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Art. XIX.—*The Factors controlling the Distribution of Trees in Victoria.*

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(With Plates XIII.—XX.).

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Introduction.

The Distribution of Trees has a twofold interest, scientific and economic. These two are closely related. Trees are the dominant members of the plant community of which they form a part, and whatever laws or factors control their distribution also control, in whole or in part, the other members of that community. The various associations of which the trees form such a conspicuous part have not been discussed herein, although the majority of those occurring in the State have been investigated, and these will form the subject of a later paper. Nor have the various forest types been discussed, although all of these have been studied. A forest type may be considered an ecological unit where only the trees are recognized. However, the forest type brings in other considerations which do not enter into ecological work. The recognition and definition of these types is necessary for the purposes of forest management, and these also will form the subject of another paper. The present work aims at being basic either for the student of botany or of forestry, but it is this latter point of view which has been kept mostly in mind in the present paper. A study of our trees and their distribution shows that only a comparatively small area of the State is clothed with good forests. The investigation has shown that the mere setting aside of large areas of country for dedication as forests may not achieve anything at all. Nature may not have produced merchantable timber on those areas. These areas may be capable of producing timber of high commercial value, but before that can be achieved the species most suited to those areas must be found. Hence the importance of knowing all the factors of the environment, which is after all the work of pure science. Species must be introduced not only to augment our national wealth but also to clothe those areas where Nature has not provided a timber producing tree. To plant species without reference to the conditions of their natural habitat is to invite disaster. Very valuable time may be lost in such a proceeding. While we are richly endowed with hard, heavy, durable timbers we are very deficient in softwoods. Of these latter, the two most important genera are *Pinus* and *Picea.* In general these two differ markedly in their requirements as regards environment. Many species of pines are what are known as thrifty, that is, they can grow where conditions are very unfavourable. Thus we have the outstanding example of *Pinus sylvestris,* of which such great use has been made in Europe. Other prominent examples are *P. pinaster* in the South of Europe and *P. rigida* in U.S.A. The genus *Picea,* on the other hand, does not produce thrifty trees. Its species usually demand very favourable conditions of growth. In comparing then the natural environment of the species of the two important genera with conditions in our own State we may be reasonably sure of establishing successful forests artificially.

The study of the environment of our trees has taken a long number of years to accomplish. The whole of the State has been covered, but not every part studied with the same detail. It was originally attempted to examine the State at intervals of 20 miles and this has very generally been adhered to. In the northwest, where the factors affecting distribution do not vary, the intervals have been much wider, but where the factors have changed rapidly the intervals have been much closer. Every zone of rainfall has been studied and also every geological formation. Almost every species has been seen in its native habitat, and the range of most of them has been ascertained. These ranges will be given in conjunction with forest types.

Nomenclature should not normally enter into an ecological discussion, but the very great differences of opinion which exist, particularly in regard to our principal genus, *Eucalyptus,* demand some statement as to the use of specific names. In general, a conservative use has been followed in this work. There is nothing more confusing to the field worker, be he either ecologist or forester, than to find that there is no unanimity of opinion regarding the species with which he is working. It is preferable that a species should be wide, admitting varieties, rather than that there should be a large number of species differing but little. The history of all the species of *Eucalyptus* has been investigated by the author and this will be given when the ranges of the species are published. In the following pages it has seemed best to use *E. amygdalina* in its wide sense as formerly understood. The same applies to *E. capitellata.* The widespread *E. viminalis* occurs in two very well marked varieties, (a) *alba,* which has a long clean bole and is found in the wetter parts of the State, and (b) *arenaria,* which has persistent rough bark and which is almost always a broad-crowned, short-boled tree. Species have been selected for illustration of the influence of the various factors, so that there shall be no ambiguity.

Classification of Factors.

Every student of plant distribution recognises that external influences play an important part in the distribution of plants, but just how much influence each factor exerts is yet a matter of discussion. This difference of opinion arises from many causes. It is partly due to the newness of this branch of botany, and it is but natural that there should be differences according to the view-point of the investigator. Divergent opinions arise, too, from the fact that botanists are working in widely differing centres and therefore with conditions widely different. It is not unlikely that, under such circumstances, the factors themselves are not comparable as regards their influence on the plant. Differences of opinion, too, arise from the fact that there is a lack of detailed information concerning the factors themselves. This is notably the case with climate. The investigation of plants calls for fuller information. Lastly, investigators differ, it may be, because they fail to recognise that all plants in an area are not equally affected by the factors of the environment. These appear at the moment to be the chief causes of varying conclusions.

In regard to investigators arriving at different conclusions regarding the same factor, reference may be made to Warner (1). When speaking of Texas soils, he says, "No ecologist in travelling through eastern and central Texas could fail to notice how closely plant formations follow certain types of soil in this region." Hutchinson (2), on the other hand, working in another part of the same continent, says, "The original composition of the soil is seldom a limiting factor, at least in so far as the forests of Ontario are concerned." Both of these investigators are no doubt correct in so far as these areas are concerned. The science has not progressed far enough for generalizations to be made. It is highly probable that in the two cases mentioned two totally different types of plants, in so far as their response to their environment is concerned, are involved. In this State of Victoria, there are outstanding examples of plants which appear to be wholly independent of the environment over very wide tracts of country, and very erroneous conclusions might be drawn from them. Thus *Goodenia ovata* occurs anywhere from sea level to almost subalpine elevation; it is found in every rainfall from 25 inches to 60 inches; it grows on every kind of soil; and it will thrive equally as well in the open scrubs as in the mountain forest. Of still wider distribution are *Wahlenbergia gracilis* (Campanulaceae) and *Vittadinia australis* (Compositae). Such plants may be very conveniently termed versatile wides. It is more than probable that a large number of the wides of the Age and Area Hypothesis (3) are versatile wides. On the other hand, there are many plants which are definitely restricted in their distribution because they are not independent of their environment. It is the aim of ecological research to discover these limiting factors. Some of these are very obvious, but others are very obscure.

With regard to lack of information, Livingston and Shreve (4) say, "Climatological methods and climatological interpretation, as so far developed, are woefully inadequate for the solution of problems dealing with the control of plant distribution." They say, further, "It may readily happen that some of the most satisfactory methods for ecological climatology will be strenuously opposed by students of climatology, as this special science has been hitherto developed, but such students may remember that the main reason why greater progress concerning the relations of climate to organisms has not been made lies in the fact that those interested in climate have seldom been seriously interested in physiology, while most writers in physiology have had little active interest in climate."

It has also been suggested that differences of opinion may arise from the fact that all plants, in any community, are not affected to the same extent by the factors of that environment. In any habitat plants are found which occur also in other habitats. The habitat is the sum total of a large number of factors and all of these may not be known. Each factor of the habitat contributes its quota to the conditions existing there. No one habitat can be defined in exact terms, and the precise reason why each individual enters the habitat is not the same for all. Each enters because of some individual factor or combination of factors. Thus if we consider what may reasonably be called a climax association, e.g. the Fern Gully Association, we see a number of trees which might be considered as forming collectively a very definite unit of vegetation; but when we analyse the distribution of each individual species occurring there, we find that what appears to be a very definite association is, after all, only a compromise. In this Fern Gully Association we have *Eucalyptus regnans, Nothofagus Cunninghamii, Acacia dealbata and Acacia melanoxylon* among others. Of these, *Nothofagus Cunninghamii* has the most restricted distribution, being confined to the sheltered and moistest areas. *E. regnans* passes from the valley floors to the crests of the ridges, and with it is associated the hill tree fern, *Alsophila australis.* Its range is restricted mainly by rainfall and soil. *Acacia dealbata* evidently enters these gullies on account of abundant soil moisture. It passes out from these gullies to the banks of the streams arising in them. This tree species passes right into areas of comparatively low rainfall and into areas far removed from mountains, but its habitat, so far as soil conditions are concerned is essentially the same. Shelter means nothing to it, yet this is essentially the factor affecting *Nothofagus Cunninghamii. Acacia melanoxylon* reaches its maximum development as regards individual specimens in these gullies, yet what factor of the environment favours its entrance? It occurs among other widely differing habitats on the basalt plains, where it is a very poor specimen of a tree compared with its development in the gullies. In the plains, *A. melanoxylon* is associated with *Banksia marginata*, but this latter never enters the fern gullies. Instead, it occurs on the Tertiary sands, which are very dry in summer and which are covered with a very xerophytic vegetation. These two species, then, are associated on some habitats, but not on others. This gully association, which appears to be a unit, is actually not so, since all its components are not equally distributed. Any association of plants, then, cannot be regarded as a unit as is a species, as has been suggested, but must be regarded merely as an assemblage of wandering units, not held together even by a common bond of the habitat itself, but rather a company of dissimilar units accidentally united. This may seem to be a new conception of a habitat, but it appears to be the only rational one from a study of the range of the individual species forming any association. If we study any association at all, we will find that in no case do we find that all members have an equal range. The truth is, that each species has its own range, and within that range conditions pass from the most favourable to those that are inhibitory. This is seen to be the case with the red ironbark, *E. sideroxylon*. In the Gippsland areas it occurs sparsely though fairly widely distributed. In the Bendigo area, where conditions are drier and hotter, it forms pure forest. Its frequent associate in this latter area, red box (*E. polyanthemos*), accompanies it to Gippsland, but not so its other associate, grey box (*E. hemiphloia*). Likewise, its associates in Gippsland do not enter the Bendigo zone. Each species of any habitat has its own specific range and a community may be regarded as an area where a sufficiently large number of species overlap so as to give that area a distinctive appearance. Each individual is present because of some particular set of conditions, and hence we cannot regard the habitat or the community as anything individualistic.

As time has progressed successive workers have added more and more to the factors which control the distribution of species. We are yet far from knowing all, but each contributes his quota. Schimper (5) stressed climate, almost to the exclusion of geological factors. He says, "The differentiation of the earth's vegetation is thus controlled by three factors—heat, atmospheric precipitation (including winds), soil. Heat determines the flora, climatic humidity the vegetation; the soil as a rule merely picks out and blends the materials supplied by these two climatic factors, and on its own account adds a few details." That climate is not the only factor, or at least as important as Schimper says, is indicated by the statement of Clements (6) in regard to North America. "It will suffice," he writes, "to point out that no climatic chart, no matter how accurate, can hope to outline the vegetation of North America." The most recent worker, Tansley (7), considers that "Factors may be conveniently grouped in four classes, according to the nature of the environmental conditions to which they give rise, namely, climatic, physiographic (topographical factors, etc.), edaphic (soil) and biotic (the effect of animals, including the whole of man's influence on natural vegetation)." In his other work, Tansley (8) has set out in greater detail these factors. Under the heading Physiographic, two sub-headings are included, Geology and Topography. This does not appear to be a natural sequence, for topography is the outcome of physiography and therefore is correctly placed as a subdivision, but physiography in its turn is the outcome of the geological past and therefore it would follow that physiography ought to be placed as a subdivision of geology. The present physiography of the earth's surface is due mainly to the following causes: Subsidence and elevation, varying lengths of time that have elapsed since uplift occurred, varying hardnesses of the constituent rocks of the earth's surface, and the juxtaposition of hard and soft rock masses. Since all these agencies are purely geological, it seems fitting to make physiography subordinate to geology in the classification of factors. Physiography is concerned with the forces that have moulded the rock masses into their present configuration, which result we know as Topography. But physiography is not the only result of the geological past, for so also is soil. Soil results from the disintegration of the rock masses. Some rocks weather very rapidly, but others are highly resistant for various reasons. The quality of the resulting soil is primarily governed by the chemical and physical composition of the rock from which the soil is derived. Thus we have the dark rich chocolate soil arising from the dacite, and the poor infertile soil arising from the sandstone. No matter, however, what the climate may be, if the soil be unretentive or too retentive as regards water, or if it contains abundant mineral nutrients or be very deficient in this respect, the plants of the area concerned will be materially affected. This is to be seen throughout the State. It seems quite fitting, therefore, that soil should be made a subdivision of geology, of equivalent rank with physiography. Each of these two subdivisions lends itself to further subdivision as will be discussed later.

In discussions regarding the distribution of plants, geology as a factor in affecting such distribution has very frequently been but little considered. It has already been remarked that Schimper (5) stressed climate to the exclusion of other factors. This is borne out by another statement of his in reference to the temperate zone. He says, "Atmospheric precipitations determine, in the first place, the distribution of woodland, grassland, and desert, also the vegetative characters of their individual formations within the temperate zones." It will be noted that there is no reference to any geological factor, although it will be shown later that the soil factor influences the type of vegetation very materially. Schimper regards the main formations as given above as due to rainfall. Grassland, for instance, he considers to be the outcome of a particular climate in which the precipitation is fairly evenly distributed throughout the year. It is a remarkable fact that the large grassland areas of the world are wide open plains. In this State, both the northern and southern grassland areas are plains, and wherever these plains abut on hilly country, the grassland ceases and trees occur, no matter what the rainfall may be. This is well seen to the north of St. Arnaud. The plains are treeless over extensive areas, but as soon as hills are reached various species of trees occur, and in a few miles forest conditions are reached. The differences in elevation are very small. At Bacchus Marsh trees occur abundantly on the Permo-Carboniferous and Ordovician rocks,

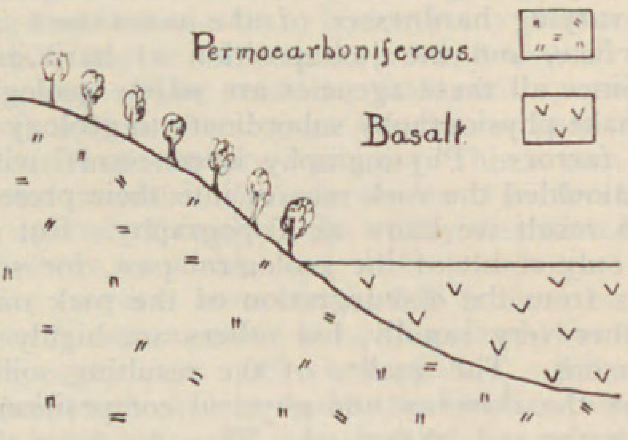

Fig. 1.—Trees growing on the Permo-Carboniferous Rocks, but not on the Basalt.

but none occurs on the small adjacent basalt plains, although these are almost surrounded by trees (Fig. 1). Numerous other examples might be quoted to show that climatic factors are not the only factors concerned. A good illustration also occurs in the Melbourne area. Here there are three geological formations, all extensive, all enjoying the same climate and all differing but little as regards their elevation. Any differences in vegetation therefore cannot be due to climate or to elevation. The three have markedly different associations, so marked, indeed, that a geological map defines the respective associations. One is grassland, one is scrubland, while the third is forest. Soil is the controlling factor, not climate. Grassland, as far as this State is concerned, is not controlled by climate. There does appear to be, however, a very close connection between grassland and physiography or between grassland and soil, or it may be between all three. Grassland is essentially associated with plain country.

In this State there are the basalt plains of the west and the Tertiary plains of the north, and also the High Plains of the northeast. These areas are well marked out physiographically. The hill country of this State and similar parts of the adjoining States favour woodland. From what has been said, it is clear that geology plays an important part in the distribution of the various formations in this State.

Under the factor Biotic may be included quite a number of phenomena. Up to the present this factor has had rather a restricted meaning. Practically only the influence of animal life on plant life has been considered. Theories such as Willis's Age and Area Hypothesis must surely be included in any discussion on the present distribution of plants. Under the Biotic factor, too, must be included fire, for although fire may be caused by natural means, there is no doubt that in newly civilized countries forest fires are now both much more frequent and much more devastating than formerly. It is not very probable that the native animals have had much to do, if indeed anything at all, with the distribution of our trees. The seeds of our eucalypts are very small and are borne very high up on some of our trees, and are not any inducement for animals to obtain them. Under Biotic factors, too, must be included the virility of the species or genera of trees. Some are much more aggressive than others, and this is an important feature in their distribution.

The factors, then, affecting the distribution of the trees in this State will be discussed under the three headings, Climatic, Geological, and Biotic. These have been further subdivided, as is shown in the following classification.

