PRINCIPLES OF PRIMARY FOREST ECOLOGICAL SURVEY:

THEIR APPLICATION TO THE FORESTS OF OTAGO AND SOUTHLAND.

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The inception of extensive resurvey of the remaining indigenous forests of New Zealand has required a fresh evaluation of the principles upon which such work should be carried out and consideration of primary objectives. Such an evaluation is necessary both to permit intelligent direction of the work and to suggest profitable lines of enquiry. In this article the general principles upon which primary forest ecological survey should be based will first be discussed and, to serve as illustration, these principles will then be applied in considering the composition, distribution and the silvicultural potentialities of the forests of Otago and Southland.

I.—The Immediate Objectives of Ecological Work in the Indigenous Forests of New Zealand.

The modern conception of plant ecology is not that it is a specialized independent branch of botanical science, but that it is an applied science (and in part at least an art) effecting "a synthesis of the special knowledge obtained by the study of particular departments of botany in relation to the life of plants in their natural habitats."* Such a synthesis must be concerned primarily with the inter-relationships of observed phenomena and with the elucidation of causes and effects; and, since ecology is not fundamentally a science in its own right but an applied science, the application should be made with a definite end in view. This purpose can only be the wise use of the vegetation of the earth. This definition of the subject does not mean that the more abstruse ecological phenomena need not be studied, but serves primarily to focus attention upon problems of more urgent importance.

Forest ecology is then an applied science, effecting a synthesis of all sciences concerned in the study and practice of forestry. Its objective must be the interpretation and co-ordination of the data amassed by its component studies and its results must be presented in such a way as to permit the wisest possible use of all forest resources. To produce results of value this objective must be kept steadily in view in the study of forest ecology in the field.

A further function of the study of ecology is concerned with the education of forest officers. The broad principles of the subject with continuous stress on causes and effects and upon purpose may be

* Tansley, A. G. Introduction to Plant Ecology. George Allen & Unwin Ltd. 1946. pp. 17-18.

taught readily, and inculcate a sustained interest in related botanical and other forest sciences in a way not otherwise possible. Forest education should proceed from the elementary principles of forest ecology to the detailed study of forest arts and sciences returning to their re-integration in the broad fields of ecology and silvicultural practice.

In view, therefore, of the paucity of forest ecological literature in New Zealand, the results of ecological studies should be presented not only, as has already been stated, in such a way as to permit the wisest possible use of forest resources, but also in a way that they may be of value in the educational field. The first objective in New Zealand forest ecology must be to increase the number of competent observers and to ensure the wider diffusion of ecological habits of thought. So comprehensive is the subject and so limited our present knowledge that major advances must be the result of teamwork. Individual workers fall too easily between the stools of over specialization in detail and vague and valueless generalizations.

All ecological work can be classified under the two headings, extensive and intensive study. Such studies are complementary. Extensive studies indicate the extent and nature of the problems with which we are confronted. Intensive studies seek to resolve these problems into units and to solve them by detailed investigation. Extensive study or primary survey should always precede the inception of local intensive work since otherwise the true nature of the local problem may not be realized, with consequent invalidation of results. This is not to say that inception of intensive work must await the completion of primary survey, but its limitations in the absence of sound primary survey must be recognized. The piecemeal attack by way of a host of unrelated local investigations supported, as is often the case, by masses of statistical results of dubious value must fail to achieve the over-all objective.

Similarly a primary survey ending in the formulation of hypotheses fails if these hypotheses are not fruitful of detailed research and provocative of further advance. The primary survey is not an end in itself except in so far as it maps and records the distribution of the forest types. It should indicate the nature and inter-relationships of the various types of forest in such a way as to provide a starting point for the inception of more detailed study. The *magnum opus* of New Zealand ecological literature fails at this point. In Cockayne's *Vegetation of New Zealand* the comprehensive account of the various types of indigenous forest and the general account of their distribution concludes with vague theory concerning the origin of the vegetation in the remote past. It offers few ideas for proof or disproof. Further, and through no fault of Cockayne's, the work has been accepted as final and complete; that is to say, the primary survey has been considered an end in itself with consequent stultification of further advance. It should have been regarded solely as a starting point. The same argument applies to Cockayne's monograph on the *Notho-*

fagus forests. This also is no more than a primary survey and as such is of considerable value. But its full value cannot be realised unless and until it is followed by detailed local investigations.

