Multiple Use Management in a Mediterranean Ecosystem—the Jarrah Forest, a Case Study[1]

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Abstract: The jarrah (Eucalyptus marginata Sm.) forest of southwestern Australia extends over 2½ million hectares. In addition to the climatic constraints on the formation of high, dense forest, the soils are impoverished and the vegetation is subject to frequent fire. As a consequence, the forest has developed unique adaptations. For 150 years, hardwood timber production was the principle objective. Now, there are true multiple use demands plus special disease problems and political constraints. This paper describes approaches to multiple use forest management in the presence of severe biological and political constraints.

The jarrah (Eucalyptus marginata Sm.) forests of Western Australia are located in the southwestern corner of the State and extend over 1.5 million hectares. The dominant species, jarrah, is a high quality, durable hardwood and the forest has been exploited for timber over the 151 years since European settlement of the State (fig. 1). Logging of the forest in the first 100 years following European settlement was uncontrolled, but in 1918 forest management was placed under the control of a professionally directed forest service. In the following 40 years, traditional hardwood forest management practices, for example, inventory, fire protections, thinning and regeneration, etc., were progressively introduced. Management and research intensified in the 20 years following the second world war but was almost entirely concerned with regulation of timber exploitation, improving timber production, and protection from fire.

The 1960's saw the beginning of a series of major events which have resulted in radical changes in jarrah forest management and research. In 1965, the causal organism of a serious forest disease, "Jarrah Dieback," was identified as an introduced soil-borne fungus Phytopthora cinnamomi Rands (Podger 1972) (fig. 2). By the late 1960's, increased recreational use of the forest, together with greater public awareness environmental issues, caused intensive public questioning of standard management practices such as prescribed burning. During this period, the whole forest was placed under a lease for bauxite mining, and strip mining for bauxite commenced. A series of severe droughts, an increased demand for water, and serious salination of irrigation and domestic water supplies resulting from clearing of forest and woodland areas for agriculture focused attention on the catchment protection values of the forest (fig. 3).

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Many of the unique characteristics of the forest fire regime, hydrology, and pathology can be attributed to the Mediterranean environment. These characteristics are summarized and discussed in relation to multiple use management.

THE JARRAH FOREST ENVIRONMENT

Climate

Rainfall occurs predominantly in the 5 months from May through to September and averages 128 cm annually. Little or no "effective" rainfall falls from December to March, and daily potential evapotranspiration rates exceeding 1 cm are common during this period. Spatial variation in potential evapotranspiration is small within the forest, but rainfall is at a maximum at the western margin of the forest (178 cm) and declines to less than 76 cm on the eastern boundary.

Landform and Soils

The forest is located on the western boundary of the ancient and extensively laterized Great Plateau of Western Australia. The river systems in the western edge of the plateau have been rejuvenated following uplift and formation of the Darling Scarp which forms the western boundary of the forest. Thus, within the forest zone, there is a succession of valley types characterized by varying degrees of incision.

Soils consist of fully developed laterites or are formed on truncated laterites or colluvium. The laterites, which are the predominant soil type, consist typically of 10 to 20 cm of sandy loam in a gravel matrix underlain by concreted laterite and/or unconsolidated laterite to a depth varying between 2 to 16 meters which is in turn underlain by a deep horizon of pallid zone clay (Shea and others 1975).

Vegetation

Overstory composition can be used to broadly categorize the vegetation, although there are

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Figure 1--Virgin jarrah forest.