Factors controlling Distribution of Plants.

A. Climatic:
- (*a*) Rainfall:
  1. Annual Precipitation.
  2. Monthly Distribution.
  3. Reliability.
- (*b*) Evaporation.
- (*c*) Temperature.
- (*d*) Ocean Currents.
- (*e*) Wind.

B. Geological:
- (*a*) Soil:
  1. Physical Constitution.
  2. Chemical Composition.
  3. Water Content.
  4. Subsoil.
- (*b*) Physiography:
  1. Elevation.
  2. Contour.
  3. Slope.

C. Biotic:
- (*a*) Fire.
- (*b*) Virility.
- (*c*) Age and Area.

A.—Climatic.

Victoria has a very wide range of climate, containing as it does every phase from sub-alpine to semi-desert, and it naturally follows that with these widely differing climatic conditions there are naturally widely differing plant communities. All these communities, however, as already indicated, are not entirely due to climatic effects. Although the area of the State is comparatively small, being 87,000 square miles, several distinct climates may be recognised. Griffith Taylor (9) has pictured Victoria as belonging to two different climatic divisions; the boundary line between the two being approximately a north-easterly line running from Wilson's Promontory to Tallangatta. The line of demarcation between these two divisions cuts through the South Gippsland hill country, which is itself a very distinct unit. Taylor admits that the boundaries are somewhat arbitrary. They are indeed. The line passes right through the alpine area. Thus we find that Mt. Howitt, 5718 feet, is separated from Mt. St. Bernard, 5060 feet, although they belong to the same range and enjoy the same climate. The western portion of the alpine area (e.g. Mt. Howitt) is included with the Mallee in the other division. The alpine area is just as distinct a unit as is the Mallee. No division of the State into climatic districts could be more artificial, and the work serves no useful purpose in the study of the distribution of plants. All of the State east of this line he pictures as belonging to the Canberra zone, which passes up along the east of New South Wales. The other zone is known as the Victoria division and contains all of Victoria lying to the west of this line. Following the work of Diels (10), Taylor has given in the work quoted above (9) a vegetation map covering these two climatic districts so far as Victoria is concerned. The two maps by Taylor, the climatic and the vegetational, are rather inconsistent. The district known as the Canberra contains alpine areas as well as coastal plains. In the vegetation map the alpine area is shown as such, but no alpine climatic area is shown on the other map. The remainder of the area of the Canberra climatic district is shown as having the same vegetation as Southern Victoria. This latter is shown as passing down into Tasmania. This is assuming too much. The vegetation of South Gippsland is similar to that of the Otway area and this type of vegetation does pass down into Tasmania; but the vegetation of eastern Victoria is of a particular type which is discussed under Ocean Currents, and this does not pass into the southern State. It is true that the forest vegetation of these two areas is superficially similar, but the species of the two differ both in the dominants and the sub-dominants. It is not proposed to give in this work a vegetation map, but it may be noted here that the vegetation of the area given by Taylor as Rain Forest is fairly complex, containing as it does mountain forest, lowland savannah and dense jungle communities. The western section given as the Victoria district is more happily drawn in that the northwest of the State is included with South Australia, the northern plains with the Riverina, while the Otway area is associated with corresponding areas in Tasmania. The grassland of the Western District is also recognized. Climate does express itself most forcibly in our vegetation, and hence there should be a close approximation of a climatic to a vegetation map. Climate is defined as the sum total of weather conditions. These conditions are very variable and are all more or less operating at once. Just how much each factor affects the distribution of plants is very often difficult to determine. We cannot experiment with the factors of climate, varying one at a time and keeping the others constant, and therefore recourse must be had to comparing one area with another and noting the fluctuations of both vegetation and factors of climate. All the factors do not usually fluctuate to the same extent over any given area and it is from these unequal variations at various places that deductions may be drawn.

(a) Rainfall.

The average annual rainfall, with which aspect we are most accustomed, while in itself an excellent guide to the vegetation of an area, yet is not sufficient for a complete understanding of the effect of rainfall, for the same average rainfall may produce entirely different types of vegetation. The distribution of the average rainfall is an equally determining factor. In Australia we have pronounced examples of rainfall distribution. At Darwin, for instance, the bulk of the rain is received in the

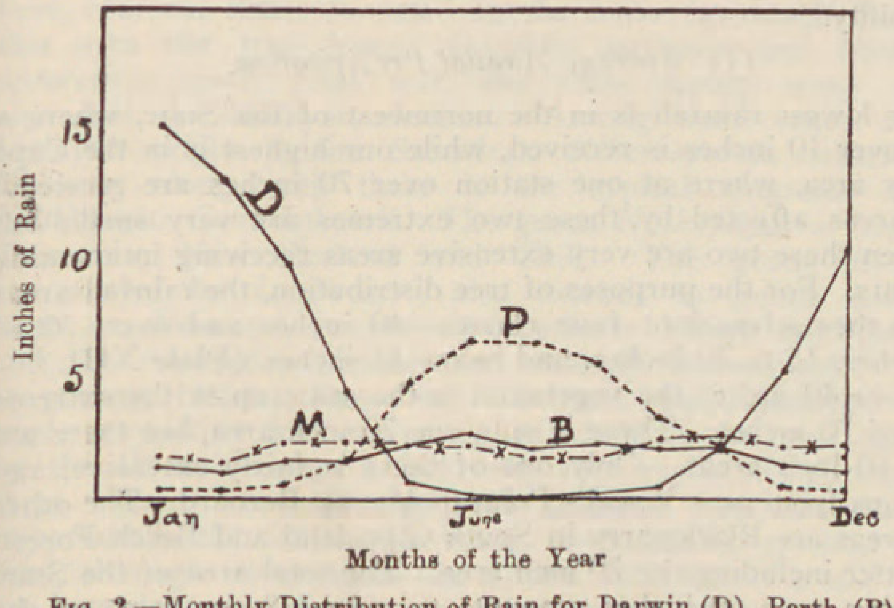

Fig. 2.—Monthly Distribution of Rain for Darwin (D), Perth (P), Melbourne (M), and Bendigo (B).

summer and very little in winter (Fig. 2). For the six summer months, October to March, 55·65 inches of rain are received, while only 6·07 inches are received in the months April to September. Precisely the reverse of this happens at Perth. At this station, 5·17 inches are received during the six summer months, while 29·15 inches fall during the six winter months, April to September (Fig. 2). Over the greater portion of Victoria the distribution is a very modified winter type, as reference to Fig. 2 will show. Indeed, it would be more correct to say that our rainfall is more a modification of the even distribution rather than of the winter type. In Fig. 2 the rainfall for a typical inland station, Bendigo, is given. At this Station 8·71 inches fall in the summer, while 12·79 inches are received during the six winter months. Melbourne represents an even distribution of rainfall, as reference to Fig. 2 shows. At this station actually slightly more falls in the six summer months than during the winter, the amounts being 13·10 inches and 12·68 inches respectively. Besides these two conceptions of rainfall, the Average Annual and the Average Monthly, there is a third point of view. No matter what the average or the distribution may be, if the rain be not regularly received vegetation will be very materially affected. Regularity has more effect on evergreen trees and shrubs than upon annuals and perennials. The two latter may remain dormant during periods of dryness, but the former are always subject to transpiration, no matter what the season may be. Hence prolonged dryness, if it passes a certain limit, must eventually cause the death of the trees or shrubs. This happened during the dry periods of 1923 and 1927.

Rainfall, then, will be considered from the three points of view: Average Annual Precipitation, Distribution, and Reliability.

(1) *Average Annual Precipitation.*

Our lowest rainfall is in the northwest of the State, where a little over 10 inches is received, while our highest is in the Cape Otway area, where at one station over 70 inches are received. The areas affected by these two extremes are very small, but between these two are very extensive areas receiving intervening amounts. For the purposes of tree distribution, the rainfall areas group themselves into four classes: 40 inches and over, 30 to 40 inches, 15 to 30 inches, and below 15 inches (Plate XIII.).

Above 40 inches the vegetation is the same up to the extreme limit of 70 inches. There is only one 70 inch area, but there are three 60 inch areas. Only one of these is fairly extensive, and this runs from near Wood's Point to Mt. St. Bernard. The other two areas are Blackwarry in South Gippsland and Beech Forest, the latter including the 70 inch area. The total area of the State receiving over 60 inches amounts to only 1·8 per cent. of the State (11). The 40 inch isohyet may be regarded as a critical one for some of the most important tree species of the State. The tall timber-producing species, *E. regnans* and *E. gigantea,* do not pass below it, while the heavy timbered species, *E. sideroxylon, E. polyanthemos, E. hemiphloia,* and *E. rostrata,* do not pass above it. The total area receiving 40 inches or more amounts to only 14 per cent. of the State. Four separate areas are enclosed by the 40 inch isohyets, and of these four the largest and most important is that associated with the high mountains of the north-eastern part of the State. All four are important, however, from the fact that they carry high forest. Three of the areas, the Gippsland, the Otway and the North Eastern, carry the tall eucalypt, *E. regnans,* but this species does not occur everywhere throughout these areas. The fourth area, which lies around Trentham, although carrying high forest, does not contain *E. regnans.* Besides this very tall species, however, there are a number of other species of Eucalypts that also grow to immense size within the 40 inch isohyet, although they are not confined to that region. In the regions of lower rainfall they never attain the size that they do in the higher rainfall areas. The following species commonly reach very great size: *E. obliqua, E. capitellata, E. Sieberiana, E. goniocalyx, E. rubida,* and even *E. amygdalina,* which is quite commonly a very small tree. It is in this area, too, that the variety *alba,* of *E. viminalis,* reaches very great proportions. Not all trees, however, that cross from the lower rainfall areas into the higher are affected as regards size. The long-leaved box, *E. elaeophora,* for instance, which is always a poor tree, does not increase in size in the higher rainfall areas.

This heavy rainfall area is of great interest because it forms a meeting place of the Malayan and the Antarctic elements of our flora. Where these meet we find the tallest of our trees and here, too, our finest forests. In the more favourable parts of this area the tree ferns, *Alsophila australis* and *Dicksonia antarctica,* reach great size, and these among many others represent the Malayan element. Among trees which are of Malayan origin is the Sassafras, *Atherosperma moschatum.* Growing along with these is the typical antarctic species *Nothofagus Cunninghamii.* The genus *Nothofagus* is found in Tasmania, New Zealand and Chili. The genus *Lomatia,* represented by *L. Fraseri,* also extends to South America. Both of these are exclusively southern. Both the Malayan and the Antarctic elements are strongly represented. There is present besides these two an Australian element. This triple association does not cover the whole of the areas enclosed by the 40 inch isohyets, but only very restricted portions of them. These areas, from a forest point of view, are the most important in the State. They are, in the main, typically forest land, although within them are natural agricultural areas. They are important also because they form the catchment areas of our chief irrigation, hydroelectric and water supply systems.

The country lying between the 30 and 40 inch isohyets is in the main true forest land, although the forests occurring there may not be regarded at present as merchantable. Portions of this area have been selected for settlement, but not always with success. This area occupies 16 per cent. of the State, and this, together with the high rainfall area, makes 30 per cent. of the State true forest land. Not all of this is carrying forest, and of the forested area only a percentage is merchantable. This zone, between the 30 and 40 inches, is the home of a large number of rough barked, widely distributed species such as *E. obliqua,* messmate; *E. capitellata,* brown stringybark; *E. eugenioides,* white stringybark; *E. Muelleriana,* yellow stringybark; *E. Sieberiana,* silver-top; *E. macrorrhyncha,* red stringybark; *E. goniocalyx,* mountain grey-gum; *E. amygdalina,* peppermint; and *E. dives,* broad-leaf peppermint. This zone might well be called the stringybark zone. It is the home of the widest-spread forest type we have, the Messmate-Peppermint type. These species, however, find their way abundantly into the higher rainfall areas wherever the soil or other conditions are unfavourable for the growth of those species which are restricted to a high rainfall. They may also be found at a lower rainfall, but they never reach the same size as they do in the 30-40 inch zone, nor are the forests so dense. Below 30 inches conditions are not favourable for the best development of the above species.

Between the isohyets 15 and 30 inches no less than 48 per cent. of the State is enclosed. This area is agricultural in the main and is eminently suited for that purpose on account of its fertility, its lack of contour, and its climate generally. It has been widely cleared and evidences of its tree distribution are fast disappearing. Large portions of it were, however, either devoid of trees as in the western plains, or were in savannah formation as in the northern parts of the State. In both of these areas the eucalypts are often replaced by species of *Casuarina,* as for instance *C. stricta* on the basalt plains, and *C. lepidophloia* in the northwest. In this region, however, are found our most important heavy-timbered species, *E. sideroxylon,* red ironbark; *E. leucoxylon,* white ironbark; *E. hemiphloia,* grey box; *E. melliodora,* yellow box; and *E. polyanthemos,* red box. These are not confined to this zone, for they make their way into higher rainfall areas whenever conditions for their entry are favourable, but the best forests containing them are found in the 15 to 30 inch zone. The areas containing these forests are not extensive and the land carrying them may be regarded as true forest land, mainly on account of the high quality of timber that it carries. The percentage of the State occupied by these forests is only small. These forest areas will be considered in a subsequent publication, both as regards area and type.

The area below 15 inches coincides generally with what is known as the Mallee. This is a very extensive area enclosing no less than 22 per cent. of the State. Physiographically, the area consists of an open plain, broken only by low sand ridges. These sand ridges are not sand dunes in the ordinary sense of the word, for the material of which they are composed is not quartz only, but other minerals as well. They are at times quite loose, but at other times are quite compact. These ridges are covered with species of *Callitris*, and this is one of the few instances where the eucalypt is not the dominant tree. In the extreme northwest the rainfall is only a little above 10 inches. The Mallee is really a transition from desert to better conditions. The eucalypts, which themselves are known as mallees, are all generally small and they are the dominant vegetation over the greater part of the area. The individual mallee consists of an enlarged butt from which several shoots may arise (Plate XVII.B). When the shoots are slender it is known as whipstick mallee, but when the trees are large it is then known as bull mallee. The species are very variable and this has caused the nomenclature to become very involved. The mallee is usually associated with the poorer classes of soil, while the better classes of soil are usually occupied with other species. Associated with the species of *Callitris* in the northern part of the Mallee is *Casuarina lepidophloia*, Belar. Both may occur together or either may form pure forest. Both of these are very valuable, but it is very doubtful if the areas where they grow can be classed as forest land, since the soil is very fertile. Other tree species which are present are *Myoporum Dampieri, Pittosporum phillyraeoides, Hakea leucoptera*, and *Heterodendron oleifolium*. These are all strongly xerophytic. Besides these trees the two eucalypts, *E. rostrata* and *E. bicolor*, also are found, but their distribution is not governed by rainfall, and they cannot be regarded as members of the Mallee community. This area is, on the whole, agricultural, but there are areas unsuited for that purpose, and as these cannot be utilized for forest purposes they must be regarded as waste land.

(2) *Monthly Distribution.*

As has already been remarked, a very modified type of winter rainfall prevails over the greater part of the State, while over the remainder an even distribution occurs. In the former case, the wettest month is June and the driest is either January or February. In the even distribution the wettest month is usually towards the end of the year. The following table gives the monthly rainfall for representative stations throughout the State:—

TABLE I.—AVERAGE MONTHLY DISTRIBUTION OF RAIN IN VICTORIA.

