TEACHERS' HIGHER CERTIFICATE

OPTIONAL THESIS.

The Significance of Ecological Influences on the Environment of Western Australia and an Economic Appraisal of the Secondary and Minor Forest Products which subh Ecological Influences Produce.

John Noel Smith,
Government School,
Burracoppin.

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TABLE OF CONTENTS.

PREFACE.

The following definition of ecology supplied by Dr. A.R. Main of the University of Western Australia,(1) together with a natural appreciation of our forest heritage which has stemmed from my interest in beekeeping, has led to the undertaking of this study.

> "Ecology is that branch of biology dealing with the relations between organisms and their environment. The general term organisms includes both animals and plants and since plants are an integral part of the environment, it is important that they be included."

Problems within environments are accompanied by controls or influences which are at work on the vegetation within a given locality. These forces may be either climatic, edaphic or physiographic in nature. It is the intention, in Section One of this thesis, to illustrate, as far as possible, within the limits of edaphic and climatic factors in Western Australia, the significance of these ecological aspects of forestry in relation to our own use.

Since little research of this nature is available for local conditions, I have had to draw heavily upon overseas publications and my appreciation for assistance in this respect must be accorded to Miss Margaret Redman, Librarian of the Forests Department, W.A.; and to Mr. G. Brockway, Superintendent of Research, Arboriculture and the Interior; also of the Western Australian Forests Department.

So great is the diversity of ecological influences upon the vegetation of Western Australia that a truly complex flora has resulted. The number of different species recorded is in excess of 6,000.(2)

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(1) Main, A.R.: A Guide for Naturalists. W.A. Naturalists Club Handbook No.4 Perth. p.11

(2) See page 6

The presence of this multitude of individual plants, bushes and trees affords ready material for the development of minor forest products. Minor products being distinct from the direct use of timber for building and constructional purposes of all types, packing-case material and the like.

It is an examination of these minor or secondary forest products which is undertaken in Sections Two and Three. As far as possible, their economic aspects, within the lim ts of availability of the source material, methods of production, markets and financial data are presented. However the complete economic contribution of some items is not available because of the manner in which statistical returns are compiled. This is particularly evident when investigating particulars of the sandal-wood, sandal-wood oil and essential oil industry.

For Sections Two and Three, my thanks are again due to Miss Redman of the Forests Department Library for her ready assistance with source material; and to both Mr. Rock, Operations Manager, Plaimar Ltd., and Mr. A. Baldock, Operations Manager, Industrial Extracts Ltd. These gentlemen have volunteered reliable information and assisted furthermore by proof reading the sections concerning tanning materials, sandal-wood and the essential oils. Mr. Rock's and Mr. Baldock's contributions are particularly valuable as both gentlemen have long and close associations with the commercial extraction of minor products from the Western Australian vegetation. Both men worked in close collaboration with the late H.V. Marr, the man responsible for early investigations into the extraction and properties of oils from local species of trees, and was particularly instrumental in perfecting the extraction of tannin from Wandoo. Together with this, the improved method of distilling oil from the sandal-wood tree to such a degree that it was accepted by the British Pharacopoeia to become a world competitor with East Indian sandal-wood oil on world markets, is accredited to the late Mr. Marr, Mr. Rock and Mr. Baldock.

SECTION ONE

THE SIGNIFICANCE OF ECOLOGICAL INFLUENCES ON THE ENVIRONMENT OF WESTERN AUSTRALIA WITH PARTICULAR EMPHASIS ON FOREST AREAS.

1. INTRODUCTION.

Over the centuries, and in present times, men look to their forest covered areas for most of the natural resources they require. From within such areas come minerals of various kinds; wood for buildings and for fuel; foods for animals and man alike; shelter and water.

Forest areas provide the land with a protective covering, which when left intact has the moderating effect of retaining natural land forms and preventing soil removal so that much good agricultural land together with water catchment areas are secured against soil erosion.

As world populations increase, more and more land is required for farming purposes. With the consequent removal of natural vegetative covering to meet this requirement, the need for sound forest management has arisen. Much literature is available on the results of researches conducted to determine the effect of forest preservation compared with forest denudation. Such results reveal the tremendous advantages that are to be gained from forest preservation, reforestation and afforestation. In this respect Western Australia is no exception, but before considering in some detail the significance of ecological influences on this State's natural forests and vegetation, it will be necessary to define in some detail the climatic, geomorphic and vegetative characteristics of this State.

The vegetation of Western Australia conforms to three natural regions which are termed "provinces." They are governed by temperature and the amounts and incidence of the seasonal rainfall and soil types, and have been termed respectively, the Northern, the Eremean and the South-West Provinces.

Climatic Characteristics

The Northern Province extends over the Kimberley Division to some few miles southwards from the Fitzroy River, thence contracting into a narrow coastal isthmus in the vicinity of the Eighty Mile Beach, and expanding southwards to include the De Grey River and the greater part of the Fortesque system. It is the area lying to the north of the Tropic of Capricorn, which receives its rain entirely in the summer months, with a seasonal rainfall during the four wettest months ranging from about seven inches in its southern portions to over forty inches in parts of the Kimberley Division. The season from the commencement of April until the end of October is relatively rainless.

The South-West Province extends from the southern end of Shark Bay in the north to Israelite Bay in the south; on the west and southern sides it is bounded by the ocean, whilst its inland boundary passes close to Mullewa, Morawa, Koorda, Bencubbin, Barracoppin, Hyden, Ravensthorpe and Grass Patch. It is a winter rainfall region which receives its maximum rain from May to August, inclusive, and with the exception of the southern portion, experiences a seasonal drought extending from November to March or April.

The Eremean Province lies sandwiched between the other two, and occupies approximately two thirds of the total area of the State of Western Australia. It is intermediate in character between the other two. Its rainfall is received either from extensions of summer rainfall southwards (and this makes up the greater portion, especially such rainfall as is received from tropical cyclones during the late summer months), or in the south from extensions of the winter systems, while rarely a general rainfall may occur throughout.

Vegetative Characteristics

The Northern Province is essentially the savannah-steppe Province, in that an herbaceous ground-covering mainly composed of grasses occurs; this varies from the rich grasslands of Kimberley to the harsh spinifex 'steppe' of the country southwards from the Fitzroy. Scrubland as such is unknown, except to a very limited extent in the rough sandstone range country of north-west Kimberley, and forests as such do not occur; mulga too is absent. Botanically the Province is characterized by the part played by the 'Indo-Melanesian Element' in its constitution. In places this element may predominate to the extent that amongst the trees Eucalyptus plays a secondary role, and deciduous trees are prominent. The Baobab is common, together with various soft-wooded trees, while the herbaceous growth is rich in members of the Hibiscus family and several others. With the exception of the river bank and swamp formations, most herbaceous growth is either dead or resting during the winter months.

The South West Province, on the other hand, is characterized by a total absence of the Indo-Melanesian influence, and its flora bears a distinct southern or 'Antarctic' impression. Trees and shrubs predominate with a marked diminution of grasses, and there is no true grassland; the herbaceous species are of winter growth, and the plants remain dormant during the dry summer months, especially the species of Acacia and Casuarinaceae. The Proteaceae, which assume a minor role in the North, here hold sway, as do the Myrtaceae and Leguminosae. The principal formations are forest woodland and scrub land, with extensive tracts of sand-heath; mulga and spinifex are absent; the various salt-bushes either exist as inhabitants of the physiologically dry salt pans, or occur only marginally. There is a distinctive plant architecture amongst the woody plants in which the effect of the dry season is apparent.

The Eremean Province is again intermediate. Floristically, it is characterised by the "Australian Element," recruited from northern and southern influences, and those hardy species which have arisen in response to an adverse environment. Notably there is an increase in the spacing of plants due to root competition between neighbours; the result is a series of "open formations" - Mulga bush, consisting of leafless species of Acacia with resinous or stiff leaf-like phyllodes together with a predominance amongst the shrubs of species of Acacia, Cassia and the attractive species of Eremophila, notable for the size and colour of their blossoms. The Northern influence is expressed most strongly in the Spinifex which is the dominant tusky grass of the lighter and stony soils, while the Mulga occupies the closer-grained soils, the true mulga (Acacia ancura) being restricted to hard-pan soils. The Southern Element is most strongly evident in the loose red sand and around granite rocks; the former carrying those sand-loving species for which the South-West is famous. Even the Blackboy extends into the heart of the Eremea, while the species near the granite rocks owe their existence to an improvement in the water content of the soil in addition to the shelter and shade provided by declivities. In the northern portions of the Province we find, where watercourses provide permanent pools and moister conditions than elsewhere, an intrusion of the Northern Element especially in the grasses and the herbaceous flora generally. Savannah and Steppe occur in the North. Mulga and spinifex steppe occupy the middle areas, while in the South we have woodland formations, with some degree of heath development. The salt soils carry distinctive formations of salt tolerant plants amongst which salt-bushes are prominent, and this same formation occurs on the limestone soils of the Nullabor Plain. Forests are absent.[1]

This introduction has defined in broad outline the three vegetative Provinces of Western Australia as well as showing the ecological climax which has taken place between the climatic factors and soil types to bring about the vegetative peculiarities of each Province.

In a country comprising some 6,800 species of flora,[2] it is surprising that so little is known concerning the economic value of many species for comparatively few have been commercially examined. Those which have received or are receiving attentión in this direction are mentioned in Sections Two and Three of this work, while general ecological aspects of the State's vegetation - in particular its forest areas - are examined in Section One.

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(1) Gardner, C.A. Official Year Book of Western Australia. No.1 1957. pp42-52.

(2) Gardner, C.A. Ibid. p.42.

11. THE ECONOMICS OF EROSION.

The soil is the source of our food and clothing, and is our basic heritage which must be conserved if human living standards are to be developed, maintained or even preserved. In the course of the last half century, extraordinarily rapid exploitation of wide areas of Western Australia has been possible because of modern transport and efficient machinery. At the same time the importance of conservation was not fully recognised. For years the steady removal of the topsoil and decline in yields of crops were barely perceptible. But a succession of bad seasons [1] revealed only too clearly the deterioration of the soil and the maladjustments of the balance of agriculture.

During the past quarter of a century the rural community in Western Australia, as in America and other countries, has become increasingly aware of the threat of soil erosion. In place of the former almost unwitting mining of the resources of the soil, farmers have taken active measures to control erosion and to establish a stable basis of agriculture.

It was discovered that changes occurred with the way the land was used. Greater run-off of rainfall took place as water was absorbed more slowly into the soil. Some of the organic matter disappeared; the land was harder to work into a tilth, shortages of various plant nutrients such as nitrogen and other trace elements became apparent and the quality of crops was poorer than when the land was first farmed.

Various measures have been developed to check the ravages of soil erosion. Cultivation on the contour, with graded banks and other mechanical means of protecting the soil, have been practised.

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(1) e.g. The 1914 drought.

However soil conservation involves the whole range of good husbandry, backed by developing agricultural science. These principles can resist and overcome the natural and man-influenced forces of deterioration and restore already exhausted land to higher fertility.