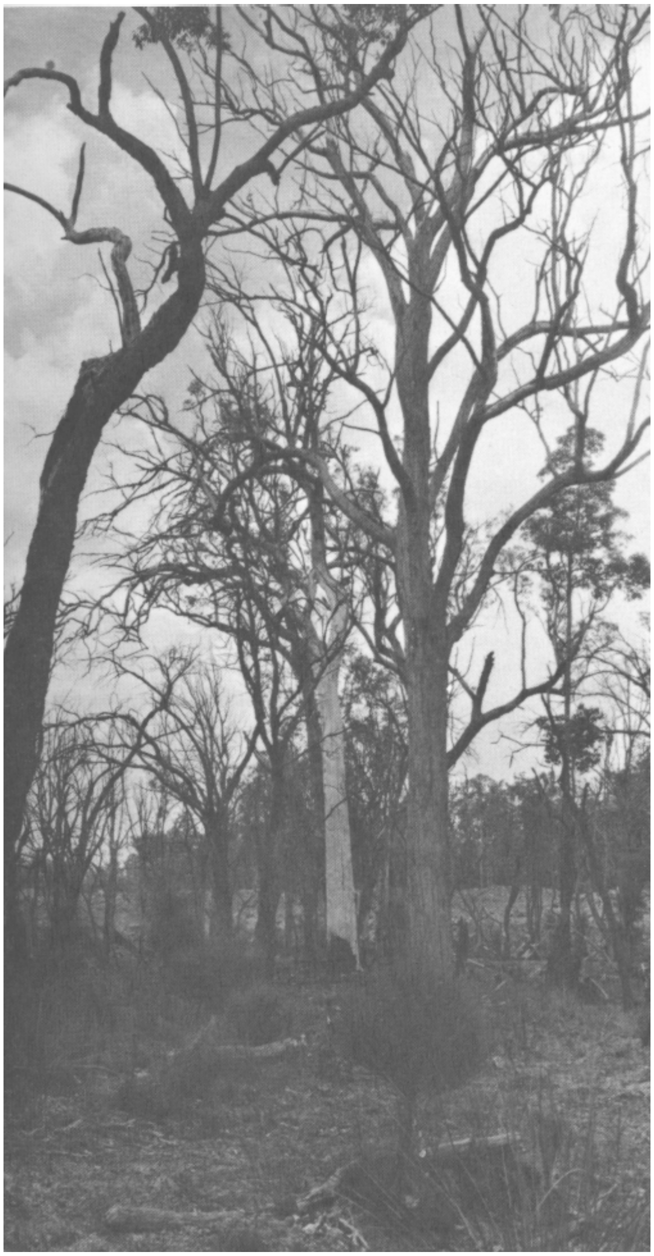

Figure 2--Jarrah Dieback, a disease caused by the soil-borne fungus Phytopthora cinnamomi.

numerous vegetation types that are associated with particular climatic and edaphic conditions (Havel 1975). The predominant type is dominated by jarrah and occurs on the lateritic uplands. Marri (Eucalyptus calophylla R. Br.) forms a minor component of the overstory; Banksia species are the major components of the understory, and numerous species form the shrub layer. In the western valleys, Eucalyptus patens Benth., Eucalyptus megacarpa S. Muell, and marri replace jarrah in the overstory. In the eastern valleys, Eucalyptus wandoo Blakely and Eucalyptus rudis Endl. are the dominant overstory species.

FOREST HYDROLOGY

The two outstanding features of jarrah forest hydrology are the low water yields and the presence of large salt accumulations in the soil profile in some forest areas. The average percent water yield from fully forested catchments varies from 10 to 20 percent in the western high rainfall zone of the forest to less than 1 percent in the eastern low rainfall zone. Total salt content of the soil profile may exceed 500,000 kilograms per hectare. Salt concentration is generally low in the western zone of the forest, increasing with distance from the Darling Escarpment, but there are significant departures from this gradient.

The low yield and salt accumulations in jarrah forest catchments are a consequence of the Mediterranean climate, the presence of deep soil profiles with a high moisture storage capacity, and the method by which the forest vegetation has adapted to the environment (Shea and others 1975). Between 31 and 133 kilograms of salt per hectare are deposited annually in rainfall in the forest (Peck and Hurle 1972). In high rainfall areas or where soils are shallow, most of this salt is flushed through the soil profile. However, in approximately two-thirds of the forest, there is a net accumulation of salt. This is a consequence of the ability of the vegetation to maintain transpiration rates approximating the potential rate throughout the year.

The exploitation of the water stored in the soil profile during the summer months is only possible because of the development of extensive vertical root systems (Kimber 1974).

Stream salinity levels in forested catchments are usually less than 250 ppm T.D.S., even though there are large salt storages in the soil profile because the system is in equilibrium. Removal of the forests by disease or changes in land use practices disturbs the equilibrium and excess salt discharge occurs. For example, weighted average stream salinities in excess of 18,000 ppm T.D.S. have been recorded in streams discharging from catchments which have been cleared for agriculture (Peck and Hurle 1972).

JARRAH DIEBACK

Small areas of dying forest were first recorded shortly after the turn of the century. The effected area increased slowly up until the end of the second world war. In the decade following the end of the war, the tramline system of log removal was replaced with one based on log trucks which required the development of an extensive roading system. The rate of disease development increased dramatically during the period and by 1972, 10 percent of the forest was severely diseased. As the severity of the disorder increased, research was intensified but it was not until 1966 that the causal organism, Phytopthora cinnamomi Rands, an introduced soil-borne fungal pathogen, was

Figure 3--Aerial view of bauxite mines and water reservoir within the jarrah forest.

identified (Podger 1972). The pathogen causes death of susceptible species by destruction of the root system and/or invasion of the lower stem.