Station	Monthly Averages in Points												Total inches
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Mildura	55	78	75	63	107	138	84	115	112	103	81	83	10·94
Swan Hill	62	75	82	94	139	168	112	139	138	113	98	113	13·33
Yarrawonga	125	116	154	146	193	237	172	199	182	179	138	134	19·75
Omeo	209	199	205	157	194	227	208	199	258	260	209	237	25·29
Melbourne	191	172	219	219	217	207	185	187	245	263	224	229	25·58
Orbost	288	237	235	260	264	308	265	232	303	300	223	272	31·87
Portland	137	133	164	259	368	412	419	411	346	285	193	179	33·06
Trentham	197	187	284	260	430	534	441	449	442	340	270	254	40·88
Blackwarry	389	354	394	476	502	642	498	590	583	453	354	257	55·92
Wood's Point	311	228	355	353	524	759	661	696	665	571	403	403	59.29
Beech Forest	312	249	399	542	671	837	759	762	731	590	434	351	66·37

The last three stations are representative of the heavy rainfall areas. It is this comparatively even distribution that provides the conditions necessary for the rich development of our temperate rain forest. Although more rain falls in the winter months than in the summer, yet sufficient rain falls during the summer to prevent any xerophytic habit arising. This is typically a temperate rain forest. In this heavy rainfall area there are two distinct types of soil controlling the vegetation found there; one is favourable to the development of the rain forest, while the other is unfavourable. In the favourable soil areas the trees reach a height of over 300 feet, the record being 326 feet. The rapidity of growth and the volume of timber produced are both indicative of the favourable conditions of growth. The trees form close-canopied high forest, which is, however, very broken, as is usual with virgin forests. Associated with these tall eucalypts are a number of rain-loving trees and shrubs, and in the gullies the extremely delicate filmy ferns belonging to the genera *Trichomanes* and *Hymenophyllum* grow in profusion. A tropical colour is lent to these forests by the presence of lianes, but these are not numerous. All of this vegetation is indicative of an abundance of water. The presence of the antarctic element is also a witness that there is no deficiency of water. Further evidence that the rainfall is abundant may be found in the fact that the vegetation in the gullies consists of several stories. An increase in the amount received or a greater proportion falling in summer would not disturb the existing vegetation, since latitude is now the controlling factor. Growth is at a maximum, for both soil and rainfall present the most favourable conditions possible.

Where, however, the soil is not favourable for the production of *E. regnans* forest and its associates, it is also improbable that there would be any disturbance of the existing vegetation even if the rainfall were higher or more were received in summer. We find *E. elaeophora* ranging right down to 21 inches at Stawell and still lower at Mt. Arapiles. It also occurs in the heavy rainfall areas as at Wood's Point, where the rainfall is 60 inches. This species is never a timber tree; its bole is always short and carries a large spreading crown. Its presence everywhere indicates the unfavourable soil conditions. Soil is the limiting factor, and any increase in the amount of rain received during summer would not affect its unfavourable influence. This species is also associated with the broad-leaved peppermint, *E. dives*. These are found together at many places, as, for instance, Wood's Point and Daylesford. Rainfall can only produce its effect when the soil is responsive and receptive.

In the areas with a rainfall below 40 inches, however, the monthly distribution has undoubtedly a very marked effect on the eucalypts present. A large percentage of the rain falling in winter is lost so far as the trees are concerned owing to their dormancy during that season. In summer less rain falls than could be utilized by an optimum vegetation. Below 40 inches the plants associated with the eucalypts are markedly xerophytic.

In the southwest and the southeast we have the most marked effect of the distribution of rain. In the southwest the forest extending westward from Portland consists of *E. capitellata, E. vitrea,* and *E. viminalis,* and is much inferior both in the height of trees, quality of timber, and number of species, to that occurring in the east. This latter forest consists of *E. capitellata, E. Muelleriana, E. eugenioides, E. Stuartiana,* and *E. Sieberiana.* There is also a little *E. globulus* present. Both of these forests occur on Tertiary sands, and both have stringybark as the dominant tree. The rainfalls are very similar, Orbost having 31·87 inches and Portland 33·06, but the distribution of each is very different. At Orbost, the winter and summer falls are about the same, being 16·32 and 15·55 respectively. At Portland, on the other hand, the winter rain is 22·15 and the summer 10·91 inches; that is, the summer is less than half the winter. It is this summer rain at Orbost that is in part responsible for the better forest in the southeast.

(3) *Reliability.*

While both the total amount of rain falling and its distribution through the year have a profound influence on the character of the vegetation present in any locality, the reliability of that rainfall has an equally profound influence. It may be regarded as an axiom that the lowest rainfall periodically received is just as great a determining factor in the vegetation as are the average amount received annually, and its distribution. So far as annuals and perennials are concerned, any year of low rainfall, even if it be exceptionally low, does not affect them greatly, since they are usually only active during the most favourable period of the year, and they pass into dormancy or seed before the unfavourable period arrives. A year of low rainfall merely shortens their period of vegetative activity. During such years these plants are smaller in size, but the essential functions of flowering and seeding are performed as usual. In very dry seasons it may occur, as happened in 1927, that the seeds do not germinate at all, but remain dormant until the ensuing year. Dry seasons, then, do not interfere with the persistence of annuals, or even perennials. But with trees and shrubs it is entirely different. While it may be true that they, too, are most active during the most favourable period of the year, yet they have to persist throughout the year and right through very adverse dry periods. With evergreens, such as all our plants are, the difficulties for plant life increase. Transpiration goes on, no matter what the rainfall may be, and the plants must obtain, if they are to persist, sufficient water for their needs. If the soil fails to provide the necessary water, the plants must die. Periodic seasons of dryness are constantly recurring, and the plants must be organized to withstand these long dry seasons. If they are not so organized they must cease to exist. Many native plants showed signs of distress during the dry years of 1923 and 1927. If the dryness had continued for a longer period many must have died. The plants had reached the limit of their resistance. The plant is, to a certain extent, plastic, in that it varies its amount of growth with the amount of rainfall received in any season. This is well illustrated in the width of the annual ring, which has indeed been used to study the weather in times preceding the period of taking accurate records. Although the plant is to a certain extent plastic, yet there are limits to that plasticity. A xerophytic plant can take advantage of a very favourable season only to a very limited extent. Xerophytism is brought about, among other means, by reduction of leaf surface and reduction of the number of stomata. Both of these restrictions automatically prevent a large amount of transpiration, even if the water be available in the soil. A reduced leaf surface also limits the formation of carbohydrates, which are necessary for growth. It is probable, then, that the full effect of an abnormal year, such as 21·90 inches at Mildura, is not taken advantage of by the native evergreen vegetation. It is the minimum amount received that determines the existence of the plants of the area. The lowest annual rainfall received at Mildura is 4·71 inches, and the plants must be organized to withstand this. Plants, such as trees, then, are concerned with the minimum amount received periodically. Trees do not bear seed until they are some years old, and therefore, if an adverse season destroyed the tree vegetation, and if a subsequent equally dry season occurred before the trees again bore seed, many species would cease to exist. These conditions were nearly reached in the years 1923 and 1927. The first four months of these two years were particularly dry, and much of the native xerophytic vegetation about Melbourne showed that the limit of endurance was being reached. The average rainfall for Melbourne for these four months, January to April, is 8·01 inches, but in 1923 only 1·92 inches were received for this period, and in 1927 only 3·26 inches were received. It is not likely that any widespread destruction of plant life would occur, for the native vegetation is undoubtedly in harmony with the existing climatic conditions, but, nevertheless, the lower limits reached by rainfall represent about the limit of endurance on the part of the plants. The rainfall records for Melbourne have now been kept for 72 years, and during that time the lowest annual rainfall recorded is 15·61 inches. The average for Melbourne is 25·58 inches. At Mildura, the lowest rainfall station in the State, the average for 38 years is 10·94 inches, while the lowest rainfall received in any year is 4·71 inches. In all parts with a rainfall below 40 inches the periodical occurrence of a dry season has undoubtedly had an effect on the tree distribution.

In areas with a rainfall above 40 inches, the lowest occurring fall does not have any effect where the soil conditions are favourable. In these favoured areas are found the filmy ferns *Trichomanes* and *Hymenophyllum*, which are exceedingly sensitive to dry conditions, and their presence indicates that these areas are not affected by periodic dryness. However, during 1927, in parts these ferns were dry and shrivelled, having that season, here too, reached the limit of endurance. Wood's Point has an average of 59·29 inches of rainfall. The lowest fall recorded was in the drought year of 1914, when 36·81 inches were received. In these areas rain is not a limiting factor. More than sufficient is being received, and this is reflected in the luxuriant growth where soil is not a limiting factor.

The average rainfall, from what has previously been said, does not convey any idea as to the regularity of the amount annually received. Two areas may have the same average, yet one may have a much more reliable fall. A comparison of averages is afforded by means of the Standard Deviation which is given in Table II. for representative stations in Victoria. The Standard Deviation, however, is only a measure of dispersal where averages are comparable, as in the case of Omeo and Melbourne, but where there is a steady variation in the value of the averages as given in Table II., another measure is required for comparison. This is afforded by the Coefficient of Variability, which is obtained by dividing the Standard of Deviation by the average and multiplying by 100. This gives an absolute measure of variation, and, therefore, very widely differing rainfalls can be compared.

From the table it will be seen that the variability of the rainfall is highest in the region of lowest fall. In other words, the lowest rainfall is the least reliable. Generally speaking the degree of reliability increases with the increase of the annual amount received. This uncertainty of water supplies, especially in dry districts, must, of necessity, exclude plants which could exist if conditions were more uniform.

TABLE II.— COMPARISONS OF VICTORIAN RAINFALL.

Station	Average Annual Rainfall	Standard Deviation	Coefficient of Variability
Mildura	10·94	3·6	33·2
Swan Hill	13.33	4·1	30·7
Yarrawonga	19·75	5·0	25·4
Omeo	25·59	4·3	16·8
Melbourne	25·58	4·9	19.1
Orbost	31·87	7·7	15·98
Portland	33·06	4·48	13·6
Trentham	40·88	7·6	18·6
Wood's Point	59·29	12·1	20·4
Beech Forest	66·37	9·5	14.4

Statistical determinations, however, while conveying important information in regard to the relations between plants and climate, do not convey all the variations that affect the distribution of plants, particularly trees. While it is true that the variability in the Mallee is greater than in any other part of the State, and, therefore, the struggle to exist is increased, the intensity of that struggle can only be understood when the absolute variations themselves are considered. Thus, in the case of Northwest Victoria, as represented by Mildura, only a study of the records themselves will reveal how acute at times is the struggle to persist. The average for the 38 years of record is 10.94 inches. In the law of averages one naturally assumes that good and low rainfalls will alternate fairly regularly. In other words, it might be expected that rainfalls will occur as if they were selected at random. One is not prepared to find that eight successive years, 1895-1902, had rainfalls below the average, that is, that there were eight years of drought. The successive years, 1919-1927, were also all below the average. Under such conditions of life the average rainfall has very little meaning. It is the average of the successive lean years that has a real meaning. The average of the years 1895-1902 is only 7·91 inches. Again, it would not be expected from the law of averages that an extremely bad year would be followed by an almost equally bad year. Thus, in 1914, only 4·71 inches of rainfall were received, and, in the following, 6·77 inches fell. The two years together only produced a little more than the general average. The recurring periods of dry years suggests that the rainfall occurs in cycles, and that the year is not the correct unit to use. However, sufficient data have been given to show that the adversities against which plants have to struggle are extremely severe, and these adversities have an important bearing on the tree vegetation of the northwest of the State. It is of interest to note that the two most successful trees, *Callitris glauca* and *Casuarina lepidophloia*, have very reduced leaves. The genus *Eucalyptus* is not equal to the task of producing a tree comparable in size to these two. This latter genus has, however, produced the peculiar "mallee roots," the large root stocks from which many shoots arise. These swollen root bases must be regarded as an adaptation to the environment.

Summing up, then, the influence of rainfall on the distribution of trees in Victoria, we may note that all three aspects have a very profound influence. The influence of the unfavourable conditions increases as the rainfall decreases in amount. The trees in low rainfall areas have to contend with unfavourable quantity, unfavourable distribution, and unfavourable reliability. All these aspects are expressed in the peculiar form of the eucalypt known as the mallee. On the other hand, where the tall timber grows, all three aspects are favourable and the forests assume a tropical appearance.

(b) Evaporation.

It is generally recognised that there is an intimate connection between the transpiration of the plant and the humidity of the air. Humidity is a very variable factor both from day to day and during the day itself. Humidity is not an absolute quantity in itself, but is only relative, and it therefore falls short as a measure of reaction by the plant to its environment. Relative humidity may convey wrong impressions. Thus, a given humidity at a given temperature does not have the same transpiration effect as the same humidity would have at another temperature. This fact is frequently lost sight of. Humidity, then, being only relative and not absolute, therefore requires the statement of some absolute quantity so that its connection with plant reaction can be studied. This is cumbersome and cannot be readily given effect to. Under the various aspects of rainfall considered, averages of absolute quantities were used, but no such averages can be obtained for humidity. Livingston and Shreve (4) have very aptly summed up the position in regard to Relative Humidity in the following words: "This (i.e., Relative Humidity) bears no quantitative relation to atmospheric evaporation, even with wind and barometic effects left out of consideration, for it is obvious that air with a given relative humidity must be more effective in promoting evaporation at a higher temperature than at a lower." Further on, the same authors say: ". . . . it is simply a mathematical abstraction and its value to agriculture or ecology will have to be determined by direct empiricism." Relative humidity as a means of ecological investigation must be considered a very imperfect instrument.

This meteorological quantity has therefore been discarded in favour of evaporation, which is a more effective measure of the reaction of the plant to the amount of moisture present in the atmosphere. Evaporation is an absolute quantity, being the amount of water lost from a free water surface. The quantity of water lost by evaporation is a cumulative effect of the vapour pressures of the air and the temperature. As these two vary, so does the evaporation. The vapour pressure of the air is again the result of other factors, one of which is rainfall itself. It is perfectly obvious that the more rain that falls the more humid must be the air, and therefore the less must be the evaporation. In other words, rainfall and evaporation will vary inversely, but this does not hold always absolutely, because the distribution of the rain throughout the year is not uniform. Various types of distribution have been shown in Fig. 2. Unfortunately, evaporation data are very meagre, and therefore any detailed discussion of this factor is impossible. Evaporation, being measured from a free water surface in inches, is therefore readily comparable with rainfall. It may be regarded as axiomatic that the more the evaporation exceeds the rainfall the more xerophytic will the resulting vegetation be. Melbourne has a rainfall of 25·58 inches, but the evaporation from a free water surface is 38·77. For the six warmer months of the year evaporation exceeds rainfall, and therefore the vegetation is xerophytic. Evaporation is not the same as transpiration from the plant, and it has been shown by various workers on transpiration—e.g., Knight—that maximum water losses from the plant and from a water surface do not always coincide, but they do occur in the same period of the day. Those causes which accelerate transpiration accelerate evaporation, and therefore evaporation is a good measure of the influences to which the plant is subject. In our most xerophytic areas evaporation exceeds rainfall for the greater part or for the whole of the year, as, for instance, Coolgardie, with a rainfall of 10·07 inches, where the rainfall falls below the evaporation for every month of the year. In the northwest of Victoria evaporation exceeds rainfall for every month of the year except one. It has already been noted that here the eucalypts have the peculiar habit known as mallees (Plate XVII.B). While evaporation data are somewhat meagre for this State as a whole, it is entirely absent when we consider the heavier rainfall areas of the State. Data are lacking in other countries besides our own, and many formulae have been suggested (12) for obtaining the required information. Since evaporation is the direct result of varying humidities and temperatures, a simple relation ought to exist between all these quantities. Humidity, as ordinarily given, is a relative quantity, and is a function of temperature. If the relative humidity and the temperature be known, then the actual humid condition of the air can be readily ascertained. This relationship has been availed of in these studies, and, in the light of this, existing evaporation data have been examined. From these examinations the following formula—

$$e = 0{\cdot}8\, d$$

has been derived, where e = evaporation in inches of water and d = deficiency of vapour pressure in mm. of mercury. The closeness of the calculated evaporations to those actually found (13) is given for the capital cities in Table III.

TABLE III.—EVAPORATION DATA FOR THE CAPITAL CITIES.