Though soil deterioration may be caused by any one of the following set of conditions, it is the last mentioned which concerns the development of this thesis and attention must accordingly be devoted in that direction:

1. Loss of nutrients, organic matter and lime.
2. Compaction and sealing of the surface.
3. Soil erosion-stripping of the surface soil.

Soil erosion.

The most serious aspect of deterioration is the removal and deposition of soil. If the soil were simply weathered or ground up rock material, erosion or stripping of the surface soil would not be so serious. Soil however is more than this. It is weathered material which has been acted upon by many agencies to develop layers, called "horizons" which together form the soil profile. In most soils there are two main horizons, the surface horizon and the subsoil horizon. Below the latter is the weathered rock from which the soil has formed. The soil is fertile only when the different horizons are intact, when the different horizons can play their part in meeting the needs of plants.

Soil erosion is caused by two agencies - water and wind. These agencies, by virtue of their movement, have energy, and this energy may be used to cause soil erosion. First, soil particles are detached from the soil mass and then transported elsewhere. Erosion control therefore, involves treatment that will reduce the energy of the agencies and which will decrease the amount of soil detachment and transportation.

The destruction of forest lands in Western Australia to make land available for social and economic development of the settlers led to many harmful land-use practices. The removal of native vegetative cover, to clear the ground for planting agricultural crops laid bare many acres of rich soil to the ravages of wind and water.

Light misty rain, with small drops gently falling, has little kinetic energy to detach soil particles. This light rain may be completely absorbed into the soil as it falls thereby causing little run-off and hence only a small amount of transportation. When moderate and heavy rain occurs the drops are larger and hencecause greater disintergration of the soil as they strike the bare earth. The energy of the wind will cause erosion if the soil is unprotected and particles of soil are detached. The wind moves the particles in two ways, as dust suspension in the air, and as grains or particles which are blown along the ground in a process known as saltation. These grains may push others along producing surface creep. These moving grains are transported, resulting in depressions, or they pile up around obstructions to form hummocks.

Vegetation acts as a blanket over the earth's surface, so that most of this energy of wind and water is dissipated before the soil is affected. Under natural conditions a cover of forest vegetation decreases the rate of run-off because of the many small pits and irregularities of the forest floor and because the litter and humus collected there is highly absorbent of moisture, thus tending to hold rain water until it can escape slowly. When the natural vegetation is removed the soil is alternatively subjected to rain and dried by sun and wind. It is then that the erosive influence of these two factors become evident.

Furthermore, a vegetative cover renders the soil itself more resistant to erosion, for the natural soil crumbs when undisturbed by cultivation, are harder to detach and remove. The growing plants too release water by transpiration as well as evaporation, thus increasing the soil's capacity to cope with rainfall. Even so, the roots of many agricultural crops such as wheat and lupins have little effect in preventing soil erosion by water once their tops are removed at ground level, for it is the surface cover provided by the aerial portions of these plants which are of greatest value in that they produce a thick mat-like surface covering.

Nevertheless, in the growing of crops the farmer can do much to prevent erosion. By maintaining a high degree of organic matter in the soil and thereby preserving its self-binding structure and hence good drainage and absorbing capacity; he will be employing sound remedial measures to offset erosion. The ground should also be kept covered with vegetation for as much of the year as possible. Such cover can be effectively introduced to depressions and gullies which are caused by erosion, by first filling them with soil obtained from ploughing the area on each side of the gully or depression and bulldozing some of this loosened earth to level off the adjacent ground and then compacting the whole portion treated, by driving over it. This area could then be planted to eventually produce a windbreak structure.

Where erosion is a serious threat, trees play a very important part as a means of protecting the soil. Areas in this State which are more susceptible to erosion appear to lie near Perth in the vine growing districts where the winds funnel between the rows, tearing the sandy soil from the roots; in the wheatbelt; in agricultural areas of the Mallee country; on the sand plains and in that area of the South West which is given over to the cultivation of orchards. Vast areas of Kimberley also suffer from extensive wind and water erosion, so much so that present day developments on the Ord River aim not only at storing sufficient water to irrigate large tracts of hitherto unproductive, yet fertile, land; but also to regulate the tremendous loss of surface soil by both wind and water agents. The raising of cash crops on the banks of the Ord will produce a vegetative cover and root systems which will result in a reduction of erosion by wind and heavy rainfall. Construction of the Ord River Diversion Dam will so regulate and control the amount of run-off that only a very small amount of soil will be lost through flooding when compared with that lost in previous years. Mention must be made of a tree planting project at Esperance which was commenced in 1960; and also the planting of Marram grass on certain areas of drift sand on the coastal strip from Shark Bay to Eucla; both of these projects will arrest wind erosion.

The area of land available for primary production in Western Australia is controlled by factors of climate and geomorphology, together with the direct social and economic influences of isolation and distance from markets, though the latter two have now been reducedto a large degree by improved methods of communication and transportation. Nevertheless, the approximate area of rural holdings in proportion to the whole area of the State is only 37 per cent.(1) With this small proportion, the main avenues of increased production lie in developing agricultural areas and in the more effective use of those areas which are already occupied.

It is more than reasonable that both programmes proceed side by side and it is automatic that improved farming practices in the form of an

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(1) Official Year Book of Western Australia No.1. 1957. Govt. Print, Perth, W.A. p.182.

awakened interest in soil erosion are necessary to improve the heritage of the soil. The farmer who allows soil deficiency to develop will be allowing his principal asset to disappear before his eyes. Yet many farmers whom I have contacted do not appear to realize that soil erosion seriously affects the value of land.

The primary responsibility for soil conservation and soil erosion rests firmly with the farmer who occupies the land. He must be able to recognize the signs of soil erosion and know the best methods for its correction. Further, he must put them into practice. No one knows his farm like the farmer and no one can relieve him of his obligations to himself, his land, and its future productivity.

The ecological affinity of forests with the preservation of land productivety should therefore occupy an ever increasing part of everyone's life.

111. STABILIZING CATCHMENT AREAS.

Water is necessary for the preservation of all forms of life, both plant and animal. Even man, who has managed to adapt himself to a variety of environments has not been able to adapt himself to life without water. He needs water to keep himself alive, and he obtains all his requirements in the way of food, clothing and shelter from plants and animals which in their turn must have water in order to keep alive.

The water resources of a country therefore play a big part in governing the development of that country, for man cannot develop agriculture or build cities and towns where water requirements cannot be met.

Western Australia is one of the driest regions of the world as far as the supply of natural surface water is concerned. Nowhere on its surface are there large tracts of fresh water like the Great Lakes of America, or are there large fresh-water rivers like the Amazon and Nile. Consequently there is a tremendous need to conserve water for agricultural and pastoral industries as well as meet the requirements of towns and cities.

The main method of conserving water here is by the construction of large dams. This means building dams in regions of high rainfall and piping water to areas which receive less rain. The history of large scale conservation in Western Australia dates from the opening of Victoria Reservoir on Munday's Brook in 1891. Other large scale projects include two which were begun during the 1920's, one on the Bickley Brook and the other on Churchman's Brook; the Canning Dam in 1933; the Serpentine Pipehead Dam in 1957; and the last and more recently constructed Serpentine Dam, which is by far the largest undertaking of its kind, containing 39,000 million gallons.

With rapid expansion of secondary industries in the State during the 1950's, considerable attention had to be given to providing additional water supplies in those directions.

Mention must also be made of the Goldfields Water Scheme, built originally to bring water to the mining population on the Golden Mile and which still supplies this need by carrying water from Mundaring Weir in the Darling Ranges near Perth. As the goldmining industry declined during the early 1900's, the fact that this water pipe traversed large areas of good agricultural and pasture lands influenced ex-miners to commence farming in those areas which it served. Present day extensions to the parent pipe are shown by the addition of some 1,000 miles of smaller pipeline for the convenience of farmers living to the north and south of the main line.

Similarly, the Comprehensive Water Supply Scheme has enabled towns from Koorda in the north to Katanning in the south to be connected with a dependable all year water supply.

Such projects, together with the Harvey Irrigation Scheme, necessitate the construction of considerable storage areas within high rainfall regions which have suitable catchment areas.

The water user demands reliability in his water supply, i.e. a regular availability of water, free from failure in times of drought and from damaging floods in times of heavy rainfall. A second requisite is that the consumer has an adequate quantity of water. Thirdly, the supply must be free of silt for domestic or industrial purposes. As the population of this State has increased rapidly particularly in the post war years, the need for increased storage capacity and catchment areas has intensified resulting in the addition of new storages.

Of the three requirements which the catchment and storage area must satisfy, that of adequacy receives greatest priority, and any changing of land form which is already providing regular and adequate run-off must be carefully examined.

Although the results and reports of experiments and measurements of stream flow, run-off, and estimates of loss by evapotranspiration from various land-form areas are numberous, the results are often contradictory. Laurie (1) cites instances of conflicting results in hydrological investigations: Four reports from Russia (Lebedev, 1959; Bochkov, 1959a; Valek, 1959; Bochkov, 1959b) instanced higher water yields from forest than from clearings or pasture, while a summary of 26 studies from different countries showed the opposite to be the case.

Laurie (2) agrees that there is some factual basis for the generally accepted view that forest covered area produce clear perennial streams, reduce silting and prolong the base-flow, but adds that when it comes to finding critical experiments, there is less supporting data.

One such piece of evidence is supplied by an experiment conducted by Casparis (1959) in which an analysis of thirty years of

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(1) Laurie, M.V. Forests & Water Supplies, Eighth British Commonwealth Forestry Conference, 1962. Forestry Commission, London. p.2

(2) Ibid. p.3.

measurements of forested and mainly pastoral valleys showed that the mean daily flow is normally about 15 per cent higher from the mainly pastoral area but falls below that of the forested area after five to six days of drought and remains steadily below it thereafter. After a long enough drought, flow would cease from the mainly pastoral area some time before that from the forested area.

On the graded slopes of the catchment area, the stability of the soil depends upon the natural vegetation. If this vegetation is rich and flourishing it may bind the soil so that even on a steep slope, streaming (1) of the soil towards the lower storage area will be arrested and only creep (2) permitted. When this occurs, there is a state of balance between the rate of removal of soil and the rate of new supply by weathering. Hence sufficient soil is being maintained for the regrowth of vegetative cover, whether it be forest or some other smaller growth, which in turn produces its own humus for soil enrichment and so maintains the balance of nature.

When the natural vegetation, whether forest or grass, is interfered with, soil dissection begins. Clearing and burning the forest from any slopes seriously disturbes this state of balance between the rates of erosion on the slope and weathering. Removal of soil by erosion becomes more rapid because of the soil's increased exposure to rain-wash and wind transportation owing to the absence of binding ground cover and consolidating root systems. This loss of surface soil and subsoil could eventually result in the exposure of the bare rock, which in turn - in the far distant

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(1) flowing.

