 years old.

Leaves

Blakely (4) describes the leaves as follows - 'Juvenile leaves opposite for 6-7 pairs, shortly petiolate, ovate to broadly lanceolate, 5-8 x 3-5 cm., rather thin, pale green on both surfaces. Mature leaves alternate, petiolate, acutely lanceolate, 10-14 x 3-5 cm., venation rather fine. Mature leaves are appreciably paler in colour on the lower surface.

Buds, flowers, fruit and seed

Work carried out by Loneragan (3) has shown that substantial variation can occur in bud differentiation and development, however for the purpose of this discussion and for virtually all practical purposes the karri flowering and seeding cycle takes place as follows:

Flower bud initials can be recognised in January, but do not differentiate as buds until March, usually becoming easily recognisable in April as buds approximately ¼ inch long. Development can be delayed by up to nine months, possibly longer.

Flowering and Development of Fruits

Flowering commences 27 ± 9 months after bud initiation, (i.e. bud development may take from 18 months to 3 years, being generally upwards of 2 years) usually commencing in February - March, becoming general in May - June and continuing throughout winter into the following summer.

The capsule ripens and seed matures 12 - 15 months after flowering so that the elapsed time from bud initiation to first natural seed release is 4 years. It should be noted that whilst seed is mature at 4 years and release may be triggered by a regeneration burn at that stage, natural release in quantity may be delayed while the capsule cures, i.e. elapsed time may extend to 5 years (becoming closely comparable with Mountain Ash E. regnans - Cunningham - 5).

The major part of the karri forest blooms in phase at intervals of 4 to 6 years. Between such general flowerings partial intermediate light to moderate flowering occurs. Whilst the interval may be 12 months it is more frequently 2 years, in either case giving an extended seeding period.

Seed Count

There are approximately 4,000 to 5,000 seed plus chaff to the ounce and there are approximately 16,400 clean viable seed per ounce, i.e. approximately 33 per cent by weight of seed plus chaff is viable seed.

Seed Fall

Heaviest natural seed fall occurs in mid summer and may, under ideal conditions, be as high as 1 million

per acre during a period of several weeks following the regeneration burn. Mortality is high, but seedling numbers at the end of the first year may approach 30,000 per acre.

Seeding may commence at approximate age 15 years in open grown karri and at 25 years in dense regrowth, however, in the latter case little seed is produced at this stage.

Seed Dispersal

Seed traps are in use to systematically test seed dispersal. Most seed falls directly beneath the crown and only a small proportion is carried to a distance approximating the height of the tree. Gaps of 6 chains in width have seeded effectively from trees of 200 feet in height.

APPENDIX B

JARRAH (Euc. marginata) Botanical and Silvicultural Characteristics

A. Site

Climate:	Maritime
Rainfall:	25-50 inches 35 inch minimum for prime forest.
Temperature:	Winter mean 50°F Summer " 69°F

Soils: Fossil laterite - 40-90 per cent pisolitic gravel.

B. Silvicultural

Jarrah occurs as a high forest type with a small admixture of marri and blackbutt (E. patens). The tree and shrub understory is xerophytic.

The forest canopy is generally open and crowns appear to have suffered from the effects of past uncontrolled fires and excessive exposure of site by early unregulated sawmilling.

Bole

Typically, jarrah attains a total height of 90 to 130 feet, occasionally 150 feet. Bole length may reach 80 feet but is usually between 25 and 35 feet. Maximum height measured is 180 ft. and maximum bole length 105 ft.

Crown

The sapling crown is conical. The flush of growth commences in September and is maintained through summer into autumn. The leaf flush in the mature tree is restricted to early summer, leaves maturing rapidly in January and February.

C. Botanical and Silvicultural

Flowering and development of fruits - flower buds are developed in the axils of the spring flush of leaves. Flowering occurs in the following November and December. Capsules develop to mature over the winter and shed ripe seed during the third summer, i.e. the period from bud initiation to natural release of seed is approx. 2 years. Some seed may remain in the capsules to fall the following summer.

Seed periodicity - although some jarrah seed may be present every year, general seeding is periodic at intervals of five and six years. Heavy seeding is

associated with depletion of the jarrah crown which loses a high proportion of its leaves and takes several years to fully recover. This may explain the periodicity of seeding.

Seed count - the seed is black and trihedral and approx. one eighth inch long. There are approx. 4,000 clean seed per ounce or 1,500 per ounce when chaff is included.

Seed dispersal - most of the seed falls directly below the crown and little of it is thrown beyond a distance equal to the height of the tree.

Seedling development - under ideal conditions stocking can approach 500,000 per acre, however mortality is high.

The surviving seedlings develop small lignotubers which develop into woody reserves of food material from each of which extend a number of semi prostrate stems 2-3 feet high. This condition may persist for many years under jarrah forest conditions although under cultivation in W.A. and in other countries with more favourable soil conditions the seedling develops into a sapling without undergoing a period of stagnation.

As a rule the lignotuber must attain a diameter of four inches before it is capable of producing a dynamic sapling.