Station	Average Evaporation	Calculated Evaporation $e=0{\cdot}8d$	Percentage Difference
Hobart	32·10	30.81	4·0
Sydney	38·43	38·08	0·9
Melbourne	38·90	42·34	8·8
Brisbane	53·37	54·96	2·9
Adelaide	54·55	65·90	20·7
Perth	65·80	55·40	15·8

The first four calculated results are reasonably close to the observed data. In the last two, however, there are fairly wide divergences. There appear to be discrepancies in the data given. Thus, both Perth and Adelaide have approximately the same mean annual temperature, but, while Perth has a higher mean humidity, it has also a higher evaporation. This high humidity and high evaporation do not appear to be consistent.

Data on which calculations may be based for other places are also very meagre, and therefore only a few stations with calculated evaporations are given in Table IV. In this latter table are given stations from other States as well as from Victoria.

TABLE IV.—EVAPORATION DATA FOR SELECTED STATIONS.

Station	Rainfall	Evaporation	Months when rainfall exceeds evaporation
Kalgoorlie *a.*	9·27	87·74	0
Wentworth *a.*	11·50	62 21	1
Werribee *a.*	19.66	45.74	2
Adelaide *a.*	21·08	54·29	4
Rutherglen *a.*	22·29	50·82	4
Melbourne *a.*	25·58	38·38	6
Hobart *a.*	23.57	32·38	6
Beechworth *c.*	34·66	52·70	5
Cape Otway *c.*	33·79	35·17	6
Wilson's Promontory *c.*	40·73	24·32	10

a = actual average. *c* = calculated average.

Table IV. shows that with increasing rainfall there is a decreasing evaporation, and it has been calculated that evaporation equals the rainfall when the annual totals are about 36 inches (13). The evaporation is intimately associated with temperature, but nevertheless it does represent a condition against which the trees have to contend.

The station Wentworth represents the conditions existing in the Mallee. Here the eucalypts have only partly succeeded, and, although they are numerically superior in point of individuals, they are not successful on the better soils. The stations Werribee and Rutherglen probably represent the conditions under which *E. hemiphloia, E. polyanthemos, E. melliodora, E. sideroxylon*, and *E. leucoxylon* grow. These species seek the drier portions of the State, and are therefore to be considered among the most thrifty trees we have. Trees whose timber is of such high technical value, and which can grow under such high evaporation conditions, are of the greatest importance to the State.

The conditions as they occur at Melbourne represent the commencement or the lower limit suitable for the widespread Messmate-Peppermint association, and the White Gum-Bracken association. The chief interest lies in Wilson's Promontory, where the rainfall is 40 inches. Only two months have evaporation greater than rainfall. In the still wetter areas it is more than probable that in all months of the year, on the average, rainfall exceeds evaporation. In certain years the actual evaporation is greater than the rainfall for some of the summer months, and then dry conditions exist, and in those years bush fires are frequent. That the evaporation is generally less than the rainfall is shown by the luxuriant growth of the fern gullies. The plants of this association love a humid atmosphere and a humid soil. It is under these conditions that *E. regnans* reaches its greatest development. This is one of the world's most remarkable trees, and, as it is restricted to these humid areas, every protection should be given to the forests in which it occurs.

(c) Temperature.

Evaporation is controlled largely by temperature, and therefore it is natural to find that where temperatures are highest evaporation is greatest. At Mildura, the record temperature, 123·5 degrees, has been obtained for the State. At this station the month of January has always had maximum temperatures of 100 degrees and over since records began. In the period of the record the maximum temperature for January reached or exceeded 110 degrees F. sixteen times. For February the maximum has exceeded 100 degrees twenty-seven times. December has always had a maximum of over 100 degrees. There are no records of continuous high temperatures, but at Wentworth, which is situated a few miles away, there have been during February nine consecutive days with a temperature of 100 degrees or over. Under such conditions it is not surprising that tree growth is very restricted. Nevertheless, forest is not unattainable, for *Callitris glauca* and *Casuarina lepidophloia* form reasonably good forests. It is interesting to note that this is one of the few places where the genus Eucalyptus is not supreme, and it is interesting also to note that all the three genera, *Eucalyptus, Casuarina,* and *Callitris,* are co-extensive throughout Australia. The upper extremes of temperature, coupled with low rainfall and high evaporation, are unfavourable to the development of the eucalypts. But, besides this inhibiting power, we have another marked effect of temperature. The species *E. rostrata* is the most widespread of all the species of the eucalypts. It extends to all States except Tasmania, where, indeed, no other red-wooded species extends, although there are several red-wooded species in Victoria. This species is essentially riparian (Plate XVIII.A), but is also found extensively in seasonal swamps, or in areas where the water table is not far below the surface. It is not a true riparian species, since the levels of our rivers vary enormously. On the flats and along the billabongs associated with the rivers, *E. rostrata* is found abundantly. When the river overflows all the trees live under swamp conditions. The water may remain for months and the trees are unaffected. During summer, when the rivers are very low, or even cease to run, even the riparian individuals are living under conditions of drought. Red Gum may be regarded as an indicator of wet conditions during at least some time of the year. This tree lines all the rivers of the Murray basin, where the streams open out on the plains. It does not occur on the plains if these are permanently deficient in abundant supplies of water. *E. rostrata* is found right along the northern plains themselves, then it sweeps southwards at the western end of the State, and comes eastward spasmodically along the basalt plains to Melbourne, and slightly beyond. In many of these southern areas it is found associated with the swamp gum, *E. ovata,* which does not occur either along the streams or on the plains of the northern or northwestern portions of the State. The swamp gum passes beyond Melbourne, and it extends both northerly and easterly. *E. ovata* passes right upwards into the mountains, into the regions of heaviest rainfalls, and occurs on varying elevations and soils. It occurs right throughout the mountain block in the centre and northeast of the State, but, besides this, it occurs also on the plains of that area. Wherever drainage is bad this species is found. It passes down into Tasmania. The two species, *E. ovata* and *E. rostrata,* meet at many points, and are intermixed at many places, but *E. rostrata* ceases as soon as the country rises sharply and the valleys begin to narrow. It follows up the Goulburn River along the river flats until they cease to exist. It occurs a few miles from the Alps to the east of Mansfield, and on the north follows the Mitta Mitta River nearly down to Mitta Mitta, but here, as elsewhere, it fails to enter the mountains, although it is attacking them, so to speak, in a hundred places. *E. ovata*, on the other hand, although very widespread throughout the mountain area, and spreading out on the southern plains and down to Tasmania, yet never follows out in a northerly direction. The controlling factor is temperature. No isotherm fits the distribution of these two trees exactly, but it is somewhere between the 55 degrees and the 60 degrees isotherms. The mean annual wet bulb isotherm, 50 degrees, excludes *E. rostrata*. The wet bulb isotherm seems to agree with the distribution of the flora generally better than those of the dry bulb. *E. rostrata* avoids the low temperature areas of the State, and *E. ovata* avoids those with high temperatures. As both these species are controlled in their distribution by soil water, they are therefore independent of rainfall, and they may occur on any kind of soil. Red gum occurs on sands, basalt clays, alluvium, granite soils, and shales. The boundary lines of these species also mark the limits of other species, but these latter are controlled by other factors. Thus, for instance, within the boundaries of *E. ovata*, *E. regnans* occurs, but this latter species is not governed by temperature. Within the limits of *E. ovata* is to be found all the rainfall over 30 inches. Other widespread species within the limits of swamp gum are *E. capitellata*, *E. goniocalyx*, *E. Stuartiana* and *E. obliqua*. Within the limits of *E. rostrata* is found *E. hemiphloia*.

(d) Ocean Currents.

In the extreme east of the State the bloodwood, *E. corymbosa*, just crosses the border, and only extends for a few miles. It is essentially a tropical or sub-tropical species that reaches Victoria by means of the coastal lands of New South Wales. It extends right up into Queensland, and is even found in Central Australia. This species is not the only one that reaches Victoria, for there are a large number of others that reach eastern Victoria, from the north, but extend no further. Taylor (9) has included this part of Victoria with Tasmania in his vegetation map. Superficially this appears to be the case, but none of the very special tree species occurring here reach Tasmania. Ecologically, Tasmania is connected with the three heavy rainfall areas, South Gippsland, Otway, and the Warburton-Healesville area, but not with eastern Victoria. Ecologically, this region is not connected with any other part of Victoria. Its flora is very distinctive. Besides *E. corymbosa*, there are a number of other species of Myrtaceae that occur here, but nowhere else in the State, nor in Tasmania. Thus, among the Myrtaceae we find *Angophora intermedia*, *Melaleuca armillaris*, *Eugenia Smithii*, *Tristania conferta*, and *Eucalyptus botryoides*. The first two have a very restricted range. *Eugenia Smithii* extends westwards to the Gippsland Lakes, which is the western limit of this tropical vegetation. All of these species of Myrtaceae extend to Queensland, but none occur in Tasmania. Other tree species found here are: *Brachychiton populneus, Eucryphia Moorei, Acronychia laevis, Elaeocarpus holopetalus, E. reticulatus,* and *Banksia serrata.* The Illawarra Palm, *Livistona australis,* occurs as an isolated patch near Orbost. This also extends to Queensland, but not to Tasmania. Besides these tree species, there are many other plants occurring here not found elsewhere in Victoria nor in Tasmania. In the so-called jungles of this area there is a much greater number of lianes than occurs in the much heavier rainfall areas of other parts of the State, particularly where *E. regnans* grows. In these latter areas there are only three climbers, but in East Gippsland there is a comparatively large number. The mostly tropical family Asclepiadaceae, which is not represented in the Tasmanian-Victorian heavy rainfall vegetation, is here represented by three species. The family Menispermaceae, which is tropical and warm temperate, has two species here. The following list shows the climbers that are represented here, but which do not occur in other parts of Victoria, nor in Tasmania.

Family	Species	Remarks
Menispermaceae	Sarcopetalum Harveyanum	Extends to Queensland
,,	Stephania hernandifolia	,, ,, ,,
Asclepiadaceae	Tylophora barbata	,, ,, N. S. Wales
,,	Marsdenia flavescens	,, ,, Queensland
	Marsdenia rostrata	,, ,, ,,
Vitaceae	Vitis hypoglauca	,, ,, ,,
Passifloraceae	Passiflora cinnabarina	,, ,, N. S. Wales
Liliaceae	Smilax australis	,, ,, Queensland
,,	Rhipogonum album	,, ,, ,,
,,	Eustrephus latifolius	,, ,, ,,
,,	Geitonoplesium cymosum	,, ,, ,,

It is remarkable that these do not occur in the heavy rainfall areas where conditions of growth are much more favourable. These latter areas are very distinctly rain forests. Their distribution is therefore not one of rainfall.

This East Gippsland province is a meeting ground of two floras. In it are found many eucalypts, which reach their best development in drier and hotter areas. *E. sideroxylon,* red ironbark, is found in many parts of the east, but nowhere in extensive pure forests as occur at Chiltern and the Bendigo area. The red box, *E. polyanthemos,* is very widely distributed in the east, but it is not so big a tree here as in the drier parts. These species are a reflection of a somewhat dry or warm climate, although in places here they may be found about the 40 inch isohyet. These trees are getting out of their range. Nevertheless, they represent a degree of warmth and a certain degree of dryness. On the other hand, the tropical climbers and trees represent a degree of wetness and absence of cold. Their absence from the big timber areas is due to their antagonism to the wet cold winter. This area, then, in reality represents a meeting of tropical rain flora with a dry sclerophyllous flora. These climatic conditions are due to the warm ocean current that travels down southwards along the coast of New South Wales. This current has its origin in the warmer parts of the Pacific Ocean, and moves westerly until it meets the Australian coast, when it turns southward. At the southeastern corner of Australia it passes out into the Tasman Sea. This ocean current has been mentioned by Taylor (15), but he does not consider its influence amounts to much. While the meteorological data do not show that this area has any marked peculiarity, the abundant presence of tropical species indicates that there are, indeed, distinct features as compared with the climate of the areas to the immediate west. The sudden termination of this flora in a westerly direction is due to the presence of cold ocean current which travels easterly along the south coast of Australia. Its influence extends to about Wilson's Promontory.

(e) Wind.

It does not appear as if wind, apart from its general influence on other factors of climate, has had any direct influence on the distribution of species. The prevailing wind is southwest and the next common is northwest. South Australia has species which are not found in Victoria, notable among which is *E. cosmophylla*. This lies in the path of the wind, but it has not crossed the border. *E. diversifolia* is a south coast species extending from Western Australia and occurring also on Kangaroo Island. This just crosses the border, coming along the coast as far as Portland, but not extending far inland. It is quite possible that its distribution eastwards is due to wind. It is probable that its easterly movement has not yet finished, but the distribution of a eucalypt by wind is a very slow process, since the seeds are not winged, and there is no provision for the distribution of the fruits. *Eucalyptus*, like many other genera of Myrtaceae, *Callistemon*, *Melaleuca*, etc., has hard woody fruits which do not readily shed their seed, but retain it for years. These fruits remain attached to the tree, still green, for years, and it is not until some accident happens that the seed is shed. The copious reproduction of eucalypts after a fire or after a clear felling is thus accounted for. But this, while giving a good reproduction, distinctly lessens the time of spread. No other species appears to have been affected in its distribution by wind except, perhaps, *E. Behriana*. This is a mallee fairly widely distributed in the northwest of the State, but it also occurs as an isolated patch to the north of Bacchus Marsh, where the rainfall is below 20 inches. Between this area and the northwest the country is forested, and the rainfall rises to 40 inches. Its presence in this spot, unfavourable to the surrounding trees, is evidently due to the commonly occurring northwest wind blowing seed on to the area. It may be that wind has also played an important part in the distribution of the other species, but that cannot be shown. It is a curious fact that all species have found the areas, no matter how separated, suitable for their needs. It would appear as if seed is distributed accidentally in a very widespread manner over a very wide range, and each species in time finds those habitats which suit it.

B.—Geological.

It is not surprising that so far in ecological discussions geology has only occupied a subordinate place. Climatic data are readily available. Moreover, everyone is more or less directly interested in climate, for it affects our daily lives and interests. Climatic data are easily understood, and, therefore, the importance that has been attached to climate in the distribution of plants is quite natural. Soil has, indeed, been recognised as a factor, but only comparatively slight importance has been attached to it. Thus Schimper (5) says: "Soil merely picks out and blends." Others, also, have considered it of very little importance. Hutchinson (2) makes the following statement: "The original composition of the soil is seldom a limiting factor, at least in so far as the forests of Ontario are concerned." On the other hand, Stamp (14) says: "Everywhere to the trained eye, geology—and the resultant soils—is seen to be the controlling factor on the local distribution both of forest types and of individual species." In Victoria geology plays a most important part in the distribution of plants. The geology of an area can very frequently be easily discovered from the distribution of the trees on that area. The line of demarcation is frequently very sharp, as is seen in the case of the basalt plains. These, in the main, are devoid of timber, but wherever any other geological formation outcrops in the basalt, there trees are found. It is exceedingly common to find trees, growing on the Silurian shales and sandstones, ceasing as soon as the contact with the basalt is reached. The majority of the forest areas in this State occur on the formations of the oldest of the three geologic periods. These three groups—Palaeozoic, Mesozoic, and Cainozoic—are all well marked in the distribution of trees in this State. Although each of these groups contains geological systems, these separate systems do not have, generally speaking, separate influences on the distribution of the tree species. The origin of the rocks causes them to fall into the two well recognized classes—Igneous and Sedimentary. Both the Palaeozoic and the Cainozoic contain each of these two classes, but the Mesozoic, which is of very limited occurrence, contains only the one class—Sedimentary. So far as the distribution of the trees is concerned the rocks may be considered as consisting of the following five classes (Plate XIV.):—

PALAEOZOIC—Sedimentary.
Igneous.
MESOZOIC— Jurassic Mudstone.
CAINOZOIC— Sedimentary.
Igneous.