(2) almost imperceptible movement.

future - and as the result of increased run-off, could be eroded to a series of ravines. The resulting ravines would weather back into the hillside by head erosion if nature were left to take its own course, to form low convex summits. Thus the catchment system is broken up completely and with the excessive transportation of unwelcome waste to the lower level, i.e. the valley of the storage area, the whole conservation area is destroyed. There is therefore, in Western Australia as in other parts of the world, a very real need for rigid control of State forests in water catchment areas if the State is to meet its water requirements in the future.

Where there is abundant vegetation, the soil is largely protected from erosion. The rocks are not exposed at the surface, much of the rainwater soaks into the ground instead of evaporating and is therefore conserved and drains into the storage area, there is less erosion by rain on the slopes, less flood action by streams forming and the corrosive action of the wind is at a minimum.

The effect of forest cover on catchment areas is controlled by the following considerations, each demanding special investigatión.

(a) The quantities of rainfall intercepted by various forms of vegetation (forest as well as grass or field crops) and held, ultimately to be lost by evaporation.

(b) The porosity or rather rate of acceptance of water by the soil ('infilterability') under different kinds of land usage, so as to be able to estimate the rate of rainfall that will result in surface run-off starting, and the rate of entry of water into the soil.

(c) The effective rooting depth of different forms of vegetation, i.e. the depth from which roots can abstract moisture from the soil, and below which loss of moisture by transpiration of the vegetation is negligible.

(d) The distribution of moisture in the effective rooting zone, not only in depth, but also laterally. This may be important in forest where soil wetting from stem-flow or from tip-dribble may be irregular, and as the soil water is taken up by the roots, parts of the soil may remain above field capacity and contribute to ground water flow after other parts have been relatively dried out by the roots. The stage at which stomatal control of transpiration commences under forest, may be at a higher average moisture content in the effective rooting zone than under a crop like grass, owing to irregular drying-out of the soil in the regions of active root tips.

(e) For different types of vegetation, the quantity of rain required to saturate the vegetation and to charge the effective rooting zone of the soil to field capacity needs to be determined, as it is only after that stage is reached that water can percolate downwards and contribute to ground water flow. The complications due to uneven wetting under forest need also to be taken into consideration.

(f) The rate of loss of water under varying meteorological conditions from the soil in the rooting zone by both direct evaporation and transpiration.

(g) The effect of foliage wetting on the rate of transpiration and on net water loss, i.e. the extent to which reduced transpiration compensates for loss by evaporation of intercepted water.

(h) The variation in rate of transpiration under different conditions of incident radiation, atmosphereic humidity, wind speed, air temperature, etc. and, in particular the ability of vegetation to control evaporation in times of water stress.

(i) The differences in rate of transpiration by different species under the same atmospheric and soil moisture conditions. To what extent is water consumption correlated with rate of growth?

(j) To what extent can any reduction in combined evaporation and transpiration losses be effected by (a) choice of species, (b) reduction in undergrowth, and (c) thinnings in the upper storey. Similarly in arable crops or grass, does density of stocking affect the amount of water lost.

(k) Hydrological conditions in the soil below the rooting zone. Rate of release of water as base flow when (a) at or above field capacity, and (b) when below field capacity. Moisture gradients and general moisture distribution in the soil below the rooting zone, where, presumable, losses by evaporation are negligible." (1)

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(1) Forests & Water Supply, M.V. Laurie, Eighth British and Commonwealth Forestry Conference, 1962. Forestry Commission. London. pp. 5,6.

IV. WIND BREAKS AND SHELTER BELTS.

As has been previously stated, erosion can be caused by either wind or water or a combination of both. The ecological aspect of forestry and vegetation in this State with relation to the preventiòn or diminution of soil erosion embraces man's adaptation of suitable trees, shrubs, plants and grasses in an attempt to reduce such erosion and provide protection for stock from sand-laden winds.

The provision of shelterbelts and windbreaks of trees and shrubs is not the complete answer to wind erosion, though in many cases the wheatbelt farmer considers this to be so. Trash-ploughing; and the degree to which grazing is permitted together with suitable cropping techniques, are of far greater importance. But, the destructive effect of wind is reduced by the presence of belts of trees.

Very little baffling and resistance to wind is necessary to prevent soil being picked up and carried along by winds. The comfort to be found on the lee side of a belt of timber on a windy day is apparent to both man and animal. The trees and scrub reduce the speed of the wind within a few feet of the ground and therefore have their place on every farm. In many instances though, no thought is given to providing a shelterbelt around a homestead or farm buildings. I have witnessed during this week, the erection of a new home in the wheatbelt. The house site is utterly devoid of any protection whatsoever. The nearest shelterbelt to this house is around the next door neighbour's home two and a quarter miles away. The front door of the new home looks out in a north easterley direction across miles of cultivated land and almost directly into the eye of hot, dry, easterley winds, which blow for most of the year.

In places where belts of natural vegetation in the form of shrubs or trees have been left along fence lines or roadsides, very little accumulation of wind-blown soil is evident. On the other hand, where no such natural bush is evident, it is not unusual to see drifts of soil piled up along fences and across roads. This is especially so in the light sandy country of the wheatbelt. Many farmers in the Bruce Rock area have recently commenced planting shelterbelts and windbreaks to help reduce erosion and provide shelter for stock. Similar activities are receiving attention in the Esperance district.

Some considerable research has been done to determine the effectiveness of certain types of shelterbelts and windbreak structures and the following appear to be most important.

Height. 'Reducing the wind speed at ground level on farm paddocks is the key to reducing or preventing soil erosion by wind.' [1] Though belts of timber do reduce the speed of the wind both on the leewood and to a much lesser extent on the windward side, [2] the area of ground so affected is very small. Generally speaking, there is close relation between the area over which a reduction in wind speed is experienced and the height of the shelterbelt.

Caborn [2] has shown that the most benefitial coverage is experienced within an area of 15 or 20 'shelterbelt heights' downwind of the barrier, and in addition, that there is a falling-off in wind speed up to 10 windbreak heights in front of a shelter, 'according to the degree of open-ness of the structure. [3]

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(1) Burvill, G.H. Windbreaks and Shelterbreaks in Relation to Soil Erosion. Dept. of Agriculture, Perth, W.A. 27 (2) June, 1950. pp 180-184.

(2) Caborn, J.N. The Dependence of the Shelter Effect of Shelter Belts upon their Structure. Fifth World Forestry Conference, 1960. p.1

(3) Ibid. p.1

Density. Studies conducted so far, to reveal the effects of the density of Shelterbelt structures, have revealed that the more porous the design, the more shelter is provided in terms of shelter for field crops. 'It is now generally agreed that a shelterbelt which filters the wind rather than arrests it completely, produces a longer range of effective shelter.' (1) Dense windbreaks - those having a degree of porosity to the wind of less than 40 per cent - afford a pronounced wind abatement immediately to leeward but this is counteracted by vigorous downdraughts and the free wind speed is regained relatively quickly. With shelterbelts moderately penetrable (2) to the wind, the minimum velocity is found a short distance, usually between 2 and 5 heights, to leeward and there is a more gradual resumption of the open ground velocity. The more open is the structure, the further from the belt is the minimum wind speed attained and the degree of wind abatement is progressively decreased. Furthermore, structures which are open near the ground cause an acceleration of the wind as it funnels through the shelterbelt, often to values far in excess of the free wind speed. Such an acceleration is undesirable but can be offset by planting a margin of low shrubs or scrub within the belt. The total shelter produced by dense belts is not necessarily less than that afforded by a moderately porous belt, but there is a difference in its leeward distribution. Dense belts show a greater wind reduction near the belts but a lesser effect downwind, and it is considered that this is less desirable for the protection of crops

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(1) Ibid. p.1

(2) Caborn recommends the optimum degree of penetrability to the wind for a shelterbelt is approximately 40 per cent.

and soils though more appropriate for sheltering stock against severe weather conditions.

Width. The width or depth of a shelterbelt, measured parallel to the wind, would seem to have no direct effect on wind abatement except that it relates to the degree of penetrability of the structure. Thus, depending on the closeness of the trees, two belts of unequal widths could have the same degree of wind porosity. The most economical belt then would appear to be one in which adequate planting is practised in accordance with sound forestry principles. Hence, the narrower a belt can be whilst still giving maximum protection, the greater is the area of land available, for agricultural pursuits.

It has also been shown that once the width of a belt passes a critical point, the pattern of wind flow may alter as the [illegible] wide belt 'consumes' some of its own shelter thereby reducing its effectiveness.

Cross Sectional Profile. The most effective shelterbelts have been proved as being those whose cross sectional profile resembles that of a gable roof with a wide sweep at the eaves.(1) This design has been used extensively in the majority of shelterbelts planted in the Great Plain's Shelterbelt Project of the United States of America during the 1930's. Caborn (1960) cites the basis of shelter construction as 'breaking the uniform current of the air, shattering the cutting blasts and throwing them into eddies, thus ameliorating the air to some distance from them.

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(1) Ibid. p.3.

The only criticism of such a design is that the main height growth is concentrated within one or two rows and in the event of their dying out in the course of time, the effect of the shelter provided is quite suddenly reduced. Caborn states that such a reduction could be in the order of 30 per cent.

The Crown Surface. Recently it has been suggested that a broken crown surface may be more effective than a smooth rounded surface in breaking up wind currents and thus producing shelter. If this is the case, the planting of future windbreaks in Western Australia will have to follow the Canadian procedure whereby trees of different species and height are planted in each row. Apparently the general 'gable-like' pattern could be retained whilst breaking up the smooth evenness of each sloping side. As Caborn points out, such a planting procedure would ensure maintaining a shelterbelt of optimum density while guaranteeing permanence.

Conclusion. With the present rapid clearing of many new areas of light land in the State by modern machinery, all too little attention is being paid to the retention of natural belts of scrub, mallee or trees to form shelterbelts. In cases where insufficient shelter is left, consideration will eventually have to be given to producing these by allowing natural regrowth or new planting. Where the latter is the case, careful consideration of the types of trees selected for planting will be necessary, if the resulting protection belt is to be as efficient as possible. Expenditure of time and money involved in porivding a shelterbelt is such that every precaution should be evaluated before planting or clearing the land, so that the resulting structure will be as efficient as possible.

Consideration of such vitally important factors as root competition with nearby crops, density of foliage, height of foliage above ground level, maximum height of growth, soil suitability and resistance to aridity and wind all play their part in producing a shelterbelt of maximum portection from soil erosion and wind.

Suitable trees recommended for windbreak planting in Western Australia are suggested by the State Forestry Department and are listed for reference in alphabetical order:- Acacia acuminata, (Raspberry Jam); Actinostrobus pyramidalis, (Native Cypress); Callitris glauca, (Native Pine); Callitris robusta, (Rottnest Pine); Cupressus arizonica, (Arizona Cypress); Eucalyptus botryoides, (False Mahogany); Eucalyptus brockwayi, (Dundas Mahogany); Eucalyptus camadulensis, (River Gum); Eucalyptus lehmanni, (Bald Island Marlock); Eucalyptus sargentii, (Salt River Gum); Pinus Canariensis, (Canary Island Pine); Pinus pinaster, (Maritime Pine); Pinus pinea, (Stone Pine); Pinus radiata, (Monterey Pine); Populus niara, (Black Poplar).