There is no need to cite examples of intensive studies made individually without reference to their position in the theoretical framework of the subject: there are too many such in literature. Their only value depends upon the extent to which the observed facts recorded therein can be separated from the ground work of invalid hypotheses and fictitious conclusions. A jaundiced view would be that the greater the mass of detail (particularly numerical) given, the less valid the results, since in such cases the less time must have been devoted to primary survey with greater probability that the basic assumptions were unsound.

All published work on New Zealand forest ecology does not, of course, fall into these errors. But at this date we face considerable difficulty in separating the good from the bad. In effect we must begin again at the beginning with a primary survey covering the whole field assisted by such items of fact as are recorded in the literature. The framework of this primary survey is being and will be provided by the field work of the National Forest Survey. The work of the Forest Survey provides an unequalled opportunity for a detailed and comprehensive study of the various types of forest now in existence, and of their distribution. In addition, the use of air photographs permits a rapid visualization of distributional patterns in a manner formerly impossible. It is now possible to see the whole of a forest area as a unit instead of seeing random items along a line of march.

On the basis of fact as recorded in the air photographs and as detailed in the Forest Survey records, working hypotheses and theories must be developed. These theories again are not an end in themselves. They serve to weld the mass of fact into a coherent body of knowledge and to act as concentration points from which to launch a fresh attack. Theories and hypotheses so propounded must therefore be both stimulating and provocative, while at the same time being suggestive of improved methods of control and use of the forest resources. One source of error must here be guarded against. For the sake of mutual understanding the terminology of the subject as developed overseas must be used. But all care must be taken at all times to avoid distortion of the facts to fit the terms. The terms are servants of the facts not the facts of the terms. New Zealand forest phenomena might not be translatable into the current language of ecologists. Let the interpreter beware !

The hypotheses we need must cover the inter-relationships of the two major forest formations, the *Nothofagus* forests and the podocarp-hardwood forests. They must distinguish between the various forest associations making up each formation, determining the history and relative stability of each. So long as we regard all *Nothofagus* forests or all podocarp-hardwood forests as identical or even as comparable,

no advance in our knowledge of them, and therefore in our management of them, will be possible. As shown for the *Nothofagus menziesii* forests of the Longwood Range,* even an apparently uniform forest characterized by a single dominant may be, in fact, a complex of many distinct consociations, varying in history, in timber qualities and volumes, in the mechanisms of regeneration and in stability in the face of exotic animals.

It would be absurd to expect observations made in the podocarp-hardwood forests of North Auckland to hold true for the podocarp-hardwood forests of Southland. It would be equally absurd to devise silvicultural methods to ensure regeneration in silver beech forests of the Tongariro National Park area and expect to apply these methods with success to Southland silver beech forests marginal to the central grassland climates. But errors of this type are frequently made. Only by careful examination and by detailed comparison assisted by theory can the degrees of equivalence of the different associations be determined.

Systematic intensive studies must await the formulation of basic theory. All intensive work done prior to this partakes more or less of the nature of a lucky dip and results will have a local application only. Some such work must be done where local areas of indigenous forests have been put under management, but to carry out such experiments before we understand the nature of the problems to be faced, and before we appreciate the true ecological status of the forest associations experimented with, would be at best an interesting academic exercise.

II.—The Distribution Pattern of the Forests of Otago and Southland.

In current literature forest distribution has been described largely on a factual basis. Few attempts have been made to treat these facts as inter-related phenomena capable of being welded together into a comprehensive and explanatory framework. The absence of such an exposition is brought forcibly to mind in the preparation of necessarily brief lecture notes on forest ecology and forest distribution for junior forest trainees. The only alternative is to present a series of unco-ordinated statements, mentally indigestible and incapable of stimulating interest. At the same time the lack of co-ordination prohibits any attempt at analysis of the distributional pattern and therefore any advance in our understanding of it.

In the state of our present knowledge it would be most difficult to present such an account for the whole country, but it is possible to do so for definite regions. Any such presentation should explain all the known facts of distribution, violating none, and, equally important, it should be suggestive of further lines of enquiry. The success of the presentation might be judged on the volume of argument

* Holloway, J. T. Forest Associations of the Longwood Range, Southland. *N.Z. Journal of Forestry*, Vol. V, No. 3, 1946, pp. 199-209.

it arouses, since only by exacting debate can the special knowledge of individual observers be incorporated into, or serve to modify, the framework.