In the Palaeozoic sediments several systems are represented, but the Silurian and the Ordovician are the most widespread. Generally speaking, the Palaeozoic sediments affect distribution similarly, but the Carboniferous at Mansfield is a marked exception. This differs greatly from the others in that the strata are not folded, but are gently inclined. The soil is rich and there is an absence of infertile rocky subsoil. This area is sparsely covered with red gum, *E. rostrata,* giving it a park-like appearance. The other systems of the Palaeozoic group consist of shales or sandstones, or both, which yield very poor soils. These are highly folded, faulted, and broken, and in these the roots do not find either abundant water, mineral nutrients, or, at times, even good foothold. The soil is frequently very thin (Plate XV.A), and this adds appreciably to the difficulties of the trees growing on them. It is only rarely, and then only on favoured slopes in the high rainfall areas, that the best type of high forest is found on these formations. On the contrary, very poor species of trees, as far as timber is concerned, are found on them, even in very high rainfall areas. Thus, at times, *E. cinerea* var. *multiflora, E. dives,* and *E. elaeophora* occur together. This combination, which is rarely found, indicates very poor soil conditions. On the ranges at Wood's Point, in the 60-inch rainfall area, both *E. elaeophora* and *E. dives* occur. South of Mitta township, also in the heavy rainfall area, *E. elaeophora* occurs sparingly on the ridges. This tree is really a tree of low rainfall areas. It occurs at Arapiles, where the rainfall is below 20 inches. It is found at all intermediate rainfalls. Its presence, particularly when associated with either *E. dives* or with *E. cinerea,* or both, is indicative of almost the worst possible soil conditions. These trees are independent of rainfall, and their presence indicates that they are merely occupying areas too unfavourable for better timber species. These Palaeozoic sediments are always tree-covered, even in low rainfall areas, mainly with the rough-barked species, *E. amygdalina, E. obliqua, E. macrorrhyncha, E. capitellata, E. polyanthemos,* and *E. sideroxylon.* Besides these, however, there are a large number of others. At Inglewood and

Wedderburn, where the rainfall is below 20 inches, the mallees intrude on to these sediments. This is most unusual.

The igneous rocks of the Palaeozoic group provide the finest forests we possess. Some of the soil is highly fertile, but on the whole these areas have not been successfully used for settlement. These igneous rocks all possess the same general chemical composition, but physically they may be somewhat widely different. Their widely differing physical constitutions naturally result in widely differing soils. These igneous rocks, which are widely scattered in the State, are grouped into three sections according to their crystalline characters: the granite which is coarsely-crystalline, the porphyry in which large crystals occur set in a fine ground-mass, and the dacite which is finely-crystalline. The term granite is used here in a wide sense, covering all acid, coarsely-crystalline rocks. The first two occur over a wide range of rainfall, but the dacite is mainly confined to the heavier rainfall areas. Although these three classes of rocks produce different soils, they carry the same forest species where the rainfall is similar. These soils are all highly siliceous and are very favourable to tree growth. This is well illustrated on the basalt plains at Bulla. These plains are wholly or almost treeless, but wherever the granodiorite outcrops on the surface it is freely covered with grey box, *E. hemiphloia* (Fig. 3). The same state of affairs is seen in the same area where the

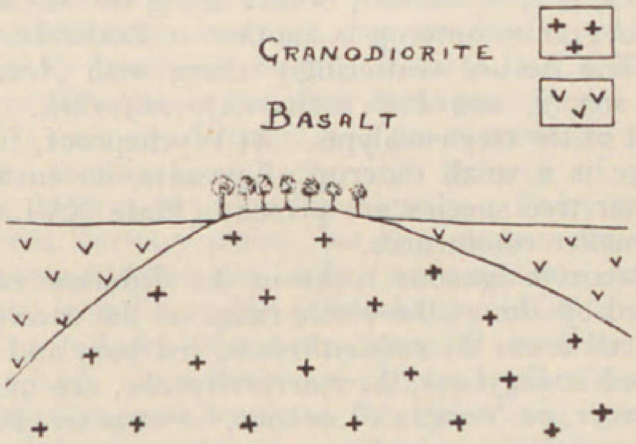

FIG. 3.—Trees covering the outcrop of Granodiorite but not growing upon the Basalt.

granodiorite has been exposed in the floors of the valleys carved out of the basalt plains. Here the trees occur, mainly red gum, *E. rostrata,* owing to the abundance of water present in the granite rocks. The red gum does not pass on to the basalt (Fig. 4).

In the large granite area to the south of Bendigo, red gum is found even high up on this formation. Red gums are essentially lovers of moisture, and this accounts for their being found on river banks. Their presence on the granite suggests that there is abundant soil moisture present. Immediately to the north of this area the Ordovician shales carry a pure forest of red ironbark, *E. sideroxylon,* but this species does not come

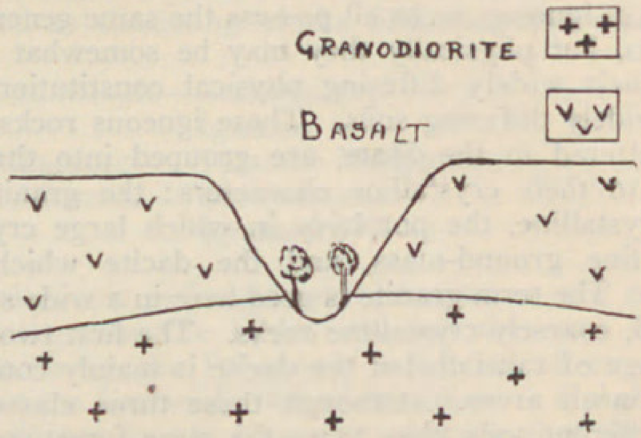

Fig. 4.—Red Gum (*E. rostrata*) growing in the valley where the Granodiorite is exposed.

on to the granite. The large granite outcrop at Maloga carries almost a pure forest of *Callitris glauca* and scattering grey box, *E. hemiphloia.* On the surrounding plains trees are very sparse, but the black box, *E. bicolor,* occurs along the streams. To the west of this granite outcrop is another at Buckrabanyule, where *E. hemiphloia* occurs scatteringly along with *Acacia implexa, Casuarina stricta,* and *Exocarpus cupressiformis.* This is the last outpost of the tree eucalypts. At Wycheproof, further north, where there is a small outcrop of granite, no eucalypts occur, but the other tree species are present (Plate XVI.A). Further north the mallee commences.

The Palaeozoic igneous rocks in the different rainfall zones are occupied by almost the whole range of the eucalypts. In the lower rainfall areas *E. polyanthemos,* red box, and its common associate red stringybark, *E. macrorrhyncha,* are quite common, as, for instance, on Morgan's Lookout, Glenrowan (Plate XVI.B). *E. elaeophora* also occurs here as well as elsewhere. In these drier areas all those trees which are found on the Palaeozoic sediments are found on the granite, with the very marked exception of red ironbark, *E. sideroxylon.* This is the more remarkable, since it prefers the dry, gravelly hill-tops of the Ordovician country. In the high rainfall areas *E. regnans* occurs as pure forest (Plate XV.B) on igneous rocks, but only scantily on the sediments. In these areas soil very materially affects the distribution, which is quite the reverse of the opinion of Russell (16). No soils are so responsive to tree growth as those derived from the Palaeozoic igneous rocks. In general it may be said that these latter are true forest soils except those derived from dacite, which is very rich, but limited in amount. The granite soils are usually too poor for agriculture, although they make good grazing land. In the heavy rainfall areas, where this land has been cleared scrub and bracken fern have overrun it, and these plants have greatly increased the intensity of the fires that periodically ravage these parts of the State.

The Palaeozoic rocks are the most important forest areas the State possesses, and they must always be the chief source of our timber supplies. The woolly butt or red mountain ash, *E. gigantea,* is restricted to these rocks. Our chief forests of *E. regnans,* white mountain ash, occur on them. Besides these, a large number of other species reach their best development, as mountain grey gum, *E. goniocalyx*; candle bark, *E. rubida*; messmate, *E. obliqua*; brown stringy-bark, *E. capitellata*; peppermint, *E. amygdalina*; and red ironbark, *E. sideroxylon.* These rocks occupy some 30 per cent. of the State, but not all of this, however, is forested, for there are contained in it large upland areas which are only suited for grazing.

The Mesozoic rocks all occur on an east-west line in Southern Victoria (Plate XIV.). They probably were once continuous, but subsequent geological changes have isolated them into three areas—the South Gippsland, the Otway, and the Western District around Casterton. The first two of these were heavily forested, but they have been now almost completely opened for settlement. Settlement, however, has steadily failed, and these areas are rapidly becoming worthless waste land. The western area is below 500 feet in height. Settlement began here very early, and it is undoubted that it was the remarkable treelessness of this area, combined with the rich growth of grass, that attracted the Hentys to it in the 'thirties. Trees occur freely on the adjacent Tertiary plains, but they do not cross on to the Jurassic. Economically, the other two areas are really forest soils. The soil is undoubtedly rich and the rainfall abundant, but the successive failures that have attended settlement mark it out as forest land. In addition, too, there is the fact that these areas bear equally good forest as the Palaeozoic igneous rocks, and neither of these areas is very extensive. These rocks contain the same species of eucalypts as the Palaeozoic rocks of the high rainfall areas, with the marked exception of *E. gigantea.* The blue gum, *E. globulus,* is abundant in the southern parts, but almost absent in the igneous area. Although formerly carrying wonderful forests, to-day these Jurassic rocks are of very little value. The total area occupied by the Jurassic mudstones amounts to only a little over 2 per cent. of the State. Owing to their favourable conditions for tree growth, and the fact that they are largely waste lands, they form natural areas for reafforestation with suitable coniferous species.

The Cainozoic rocks are the most widespread, covering about 67 per cent. of the State. These areas are mostly at low elevation, and are therefore not sharply contoured. Very small areas of these lie in areas of high rainfall, and the bulk occurs in areas having rainfall below 30 inches. These areas are chiefly agricultural, comparatively little being forest land. Tree growth is entirely absent over wide areas of fertile soil, and in other parts typical savannah prevails. It is only in the eastern portion of the State that good high forest prevails on this Cainozoic formation. There are two distinct rock types in the Cainozoic, the Igneous or Basaltic, and the Sedimentary. On account of its treelessness the first of these may be said to be strongly antagonistic to trees. The sheoke, *Casuarina stricta,* forms small patches of pure forest on the basalt plains in parts, and this is the most successful tree occurring naturally. *E. rostrata* also forms pure colonies (Plate XVII.A) in parts, or mixed with *E. ovata,* swamp gum, but these trees are here large-crowned and short-boled. The second rock type produces grassland in parts, but more generally some form of woodland. The north-west or mallee contains, besides the various species of eucalypts forming mallee (Plate XVII.B), quite a large number of other species, most of which are not found elsewhere in Victoria. The cypress pine, *Callitris glauca,* which occurs abundantly at various parts along the valley of the River Murray, extending as far east as the Melbourne-Sydney Road, is plentifully found here, forming pure forest on the lighter soils. The belar, *Casuarina lepidophloia,* also forms pure forest or mixed forest with *Callitris glauca.* This species of *Casuarina* is exclusively restricted here. The needlewood, *Hakea leucoptera,* may also form small isolated pure colonies. Other tree species found, but never in abundance, are *Pittosporum phillyraeoides, Fusanus persicarius, F. acuminatus, Acacia homalophylla,* and *Heterodendron oleifolium.* In the southern parts of the State the sedimentary rocks are much better clothed with trees than in the northern. These southern parts are more sandy and this is more suitable for tree growth. The species of trees are mainly rough-barked eucalypts. The dunes just away from the seashore have a special tree vegetation which includes *Casuarina stricta, Banksia integrifolia, Acacia longifolia, Myoporum insulare* associated with *Leptospermum laevigatum.* In the east there is a very great variety of eucalypts, the species occurring on the Palaeozoic also occurring on the coastal plains. This area is distinctly forest land.

(a) Soil.

1. *Physical Constitution.*

Considerable attention has been paid to the physical constitution of the soil, but this has been chiefly on account of its agricultural importance. As yet, however, its importance in ecology has not been recognized except casually. As a factor, however, in distribution it is just as important for some species as other factors are for other species. It cannot be too strongly stressed that there are a large number of factors affecting distribution, and that in the past ecologists have sought to relate distribution to too few factors rather than to seek explanations in new ones. It has been well recognised in agriculture that some soils are more suited for some crops than for others, but that fact has never been fully grasped by ecologists. It is probable that the influence of Schimper has clouded the outlook of investigators by insisting on the great influence of climate, particularly rainfall, and the minor importance of soil. In this State, however, soil is a most important factor, and just as important as any climatic influence. It may be said that, in general, the eucalypts favour sandy soils and loams and are not favourable to heavy soils. The tallest trees in the State are found on the lighter soils derived from igneous sources. On the basalt, where heavy soils are found, trees are entirely wanting over large areas.

The most outstanding case of the control of distribution by the physical constitution of the soil is seen in the case of *E. viminalis*, the white gum. This tree occurs in two well-marked varieties, *alba* and *arenaria*. The first variety, *alba*, is to be found in the valley floors or on the small alluvial flats of the heavy rainfall areas or along the streams from these areas. In such places, it frequently forms small pure forests, as may be seen on the Watts River at Fernshaw. This variety of *E. viminalis* never passes from the relatively lower elevations of the valley floors to the higher ground. In the valley floors, the hill wash and the detritus collect, and this holds the moisture, but is at the same time well drained, and in this *E. viminalis* finds its most favourable environment. On the sandy flats *E. viminalis* frequently forms a pure colony with *Pteridium aquilinum* as the only associate. These sandy flats and the floors of the gullies are comparable in that, while they are well watered and constantly moist, they are well drained and there is no free water present. The variety *alba* is essentially an inhabitant of relatively low elevations, but at Drouin and at Loch it occurs as very large trees on the crests of the ridges. The soil is rich and well watered, and the presence of *E. viminalis* here is indicative of the fact that there are other factors present which are inhibiting the usual mountain species. The presence of this variety in the Wombat Forest, where it extensively occurs, associated with *E. obliqua* and *E. amygdalina*, cannot at present be satisfactorily explained. These three species are frequently associated, either all together or any two of them, on various types of soil, but these are always well drained. The sandy soil is the habitat in which *E. viminalis* is commonly found, and it is frequently associated with these two rough-barked species. On the hill slopes, however, *E. viminalis* does not occur. It is therefore probable that the Wombat Forest marks the meeting-place of two soil types. The basalt plains are normally destitute of trees, but at the Stony Rises, between Colac and Camperdown, the variety, *alba,* is found. As the name of the place implies, the plain is here broken into stony ridges and hollows. It is in these hollows that this variety is found. The basalt has not here weathered into the heavy black clayey soil that is usually the case. In the hollows this species finds among the stones those conditions of moisture and drainage that are favourable to its development.

The other variety, *arenaria,* occurs where the rainfall is lower and where the water supply is deficient during the summer months. Both varieties agree in this, however, that no matter what the rainfall may be, the soil must be well drained and generally very friable. It does not matter how damp the soil may be so long as it is well aerated. The soil must never be saturated. A common associate of this variety throughout its range is the common bracken fern, *Pteridium aquilinum.* These two species are indicative of a porous condition of the soil. Sandy soils which have borne this species of eucalypt, when cleared are commonly overrun with bracken if left uncultivated. *E. viminalis,* var. *arenaria,* is found right throughout the southern areas of the State wherever the coastal plains occur. This variety may be seen at Lakes Entrance, Inverloch, Port Phillip, Peterborough, Warrnambool, and Portland. The soils on these coastal plains are very sandy and have a low water-holding capacity. They are very loosely compacted and hence are both very well aerated and drained. They are underlain at varying depths with a very stiff clay whose distance from the surface determines whether trees or scrubs occur. Where trees do not occur, the flora of these sands is seen to be very xerophytic and consists of low scrubs, typical species being *Epacris impressa, Leucopogon virgatus, Banksia marginata, Leptospermum scoparium, L. myrsinoides, Acacia oxycedrus,* and *Casuarina distyla.* Thin stems and small pungent leaves are common. These sands are the commonest habitat of *E. viminalis,* var. *arenaria,* and the controlling factors appear to be the porosity of the soil and its well-drained condition. These conditions are normally not present on the basalt plains. There the soil is heavy and is not well drained owing to the flatness of the contour. Normally, *E. viminalis* is absent from these plains, but at Branxholme, where the basalt has broken down to an ironstone rubble, this species does occur. This gravelly soil, while it is chemically widely different from the sands of the coastal plains, yet physically is comparable to them in that it is well aerated and well drained. The basalt breaks down also into other types of soil, but *E. viminalis* is not found on them. If the soil be not porous then this species is absent.