V. LIMITATIONS ON EVAPORATION.

Rainfall that falls on any land areas is dissipated in either of three ways. It either evaporates, runs off the surface or penetrates the soil to form ground water supplies. The amount that is drawn from the soil by vegetation and transpired through the leaves is termed evapotranspiration.

Water is lost from all land surfaces whether they be covered by vegetation or not. Under Western Australian conditions, this loss is dependent upon the amount of water available and temperature. In the main, supplies are from rainfall, this being the State's major precipitation form. Insignificant falls of snow occur on rare occasions and even then affect an area of only a few square miles, so that this contribution of snow as a source of water supply is negligable. Water loss is also variable depending upon differing land surface characteristics.

In a State of vast areas receiving a low rainfall - half the area of the State has less than 10 inches per annum - seasonal droughts are a feature. It is not surprising therefore to find that conditions governing vegetation here are in almost total opposition to those which were present in the cool temperate lands of Europe from where the principles of forest management emulated. In European countries the two most variable factors which influence transpiration and evaporation in forest areas are the amount of solar energy available as well as the temperature range. Until quite recently it was thought that these two variables exerted similar influences on water loss in forested areas the world over. Alas, foresters in Western Australia realised very early in the century that such generalizations could not be applied in the same manner to the sclerophyllous and savannah type land coverings which were found in this country. They found the sunlight more abundant, reliable and intense; temperatures generally higher and less extreme; and the percentage of moisture smaller though more stable. In view of this appreciated divergence in basic climatic conditions, the need for a re-oriented approach to ascertain which conditions governed the promotion of local forests became obvious.

There is probably no part of Western Australia where evaporation is balanced by rainfall throughout the year, as is the case in cool temperate Great Britian and Europe and it must be remembered that it was from these countries that former forestry practices were derived. Perhaps in Kimberley, during the 'wet' season, and in the south western corner of the State, this balance may occur for short periods. However exhaustive experiments have yet to be undertaken to support this hypothesis.

In view of this set of new conditions, it was soon realized that "Water was the variable, the greatest limiting factor governing growth characteristics, regeneration and further development of the hard-leafed evergreen forests, and not, light." (1)

Bearing in mind the fact that Western Australia is already short of natural water supplies and that such shortage may further be depleted through transpiration and evaporation in forest areas, an examination of the extent of such loss from various types of

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(1) Lane-Poole, C.E. The Forest and Water. Extract from Report of Science Congress, Govt. Print, Canberra. 1933. p.l.

vegetative cover under local conditions should now be undertaken to determine the economics, or otherwise, of preserving present forest reserves. The outcome of such research, providing sufficient funds are made available to ensure its entire conduct without interruption, would indicate the value of retaining present forest areas or the advisability of their replacement with some other surface cover in the light of conserving the State's water supplies by reducing the loss of present precipitation through evapo-transpiration.

As a generality, evapo-transpiration will increase with increased supplies of available soil water, up to the point at which actual evapo-transpiration equals 'potential': i.e. the maximum amount of water which will be consumed through evapo-transpiration under a given set of climatic conditions, given an ample supply of water to the roots of vegetation. This means that evapo-transpiration is expected to increase with annual precipitation until it reaches the level of potential evapo-transpiration at which point it should tend to stabilize.

In very wet climates, total evapo-transpiration may even tend to decrease with increases in precipitation. The mesophytic (1) forest of the extreme south west corner of Western Australia may be suggested as a possible example when this takes place. There, where an annual rainfall of about 50 inches per year is received the forest cover is dense, and thick undergrowth prevails. A comparison of precipitation and run-off may indicate that total evapo-transpiration is surprisingly low, even though temperature is somewhat tempered by the close proximity of the sea. In the light of African studies (2) it is suggested that with over-

(1) Karri.

(2) McCullock and Dagg. Hydrological aspects of Protective Forestry East African Agriculture and Researcg Organization. Muguga. Kenya, 1962.p.4-5.

abundant precipitation and continuously wet soils, the opportunity for evapo-transpiration is decidedly less than in more moderate climates such as those of the sclerophyllous [1] region where lower precipitation - 20 to 30 inches per annum - and periods of drought conditions, from November to March, are experienced.

Evapo-transpiration losses depend also upon limitations in available water caused by factors other than total precipitation. If, for example, the soil horizons are shallow above some impervious clay or rock structure, the roots of vegetation will have access to considerably less water supply that can be developed in deeper soil mantles. Water storage in the soil may also be limited by comparatively impervious layers at or near the surface of the ground. If the soil surface is compacted by trampling, by erosion, or by the impact of falling water, much of the precipitation in any storm may be lost through overland flow and not get into the soil storage at all. Then, drought-like water storage conditions are produced, even in areas with otherwise ample rainfall.

With respect to the vegetation itself, transpiration may be expected to increase with increasing volume of the vegetative cover, up to the point where the soil becomes fully occupied with roots. Direct evaporation from the upper soil, on the other hand, may be expected to decrease with increasing vegetative density. In shallow soils, where the depth of the root systems is comparable to the depth of the soil appreciably affected by direct evaporation, the changing losses with changing vegetation density may so offset each other that their combination tends to remain constant.

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(1) Jarrah.

While exceptions to these generalizations must exist, evapo-transpiration from an area of low rainfall and high temperature extremes even after the complete recharge of soil water storage in the root range must add to the trees' suffering water shortage in the dry season and affect their adaptability to resist drought conditions in our Mediterranean and semi-arid climates.

Replacement of natural vegetative cover by some other form must be preceded by intense research to ascertain the permanency of such cover during dry periods which are so notable in this State. To replace an already stable covering with one possessing lower evapo-transpiration qualities may appear justified under Western Australian conditions to reduce water loss by evapo-transpiration, provided that the alternative cover can be guaranteed to retain its permanency under our prevailing climatic conditions. Unless this guarantee can be proved, the soil may be laid bare to erosive agents and the whole land surface changed completely resulting in the utter loss of present water conserving factors.

Obviously, there is an apparent opening for research along these lines in Western Australia, but because of the many factors controlling evaporation and evapo-transpiration and because of the few records of these phenomena available so far, only approximate formulae have been evolved for its measurement. Dr. Gentilli [(1)] suggests their classification as follows:

1. Functions of annual total precipitation and mean temperature.
2. Functions of annual total precipitation and maximum and minimum temperatures.
3. Functions of total precipitation, number of wet days, and temperature.

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(1) Gentilli, J. Unpublished paper, University of Western Australia.

4. Functions of annual total precipitation, temperature, and latitude.
5. Functions of seasonal precipitation and seasonal temperature.
6. Functions of monthly total precipitation, latitude (length of day) and mean monthly temperature.
7. Functions of monthly total precipitation and mean monthly temperature.
8. Functions of precipitation and saturation vapour pressure.
9. Functions of precipitation and relative humidity.
10. Functions of precipitation and saturation deficit.
11. Functions of precipitation and evaporation.
12. Functions of precipitation and evapo-transpiration.

Some of the formulae fall within more than one class because they aim at expressing the ratio between precipitation and evaporation indirectly, by using temperature and relative humidity data instead. Others are evolved for annual data only, some for monthly data only, and several use either sets of data, and some are for data relating to shorter periods as well.(1)

While there is little doubt as to how much precipitation is received at any given time and place, there is an urgent need for co-ordinated work by plant physiologists and soil scientists on the one hand, and by climatologists on the other, to determine the relative proportional values of precipitation disposal.

Such work would be costly. However, with growing population figures forecast for the State over the next half-century, increasing attention will be focussed upon increasing the sources of water supply and conserving the maximum quantity possible. In these respects, all possible avenues will bear investigation and it will be interesting to witness the out-come of such investigations in the light of technical progress in the use of such substitutes as steel, concrete and aluminium, for wood.

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(1) Ibid.

VI. THE FOREST AND CLIMATE.

The subject of climatic change provides an extremely fascinating, though highly speculative aspect of climatoloty which has long interested botanists. In recent years the change of outlook by botanists with an ever increasing emphasis on ecology has led to the exploration of fresh avenues of approach to the subject. It has become evident that the climatic element in the plant environment is not stable, as was once thought, but is rather a constantly fluctuating control; the concept of a 'climax' vegetation is no longer unconditionally valid.

Climatic change seems to have taken place everywhere in the world but often at different times. There is no widespread change in any one direction and as yet the problem of how and why these changes took place is unsolved although there are many theories in existence which attempt an answer.

One of the most widespread conjectures on the effects of forests on climate, concerns the effect upon total precipitation falling over a given area or region.

Precipitation.

For a number of reasons this effect is difficult to establish quantitatively. Therefore, although it seems probable that some changes in precipitation are likely to be accompanied with the denudation or reforestation of large land areas, the actual magnitude of such changes is conjectural. Nevertheless, foresters have maintained for a long period of time that extensive areas of forest, of the order of square miles, have an ameliorating effect upon climate and hence on the rainfall of the region. Some early evidence advanced in Europe supporting the view that rainfall in forest clearings tended to be up to 10 per cent greater than that in the open, may well have resulted from differences in exposure of rain guages than from differences in precipitation.

It is well known even from direct observation, that in areas subject to low cloud or mist, quantities of water can be withdrawn from the atmosphere through interception by vegetation. I have seen this at Mount Chudalup near Pt. D'Entrecasteaux, on the south west coast of this State where 200 feet high Karri trees appear to be perpetually shrouded in low cloud and mist as though the two possessed an affinity for each other. In this case precipitation in the form of condensation takes place on account of a relatively high humidity, about 97 per cent, and the presence of a most effective nuclei of condensation in the form of salt particles blown across from the nearby ocean spray.

Such precipitation by interception is naturally proportional to the area of the receiving surface. Even in the case of a single tree a considerable surface area is available and considerable quantities of water may so be extracted from the atmosphere. Water intercepted by this method is termed "occult precipitation" and reaches the ground surface by drip and by stem flow. A simple experiment to investigate the quantitative magnitude of this occurrence in South Africa is being undertaken at Muguga Forest. (1)

In addition to such directly measurable precipitation, it is possible for the aerial parts of vegetation to take up small quantities

(1) Kerfoot, O. and McCulloch, J.S.G. (1962). Eighth Commonwealth Forestry Conference, East Africa.

of water from the atmosphere by direct absorption.[1] Any water which remains on the vegetation may be considered quantitatively as a nett gain in precipitation, since the energy used in its evaporation from the leaf surfaces, when misty conditions have ceased, would have been used in the transpiration of an amount of water from the soil surface available to the plant. The conservation of soil water in this way may be an important factor in "occult precipitation."

Transpiration.