For the region of Otago and Southland, the forest distributional pattern seems to be fundamentally regular and uninvolved. There is little if any need to invoke the aid of hypotheses concerning past history. The broad outlines can be satisfactorily explained and expounded on the basis of present climatic conditions.

We might imagine Otago and Southland as being the squared southern end of a north-south oblong. This square region is exposed to rain-bearing winds from the west, south and east, the north central "core" being therefore comparatively dry. From the coasts inland there is a steady diminution in annual rainfall accompanied, as distance from the sea increases by increasing seasonal climatic differentiation with progressively colder winters and hotter summers. The overall climatic regime varies therefore from coastal regions with temperate oceanic climates to inland regions where the climate approaches the sub-continental. The climax forest of the coastal "temperate oceanic" climatic regions is podocarp-hardwood forest, the distribution of the various associations making up the formation being dependent upon minor variations in local climatic and other site factors. The characteristic climatic features of these regions are the cool summers and mild winters, the well distributed rainfall, and the consistently high humidity. Inland, with decreasing and more irregular rainfall, with colder winters and hotter summers, the climax podocarp formation is replaced by climax "sub-continental" *Nothofagus* forest. Inland again towards the north-central core this *Nothofagus* formation is succeeded by the more xerophytic *Leptospermum* scrubland and tussock grassland formations.

This simple pattern of coastal podocarp forests bounded inland by *Nothofagus* forests enclosing a central grassland and scrubland region is interrupted by diversity of land form. The presence of high mountain ranges destroys the symmetry of the pattern and superimposes a third forest formation. This is the "mountain climate" *Nothofagus* formation. Though composed of the same species of *Nothofagus* as the sub-continental *Nothofagus* formation, the relative proportions of the species present and the composition of the subordinate vegetation differ markedly. Thus the coastal regions of the west are extremely mountainous with consequent wide development of mountain climates. Wherever these cold winter, cool short summer climates occur near the coasts, the coastal podocarp forests are replaced by "mountain climate" *Nothofagus* forests, leaving isolated pockets of podocarp forest in the more sheltered valleys and other lowlands.

In the same way along Foveaux Strait, wherever the mountains run seaward, as in the Longwood Range or to a lesser extent in the Catlins river basin, the mountain climate *Nothofagus* forests approach or reach the coast.

The mountain climate *Nothofagus* forests of the west coast merge imperceptibly into the sub-continental *Nothofagus* forests on the east side of the divide. The complete transition from the one formation to the other can be traced along the line of such valleys as the Eglinton which lie across the main highland area.

Along the south and east coasts the coastal climate podocarp forests originally continued unbroken, except where wide swamps and peat bogs existed, from Preservation Inlet to north of Hampden. This coastal belt narrowed rapidly in breadth towards the north consequent on the eastward displacement of the grassland "core" by "rain shadow" conditions in the lee of the main divide. The grasslands reached the coast along the North Otago littoral, though pockets of forest must have existed in sheltered situations. Stewart Island lies wholly within the coastal climate zone there being consequently no representation of *Nothofagus* species. If such are yet to be found on the island they will be on the steeper north-western slopes of the Mt. Anglem Range, an area not yet thoroughly explored.

The inland sub-continental *Nothofagus* forests to the south and east are discontinuous in distribution and are found as islands around the grasslands periphery from the Takitimu Mountains in the south-west to the Horse Range in the north-east. The discontinuity is caused in part at least by topographic factors. Thus the forests are seldom developed on the recent alluviums of the wider river valleys, and local exposure to the dry N.W. winds prevents their development elsewhere. At the same time, however, there is much evidence pointing to their original wider extent. Lying adjacent to inflammable tussock grasslands and subject to periodic strong dry winds, the region has a fire history dating to pre-European times. Recovery of the ground so lost is not made rapidly and may be altogether prevented by recurrent fire, or, in more recent times, by grazing.

Mixed podocarp-*Nothofagus* forests exist wherever podocarp climax forests abut upon one or other of the *Nothofagus* formations. This is the case particularly in the Longwood Range, in the Catlins river basin and in the area west of the Waiau River. Close examination of many such areas may show, however, that a true mixture does not exist, but that the forest is a patchwork of both types dependent in distribution upon local site factors. In such tension belt areas apparent anomalies are frequent. In some instances local departures from normal are occasioned by the facility with which *Nothofagus* species (particularlr *N. menziesii* and *N. cliffortioides*) can act as pioneers. In other cases the distributional variations are the result of incomplete adjustment of the forest to climate changes. Again in many areas chance stands or even single trees of one formation may be found within an area now wholly occupied by another. For example, within the podocarp forests of the Dunedin District occasional trees of *N. menziesii* may be found. Or in the *Nothofagus* forest in the Waikaia Valley a few *Podocarpus ferrugineus* and *Podocarpus dacrydioides* have been reported. In the gorge of the

Rockburn Valley, Lake Wakatipu District, a few *Weinmannia* exist separated from the nearest podocarp forest by high mountain ranges. Such stands or single trees must be regarded as chance survivors from the past or, in the case of some podocarp species, chance establishments by bird-carried seed.