The rate of disease development varies with site and climatic conditions (Shea 1975). However, in many forest sites, the end consequence of introduction of the pathogen is death of jarrah trees of all ages and sizes and the majority of the species comprising shrub and understory layer of the forest. Consequently, most forest values are severely reduced in diseased areas. The disease is concentrated in the western low salinity zone of the forest where destruction of the forest does not cause a deterioration of water quality. However, the disease has caused salination in some microcatchments where it has extended into the saline zone (Shea and others 1975).

Fungal spores can be transmitted in minute quantities of soil provided it is moist. Hence, any activity which results in transmission of the soil can result in the establishment of a new infection. The fungus can move passively in water running overland. Upslope extensions through the roots of highly susceptible species can occur at an average rate of approximately 50 to 100 cm per year (Shea 1975).

Following the discovery of the causal organism, research was primarily directed towards documenting the relationship between the pathogen and the forest environment (Shea 1975). P. cinnamomi is a water mold and requires high soil moisture levels and soil temperatures greater than 15° C to complete the asexual phase of the life cycle. The fungus cannot withstand prolonged soil drying. In moisture-gaining sites within the forest, environmental conditions are suitable for survival and reproduction for long periods during the year.

However, on free-drained sites in the forest, which constitute between 60 to 80 percent of the forest area, the relationship between the fungus and the soil environment is finely balanced (Shea and others 1980). During the summer months, soil moisture levels are too low for asexual reproduction and survival of spores outside large roots is limited. During winter, fungal spores can survive but soil temperature levels are too low for asexual reproduction. Hence, the periods during which the pathogen can reproduce are restricted to relatively brief periods in spring and autumn when there is a coincident of favorable soil moisture and temperature conditions. The capacity of the pathogen to cause extensive disease on free-drained sites within the forest, even though the environment on these sites is only marginally favorable for fungal pathogenicity, is attributed to:

1. Extensive distribution of fungal spores and mycelium in soil carried on vehicles.

2. The presence of a highly susceptible dense understory of Banksia grandis. (P. cinnamomi can invade the large horizontal roots and lower stem of this species, thus fungal extension can occur regardless of soil physical conditions.)

3. Soil and canopy disturbance which prolongs the periods during which the soil physical environment is suitable for asexual reproduction and spore transmission.

4. The occurrence of severe annual summer drought stress which increases the probability that species with root systems damaged by the pathogen will succumb to drought.

FIRE

Early forest managers were strongly influenced by European forest practices and for the first 35 years following the introduction of management, a policy of complete protection from fire was adopted. By the early 1950's, it became apparent that a fire exclusion policy was not practicable and that the vegetation was adapted to fire. Although exploitation of the forest for timber increased the intensity of wildfires and the frequency of these conflagrations was probably increased by accidental and deliberate ignition by European man, there is evidence that Aboriginal man used fire as a management tool for thousands of years prior to European settlement. Even in the absence of man, it is unlikely that the forest would remain unburnt for long periods in a Mediterranean environment when ignition from lightning strikes is common (Shea and others 1981).

Following the failure of the fire exclusion strategy, a program of periodic low-intensity prescribed burning was introduced with the single objective of hazard reduction. Over a period of 25 years, a sophisticated low-cost prescribed burning program involving rotational burning of the whole forest on a 5- to 7-year cycle has been developed (Shea and others 1981).

The hazard reduction burning program has resulted in a marked reduction in the area burnt by uncontrolled wildfire (Shea and others 1981). Broad scale, low-intensity hazard reduction burning currently remains the only practical method of fire management in the forest. However, it is highly improbable that periodic low-intensity burning in spring duplicates the "natural" fire regime, and research is being directed to determine if there are long-term adverse effects of this burning regime on the forest ecosystem, and if fire can be used as a management tool for purposes in addition to hazard reduction. For example, low-intensity burning disfavors the regeneration of a leguminous understory because heat penetration from normal hazard reduction burns is not sufficient to stimulate germination of leguminous seed stored in the soil (Shea and others 1979). It is possible that the absence of a leguminous understory could have an adverse effect on forest fertility (Shea and Kitt 1976) and fauna habitat (Christenson 1980).

FOREST MANAGEMENT AND RESEARCH

Objectives

The importance of the catchment protection function of the forest to the southwest of Western Australia has placed maintenance of water quality as the first priority of forest management. Where other land use practices do not conflict with water quality maintenance, the objectives of forest management is to maximize timber, conservation, and recreational values in perpetuity.