From the point of view of the atmosphere, forested lands generally provide an evergreen, transpiring cover. This continued transpiration, throughout the dry season, except in the case of deciduous species, results in a marked alteration in the diurnal heat balance over a forest as compared with other forms of land use. Pereira and McCulloch[2] showed that the heat flux from forested areas was, in the dry season, generally about one helf that from subsistence crops and goat pasture. The same conclusion could in all probability be applied to sheep pastures and wheat farming districts in Western Australia. Such a reduction in heat returned to the atmosphere is noticeable to travellers in light aircraft. Under hot dry conditions, flight is less bumpy over dense forest or open water than over agricultural or grazing land. This is particularly noticeable during a flight from Albany to Perth.

When forest covers areas of high ground, the combination of cooling due to transpiration and orography [3] may well result in

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(1) Slatyer, R.O. (1956) Austr. Journ. Biol. Sci. 9 (4).
Slatyer, R.O. (1958) Ibid. 2, III.

(2) Periera, H.C. and McCulloch, J.S.G. (1960) Proc. Munitalp Syp., Nairobi.

(3) Presence of forests on mountain slopes.

heavier rainfall over the area in general. It is therefore possible that removal of such forests could result in a reduction in total rainfall or at least the number of days on which rainfall is received. Such rainfall would tend to be more spasmodic with heavier individual storms. However, replacement of indigenous vegetation by a similar perennial cover, such as plantation trees,(pinus pinasta and pinus radiata) which give complete ground cover throughout the year and continue to transpire throughout the year, would be unlikely to cause any appreciable difference in the local climate. Such has been the case with respect to local aforestation near Perth, Western Australia.

Micro-climates.

On a smaller scale, forests may cause amelioration in the micro-climates of crops in the immediate vacinity.

The appreciation of the importance of the science of ecology has resulted in active work on animals and plant microclimates by ecologists. The importance and magnitude of microclimatic effects is demonstrated by Geiger (1) when he remarks that the daily difference of temperature between Assam, in the Libyan desert, and Alexandria, on the shores of the Mediterranean, is frequently exceeded by that between the actual ground surface and the air a few feet above it in the same meadow anywhere in Europe.

The climate of the air near the ground depends upon two sets of factors, those which are due to the mere presence of the ground and those which result from the type of ground covering. The most useful

(1) Geiger, R. Das Klima der bodennahen Luftschicht. Die Wissenschaft, Vol.78, Vieweg, Braunschweig. 1927 & 1942 resp.

concept is that of the outer ground surface which is the surface at which absorption of the sun's energy mainly occurs and from which it is mainly radiated. Whether this is the surface of the ground itself or, as in the case of forests and shorter vegetation, the main region of leaf development, it is the level at which the highest day-time and lowest night-time temperatures are usually recorded. In other words, it is here that most extreme climate occurs.

The nature of the soil surface has been a great influence on the amount of heat required to bring about a given change in temperature. Colour texture and water content are of outstanding importance, the first two governing the ratio of absorbed to reflected energy, the last, owing to the high latent heat of water, governing the rate of rise in temperature. The effect of plants is normally to reduce the steepness of temperature gradients above bare earth and to change the height at which the outer active surface occurs. The reduction in temperature variation is due to the distribution of this outer surface through a greater vertical depth, the damping effect of the latent heat of vaporization on water (on plant surfaces, and produced ny transpiratiön) and a number of other factors. The formation of dew at night, with the resultant liberation of latent heat, results in a considerable reduction in the amount of cooling which occurs.

McCulloch and Dagg [(1)] investigate this matter in the light of maintaining soil water in tea gardens planted in forest clearings and claim that such gardens are less subject to extreme soil moisture stress

(1) McCulloch, J.S.G. and Dagg, M. Hydrological aspects of Protection Forestry. (1962). East African Agriculture and Forestry Research Organization, Muguga, Kenya. p.3.

during the long dry season than gardens without the benefit of the forest surround. They also point out however, that this compensation must be paid for in terms of root and soil moisture competition on the periphery. This they suggest may be overcome by planting shade trees throughout the gardens. However they conclude by stating, "While recent work with both tea and cocao has shown that maximum yields are obtainable without shade at all, under more rigorous conditions the shade trees serve to reduce extremes of temperature, humidity and wind." (1)

Considering this last piece of research and the generalizations stated above, there can be little doubt that micro-climatic effects are dependent upon the vegetative cover, whatever its form.

Conclusion.

As a general theory, it may safely be stated that each forest land area has a characteristic critical level which determines the comparative safety or danger of any manipulation of the forest environment. Some environmental changes are induced whenever the forest cover is manipulated in a silvicultural operation. These activities are safe as long as the forest complex tends to re-generate good conditions over a reasonable period of time. If the manipulation strikes too severe a blow at the forest community however, an accelerated cycle of degenerative change is likely to occur. As a rule of thumb, it may be said that this state of disrepair is reached when excessive volumes of surface run-off begin to appear, starting surface erosion. When this happens, slight

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(1) Ibid. p.3

degeneration is likely to become progressively more severe as each intense storm tends to build up surface run-off and erosion. The end of this degenerative cycle is a newly established condition of low infiltration and storage capacities of the watershed, high rates of surface run-off and flood discharges from the streams, and large volumes of sediment moving down the channels to the valleys below. If caught early enough after the critical level has been passed, regeneration can be established with considerable ease through replanting and structural works. As the degeneration is allowed to proceed, the restoration process becomes progressively more difficult and more expensive.

SECTION TWO

THE ECONOMIC VALUE

OF

SECONDARY FOREST PRODUCTS IN WESTERN AUSTRALIA.

I. TANNIN RESOURCES.

The foregoing chapters have attempted to picture ecological influences which act upon the natural vegetation, in particular the forested areas of Western Australia and to give some impression of the nature and extent of the changes which such influences may bring about. These influences could be interpreted broadly as improving or destroying man's natural heritage, the forest areas.

The ecological conditions under which forest cover may be maintained having been established, the economic calue to be derived from such preservation will now be considered.

The value of the timbers themselves is tremendous; their utilization for railway sleepers both locally and abroad; their qualities of durability and strength with consequent suitability for all manner of constructional purposes, affords an economic return to the State which is obvious.

Large quantities of minor or secondary forest produce are harvested annually from the forest lands of Western Australia and their value to the State in 1962 was an estimated £2,505,000.(1)

The principal minor economic forest product at the present time appears to come from Tannin extracts. For the year ended June 1957, 195,066 cwts of tannin substances of natural origin were exported to other Commonwealth States as well as European, Asian, Far Eastern and American countries for a total income of £588,544.(2) During the

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(1) Harris, A.C. Report on the Operations of the Forests Department, Western Australia, 1962. p.11

(2) Report of the Forests Department, Western Australia, 1962.

year ended June 1962, 87,345 cwts were exported to the same areas for a total return of £281,364.[1] It is unfortunate that owing to the nature of the returns submitted to the Forests Department, an estimate of the total economic value of tannin materials produced within this State cannot be presented.

The main tannin substances come from either of the following sources: Eucalyptus var.elata (Wandoo) and from Eucalyptus astringens, (Brown Mallett).

Wandoo as a source of tannin extract.

Eucalyptus redunca, var elata has a tannin content of up to 2o per cent in the (air dry) bark and up to 11 per cent in the (air dry) wood. It occurs in extensive forests along the magin of the jarrah areas of the State and the quantity of raw material for extract manufacture justified the establishment of a plant at Belmont by Industrial Extracts Ltd., which commenced commercial extraction in 1932.

Other similar plants were subsequently opened at Boddington (1935) and Toodyay (1952). The retention of the Toodyay mill and closure of the other two (Belmont, 1958 and Boddington, 1960) has been governed in no small measure by economic pressures.

The general scarcity of indigenous tanning materials in the State, notably Brown Mallett which had been ruthlessly exploited in previous years, provided the economic opportunity for the establishment of this industry to meet the existing contingency. The man to realize this was H.V. Marr, then a young industrial chemist in this State. He was mainly responsible for the foundation of the firm Industrial Extracts

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(1) Report of the Forests Department, Western Australia, 1962.

Limited which, during the last few years, has experienced fluctuating fortunes due mainly to severe competition on overseas markets where price cutting has led to conditions of some instability.

The extract produced by this company is known commercially as 'Myrtan' wood extract. For its production the whole tree is taken, including the bark, comprising the trunk and limb, down to six inches in diameter at the smallest end. Leaves are not used. At Toodyay, the only factory working today, the timber is cut within a maximum radius of 50 miles from the factory and up to 30 miles west of the town. The tree is sawn into lengths of 10-12 feet in the bush and brought in loads of 24 tons each. At the factory, the raw material (in the green state) is reduced to a pulp by rasping machines, which cut transversely across the grain. In this state it is fed into stainless steel autoclaves where the tannin is removed by a process of counter press leaching. The resultant liquid (referred to by factory operators as a 'liquor') resembles a solution of weak tea containing about 4 per cent of tannin. This liquor is passed through a triple stage Evaporator where it is concentrated to a viscous liquor (referred to as liquid extract) by removal of approximately 50 per cent of the water.

Finally the liquid extract is drawn into Calandria single-stage finishers where it is boiled under vacuum until the moisture content is reduced to between 18 and 20 per cent.

The product from these finishers is run whilst still hot into jute bags of approximately 1 cwt each. On cooling it solidifies and in this condition is shipped to overseas markets.

An alternative finishing method offers the 'Myrtan' in a powder form. Liquid extract is sprayed at a pressure of 2,500 lbs per square inch into a current of air heated to 320 degrees Fahrenheit. Upon contact with the hot air, moisture in the extract is given off, the dried particles falling to the floor as a powder. From here they are removed to the bagging machine by a screw auger.

Brief mention has been made earlier of recent price cutting on world markets as an economic aspect of the fluctuating fortunes of this Company. Cooper (1) exaggerates the effect of trading difficulties which have had to be contended with, going so far as to state that this is the reason that Industrial Extracts has "fallen so miserably". It is difficult to accept this stricture - any Company whose dollar earnings alone approximate half-a-million per annum is still the driving force. Couple this thought with a vigorous and sustained programme, born of the Company's outlook that difficulties are merely made to be overcome, and one must realize that there is determination here that will overcome any setbacks due to the mere mechanics of trading. (2)

Further to the matter of price cutting aforementioned, it can be stated that the principal offenders were the manufacturers of Quebracho

(1) Cooper, J.F. Unpublished. Teachers' Higher Certificate (.W.A. Education Department). Tannin Resources of W.A. with special reference to Brown Mallet and Wandoo.

(2) Private notes of a discussion with A.L. Baldock, Operations Manager, Industrial Extracts Ltd., April, 1963.

tannin extract in South America, who, in 1961 acting impetuously, following removal of certain rigorous governmental trading restraints, reduced the price of this product by no less than 25 per cent. Their object being to grasp a larger share of the market. Quebracho extract, it should be noted, is a somewhat cheaper product than Myrtan to manufacture, due mainly to the considerably higher tannin content of the wood of the quebracho tree.

In such circumstances it is easy to see how Myrtan found it difficult to compete. It takes time for adjustment to be achieved in face of slump conditions. It seems evident, however, that the possibility that some such development could occur, albeit in milder form, had long been realized by the management, and the application of tannin for purposes other than for tanning hides had been investigated.