It is not yet possible to analyse the local variations in site conditions which give rise to the individual associations making up the podocarp-hardwood formation. For Otago and Southland such a study is rendered difficult by the great reduction in area of podocarp forests by land clearing operations. But it is only by learning to differentiate and distinguish between these interlocking associations that any area could be confidently selected for permanent management.

In the case of the two *Nothofagus* formations, it is possible to be more definite. To recapitulate the climatic differences between them: sub-continental *Nothofagus* forest climate is characterized by irregular rainfall, susceptibility to periodic drought, variable humidity, cold winters with heavy frosts or snow, and hot dry summers. Mountain climate *Nothofagus* forest areas have cool, short summers and cold, wet winters. Frosts may be heavy. Snowfall varies greatly from year to year, but at higher altitudes is usually considerable. Humidity is high and rainfall heavy, being well distributed throughout the year.

Nothofagus menziesii is the characteristic species of the mountain climate forests. It attains its maximum growth in size in such forests, particularly where the climate is marginal to that of the podocarp forest or where it is temporarily occupying podocarp forest sites. Increasing altitude rapidly reduces its value as a timber tree, but in all cool short summer and very wet areas it reaches the timber line. Minor variations in site conditions have a pronounced effect upon its form and quality, and upon its ability to regenerate satisfactorily after exploitation. The mountain climate *Nothofagus* forests of the Catlins river basin and of the Longwood Range are wholly composed of this species, but elsewhere, especially in localities subject to heavy winter frosts with slightly decreased rainfall or on steeper drier slopes, *N. cliffortioides* may replace it. *N. fusca* is not usually represented, though it may occur on isolated sites especially suited to it.

In general, in Otago and Southland, *N. fusca* is a tree of *Nothofagus* forests which are intermediate in character between the sub-continental and the mountain climate formations. It is much more exacting in its requirements and is therefore more restricted in its distribution. Annual rainfall must be fairly high and distribution regular; the soil must be well drained and the summer not too cold. These conditions are best achieved in the mountain valleys to the east of the main divide where *N. fusca* consociations may occupy the lower valley slopes. Elsewhere it occurs where sub-continental areas

are modified by local factors. Thus in the Waikaia Valley *N. fusca* is widely developed, the sub-continental character of the region being modified by its exposure to the south-west rains.

N. cliffortioides is most widely distributed in the sub-continental forests, where it may form a simple consociation. Especially is this the case around the drier grasslands periphery to the east of the main divide and at higher altitudes. On such sites it is normally a small tree of little or no timber value. But wherever a suitable combination of site factors results in its occupying lowland stations it may grow to a large size with excellent bole form. For example in the Lillburn Valley, Lake Hauroko District, it is found either as pure consociations or in simple association with *N. menziesii*. The climate here is markedly sub-continental in character lying in the rain shadow of the Crown Princess and Hump Ranges. Local distribution of sites between the two species present depends largely upon aspect and drainage. Thus *N. menziesii* is dominant on the wetter ground and on slopes with south or east aspect, *N. cliffortioides* on drier sites lying to the sun. But in this area there is every indication that *N. cliffortioides* is extending its range at the expense of *N. menziesii*, and that under existing climatic conditions it will replace the latter on many sites.

In the selection of areas to place under management for permanent yield of *N. menziesii* timber several difficulties must be faced. Satisfactory natural regeneration after logging is best assured on the drier side of the species climatic range ; that is to say where it occurs as a constituent of the sub-continental *Nothofagus* forest. But in such forests it suffers in competition with *N. cliffortioides* which shows a faster growth rate and will suppress it. In the mountain climate *Nothofagus* forests of the lowlands where *N. menziesii* has the largest volume per tree and optimum growth rate, natural regeneration is difficult in face of severe competition with heavy fern and other secondary species. Optimum conditions for this species from a management point of view are found in areas marginal between the two major formations—on the drier slopes and soils of the mountain climate forests and on the wetter slopes and soils of the sub-continental climate forests, in the latter case preferably in the fortuitous absence of *N. cliffortioides*. Woodlaw State Forest fulfills these conditions. On the direst north and west slopes *N. menziesii* does not reach merchantable form or dimensions in so far as mill log requirements are concerned. On south and east slopes conditions are good for growth rate, size and form at maturity, and ease of securing regeneration. On the colder and wetter flats at both lower and higher altitudes, maximum volumes per tree are found with, probably, maximum growth rates on the lower flats, but regeneration is difficult to secure in satisfactory amount and quality.