Another remarkable occurrence of this variety on the basaltic formation is on the cinder cone at Mt. Franklin. This mountain is an extinct breached crater of newer basaltic times. It is formed of scoria and cinders which are not greatly decomposed, although the surrounding basaltic plains consist of heavy black clayey soils. The cone therefore physically is comparable to the sands, and on it is found a number of trees which are commonly associated with *E. viminalis* on the sands, the tree species present being *Casuarina stricta, Banksia marginata* and *Exocarpus cupressiformis.* These trees are not restricted to the sands, but this association is very common there. These two occurrences of *E. viminalis* on the basalt are entirely due to the physical condition of the soil. Another remarkable occurrence of *E. viminalis* var. *arenaria* is on the limestone soil at Buchan. This limestone country was evidently lightly timbered, as is often the case with *E. viminalis* country, and this undoubtedly accounts for its early settlement. The surrounding country which is heavily timbered has not been settled even yet. This surrounding area consists of quartz porphyry and carries a variety of rough-barked eucalypts, but *E. viminalis* is not found among them. Associated with *E. viminalis* on the limestone is *E. melliodora.* The soil, due to the abundance of lime, is friable, and this character makes it to a certain extent comparable to the sand, so far as its physical condition is concerned. As Russell (16) says, "Calcium carbonate may greatly modify the clay properties and give a considerable degree of friability to a soil which would otherwise be very intractable."

The physical constitution of the soil is also the controlling factor in the distribution of the red ironbark, *E. sideroxylon.* This species is quite comparable to *E. viminalis* in its desire for well drained soil conditions. Where it occurs at its best, the red ironbark is present where the ridges are capped with ironstone gravel, conditions under which *E. viminalis* might be expected to occur if more moisture were available. In the Bendigo district it forms pure forest at times, but at other times it is associated with grey box, *E. hemiphloia;* red box, *E. polyanthemos;* and red stringybark, *E. macrorrhyncha.* When it occurs as pure forest, it is probable that the most favourable conditions exist for its growth. It also occurs in the east of the State but never as pure forest. It mostly grows there on sandy soils where one would naturally expect to find *E. viminalis.* The optimum conditions of growth are never found in the east, but nevertheless it always occurs on well drained soil. The conditions there are on the borderland of the conditions of its environment.

While the physical condition of the soil has not only an important influence on the distribution of individual species, it also has a most profound influence on the distribution of vegetation itself. Schimper (5) has considered that the soil has only a minor influence on vegetation, believing that climate, particularly rainfall, is the determining factor. Schimper considered that an evenly distributed rainfall was the cause of grassland, and hence this type of climate was referred to as grassland climate. The metropolitan area of Melbourne has an almost even distribution of rainfall throughout the year, the two extremes of average monthly rainfall being 1·7 inches in February and 2·5 in October. However, grassland is not universally present throughout this area but is localized. This even distribution of rainfall extends easterly from Melbourne to the eastern boundary of the State and then it turns northwards. Instead of being grassland this area is mostly all forest. There is a large triangular area lying roughly in between Sale, Maffra and Traralgon which is plain country carrying *E. tereticornis.* This area was early settled, probably because it was well grassed and never densely timbered. In the metropolitan area there are in the main three geological formations present, each producing a characteristic soil: the Tertiary Sands, the Basalt Plains and the Silurian Sediments. The first produces a very sandy soil, the second and third produce clay soils. The sands are covered with trees or scrub or both, the Silurian with trees but very little scrub, while the basalt plains are grassland. Throughout the State, sandy soils are always covered with tree or scrub growth. Even the dunes near the sea shore are covered with such trees as *Leptospermum laevigatum, Casuarina stricta, Banksia marginata* and *Acacia longifolia.* Behind these again *E. viminalis* may be found. On the dunes in the Mallee where the rainfall is not much above 10 inches, trees such as *Casuarina lepidophloia* and *Callitris glauca* form reasonably good high forest. On the acid igneous rocks, as granodiorite, dacite and quartz porphyry, trees are always abundant. All of these rocks contain free silica, and hence the soil is more or less open according to the size of the silica particles present. It may be said that the lighter soils are generally suited for tree growth. It is on such soils that the tallest trees are found. On the other hand, wide areas of the heavier soils are frequently either destitute of trees or are only very sparsely timbered. Thus we find the basalt soils of the Western District quite treeless for miles. These soils contain a large percentage of clay and only a small percentage of sand. Different authors have used the term clay to define different sized particles. Howell (17) follows the American practice and uses the term clay for particles below a diameter of 0·005 mm., while the English authors, for instance Russell (16), use it for particles below 0·002 mm. In the accompanying table are given the mechanical analyses of typical soils from the treeless areas of the basalt soils. The analyses are by the Victorian Department of Agriculture.

It will be seen that all these soils are particularly lacking in sand, but all have a fairly high percentage of clay. The soils are practically made up of the finer materials, that is, with particles of a diameter less than 0·1 mm.

TABLE V.—SHOWING THE PERCENTAGES OF THE VARIOUS SOIL PARTICLES IN VICTORIAN BASALTIC SOILS.

Fraction	Size	Bungaree	Cressy	Tower Hill	Camperdown
Fine Gravel	2–0·1 mm.	0·21°/。	0·77°/。	0·12°/。	3·87°/。
Coarse Sand	1–0·5 mm.	2·45	3·04	0·76	4·23
Medium Sand	0·5–0·25 mm.	2·15	1·81	1·35	1·27
Fine Sand	0·25–0·1 mm.	6·88	4·59	7·93	4·33
Very Fine Sand	0·1–0·05 mm.	22·99	27·19	9·46	18·56
Silt	0·05–0·01 mm.	3·77	3·42	2·62	4·22
Fine Silt	0·01–0·005 mm.	16.58	6·46	6·70	9·61
Clay	Below 0·005 mm.	33·59	34·84	40·75	31·75

It is the physical composition of the soil that is, in a great measure, responsible for the occurrence of grassland or woodland. In this State, both formations occur in the two types of rainfall, the so-called winter and the even distribution. Wherever there is a high percentage of clay or clay and silt in the soil, grassland will result. In the Wimmera, which is not basaltic, grassland occurs. Here the percentage of finer materials is 57·34 per cent. Clay has a marked power of swelling when wet, and of contracting and opening into deep cracks when dry. In the plains the clay soils swell on the surface when wet, and do not permit the ready entrance of water. Percolation is very slow and the soil bcomes saturated. Aeration is bad and plants possessing deep roots find it difficult to establish themselves. In summer, the open cracks, extending it may be for several inches into the ground, permit of very serious loss of soil moisture. It has been suggested that the even distribution of rain is necessary for grassland on account of the shallowness of the root system. Grasses, however, do not necessarily have shallow roots, nor do they necessarily have a very fibrous system. Grasses such as the native species, *Poa caespitosa, Chloris truncata, Stipa semibarbata, Danthonia penicillata,* etc., do have restricted root systems and are very fibrous, but other grasses, such as *Spinifex hirsutus,* which is an inhabitant of sand dunes and has to seek a long way for its water requirements, have very few roots, but they are very long. The habitat in a very great measure controls the type of root development. A shallow fibrous-rooted plant would stand very little chance of persisting on a sand dune even with an evenly distributed rainfall. Sandy soils are very permeable to water, and it is for this reason that tree development has occurred in the Mallee. The sand ridges so called are not pure sand, as chemical analysis shows. They are wind-blown material of the nature of loess, but mechanically they have the properties of sandy soils. Howell (17) shows that the red soils of the Mallee have a very high percentage of granular material above 0·05 mm. diameter. The average percentage in the three samples given by him was 59·466. These dunes are tree-covered, although the rainfall is not so very far from being uniform. In the western portions of the State, west of the Grampians and thence southwards, the Tertiary plain is partly red gum flats and partly sandy areas, with *E. viminalis* and *E. capitellata* associated with *Xanthorrhoca minor.* The presence of the red gum is indicative of abundance of water. In the east of the State, in the large triangular area lying between Sale, Traralgon and Maffra, red gum areas again occur. The species of the red gum here is *E. tereticornis.* Here again are found sandy areas covered, not with red gum, but with a large variety of rough-barked eucalypts, as *E. eugenioides,* white stringybark; *E. viminalis,* white gum; *E. cinerea,* mealy stringybark; and *E. Stuartiana.* In both of these areas the sandy patches are always tree covered. Warner (1) has shown that sandy soil in the midst of prairie is covered with forest and he remarks, "This disjunct area is an example of a pure forest being retained west of its climatic range by edaphic conditions." Sandy soils by their looseness and lack of cohesion and of any colloidal property freely admit the rain water which passes readily down into the soil under the influence of gravity. The looseness of the soil acts as a mulch, preventing evaporation. Trees can readily grow and send their roots down.

The clay soil, on the other hand, does not admit free entry of water which, when it does enter, does not easily pass into lower levels.

The higher the percentage of clay in a soil the nearer does the water holding capacity of the soil approach the saturation value. The basalt soils all contain a high percentage of clay. The average of four analyses made by the Victorian Department of Agriculture was 35·23 per cent. of clay (i.e., particles of a diameter below 0·005 mm.). The upper and lower limits were 40·75 and 31·75 respectively. The average for the four samples of material below 0·05 mm. diameter (i.e., clay, fine silt and silt) was 48·58 per cent. It is the large percentage of clay in a soil that determines to a very large extent whether the vegetation shall be woodland or grassland. While the soils themselves are very slowly permeable to water, the subsoils are even more so, and this greatly impedes the percolation of water and the penetration of roots. Clay soils are essentially grasslands, while sandy soils are essentially forest lands. Fletcher (18) states that the soils of the prairies of U.S.A., while differing very widely chemically, are very similar physically. They all contain a very high percentage of silt and clay, thus possessing great tenacity. The silt ranges from 55 to 75 per cent. and the clay from 6 to 15 per cent. Warner (1) says that the prairie in Texas, which is not of glacial origin and which is typical of the southern prairie, contains a high percentage of silt and clay, the respective amounts being 49·1 and 30 per cent. by the American standard.

Schimper states that, on account of the fact that grasses are shallow-rooted plants, moisture in the subsoil has little influence on the covering of grass, and he goes on to say that a good grassland climate has frequent atmospheric precipitations during the vegetative season. In the tables of rainfall given by him under *Warm Temperate Grassland Climate* are cases where the conditions are very similar to those existing in Victoria. The climate of the pampas of South America is spoken of as a perfect grassland climate. In this, the winter rainfall—that is, from April to September—is greater than the summer fall. The ration is 1·3:1. Approximately similar conditions exist in Victoria, but the vegetation is not necessarily grassland. In the pampas climate, the heaviest average monthly rainfall is five times greater than the lowest. This is greater than in most cases in Victoria. Schimper notes that the climate of South-east Australia gives the impress of a good grassland climate, but he explains the absence of grassland on the view that the absence of dry periods during the spring months and the mildness of the winter are responsible for tree growth. There are widespread areas in the State which have a winter-summer ratio similar to those given by Schimper and where the rainfall is as evenly distributed, but woodland occurs, not grassland. In the north-west of the State, where the rainfall is only a little above 10 inches, the ratio of winter to summer rain is 1·5:1, while at Wood's Point the ratio is 1·7:1. As has already been remarked, there are no really great differences between the summer and winter rainfall. It has been stated in this paper that the rainfall of Victoria is really only a modified winter type. This is shown by the fact that the heaviest monthly fall for Wood's Point is 3·3 times heavier than lightest summer fall, and for Mildura 2·5 times. For the perfect grassland climate of the Savannah given by Schimper, the heaviest average monthly fall is five times greater than the lightest summer fall. So far as Victoria is concerned, the type of rainfall received has no effect in so far as woodland or grassland is concerned.

Clay soils are typically grazing or agricultural land, while sandy soils are true forest soils. Analyses given by Howell (17) and by the Department of Agriculture, Victoria, for soils in the plain country where grassland occurs, show that the percentage of clay and silt is very high. It is a significant fact that the sandy soils have been so little settled. These latter areas in many cases do not carry good forest, although the rainfall is sufficient for forest growth. The eucalypt is not a thrifty tree, but demands favourable conditions of growth. The members of the genus *Pinus* provide many examples of very thrifty trees, and it is to this genus in particular that we must look for species for making those areas that are at present valueless economically profitable. Forestry is the complement of agriculture in the effective use of the soil, and while agriculture demands the better soils, forestry on the other hand makes use of the poorer.

2. *Chemical Composition.*

Just as is the case with the physical composition of the soil, there has been a difference of opinion regarding the influence that chemical composition exerts upon the vegetation of an area. So far as igneous rocks are concerned, in this State the large continuous areas forming mountain ranges all belong to the acid series of rocks. The basic rocks, such as basalt, occur only as sheets of lava. There are no ranges of these. Basalt does occur at high levels, as at Dargo High Plains, but there also it occurs as plains. Hence no comparisons can be drawn as to the respective influences of basic and of acid rocks. The acid series of rocks are represented very widely in the State by all three modes of consolidation of the original magma: plutonic, hypabyssal, and volcanic. These three, although chemically identical, nevertheless produce different types of soil. The plutonic rock, granodiorite, weathers into its constituent crystals, quartz, biotite, and felspar, before they are decomposed. Biotite is very resistant to decay, as may be seen in any area where granodiorite is decomposing. The felspars become opaque as the rock disintegrates. These large constituents naturally give rise to a coarse soil. In the dacite, the constituent minerals occur as a very fine ground-mass in which are a few larger crystals. Mineralogically, the dacite is similar to the granodiorite, but, in some forms, hypersthene replaces biotite. The fine ground-mass readily decomposes into a fine, rich, chocolate loam. The soil is much more a loam than might be anticipated, owing to the high percentage of silica present, but this and the other crystals are exceedingly fine. The porphyry produces a soil intermediate between these two. Of the three types of acid igneous rock, two occur abundantly in the high rainfall areas of the State. These are clothed with some of the densest forests in the State. In these forests the mountain ash, *E. regnans,* is very abundant. This species is somewhat restricted in its range, but it occurs freely on three well-defined areas, all of which are enclosed by the 40 inch isohyet. In all these three areas the rainfall reaches 60 inches and over, but above 40 inches there is no difference in the vegetation. One area lies to the east and north-east of Melbourne, and this we may designate the Warburton. In this area, from north to south, this species, *E. regnans,* passes from Belgrave to Rubicon, and east to west from Walhalla to just north of Yan Yean. The other two areas are in the south of Victoria, the South Gippsland and the Otway. Physically, the soils are of different types. Very great differences exist between the soils derived from the two related rocks, dacite and granodiorite. Although these two rocks have been derived from the same magma, and are chemically similar, physically they are widely different. The dacite weathers into a rich chocolate loam which is regarded as a first-class agricultural soil, but the rapid growth of scrub and bracken fern has militated against settlement. The granodiorite weathers to a coarse gravel which is very porous, and is not sought after for settlement.

The soils of the two southern localities are derived from the Jurassic mudstone, the origin of which is still uncertain. This rock contains the same minerals as the two igneous rocks just mentioned, but the crystals are not interlocked, as when formed from a molten magma, but are just mechanically thrown together. The constituents of the rocks are undoubtedly of volcanic origin, but they have been sorted by water. The resulting soil is rich, but the areas have not been successfully settled. Each of the three areas is comparable in so far as rainfall, physiography, and elevation are concerned, but other adjacent areas are equally comparable in these respects. These three areas are, however, closely related in the chemical composition of the rocks from which the soils are derived. Typical analyses (19, 20) of these three rock types are given in Table VI. An analysis of basalt (21) is given for comparison.

TABLE VI.—ANALYSES OF TYPICAL VICTORIAN ROCKS.