One of these possibilities lay in oil drilling operations. The addition of certain tannin for thinning oil drilling mud reduces resistance on the rotation of the drill. Artificial drilling muds are composed chiefly of bentonite material which occurs when it has, at some time, been subject to bolcanic action. It is a clay like deposit which can be quarried out and ground extremely finely. This material is thixotropic i.e. it is naturally rather thick when motionless but changes to a thinner consistency when stirred. It has been found that certain tannins, added to bentonitic drilling muds, whilst not adversely affecting its thixotropic qualities, act as thinning agents whilst the drill is actually operating. Such thinning means a reduced viscosity and therefore reduced resistance on the drill stem's rotation.

Prior to 1953 the only tannin used for this purpose was quebracho because there was no other commercial tannin suitable to such an extent. About this time the investigation of an Industrial Extract's tannin product revealed that in some drilling situations it possessed properties equal to, if not superior to, those of quebracho. 'Louis,' the locally manufactured concentrate for drilling muds, is now marketed in either 50lb waterproof sacks or 40lb lug covered containers, and during 1953-1956 when drilling was at its peak on the American mainland, approximately 20 per cent of the tannin requirements for mud thinning were exported from Western Australia. At the present, April 1963, it is being used in all Australian mainland States conducting oil drilling activities, as well as many overseas locations, notably United States of America, Canada, Indonesia and New Zealand.

Present day production figures of Industrial Extracts are about 3,500 tons of tannin extract, of which approximately 2,500 tons is exported to America as 'Lovis' and 'Myrtan', the remainder being used chiefly on the Australian mainland.

A further use of tannin extract and one which has also been exploited by Industrial Extracts, is as a 'Boiler Compound Additive' to prevent the formation of scale. It has been found that the addition of tannin to boiler feed water, though it does not prevent the separation of the mineral matter dissolved in the water, which constitutes its hardness, induces it to remain in the form of a very fine sludge which can be blown out by normal blow down procedure instead of accumulating as scale on the heating surfaces. Secondly, its value as an additive is to prevent corrosion by forming iron tannate on the internal surfaces in the form of a very thin layer. This protects the metal surface against corrosion without inhibiting in any way the transfer of heat. In addition it absorbs dissolved oxygen, which otherwise would exercise a powerful corrosive effect. 'Index Boiler Compound' is the tannin product manufactured and marketed by Industrial Extracts Limited to enable boiler operators to prevent corrosion and incrustation on internal surfaces.

In addition to these avenues of disposal, a large quantity of Myrtan was sold on overseas markets in 1946 for the tanning of cotton fishing nets. The chief buyer was Norway, where the fishing industry was recovering after the setback caused by the intervention of World War II. The highest export figure for Myrtan to meet this need was 2,000 tons in one year. More recently, the market has declined owing to the introduction of nylon fishing nets.

In concluding this, a consideration of the activities of Industrial Extracts tanning products, it should be mentioned that agents and stable export markets are established in the American continent, European countries chiefly West Germany and Austria, in South-East Asian countries, New Zealand and locally in all Australian states.

The Company has naturally cut out much Wandoo lying within economic reach of its Boddington or Belmont factories, which has necessitated their closure, but plans can be put in hand to erect others in various parts of the Wandoo forest as required.

In the Toodyay area, the occurrence of Wandoo is confined to areas which were at one time unsuitable for agricultural purposes owing to the presence of Gastrolobium calycinum Benth (York Road Poison. This was the first pea-flowered poison plant to be dis covered in Western Australia, its common name arising from the heavy losses in sheep and cattle experienced in the early years of settlement on the York Road between Greenmount and the Halfway House.[1] Fortunately in recent years, more efficient methods of grubbing, ploughing and reploughing have led to the utilization of some of this cleared land for agricultural pursuits.

Finally one of the unhappy aspects of the closure of the Boddington mill has been the dismissal of approximately 160 employees. These men, together with their families, had settled in the township which the Company established for their accommodation. Some were offered employment at the Toodyay works but for many the prospect was one of finding alternative work. At Toodyay, where there is a more modern and efficient plant, the labour force numbers about 70 men.

Eucalyptus astringens (Brown Mallet).

The other source of tannin from the forest of the State which claims economic attention is the brown mallet, the bark of which has a tannin content of about 45 per cent.[2] This bark yield depends upon the density of the stand, age of the tree, the height from the ground at which the bark is taken and to individual differences in trees.[3] However, the basic fact remains that very early in the present century the tannin properties of the Brown Mallet were realized and the tree was so extensively exploited for both local and overseas markets that a rapid decline in production followed as trees were destroyed because of stripping of bark, fire and removal during the clearing of land for farming use.

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(1) Gardner, C.A. and Bennets, H.W. The Toxic Plants of Western Australia, Perth, Western Australian Newspapers, 1956, p.61.

(2) Brockway, G.E. and Hillis, W.E. Tan Bark Eucalypts of the Semi-Arid Regions of South Western Australia, Empire Forestry Review 34 (1) 1955. p.38.

(3) Ibid. p.36.

In addition to the commercial importance of its bark, the wood itself attained fair prominence as a commercial commodity due to its suitability as tool handles and as a mining timber.

The Mallets - there are two others besides Brown Mallet whose bark has been used commercially as a source for tannin, viz; Eucalyptus gardneri Maiden (Blue Mallet) and Eucalyptus falcata Turcz (White Mallet) - occur in the south-west portion of the State in a roughly triangular shaped area, the apex of which being some few miles south of Cunderdin, the western boundary following the Great Southern railway south to Katanning, the eastern boundary marked by a line joining Cunderdin, Lake Grace and Ravensthorpe and the southern limit being a line from Katanning to Ravensthorpe. The whole of this area follows closely the 15-20 inch isohyets.

As a source of tannin Mallet Bark has the distinct advantage over Wandoo tannin extract in that costly processing is unnecessary. The bark can be bought by tanners and used almost entirely in its natural state. In the early years most of the bark was exported to Germany. In 1905, the year of maximum returns for the industry, 20,700 tons were exported. Total production for 1962 was a mere 194 tons, 127 tons of which came from thinnings on Departmental mallet plantations, 9 tons from Crown Land and Reserves and only 58 tons from private property.(1) It would be fairly safe to state that almost the entire production in 1905 would have come from private property. As the average quantity of tan bark used in the state is approximately 300

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(1) Annual Report of the Forests Department of W.A. for 1962, p.11

tons per annum,[1] the yield of 1962 was insufficient to meet even the local demand.

This situation is all the more remarkable when it is realized that the present extent of State Mallet Forests covers some 58,887 acres. The drop in production from such a large area is purely one of economics. There is obviously a considerable quantity of bark available but the high costs of labour and transportation do not allow a sufficient margin of profit for the Forests Department on the one hand, to fully exploit its plantations at Dyandra; and on the other, the low royalties paid do not encourage its widespread collection from private lands. Competition by 'Myrtan' (which has now been perfected as a major blend for use with other tanning substances) has not affected overseas demand for Mallet bark, in fact a large unsatisfied demand for it exists.

In concluding the discussion on the significance of tannin bearing trees in Western Australia, mention should be made of the detailed work published by Coghill in 1927. Titled "A Survey of the Tanning Materials of Australia", the treatise covers 221 different species, 60 different genera and 26 different natural orders. Of the 221 different species he found that approximately 6 per cent contained 30 per cent or more of tannin; about 7 per cent contain between 20 per cent and 30 per cent; about 13 per cent contain 15 per cent to 20 per cent; and that the balance all contain below 15 per cent.

Western Australian timbers which received attention and deserved

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(1) Official Year Book of W.A. 1957. No.1. Government Print, Perth p.242.

special mention by Coghill as possible future sources of tannin include the following; Eucalyptus alba (from the Kimberleys), Eucalyptus diversicolor (Karri), Eucalyptus gomphocephala (Tuart), Eucalyptus calophylla (Red Gun kino), Mangrove barks, Acacia Acuminata (Jam Wood) and Acacia microbotyra (Manna Wattle). It is interesting to note that Wandoo received nothing more than passing attention.

II. SANDAL-WOOD, SANDAL-WOOD OIL AND WOOD DISTILLATION.

The story of the sandal-wood and sandal-wood oil trade of Western Australia is one of the most colourful and intriguing of any of this State's industries.

During the late 1800's, the tree Santalum spicatum, was found as far west as Toodyay and Northam in the Darling Ranges. Specimens 25 feet in height were not uncommon and the tree's occurrence was fairly widespread extending in an eastern direction to the semi-arid regions. By reason of its ready availability together with a very great demand for the wood by the Chinese (by whom it is still highly prized), settlers and gold prospectors eagerly undertook its collection to augment their income.

By 1892, exports of sandal-wood were valued at £42,870 (1) and by the end of June 1920, 331,205 tons of the wood had been exported for the very handsome return of £3,061,662. (2) Such a profitable industry, at that time in the State's history, would have been a tremendous economic asset.

Unfortunately though, the industry was unable to continue in such an affluent manner because of over exploitation of the trees during the years to follow. At the present time only about 700 tons of wood are produced each year, most of this being obtained from the semi-arid areas east of Kalgoolie. The distillation of sandal-wood oil which was commenced during the 1920's is still an active industry but the whole concept of the sandal-wood and sandal-wood oil trade

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(1) Official Year Book. No.3. 1962. p.304. Government Print, Perth.

(2) Forests Department, Western Australia. Bulletin No.2 (1921) p.132.

has declined in magnitude, so much so that it is governed by rigid controls which have been developed through close consultation and agreement by both Governmental and Private parties. An 'Order For Sandal-wood From Crown Land' which appears in Appendix A gives some impression ofthe complicated conditions governing the removal of the wood from where it grows to the nearest railway siding, but, for a complete coverage of the regulations covering the industry as a whole, a perusal of 'The Sandal-wood Act' is recommended.

Keen competition exists between buyers on overseas markets for both sandal-wood and its oil. In the face of this competitive aspect, the Western Australian exporting company and the Forests Department, are keen to maintain and improve where possible such markets which have already been established. One of the procedures they adopt to achieve this end is by strictly adhering to a policy whereby no values whatsoever, relating to sandal-wood or its oil are made public. Statistics concerning actual costs within the industry which have to be submitted for Governmental Returns are combined with those for similar substances under the collective classification - Essential Oils. In the absence of supporting figures it is not possible to justify the following conclusions, however, I wish to state that the course of this investigation has led me to believe that vast amounts of both sandal-wood and sandal-wood oil were exported furing the late 1920's and early 1930's compared with present day production and furthermore, that the export price of Sandal-wood oil could have increased considerably since the years preceding World War II.

The only present-day figures concerning the industry are relative to tonnage of wood produced and pounds weight of oil distilled. These statistics are available from Annual Reports of the Forest Department and have been used here to show within the limits which they impose, the present economics of the industry.