Site Classification

A system of site classification is being developed as the basis for the resolution of land use conflicts and the development of specific management strategies. The most important site characteristic is the presence or absence of significant salt accumulations in the soil profile. When salt is present, any activity which reduces canopy density for prolonged periods has the potential to cause salination. The forest has been classified into three broad zones based principally on rainfall isohyets--saline (eastern forest), nonsaline (western forest), and an intermediate zone where salinity is variable. Within each zone priority, land uses are designated primarily according to disease presence, landform, and vegetative type. A system of ecological site typing based on indicator species has been developed (Havel 1975) and is used to assist designation of priority land uses. For example, within the western low salt zone sections at the steeply incised river valleys which constitute a rare ecological type have been designated conservation priority areas, upland disease-free sites would have a timber production priority, whereas similar sites which are heavily diseased would have a water production priority.

Catchment Management

In high salinity areas, the management aims to maintain the native vegetation or where it has been removed by disease or prior land use practices, establishment of species which would restore the hydrological equilibrium. The rehabilitation of disturbed forest areas in salt-prone forest areas is a major problem. It is impossible to reestablish jarrah in these areas because of the susceptibility to P. cinnamomi. Hence, introduced species which are resistant to this pathogen must be used. However, in addition to disease resistance, the selected species must have the capacity to grow in a Mediterranean climate, on soils with unfavorable physical and nutrient conditions, in an environment which is subject to periodic fire of varying intensities while maintaining high evapotranspiration rates. Currently, no species have been identified which meet these criteria (Bartle and Shea 1978).

In the nonsaline forest zone, it is possible that significant increases in the yield of high quality water could be achieved by thinning (Shea and others 1975). It is possible that thinning for water production can also be made compatible with timber production. Current research is directed towards determining the range of canopy and stand densities which provide maximum water production while maintaining maximum wood increment on the minimum number of trees.

Disease Management

Currently, the only method of reducing the impact of P. cinnamomi on the forest is by restricting its spread by man. Following the identification of P. cinnamomi as the causal organism, intensive sanitation procedures were introduced. When it became apparent that these procedures were not adequate, the eastern two-thirds of the forest corresponding to the high salt zone were placed under quarantine (Shea 1978). Detailed aerial color photography is being used to permit precise identification of diseased areas within this zone so that management procedures based on avoidance of sources of inoculum can be developed.

The most promising approach to control is based on manipulation of the forest environment by changing the prescribed burning regime. Prior to exploitation of the forest, Banksia grandis only occurred as a scattered component of the forest. Disturbance and fire exclusion or low-intensity fire has favored this species, and it currently forms a dense understory on most upland sites. The presence of this highly susceptible understory is a major contributor to the spread and intensification of the disease. It has been shown that a moderate-to-high-intensity fire regime will significantly reduce B. grandis density and, in many forest sites, result in its replacement by an understory of leguminous species. It is possible that this could cause a significant reduction in disease intensity by (1) reducing the susceptible food base available to the pathogen, and (2) creating a soil physical and microbiological environment unfavorable for pathogen survival and reproduction (Shea 1975, 1978; Shea and others 1980).

Timber Production

Various modifications of the selection cut system of silviculture have been applied over the period since management was imposed. The principal species, jarrah, has a lignotuberous form and regeneration has not been considered a significant problem. The major factor affecting timber production is Jarrah Dieback, and the presence or absence of the disease is the major factor affecting logging and silvicultural procedures. In high quality regrowth stands, there is considerable potential to shorten rotation ages and increase log value by thinning, as the species does not thin naturally (Kimber 1976). However, thinning programs have been stopped because it is uncertain whether the investment in thinning would be returned because of the threat from Jarrah Dieback and competing land uses (e.g., bauxite mining).

Conservation

Conservation is recognized as an important management objective throughout the forest but in areas with special floral or faunal components, conservation is the first management priority. For example, an area of 40,000 hectares in the southwestern corner of the forest where 27 different mammal species have been recorded has been designated a fauna priority area (Christenson 1978). One of the major factors affecting fauna is fire regime and a specific fire management plan which provides for varying combinations of fire intensity and frequency, which will ensure preservation of major habitat types while minimizing fire hazard, has been proposed (Christenson, cited in Shea and others 1981).

Bauxite Mining

Economic grades of bauxite ore occur in pods on the ridge or upper slopes. Up to 20 to 30 percent of the forest may have mineable ore in high grade areas within the western zone of the forest, but the percentage decreases in the central and eastern zones of the forest. Mining involves removal of the surface soil horizons, blasting and extraction of the bauxite ore to a depth of 2 to 6 m, and replacement of the surface soil. Following ripping of the sites to a depth of 2 meters, the sites are planted with a variety of tree species and direct seeded with native shrub species.