	Dacite	Granodiorite	Mudstone	Basalt
SiO_2	63·27	70·94	64·00	50·52
Al_2O_3	16·50	13·99	15·88	16·01
Fe_2O_3	0·68	0·35	1·90	1·40
FeO	5·10	3·02	3·86	8·98
MgO	2·48	0·8	1·81	6·13
CaO	4·18	2·35	2·02	8·05
Na_2O	2·36	3·94	3·42	3·08
K_2O	2·68	3·66	1·86	2·02
P_2O_5	0·15	Trace	—	0·39

It will be noted that the three related rocks have a high silica percentage, considerably higher than the basalt. A greater difference, however, exists in their content as regards iron, magnesium and calcium. These are all high in the basalt, but comparatively low in the three others. The alkalies are approximately the same for all. This applies also to alumina.

In the three chemically related areas, the tall eucalypt, *E. regnans,* is found right from valley floor to the crest of the ridge. Wherever the soils from these rocks occur in a rainfall of 40 inches or over, *E. regnans* occurs. These soils are its home. It forms extensive pure forests, and it is commonly associated with the hill tree-fern, *Alsophila australis.* It is in the recesses of the mountains of these rocks that our magnificent fern gullies are developed. Adjoining these areas are Palaeozoic shales and sandstones enjoying the same climate, but it is only occasionally in sheltered spots that *E. regnans* is found on them. It is the limited occurrence of these Jurassic and igneous rocks that limits the widespread occurrence of *E. regnans*. These rocks occupy only a small percentage of the area receiving 40 inches and over of rain, but rainfall is only partly a controlling factor.

These three areas, Warburton, Otway, and South Gippsland, may be regarded as true forest land, owing partly to the wonderful forests (Plate XV.B) they produce, and also partly to the difficulty that has been experienced in attempting to settle them. Where settlement has been unfortunate, these areas have been devastated. These should be restored to what Nature intended them to be. Owing to the richness of the soil, abundant rainfall, moderate temperatures, and moderate contours, these areas, where devastated, present possibilities for introduced species, such as spruce, which demand very favourable conditions of growth. So much of these areas has been denuded of forest that natural reproduction is impossible, and planting is the only resource to re-establish forest conditions.

3. *Water Content.*

In discussing the physical constitution of the soil, it was mentioned that clay was an important cause of grassland. It is, however, not the only cause. In the west of the State, to the north and west of Casterton, there are patches of the sandy plain covered with savannah forest. The same occurs, as has already been mentioned, in the east in the Sale area. In both these cases the tree is a red gum, *E. rostrata* in the west, *E. tereticornis* in the east. These red gum areas alternate with loose sandy patches carrying various rough-barked eucalypts. The savannah forest is quite devoid of any scrub, although this is abundant on the adjoining sandy areas. These areas have long been settled on account of their pastures, and the trees have been largely removed. These pastures or grassland do not owe their origin to a high clay content, but to a high water content. Why these areas produce trees and grass instead of species of Cyperaceae and Juncaceae remains to be determined. It appears, however, that, although always moist, actual swamp conditions never arise. *E. rostrata* also appears in savannah formation on the basalt. This rock weathers into a stiff clay which has a high water-holding capacity. During the winter these soils are frequently saturated, and conditions of growth are very poor. Associated with *E. rostrata* on the basalt is the swamp gum, *E. ovata*. Neither of these ever produces good timber trees in such habitats. *E. rostrata* can withstand a greater degree of dryness than *E. ovata*. The former reaches its greatest development in the flats associated with the main rivers (Plate XVIII.A). These areas are mostly subject to flooding, but they are also subject to extreme drought. It is the severity of these droughts which controls the distribution of *E. rostrata* in the north-west of the State. The heavy clay soils associated with many of the rivers, particularly the Wimmera, become very loose and broken under the prolonged heat and drought of summer, and these conditions become unfavourable for *E. rostrata*. Along the rivers in the north-west, *E. rostrata* is associated with *E. bicolor*, black box, but when conditions become extreme, *E. rostrata* fails to hold its own and only *E. bicolor* remains. Along the Murray both occur from about Echuca westwards. At Donald, both species are found, but a little further north at Birchip only *E. bicolor* remains. At Horsham and Dimboola, both occur. *E. bicolor* is essentially a tree of seasonal swamp land, and is never found in normal mallee formations.

In the range of these three species, *E. ovata*, *E. rostrata* and *E. bicolor*, there is a gradation of dryness of the environment from the first to the last. The first and last are never associated, but each is widely associated with *E. rostrata*. *E. ovata* is an inhabitant of areas that have a constantly moist soil. It never undergoes long or comparatively long periods of dryness. *E. rostrata* inhabits moist areas in the south and west of the State, but, in the northern plains, conditions are much drier. Here it reaches its best development. It meets *E. bicolor* a little to the east of Echuca. West of this conditions become more severe and *E. rostrata* ceases. They occur together at Kerang, but not at Pyramid. *E. ovata* is not a good timber tree, but the other two species are. These two must be regarded as among the most thrifty species we have, for they are inhabitants of areas which are of little value for other purposes, and which are also useless for other species of trees.

4. *Subsoil.*

The subsoil varies very widely as regards its depth from the surface, and this has often a profound influence on the vegetation. Beneath the Tertiary sands is an impervious clay overlain in most cases by an ironstone rubble. It is the distance of this impervious clay from the surface that determines whether trees or shrubs shall be the resulting vegetation. It is remarkable how the depth of this clay varies. When near the surface it may truly be described as a subsoil, but when this same layer is several feet down, it is rather stretching the term to call it subsoil. In this latter case, the true subsoil is usually more or less a pure sand. Nevertheless it is the impervious clay that is the determining factor, and hence it may be regarded as a subsoil. When near the surface and the drainage conditions are favourable for the free movement of water, scrub is the resulting vegetation. The rain that gravitates to the impervious layer is lost to the local vegetation, for it drains away along the surface of the clay. Hence water supply during the summer months is very deficient. This scrub is markedly xerophytic, as is shown by the small, pungent, sclerophyllous leaves, thin stems, and stunted growth. The moisture in the soil is frequently very low, as is shown by the moisture analysis of this soil taken during a prolonged dry period.

TABLE VII.—PERCENTAGE OF MOISTURE IN THE SOIL DURING A DROUGHT.

Depth in inches		Moisture content
1	-	0·97%
6	-	1·25
12	-	1·07
18	-	1·27

It has been found by experiment that these percentages are far too low for germination. A soil with such a low percentage of water can only be inhabited by a very xerophytic flora.

Where the clay subsoil is far removed from the surface, water percolates to great depths, and hence trees can exist, for there is a supply for the roots. On such situations *E. viminalis* var. *arenaria* can exist either as pure forest or associated with bracken. It is also at times associated with *E. obliqua* and with *E. amygdalina,* as is seen at Nyora. It is these soils that are so opportune for afforestation with species of *Pinus*. Such soils occur in the Pine Barrens of North America.

If the clay be near the surface and the drainage conditions are imperfect so that the free water is not moved under the influence of gravity, then swamp conditions arise. Such a swamp may be seasonal or permanent. In the southern parts of the State in or around such swamps, either *E. rostrata* or *E. ovata,* or both, may be found. Grassland is often associated with the red gum, as is seen both in the east and in the west of the State.

(b) PHYSIOGRAPHY.

The central portion of Victoria consists mostly of a long range of old worn-down highlands, which extend from the Grampians in the west to the Alps in the east. These consist of a variety of rocks, including basalt. With the exception of the latter, this central core is well timbered, and may be considered forest land. The mountains of the east and north-east rise to sub-alpine heights, and consist also of a wide variety of rocks. This area is well watered and consequently contains good forest. Many factors within this area control the distribution of species. To the north of the central axis are the plains which constitute part of the valley of the River Murray. These plains are mainly grassland, and form part of the wheat area of the State. They are only lightly watered, but they receive quite sufficient rain for the purposes to which they have been put. This is essentially an agricultural area. These northern plains are continued westwards as the Mallee and the Wimmera. The latter is essentially an agricultural area. The Mallee, as has been mentioned already, is agricultural so far as the climate will permit. There are areas unsuited either for forestry or for agriculture, which are locally known as deserts. Apart from these, the remaining land is agricultural, but it is a question of policy whether land carrying such good timber as belar, *Casuarina lepidophloia,* and cypress pine, *Callitris glauca,* should be opened for selection.

To the south of the central range is the great southern valley lying between the central range and the old Jurassic range. This valley, to the west of Port Phillip, has been filled by the basalt flows. This is treeless, except for patches of *Casuarina stricta.* In the west of these basalt plains, both *E. rostrata* and *E. ovata* are to be found associated. This area is typically agricultural. To the east of Port Phillip this valley has been variously timbered with species of *Eucalyptus,* but it has been mainly taken up for agricultural purposes for which it is most suited. Species occurring here are mainly peppermint, *E. amygdalina,* and messmate, *E. obliqua.*

The southern boundary of this valley has already been considered under the Chemical Composition of Rocks. These Jurassic ranges, with the exception of the Casterton, carried high forest of high quality, particularly forests of *E. regnans* and *E. globulus.* Between the sea and the last range lie the coastal plains. Near the sea, the coast tea tree, *Leptospermum laevigatum,* forms pure forest over extensive areas, but associated with it are *Banksia integrifolia, Myoporum insulare, Casuarina stricta,* and *Acacia longifolia.* The commonest tree throughout this latter area is probably *E. viminalis* var. *arenaria.* In the west, *E. diversifolia* occurs for a short distance. *E. capitellata* is found both in the east and the west. It is in the east that a rich variety of species is found, and among others are found *E. Sieberiana, E. sideroxylon, E. polyanthemos, E. globulus, E. eugenioides, E. Stuartiana, E. Muelleriana.*

1. *Elevation.*

In the alpine area in the north-east of the State, the snow gum, *E. coriacea,* occurs abundantly at the higher elevations, but it does not cover all the peaks. This species attains a greater elevation than any other, and reaches timber line (Plate XVIII.B) at about 5,500 ft. Here it is reduced to a shrub, and is known as var. *alpina.* Compared with the Rocky Mountains, timber line

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is reached at a much lower elevation. At a corresponding latitude in U.S.A. timber line is reached at about 11,500 ft. by *Picea Engelmanni.* So far as *E. coriacea* is concerned, elevation is not a controlling factor in its distribution, for it is found from sea level to alpine heights. Elevation excludes other species from the alpine area, and thus extensive pure colonies of *E. coriacea* occur. Below *E. coriacea* is found the red mountain ash or blackbutt, *E. gigantea.* Its upper limit appears to be about 4500 ft. and there it is succeeded by *E. coriacea.* While this latter species comes right down to sea level, *E. gigantea* does not pass below 3000 ft. It is thus a true sub-alpine species. This species is a tall tree, quite comparable in this respect to *E. regnans* (Plate XIX.A). Wherever rainfall and elevation combined permit, this species occurs. It is practically independent of soil, and in this respect differs materially from *E. regnans,* which is very particular as regards soil. *E. gigantea* is found just as freely on the Palaeozoic sedimentary rocks as on the igneous. Its range is therefore in some respects much more extensive than *E. regnans.* On Mt. Donnabuang and Mt. Arnold, *E. gigantea* succeeds *E. regnans,* but on Mt. Macedon and the Buffalo, *E. gigantea* occurs, but there is no occurrence of *E. regnans.* At Mt. Wellington, E. *gigantea* is abundant, but there is only a very small amount of *E. regnans.*

In the two southern localities where *E. regnans* is so abundant, South Gippsland and Otway, there is no *E. gigantea.* It has been noted already that these two areas are similar ecologically to the Warburton area, but neither of the southern areas rises to an elevation of 3000 ft. and hence *E. gigantea* is absent. In the Grampians the elevation of 3000 ft. is passed and the rainfall is also above 40 inches. The soil derived from the Carboniferous sandstone of which these mountains are formed is very poor in quality and only the xerophytic stringybarks are found.

The candlebark gum, *E. rubida,* is associated with *E. coriacea* in many places at fairly high elevations, as Dargo High Plains, Moroka River and Bendoc, but, like *E. coriacea,* there is no lower limit to its distribution. Both are found near Coldstream at low elevation. Neither of these trees appears to be controlled by elevation. In the case of *E. coriacea* it would appear that its formation of pure forest at high elevation is not due to the fact that it is specialized for such habitats, but rather that the conditions there, the accumulations of snow and the comparatively short summers, are too severe for other species.

E. gigantea is restricted both as regards upper and lower limits. It is undoubtedly adapted to the limits in which it grows. This species is remarkable for the purity of its forests. It does not usually associate with other species and form mixed forests. The very height of the tree, the density of its crown and the closeness with which they grow (Plate XIX.A) exclude other species. In many respects it is comparable to *E. regnans*, which it meets at many points, but with which it does not intermix very much. The ground vegetation under *E. gigantea* is usually very scanty. This species is one of the most important we have. Apart from the fact that it produces an excellent timber of high quality, it grows at elevations where snow is fairly abundant through the winter. The dense canopy of the forest shades the snow and thus its melting is retarded and the water finds its way gradually to the streams. Every effort should be made to retain what is one of our greatest assets.

2. *Contour.*

It has already been stated that grassland is in a large measure controlled by the physical constitution of the soil. Clay soils possess many properties which prevent successful tree growth. Soil conditions, however, are greatly modified by the contour of the country. The Palaeozoic sediments, which are largely argillaceous, are worn down into highlands with fairly sharp contours in the high rainfall areas. In the lower rainfall areas they range down almost to plains. These clay soils of the highland areas are physically different from those of the basalt plains since there is never any free water lying on the surface. There is more run-off and less penetration. During the winter these hill soils are not saturated as in the plain country. On the hills the soils are usually shallow (Plate XV.A), but they never open out into cracks. They are generally more friable, due to the leaching out of the colloid constituents. Physically, then, we have an approach to the conditions existing in sandy areas which, as we have seen, are always tree- or at least scrub-covered.

These hills and mountains formed by the Palaeozoic rocks are always tree-covered, but the forests, owing to other factors, are exceedingly variable. Judged by the standard of the granodiorite and dacite they never reach Quality I. site. In the heavy rainfall areas *E. regnans* is found on the southern slopes in favoured localities. This species is found near Grant and also further south at Moroka Gap. It also occurs at Wood's Point. These, however, are rather isolated occurrences. No doubt many such other localities may be found, but they will never be extensive. In these regions of heavy rainfall, *E. obliqua* also reaches very large size, as may be seen near the old mining, but now uninhabited, town of Grant. In this same area are also exceedingly large specimens of *E. rubida.* But, although these fine specimens exist, exceedingly poor specimens of trees occur on these same soils within the same rainfall, as, for instance, *E. dives* and *E. elaeophora.* Not all of this mountainous area, although it receives moderate to heavy rainfall, is covered with forests of any value. Some of it, indeed, as the Dargo and the Benninson High Plains, does not carry any trees at all.

Between trees and plains there seems to be a certain amount of incompatibility. It has already been remarked that our plains are either mostly grassland or savannah. This State is not an exception in this respect, for the great grassland areas of the world are plains. The evenness of contour has as much to do, probably, with the distribution of grassland as the constitution of the soil itself. It will probably be found that the level surface of the earth accentuates those attributes of clay soils which make them unfavourable to tree growth. Mere elevation, without any surface relief, does not affect this apparent antagonism between plains and trees. In the alpine area there is an extensive plateau which bears mainly grass, of which the most common species is a variety of *Poa caespitosa.* These areas are just as devoid of trees over wide areas as the lowland plains. These upland pastures are covered with snow in winter, but in summer they provide excellent grazing. Although situated within what is a true forest region these plains are essentially agricultural and provide rich green pasturage at a time when the lowland areas are dry and parched with the heat of summer.