In 1957, the demand from overseas markets exceeded the supply which reached 788 tons. Although no orders for wood were placed by local oil distillers, 111 tons of roots and butts, severed from log-wood, were delivered to the distillers for oil extraction. These 111 tons yielded 6,686 lbs of Sandal-wood oil, all of which was exported. During the same year, increased prices for the wood were secured on Singapore and Hong Kong markets, making it possible for pullers to work further afield in new areas. At the present time (May, 1963) the 'getter' is paid £31 per ton on rail. An additional bonus of £4 per ton is paid if the wood is cut over 100 miles from the nearest rail siding and £9 per ton if it is cut in difficult areas over 100 miles from the nearest rail siding.

A similar report in 1962 quotes the estimated area of Sandal-wood in State Forests as being 1,930 acres with a further 23,100 acres held under timber reserves. The stock delivered to Fremantle for the year was 729 tons (59 tons less than in 1957) and of this amount 114 tons were delivered to oil distillers (5 tons more than in 1957). The yield of 10,662 lbs of oil shows an increase of 3,976 lbs over that for 1957. This suggests an increase of 40 per cent of oil recovered from almost identical quantities, (111 tons in 1957 and 114 tons in 1962), over a five year period. In the absence of financial returns to illustrate the value of this Sandal-wood oil, any attempt to explain this increased recovery must be conjectural. Nevertheless, it would be fairly safe to say that markets for both the wood and oil have remained sound, so much so that only the waste parts, roots and butts, are available for processing and an increased yield of oil per ton of raw material has been obtained over the last five years. The chief overseas markets for both the wood and oil are Hong Kong, Burma, Ceylon, Great Britian and Singapore, while some is sold in the other mainland states of Australia.

The wood is utilized in the form of paste or as incense in worship to the gods in eastern countries; in religious ceremonies; expressions of joy and sorrow: in Hindu marriages the bride and bridegroom offer sandal-wood to each other as a token of their union: the gift of sandal-paste is an act of hospitality at social functions; the casting of faggots of sandal-wood on the pyre is the last sad offering of affection at a Hindu funeral; it is utilized for wood carving, inlaid and cabinet work; and is employed in the decorative arts.(1)

During the early history of the Sandal-wood industry (1914) intermittent attempts to produce sandal-wood oil were undertaken in Western Australia but owing to inadequate methods employed, the product was unacceptable for medicinal use and hence little attention was paid to it by medical authorities when using it for combatting disease. In the early 1920's more exacting methods of extraction were developed by the firm Plaimar Limited, of Perth, with the result that up till 1948 the oil was accepted by the British Pharmacopoeia for its therapeutic properties in the treatment of gonorrhoea. In some

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(1) Parry, E.J. Sandal-wood Oil. Published by the Government of Mysore. p.45.

respects chemical and medical research disclosed that the locally produced oil from Santalum spicatum was medically superior to the more nauseous oil from the East Indian species, Santalum Album. (1)

With the advent of modern drugs all Sandal-wood oil (East Indian and Australian) was deleted from the British Pharmacopoeia and the demand for it has decreased. It is now used almost entirely for perfumery purposes.

Around the late 1920's, Plaimar Lts. had perfected their Sandal-wood oil to such a degree that it claimed world-wide prominence. East Indian Sandal-wood oil had, until this time, been the major world source of this highly prized product, and so under threat of competition from Australian producers considerable research was undertaken in East India to dispel the growing belief that the Australian oil possessed equal or superior medicinal properties. This research even went so far as to discredit the tree as being Sandal-wood. Consequently, intensive chemical and botanical investigations of the East Indian Sandal-wood tree and its Australian counterpart, and their oils, were conducted in both countries. An interesting report of this work may be found in the publication, 'Sandal-wood Oil' by E.J. Parry, which was produced at the request of the Government of Mysore when the supremacy of East Indian oil (Santalum album) was being challenged by the oil of Santalum spicatum (Australian Sandal-wood). As mentioned above, a further use for the oil is as a fixative in soaps and perfumes. Because of its high boiling point, it dissolves the odoriferous matter, allowing the perfume to come off gradually.

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(1) Marr, E.V. Australian Forestry Journal, 8 (7). 1925. The Therapeutic Properties of Australian Sandal-wood Oil.

A sandal-wood re-afforestation project at Narrogin has been undertaken jointly by the local firm Plaimar Ltd., in conjunctión with the Western Australian Forests Department. This venture is complicated because of the following factors: not only is sandal-wood semi-parasitic in nature and hence difficult to regenerate on a host, but it is also very slow growing, also very little is known about the factors which influence the formation of heartwood which is the most valuable part of the tree owing to its high content of volatile oil. When these three aspects are considered it will be seen that the experiment is a doubtful economic proposition. Work of this nature in Timor, has encountered similar difficulties. (1)

Perhaps the features of the sandal-wood and sandal-wood oil industry in this State at the present time could be summed up by saying that sandal-wood exporters as well as sandal-wood oil producers, work in close collaboration with the Forests Department through whom all supplies are obtained. The industry is rigidly controlled to preserve what trees are left and to ensure the continued stability of overseas markets for as long as Western Australia is able to market either sandal-wood or sandal-wood oil.

In conclusion, I have been given to understand that the value of the wood has been of greater economic significance than has that of the oil.

Wood Distillation.

The destructive distillation of waste hardwood commenced in Western Australia in 1948 when the State Government opened its saw-milling, wood-distillation and charcoal-iron plant using local materials.

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(1) Ormeling, F.J. (1957). The Timor Problem. Djakarta. p.172.

the hot charcoal are removed to tunnel-type steel coolers and allowed to remain for forty-eight hours. The charcoal is then transferred to bins for hoisting to the blast furnace. About 1.25 metric tons of charcoal are obtained from each buggy. This charcoal is uded instead of coke in the production of about 10,000 tons of pig iron annually. It is employed instead of coke, together with fluxing agents such as limestone and manganesite, for reducing the iron ore to metallic iron. The resultant product is of a higher grade than that produced by the use of coke, as it is particularly low in sulphur phosphorus and trace elements.

The vapours given off during the process of carbonization are collected from the retorts and cooled. The condensed liquids so formed are piped to a refinery. The gas which is not condensed, is washed with water and burnt under the retorts, together with the blast furnace gas, thus producing about one third or more of the fuel required. The crude liquid which is piped to the refinery is treated with processes of distillation and extraction until they yield acetic acid, methanol and wood tar. The annual production of the factory is approximately 500 metric tons of acetic acid, 250 metric tons of methanol, and 1,200 metric tons of wood tar, together with the pig iron mentioned above. These products have found a ready market since 1948.

The Wundowie project which is financed and controlled by the State Government illustrates the successful establishment of a combined wood-distillation, charcoal-iron and steel.industry which is reputed to be the only plant of its type in the world. Furthermore, it demonstrates the complete utilization of the Eucalypt forest.

III. HONEY FLOW.

Beekeeping in W.A. is carried on chiefly in the Jarrah and Marri, Wandoo, Mallet and Karri forests as well as in the sand-plain country along the coast south of Geraldton and around Esperance. The occurence and distribution of these forest areas is dependent upon the climate, soils, physical features and vegetation of the country and these are therefore all correlated in forming a close connection between the State forests and honey industry.

In Western Australia the principal supply of nectar comes from the eucalpyts and a few other native trees and plants which lie roughly westward and southward to the coast on a line joining Geraldton in the north to Katanning in the south-west and thence in an easterly direction to Esperance. This area conforms roughly to the 15" isohyet.

Movement of hives into areas of new blossom as soon as that of the surrounding environment becomes exhausted of nectar and pollen is common in this State. In this respect the Forests Department grants permits for apiary sites in State forests dependent upon certain conditions being observed by the beekeeper. For the year ended June, 1962, the number of such permits granted was 528.

To be able to undertake migratory beekeeping techniques with a measurable degree of success, the beekeepers must be excellent students of the nectar and pollen bearing flora. This demands the ability to foretell which trees will blossom next, and when, the extent of the honey flow, the quality and quantity of the nectar and pollen produced and how long the blossom will remain as a profitable source of honey and pollen.

Within Western Australia there are approximately 750 registered beekeepers who can be divided into three categories; commercial, semi-commercial and hobbyists. Apart from the hobbyists who own five or less hives, all employ migratory methods and the honey they produce is almost wholly gathered from the natural forest areas mentioned. A relatively insignificant quantity comes from orchards and gardens. At the present time there are some 37,500 productive hives, (the number of unproductive is an estimated 10,000), producing 5 million pounds of honey and beeswax combined, valued at £225,000.

The majority of honey is marketed through the Western Australian Honey Pool and some is sold locally direct to the consumers by producers.

Since 1947 substantial overseas markets have been established in Great Britian, West Germany and other European countries and it is anticipated that a new demand may come from Japan and other Asian countries in the very near future.

With the introduction of the Mitchell Two Point Plan (1) during 1963, more stable and profitable price will be available to the producer and a more intensive sales promotion campaign will be carried out throughout the Commonwealth. At the time this thesis is being typed, the price of honey has increased from less than 10d. per pound (to the producer) to over 1/-, due to the commencement of the Mitchell Plan.

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(1) A Marketing plan under Commonwealth Government Legislation.

__Note:__ For a further treatment of the topic of Honey Flow, the reader is referred to-
Smith, J.N. The development of Apiculture in Western Australia. Unpublished Teachers' Higher Certificate Thesis. (W.A. Education Department) 1963.

SECTION THREE

THE ECONOMIC VALUE

OF

MINOR FOREST PRODUCTS IN WESTERN AUSTRALIA.

I. BORONIA OTTO.

Boronia otto or flower oil

In Western Australia, Boronia - there are 48 species - grows in the swamp lands of the south-west region, mainly in the karri forest and southern limits of the jarrah forest. It flowers during July, August and September.

The scented variety, Boronia megastigma, has flowers of a rich chocolate brown colour on the outside and a greenish-yellow inside. Gardner [(1)] mentions that fascinating effect which the intensity of the odour has on the olfactory senses. When at close range, it is of such intensity that the senses become unbalanced and are unable to detect its presence. I have experienced this peculiarity in the Tingledale area near the Valley of the Giants.

It is the blossoms of this variety, (megastigma), which are collected for the production of Boronia otto, or flower oil, the production of which has been carried out by Plaimar Ltd., since 1925. The boronia collector is paid 4/6d. per pound weight of blossom (1963 figure), free of leaves and twigs. The quantity of blossom harvested for the year ended June 1962 was 1,317 lbs.[(2)] The processing company has suggested that 14 lbs of blossom are required to produce one ounce of otto, the value of this end-product being in the vicinity of £7 per ounce.

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(1) Gardner, C.A. Wildflowers of Western Australia. Western Australian Newspapers, Perth. 1959 p.77

(2) Report of the W.A. Forests Department, Perth. 1962.

II. THE ESSENTIAL OILS OF THE CYPRUS PINE AND EUCALYPTUS OIL.

Investigations were conducted by Plaimar Ltd., during the mid 1820's to ascertain whether the oil of Callitris glauca (Cyprus Pine) contained sufficient termite resistant properties to warrant its commercial extraction. The published report (1) of this study indicates that some inconclusive results were obtained and a further report on minor forest products in Australia (2) does not mention that its extraction was being continued.