Mining results in loss of forest in the mined-over areas and the forest areas adjacent to and downslope from the mine pits and predisposed to Jarrah Dieback because of the spread of the pathogen in infected soil during the mining process and the disruption of drainage which favors survival, reproduction, and transmission by the pathogen. Initial growth rates of the tree species which have been established on the mine pits has been rapid, but their capacity to survive in the long term in an environment which is not conducive to tree growth is not known (Bartle and Shea 1979).

CONCLUSIONS

The interactions between fire regime, hydrology and disease, and different land use practices are the major factors contributing to the complexity of multiple use management in the jarrah forest. For example, any land use practice that results in the movement of soil can cause spread of Jarrah Diehack and destruction of the forest. Loss of forest cover in salt–prone areas can cause salination. The species used to rehabilitate disturbed forest areas must be resistant to P. cinnamomi. It is possible that fire could be used to reduce disease susceptibility, but the presence of fire as a factor in the environment also means that species used to rehabilitate disturbed areas must be fire tolerant.

Given the complexity of the jarrah forest ecosystem and the severe conflicts between some land use practices, it is not surprising that management strategies which will satisfy the multiple use objectives are still being developed.

LITERATURE CITED

Bartle, J. R.; Shea, S. K. Selection of tree species for rehabilitation of degraded areas in the northern jarrah forest. In: Rehabilitation of mined lands in western Australia. Perth, Western Australia: Symposium West. Aust. Inst. of Tech.; 1978.

Bartle, J. R.; Shea, S. K. Development of the ecosystem after mining. In: Australian mining council environmental workshop, Vol. 1. Bunbury, Western Australia; 1979.

Christensen, P. E. The concept of fauna priority areas. 3d fire ecology symposium; 1978; For. Comm. Vic. and Monash Univ.

Christensen, P. E. S. The biology of Bettonsia pencillata Gray 1837, and Macropus engenii (Demarest, 1917) in relation to fire.: 1980; For. Dep. of West. Aust. Bull. 91.

Havel, J. J. Site vegetation mapping in the north–ern jarrah forest (Darling Range). I. Definition of site–vegetation types. For. Dep. of West. Aust. Bull. 86. II. Location and mapping of site–vegetation types. For. Dep. of West. Aust. Bull. 87. III. Relationship of site–vegetation types to land utilization. For. Dep. of West. Aust. Bull. [in press]; 1975.

Kimber, P. C. The root system of jarrah (Eucalyptus marginata Sm.) forests.; 1974; Dep. of West. Aust. Res. Paper 10.

Kimber, P. C. Thinning jarrah with hormone herbicides. Aust. For. 31:128–136; 1976.

Peck, A. J.; Hurle, D. H. Chloride balance in some farmed and forested catchments in south–western Australia. Water Resour. Res. 9:648–657; 1972.

Podger, F. D. Phytopthora cinnamomi a cause of lethal disease in indigenous plant communities in Western Australia. Phytopathology 62:972–981; 1972.

Shea, S. R. Environmental factors of the northern jarrah forest in relation to pathogenicity and survival of Phytopthora cinnamomi Rands.: 1975; West. Aust. For. Dep. Bull. 85.

Shea, S. R. Forest management and Phytopthora cinnamomi Rands in Australia. In: Old, K. M., ed. Phytopthora and forest management in Australia. Canberra: C.S.I.R.O.; 1978: 73–100.

Shea, S. R.; Gillen, K. J.; Leppard, W. I. Seasonal variation in population levels of Phytopthora cinnamomi Rands in soil in diseased, freely–drained Eucalyptus marginata Sm. sites in the northern jarrah forest of south–western Australia. Prot. Ecol. 2:135–156; 1980.

Shea, S. R.; Hatch, A. B.; Havel, J. J.; Ritson, P. The effect of changes in forest structure and composition on water quality and yield from the northern jarrah forest. In: Kikkana, J.; Nix, H. A., eds. Managing terrestrial ecosystems, Vol. 9.; 1975; Proceedings of the Ecological Society of Australia.

Shea, S. R.; Kitt, R. J. The capacity of jarrah forest native legumes to fix nitrogen.: 1976; For. Dep. West. Aust. Res. Rep. 21.

Shea, S. K.; McCormick, J.; Portlock, C. C. The effect of fire on regeneration of leguminous species in the northern jarrah (Eucalyptus marginata Sm.) forest of Western Australia. Aust. J. Ecol. 4:195–205; 1979.

Shea, S. R.; Peet, G. B.; Cheney, N. P. The role of fire in forest management. In: Gill, A. M.; Groves, R. Eh.; Noble, I. R., eds. Fire and the Australian biota. Canberra: Aust. Acad. Sci.; 1981.