Further suitable areas are to be found in the Lillburn Valley but, as already stated, the problem is here complicated by the aggressive character of *N. cliffortioides*. In mixed pole stands following

fire here *N. cliffortioides* is definitely assuming dominance owing both to its faster growth rate and to the fact that at maturity it is here frequently the taller tree.

Management of the forests of the Lillburn District is contingent upon the development of suitable conversion and utilisation techniques for *N. cliffortioides*. The selection of areas through the Lake country along the eastern slopes of the main ranges is made difficult by problems of market accessibility and broken terrain. In the Waikaia Valley, where climatic conditions are suitable, *N. cliffortioides* and *N. fusca* have pre-empted the sites most suited to *N. menziesii* as a timber producing tree.

It might be mentioned here that, despite previous doubts, there is no evidence of the existence of either *N. truncata* or *N. solandri* in Otago and Southland. Some of the hybrid forms *N. fusca* x *clif--ortioides* simulate these species but can always be recognised as hybrids. In a few localities in which *N. fusca* as a pure species is now absent *N. cliffusca* hybrids demonstrate its one time presence. Reports of the occurrence of *N. solandri* have largely arisen through confusion with the abnormally large lowland type *N. cliffortioides* found in the Waiau Valley, where it is growing in its optimum environment. At the same time this species seems to be a compound one including several or many distinct varieties, or perhaps true breeding sub-species.

The distribution of exotic forests throughout the region would appear to show greater success in establishment in climatic localities intermediate in character between the coastal podocarp forest climates and the sub-continental *Nothofagus* forest climates. This distribution while in some respects coincidental, has been largely the result of deliberate choice both of tree species and of site influenced by avoidance of the central grass and scrub-land "core" and by popular prohibition of the use of coastal climatic areas which have been required for pastoral purposes. The Dunedin City Corporation plantations and the State forests at Dusky, Heriot and Conical Hills occupy such stations, while the new afforestation areas at Milton, Taieri Mouth and Hampden follow suit. Pebbly Hills lies close to this climatic zone and the new Otautau areas are adjacent to mixed podocarp-mountain climate *Nothofagus* forest, and to the sub-continental type Woodlaw Forest. Extension of the exotic afforestation areas into the coastal podocarp zone would automatically demand the use of more shade tolerant and moisture demanding species. Extension inland into the grassland core, that is to say outside the true forest climates, is forbidden by the counsels of sound forest practice.

This account of the forest distribution of Otago and Southland is far from complete. Many details will be required to be filled in and much more evidence adduced in support of some statements made. The overall picture here presented is, however, proving of considerable value in the interpretation of field observations to date, and is submitted in the hope that it may prove of more general interest.

Further work may, of course, necessitate abandonment or modification of the hypotheses outlined. This in itself is of no great importance so long as these hypotheses serve their purpose in the correlation of field data, and in the indication of fresh avenues of investigation and research. The immediate purpose of this account is to serve as an illustration of the methods of approach to the field study of forest ecology as outlined in the opening paragraphs, and to stress the potential value of theoretical ecology, a value which has been partly lost sight in a maze of unco-ordinated investigations dealing with local and often petty detail.

Summary.

The general principles upon which forest ecological survey should be based are stated, emphasizing the necessity for sound primary survey before commencing detailed intensive work. On the basis of the facts adduced, theories and hypotheses may be propounded and used to permit intelligent direction of later investigations.

Illustrating the application of these considerations, the distribution of the forests of Otago and Southland is discussed. Three main forest formations are recognised :

(1) Podocarp-hardwood forests of coastal regions with temperate oceanic climates.

(2) *Nothofagus* forests of inland regions with sub-continental climates.

(3) *Nothofagus* forests of regions with mountain climates.

The specific differences and silvicultural characteristics of the two *Nothofagus* formations are briefly analysed.