Eucalyptus oil.

This was never economically produced in Western Australia to any extent. Various attempts to do so over the years have produced moderate amounts of oil which have been sold overseas but such extraction is not now carried on. Eucalyptus salmonophloia (Salmon Gum) and the mallee, Eucalyptus spathulata (Swamp Gimlet) are species which received attention in this direction.

The important constituent of medicinal eucalyptus oils is eucalyptol, also known as cineol. Eucalyptus Kochii which yields an oil containing approximately 90 per cent of this material, and occurs in the fringes of the north-eastern wheatbelt, has come under notice as a possible source of eucalyptus oil since the end of the Second World War. Attempts to produce oil from this species by Plaimar Ltd. failed owing to the low yield of oil and a scarcity of the raw material. Apparently moderately large stands of Eucalyptus Kochii were growing many years ago on land now utilized for agricultural purposes.

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(1) The Australian Forestry Journal, 8(10), 1925. pp 267-268.

(2) Wilson, D. Minor Forest Produce in Australia. Aust. Forestry 24(2), 1960. p.90.

Export values of all essential oils to the State since records were first kept in 1914 amounts to £2,694,823.(3) As previously pointed out in this thesis, this figure covers all commodities such as Sandal-wood oil. For the year ended June, 1962, essential oils exported, were worth £81,506.

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(3) Annual Report of the Forests Department of W.A. 1962.

III. NATURAL TREES FOR TOWN AND COUNTRY PLANTING; SEED DISTRIBUTION.

In 1962, 73,351 plants were sold from the Forests Department's Hamel and Dryandra nurseries to meet the needs of farmers and townspeople. Open rooted pines for private plantations and windbreaks received greatest demand while Sugar Gum was the most popular species sought after. A total of 110 species are available.

Total revenue for these sales amounted to almost £8,000.

In 1962 a project unique in the State's history was undertaken at Esperance, a treeless area, when the Forests Department guaranteed to provide trees, labour, fertilizer, transport and supervision for the planting of 66 miles of shelter trees on the understanding that local landholders undertook to prepare, to Departmental specifications, cultivated strips on the road verges covering their properties. Unfortunately, owing to the shortcomings of the local community, only 23 miles were planted. The success of the scheme has been dependent upon the thoroughness of ground preparation and the counter action of depredation caused by rabbits.

In many districts the advantages of tree planting along highways, country roads, in streets and parks, in industrial and business centres as well as on home sites has been realized by local Shire Councils who have taken active steps to encourage a wider utilization of trees along these lines. Shire and Municipal Councils are placing orders with the Forestry Department for trees, on behalf of local citizens and are promoting an ever increasing awareness of such projects by offering assistance in tree planting, protection and general growth. In 1961, orders for 4,290 trees were placed by Shire Councils resulting in a return of approximately £5,000.

IV. PAPER MANUFACTURING.

An agreement has been reached between the Western Australian Government and the Australian Paper Manufacturers Limited for the establishment of a manufacturing industry on a 400 acre site at Spearwood before the end of 1966. Construction of the project is to commence in 1963 and it is expected that 300 men will be employed on the construction of the mill and it should provide employment for 300 persons when production commences.

Initially the pulp will be imported, though the Government is hopeful that, in the light of research during the last 20 or 30 years, much of our local forest waste in the form of certain thinnings and timber that is not millable by ordinary economic standards may be utilised. The commencement of this industry could therefore integrate another basic forest project from our vegetative areas.

V. MINING TIMBER; FENCE POSTS; STRAINER POSTS; BEAN STICKS; SLEEPERS FOR GOLDFIELDS WOOD LINE; PILES AND POLES.(1)

Although the actual value of these items is not available the production quantities of each is summarised as follows:-

Description	Total Productions
Mining Timber	18,932 tons
Fence Posts	608,738
Strainer Posts	9,842
Bean Sticks	23,936
Sleepers for Goldfields Wood Line	7,244 cu.ft.
Piles and Poles	886,517 linear ft.

The sale of 8,734 Christmas Trees by the Forest Department in 1961 yielded a return of £1,583. These are supplied from thinnings in the Department's afforested areas.

(1) Forests Department Annual Report, 1962. p.11.

VI. FIREWOOD PRODUCTION AND CONSUMPTION.

The firewood consumption for the State was estimated at 761,260 tons almost half of which was used for industrial and mining fuel. The quantity of sawdust burnt as fuel was 121,292 tons.

The following table accounts for approximately 51 per cent. of the firewood consumed, the balance being obtained from private property for which specific records are not available.

Of the total quantity consumed 46 per cent. was obtained from Crown land.

	Crown Land tons.	Private Property tons.	Total tons.
Production			
Domestic Firewood-			
Firewood Permits (South-West)	61,519	97	61,616
Mill Waste sold as firewood (estimated 50 per cent. of total	37,784	17,674	55,458
Domestic use on Goldfields	25,906	-	25,906
Total Domestic Firewood as shown by returns	125,209	17,771	142,980
Industrial Firewood -			
Supplied under Licence Nos. 3 to 8 Pumps.	17,167	-	17,167
Other Pumps	638		638
Factories etc.,	73,605	97	73,702
Mill Waste sold as firewood (estimated 50 per cent. of total)	37,785	17,673	55,458
Mill Waste used as firewood	65,783	6,925	72,708
Total Industrial Firewood as shown by returns	194,978	24,695	219,673
Mining Firewood	26,473	-	26,473
Total Firewood Produced (as shown by returns)	346,660	42,466	389,126

Consumption	tons
Domestic (estimated)	410,000 (at 2 tons per dwelling)
Industrial	306,982 (ex Govt. Statistician)
Pumping Stations	17,805 (as per F.D. Returns)
Mining	26,473 (as per F.D. Returns)
Total	761,260 (1)

(1) This section has been taken directly from the 1962 Annual Report of the Western Australian Forests Department. pp.11-12.

CONCLUSION.

Not only does Section One of this treatise illustrate the ecological climax which takes place in Western Australia to produce the environmentally acceptable or unacceptable conditions known to man; but also it has attempted, by studying the results of overseas investigations, to suggest where possible, that certain man-made changes may be used to induce ecological influences to produce a more suitable environment for man in the future. While presenting these suggested changes, I have endeavoured to bear in mind, and make mention of, the possible dangers which such manipulations may bring about by tampering too greatly with nature. This has been done in the hope that as balanced an evaluation as possible may be presented.

A rather detailed examination of the climatic, geomorphic and vegetative characteristics of the State has been presented to illustrate how the interaction of these factors form the three Provinces i.e. The Northern, The South West and the Eremean.

The mechanics of erosion by wind and water and their respective significance to the State as a whole and the primary producer in particular, reveals that much arable land is lost by careless land use practices. Suggestions for arresting this loss are mentioned and specific undertakings such as the Ord River Diversion Dam and fixation of Sand Dunes are cited.

The degree of effectiveness of retaining or replacing certain existing vegetative cover on water catchment areas to ensure suitable and adequate supplies of water for both industrial and domestic purposes has received attention. The outcome of which shows that in this State, where supplies of fresh water are at a premium and the need for reliable catchment areas within areas of high rainfall is a first priority, there are many variable factors governing the effectiveness and value of retaining certain types of forest cover on catchment areas. Each one of these factors requires investigation under local conditions.

Wind-breaks and shelter-belts help stop wind erosion as well as providing shelter for homes and animals. The obvious effectiveness of these structures has led to the conclusion that many municipal bodies and private land owners could profitably commence this type of planting for re-afforestation or afforestation programmes which they may be considering. There is a great need in this country, particularly in the treeless and wheat growing areas, to provide shelter from the prevailing eastwinds.

Another aspect of water conservation (mentioned previously in the conclusion) is dealt with in 'Limitations on Evaporation', see Part V, Section One. It has been found that water losses through evaporation and transpiration are considerable. On the other hand, some precipitation is induced in areas where tall trees prevail, thereby countering to some extent the loss by evapo-transpiration. Perhaps, with the increased demand for more and more plastics and alloys, the uses for wood will become less and less, so that the replacement of present vegetative covering possessing a high evapo-transpiration rate would be justified, providing certain basic principals of forest management were observed.

It has been found that forest cover has an ameliorating effect upon temperature and that some environmental changes are induced whenever the forest cover is manipulated. Too severe silvicultural operations could begin degeneration of the whole area which, if not caught early enough, would become almost impossible to restore.

The Secondary forest products of Section Two, together with the Minor products of Section Three are valued at an estimated £2,505,000 [1] but owing to the nature of available statistics it is not possible to produce a complete table illustrating the value of each product's individual contribution.

The commercial extraction of tannin appears to be sound, with well established overseas and Australian markets for Myrtan (leather tanning extract), Lovis (oil drilling additive) and Index Boiler Compound (a boiler-water-feed additive). Large quantities of tanning bark from Brown Mallet is available for utilization and an overseas demand exists dependent upon a return to more advantageous harvesting costs and marketing prices , this industry could be re-opened.

Now that transportation methods have been effectively developed the difficulty of establishing decentralized extracting plants has been overcome to a large extent and in view of the favourable eucalyptus oil content of many West Australian species, the development of essential oils may also become a sound investment. Such development would be very largely dependent upon the nature of receptive markets together with local production costs.

With regard to the supply of mining timber, fence posts etc.,

(1) Annual Report of the Western Australian Forests Department, 1962. p.11.

the future development of mining activities and the ever increasing popularity of steel fence posts determines the future of this at present, stable industry.

A new and more intensified marketing and sales promotion campaign for honey has already shown signs of better financial returns to the honey producer and it should follow that future production figures will rise, though it must be borne in mind that returns from beekeeping are dependent to a very large degree on the flowering cycles of trees, this in turn being governed by such variables as temperature, rainfall, humidity and the degree of forest denudation.

Tree planting, seed disposal and paper manufacturing industries, together with honey production would appear to be the main avenues for future development. The need for tree planting in hitherto treeless areas to provide shade and shelter as well as for aesthetic reasons is already appreciated and activities are being undertaken in this direction so that increasing sales of trees and seed are resulting.

Perhaps the greatest economic value of minor forest products will come from the results of research into the suitability of local timbers for wood pulping. The commencement of such an industry would have far reaching direct economic effects on the State, so much so that future generations would come to regard it as another great industrial achievment.

Wood distillation at Wundowie has been heavily financed by the Government and its future will be governed by the intensity of present silvicultural activities, continued Government finance and the effect of the Broken Hill Proprietory ventures at Koolyanibbing and Kwinana.

In the light of this summary, there is every expectation that present economic aspects of forest products will be maintained and furthermore, there is every reason to believe that future production of this nature will be expanded. Possibly the only exception to this generalization lies within the Sandal-wood trade. Although markets are available for both the wood and oil, local sources are rapidly diminishing.

However, the introduction of government controls over forestry operations and a sound policy for silviculture, re-afforestation and afforestation undertakings, have averted much danger to the forest industry which is now established on a firm basis, the secondary and minor industries of which make a considerable contribution to both primary and secondary production.

APPENDIX A.

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