3. *Slope.*

In the slope of any area we are concerned with two effects, the angle of slope and the aspect. It is well recognized in the Northern Hemisphere that the slope facing the equator is always warmer and usually drier than the slope facing the pole. The equatorial slope naturally receives the rays at a much sharper angle—it may be at a right angle—than the outward slope. In this State, where the problem of water supply is constantly present, the southern aspect is always moister, and it is on these, as well as on the eastern slope, that the mountain ash, *E. regnans,* grows so abundantly. In the granodiorite-dacite areas the northerly and westerly slopes are covered with rough-barked eucalypts as *E. capitellata, E. obliqua, E. amygdalina,* and *E. Sieberiana.* These are associated with more or less xerophytic plants, as *Lomatia ilicifolia,* while *Lomatia Fraseri* is found only in the sheltered gullies along with *Nothofagus Cunninghamii.*

Another example of the effect of aspect on distribution is to be seen in the Mt. Wellington area. On the north slopes the heat-loving *E. polyanthemos* and *E. macrorrhyncha* are to be found associated with *E. Sieberiana.* On the cool, sheltered southern slopes, very fine specimens of both *E. globulus* and *E. goniocalyx* grow fairly abundantly.

C.—Biotic.

The two previous groups of factors, Climatic and Geological, do not explain all the facts of distribution. They do provide us with information concerning the environment and the relationships of the plants to that environment, but there are problems of distribution of deeper significance which are not so easily explained. Under the biotic factors, as understood here, are included any phenomena related to life itself, no matter how manifested. Of particular interest is the problem of the discontinuous distribution of a number of species. It may be assumed that any particular species, e.g., *E. gigantea*, was once continuous, but geological forces or changes in secular climate have now broken that continuous occurrence into isolated groups. Under such conceptions we would assume that *E. gigantea* was once continuous throughout its range, but denudation has since carved out the valleys and worn down the highlands, leaving the several discontinuous groups on the mountain peaks as we now have them. East and west of the area where *E. gigantea* occurs, *E. sideroxylon* is found. Are we to assume, then, that the intervening area was once drier and now has become wetter? For every disconnected group certain changes would have to be invoked to explain such distribution. It seems more natural to assume that, as the various changes have occurred, new habitats have arisen, and that seed from various species has accidentally and continuously reached those areas. Those species most fitted for the particular habitat have survived. Willis (3) and others have shown that seed dispersed is not confined to those species which have special mechanisms for the distribution of their seed. Seeds are constantly being disseminated by some irregular means. The genus *Eucalyptus* has no special provision for the dispersal of its seed, yet its species always occurs in suitable habitats, no matter how remote. A striking example of this is the occurrence of *E. Behriana,* a mallee, in the isolated low rainfall area immediately to the north of Bacchus Marsh. Dispersal, then, is a problem connected with the plant itself, and through this dispersal each species is constantly finding those conditions which suit it.

(a) Fire.

In comparing comparable areas, one is struck by the fact that like areas are inhabited by like trees. The same fact may be stated by saying that similar habitats are occupied by similar associations. It is true that some trees, as, for instance, *E. globulus,* do not seem to follow any law as regards distribution, and the same applies to the snow gum, *E. coriacea.* These species appear at unexpected places. The latter has the capacity to withstand the cold and depth of winter snows at a little below 6000 ft. elevation and is the only tree species that can. We find this species, however, on the undulating Silurian country at Yering and on the Tertiary formation at Dandenong, only a little above sea level. It occurs on the dry Silurian shales at Eltham, but it does not occur on the mountains to the north-east about Healesville. Very similar is the distribution of *E. globulus.* It occurs on the cool seaward face of the cliffs at Kalimna and comes down almost to the edge of the water. It is found on the dry northern slopes of the granite hills at Trawool, and, as a striking contrast to this, it occurs abundantly in the Otway Forest. These habitats do not appear to be related in any way. Such examples of distribution are unexplainable except on the assumption that these species are not specialized as regards habitat and will develop anywhere provided they are not crowded out by the local vegetation. Each of the areas where these two species are found, apart from the alpine home of *E. coriacea,* are typically habitats of other species or groups of species. The distribution of species of *Eucalyptus,* then, as well as species of other genera, shows that they occur in very definite areas and that the trees are in equilibrium with their environment. In other words, a climax condition exists, and therefore it follows that these areas have not been recently, or comparatively recently, subject to disturbing influences. Yet it is held by many, who have only a superficial knowledge, that fire has been an active agent in distribution and that the present associations are in a large measure the result of fire. If fire had been as intensive in its destructive power in the past as it has been since the advent of the white man we would surely find evidence of active succession, or at least a greater number of those curiosities of distribution that have just been discussed. But this is not so. It is maintained by supporters of the fire theory that evidence of adaptation is to be found in the protective defence of the rough, thick bark of the various eucalypts. Unfortunately for this theory, the thickest and most protective barks, e.g., *E. sideroxylon,* occur in areas where fires are infrequent and of no consequence. The thick-barked species are abundant in the lower rainfall areas. On the other hand, *E. regnans,* which occurs where fires are fiercest, has no protection as a young tree and only limited protection when old. In the areas with rainfall above 40 inches the forests are densest and the undergrowth greatest, and there is abundant material for fires. In the gullies of these heavy rainfall areas the vegetation may consist of several stories. With the exception of the tree ferns, none of the plants of these gullies is particularly adapted to resist fire. This is evidenced by the complete destruction that occurs (Plate XIX.B) when the fire is intensive. The amount of devastation and the intensity of the fire are closely related, and although it may be considered that this is axiomatic, yet the truth of it is frequently lost sight of.

In the secluded gullies where the several stories exist, the presence of large trees of such a sensitive species as *Nothofagus Cunninghamii* is surely evidence of the absence of fires over long periods of time. The large root burls of the musk tree, *Olearia argophylla*, are indicative of extreme age. These burls are only found on very old trees. The common dogbush, *Cassinia aculeata*, is most frequently seen as a shrub, but in gullies where fire has been absent since the advent of the white man it may be found as a small tree, and even colonies of it are to be seen. All of these trees are readily destroyed by fire and their presence as large trees is evidence that fire has been absent. In the forest itself, away from the gullies, the occurrence of those huge giants of trees, as King Edward near the Cumberland, which was 88 ft. in girth six feet from the ground, Uncle Sam on the Black Spur, and many other famous trees of similar size both in this area, in the Dandenongs, South Gippsland and the Otway, is evidence of long continued immunity from fire. These trees have now all been destroyed and none remains, and this destruction has been wrought in the few short years of white settlement. Most old trees have hollow trunks, and this increases their possibility of destruction by fire. The age of these giants cannot be accurately determined, as the rings are so narrow and ill-defined. How slow growth may be is evidenced by King William Pine of Tasmania, *Athrotaxis selaginoides*. Rings in this species may be only four cells wide, and 50 rings to the inch is not an uncommon occurrence. In the case of *E. regnans*, both height and diameter growth are exceedingly fast in its early life (22). The rate of growth rapidly falls and at 80 to 100 years of age the rings of growth are no longer distinguishable. At a century old, in ordinary circumstances, the rate of growth is about 20 rings to the inch, and this rate steadily falls. The foliage on the old trees is not dense, and this is one of the causes of slow growth. From a study of the size of these trees and the decreasing rate of growth, it has been calculated that these big trees were the world's oldest living specimens. They were undoubtedly several thousand years old. Owing to their sensitivity, it is impossible to believe that these trees have endured centuries of fire. Since the advent of the white man, firing of the forest has shown that ultimately the forest area will be reduced to bracken fern. There is a retrogressive succession. The change may be rapid or it may be slow, and in the succession other plants, as *Cassinia aculeata*, may obtrude themselves; but ultimately the end point is the same, bracken fern. This plant exists spasmodically in the forest area. It cannot succeed where forests occur since it is strongly light-demanding. Its rhizome is unaffected by fire and in the re-growth after the fire the bracken fern rapidly makes its appearance. Its subsequent growth is largely a matter of how much of the crown canopy of the forest has been destroyed. Repeated firings open up the crown canopy more and more (Plate XX.A), thus giving the fern the necessary light. The large stores of food material in the rhizome give the bracken a great advantage over plants which have to arise from seed. The latter are ultimately choked out when bracken is dense. When the white man first arrived the wide areas of bracken now seen did not exist, nor were there extensive areas of dead timber (Plate XIX.B). Fire is steadily changing the face of the forested areas.

(b) Virility.

The outstanding feature of the Victorian forests is the almost universal dominance of the genus *Eucalyptus,* particularly where conditions of growth are favourable. This dominance is exemplified in two ways, first, by the large number of species present, and, secondly, by the large numbers of individuals. The genus *Acacia* parallels *Eucalyptus* in the number of species, but only a comparatively few are trees and even these do not occur in large masses. The myall, *A. homalophylla,* is a tree in the Mallee, but this species of acacia is only spasmodic in its occurrence. The genera *Casuarina* and *Callitris,* both with winged seeds, are distributed all over Australia, but neither of these rivals *Eucalyptus* in species or in numbers of individuals. Both are comparable with *Eucalyptus* in the fact that both may form pure colonies to the exclusion of all other genera. Thus both *Casuarina stricta* and *C. Luehmannii* form pure forests in the grassland area and *Callitris glauca* in the north and north-west also forms forests to the complete exclusion of any species of *Eucalyptus.* At Beechworth (Plate XX.B), *Callitris calcarata* grows associated with several species of *Eucalyptus.* This latter condition is, however, rare. *Casuarina suberosa* is associated with many species of *Eucalyptus,* but is usually sparsely distributed and rarely in any quantity as in the Orbost area.

This virility has enabled it to colonize wide areas. As a colonizer it stands alone. It is probable that this power of exclusively inhabiting wide tracts of country is associated with its capacity to produce new species. The genus *Eucalyptus* is extraordinarily variable and this finds expression in the confused nomenclature of to-day.

(c) Age and Area.

Willis (3) in his Age and Area Hypothesis states that the area covered by any species is indicative of its age. This is undoubtedly true in general, but there are many obstacles in its application to any particular species or group of species. Willis himself recognizes that there are physical barriers in the path of a spread of a species from its point of origin, but there are, in addition to these recognized barriers, ecological barriers as well. The Age and Area Hypothesis implies rather a passive dispersal of species, but that is not the case. Thus *E. gigantea* is limited in its distribution by an insufficiency of elevated areas. There is no physical barrier to its spread, but there is an ecological one. Again, *E. regnans* is comparatively restricted in its range owing to the fact that its distribution is controlled mainly by two factors, chemical composition of the rocks and high rainfall. It is only where both these factors are favourable that *E. regnans* is found. The Mallee vegetation is prevented from travelling south-east because conditions are wetter and cooler. The tropical species of East Gippsland do not come further west as the climate is colder. In none of these cases is there a physical barrier such as seas or mountain ranges impeding the spread of a species, but there are variations in the environment. The theory really fails to take account of such cases.

There are, however, cases in the State which do appear to come within the sphere of this hypothesis. In the south-west *E. diversiflora* has come east as far as Portland. There does not appear to be any ecological or physical barrier to its progress further east. Its present limits, then, may be regarded as due to insufficiency of time.

In the Grampians there is the very limited distribution of *E. alpina,* whose origin Maiden has discussed (23). There is no doubt that it is a derivative of the stringybarks, probably *E. capitellata.* Its very restricted range on the mountain peaks would suggest that its development has been very recent. Its birth may not be an expression of adaptation to its particular environment, which cases are contested by Willis, but its spread has certainly been prevented by lack of similar environments elsewhere. This species may, indeed, be very old. It may be neither a relict nor a newly-born species. It stands in a class by itself.

Other isolated species or varieties are the so-called *E. Cambagei* on Mt. Buffalo, *E. stricta* on Mt. Wellington, and *E. neglecta* at Omeo. There is, of course, the difficulty of deciding what constitutes a species. Many modern-day botanists seek every excuse to create new species and therefore it is often futile to discuss problems of distribution. *E. Cambagei* is not entitled to specific rank. It is undoubtedly a localized variation of *E. stellulata.* It has had its birth here and has not spread even yet across the Buffalo. This form is undoubtedly a case where its limited range is indicative of its age. There does not appear to be any reason at all why this form should not spread wherever its two associates, *E. coriacea* and *E. rubida,* occur together. The same may be said of the so-called *E. stricta* on Mt. Wellington. This is not deserving of specific rank. It is, however, a distinct variety of *E. coriacea,* very localized. It has all the appearance of a newly-formed variety which has not yet had time to spread. Here, again, there does not appear to be any barrier, ecological or physical, to its further distribution.

Trees as well as other plants differ widely in their relation to their environment. It has already been pointed out that some species may be described as ecological wides since they are able to grow in a wide variety of habitats. Others, however, are restricted owing to their relationship to their environment being much more intimate. Hence no mathematical law of mechanical distribution could hold even when the species are very closely related, as *E. regnans* and *E. amygdalina*. The former is restricted by very definite ecological barriers, but the latter is very distributed and independent to a large extent of the environment.

Conclusion.

Of the three group factors discussed, the first two are the most important, namely, Climate and Geology. It may be said in general that these two are equally concerned in the distribution of trees. It is true that as we pass from high to low rainfall the height of the trees steadily diminishes, but that is only in general. Geological factors are so widespread that the effect of climate is being constantly modified, even almost obliterated. Thus in the highest rainfall areas of the State may be found trees which are typical of low rainfall. Climate, then, as a guide towards the distribution of trees is almost useless. Where these two factors are most favourable there are found the finest forests we possess. But the most favourable conditions of these two are not usually found together, and there result, at times, areas which are devoid of forest cover. The clear definition of the conditions of the environment here demand careful investigation so that trees may be introduced which will add materially to our wealth.

Public interest lies naturally in the use of land either for agriculture or for forestry. These two are complementary, not antagonistic. They provide for the most economical use of all the land in the State. Very little may be regarded as useless, that is, outside the realm of either of these two activities. Our waste land lies mostly in the north-west of the State where the rainfall is low. Both forestry and agriculture minister to the needs of the community, and as agriculture involves close attention to the soil, only the better soils are used for that purpose. Forestry has to be content with inferior soil conditions or with land that cannot successfully be utilized for agriculture. It has already been mentioned that the Otway and South Gippsland areas are, in so far as soil is concerned, really agricultural, but owing to the quantity and quality of the timber produced they are, from an economic point of view, better considered as forest lands. Areas with a rainfall below 30 inches may be said generally to be claimed by agriculture, but it is in this region that the very valuable forests of *E. sideroxylon* occur. Between 30 and 40 inches of rainfall, the soil is the determining factor in the use of the land. Above 40 inches, forestry in its wide application has undoubtedly first call. Forestry ultimately must be made to include the protection of all the catchment areas as well as the production of timber. The protection of the great gathering grounds of our irrigation systems is as vital, ultimately, to agriculture as the cultivation of the land itself. These gathering grounds are the homes of several species whose protection from fire is vitally necessary. Within the 40 inch isohyet there are two outstanding conceptions of forestry, water conservation and timber production. These two are in part interlocked, but not wholly so. The application of true forestry practice to forests of *E. gigantea* is at once doing everything for water catchment as for timber production. Practice, however, can only be applied successfully if the environment of the species concerned be thoroughly understood. All practice must have reference to the habits of the tree or trees concerned and their reaction to those habitats. Above the forests of *E. gigantea*, *E. coriacea* is mainly found. It is in places freely interspersed with *E. rubida*, but ultimately only *E. coriacea* remains. These forests, if indeed the ultimate scrub form of this species may be so designated, are of value only in retarding the melting of the snow. These have, strange to say, been severely damaged by fire. This may be seen on many of the alpine peaks. Above this belt of trees are bare areas so far as trees or scrub are concerned.

The area of the State having a rainfall of 40 inches or over amounts only to 14 per cent. of the total area. Only a fraction of this 14 per cent. is carrying trees of economic value. It is this area in particular where a complete knowledge of the habitat is so important to the welfare of the State. As has been remarked before, the geological factors exercise an enormous modifying influence on the climatic factors, and much of this 14 per cent. is at present waste. It is only by a full knowledge of the laws of tree distribution that this area, which is our most important for both water catchment and forestry, can be made more valuable and minister more fully to the needs of the community.

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