A STUDY of PRINCIPLES and METHODS of PASTURE IMPROVEMENT on NEW ZEALAND HILL LAND, with PARTICULAR REFERENCE to the EFFECTS OF THE CLIMATIC, BIOTIC, and ANTHROPOGENIC INFLUENCES upon the SWARD.

by

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PROLOGUE.

It is interesting to speculate upon what would have been the relative states of advancement of hill and low ground agricultural research and farming techniques had Jethro Tull been born of hill farming stock. Probably conditions would not have been much different; for hill farming has had its "improvers", too, in men such as Sir John Sinclair.

The cause of the undeniable neglect of hill land research is more likely to be found in economic reasons than in any lack of desire to improve this class of land. From the time when products of British hill farming came into competition with overseas produce, through international trade, this industry has been subject to all the vicissitudes of economic marginality. Research has, quite naturally, been devoted to that class of land which is further removed from the uncertainty inherent in this economic phenomenon - the more fertile low ground - because the hill farmer had less certainty that any capital he might invest in improvement would ever be repaid.

Again, remoteness and inaccessibility have added to the cost of any improvements, and have contributed to marginality by increasing the cost of the produce in the urban market, added to which the psychological effect of this remoteness made the hill land seem less important.

In Britain the effect of rising populations, both at home and overseas, rising standards of living and concomitant increased demand for food in countries which were formerly large exporters of primary produce, and strategic necessity have all emphasised the need to improve the productivity of this class of land. Under the Hill Farming Act of 1946 the British Government has made available something over £20,000,000 to reimburse hill and marginal farmers to the extent of 50% of the cost of any comprehensive improvements they may make, in order to get the industry functioning healthily again. It is further hoped that the operation of marketing schemes for such commodities as wool, and guaranteed prices for both meat

and wool will give to the industry a measure of economic stability which it has not previously known. But a stable economic skeleton can only become a healthy agricultural corpus if the flesh of sound practice, based on fundamental principles, is superimposed. It is this very technical knowledge which a neglect of hill land research has denied the industry at this crucial period of its development.

In New Zealand, for economic and other reasons, the fertility of hill land has likewise been "mined", and the effects of this are becoming increasingly apparent. As yet there has been no official attempt to subsidise a reversal of this detrimental process. On the other hand, since primary production is the basis of New Zealand's economy, and since hill country in New Zealand is relatively more important, both economically and from the point of view of area, than in Britain, the technical knowledge of improvement principles and methods is probably more advanced.

It seems important that there should be an exchange of administrative and technical ideas between two nations having the same problem in common. A programme of hill land improvement sufficiently comprehensive to rebuild a depleted national heritage is unlikely to be carried out without financial assistance and guidance from official sources. So far as the exchange of technical knowledge is concerned it is true that conditions are not directly comparable in the two environments, but biological principles are not inflexible, and agricultural techniques are limited in their adaptability only by the ingenuity and imagination of the husbandman.

At all events there is much scope, and an increasingly urgent need for agricultural research the world over to divert or extend its energies from the attempt to squeeze the last calorie from the fertile, and already highly productive low country, where even now practice lags behind technical knowledge, to the vast areas of undeveloped and underdeveloped land, including most hill land, where much larger increases in production may be obtained for an equivalent output of research

energy, and where technical knowledge frequently lags behind the desire and the economic capacity to improve agricultural practice. Such a change in the "operational area" of agricultural research would seem essential if the rapidly increasing world population is to be adequately fed.

A. INTRODUCTION.

This dissertation deals with principles rather than with practices. When trying to enfold a vast subject within limited bounds no detailed analysis of practices can be made, for these vary from farm to farm, almost from paddock to paddock, as the aspect, climate, soil type and terrain change. However, practices are based on principles which have much wider application and a cognizance of which is fundamental to the institution of any practice. The essential principles are those of raising fertility where necessary, of introducing species of grass and legume which can either utilise or enhance the increased fertility and themselves provide nutritious and palatable stock feed, and, finally, so to manage stock on these improved pastures that the improvement is consolidated and not dissipated.

Practice, however, is not ignored, but is used rather to demonstrate some of the means by which the ideals underlying the principles may be achieved.

Just as no attempt has been made to catalogue all possible practices so certain principles not strictly within the realm of plant husbandry have been omitted. The most important of these is the necessity for any farming operation to be carried out within a suitable economic context. Where the economic context is unfavourable, practices detrimental to the proper, conservative utilisation of land inevitably come into being, and the deterioration of hill swards thus brought about frequently culminates in erosion. When the economic state of the hill farming industry is favourable, however, deterioration and erosion are frequently the outcome of a failure to appreciate or put into practice the principles which are set out hereinafter.

Detrimental economic effects are, commonly, only temporary in nature, because the declining production of a depressed industry enhances the value of the products of that industry, and the economic pendulum swings back again from slump to prosperity. It is, however, also necessary for any

industry to be carried out within an adequate social context. Thus hill land deterioration may be, in part, due to a shortage of labour wherewith to carry out necessary maintenance work, or to apply in practice the principles of improvement. Unfortunately this problem, unlike the economic one, does not contain the germ of its own redress because the attractions of urban life cannot always be computed in terms of cash, and their renunciation so compensated for by higher wages. Moreover, this problem is only in part soluble by reducing labour requirements through the increased use of machinery, and these substitutes are of less value in hill land farming than in other forms of agriculture.

These, then, are two of the principles which are not subjected to comprehensive analysis, although certain economic aspects of more direct practical application are included for the sake of completeness.

Any adequate definition of the term 'hill land' as used in the title and context of this dissertation is well-nigh impossible, as is any delimitation of its boundaries. It may perhaps best be defined and delimited by reference to its chief characteristics. These are slope and/or relatively high elevation, which in turn impart specific climatic and soil conditions, producing a more rigorous environment for plants and animals than is found on low ground. Further, this land may be recognised by the nature of the industry which it supports. This industry is predominantly pastoral, but it differs from low ground pastoral farming in being relatively more extensive and less flexible, and in the limited opportunities for using the plough preparatory to pasture improvement.

The problem of hill sward improvement is largely one of applied ecology. It is one aspect of the problem of animal - pasture interaction under differing climatic and edaphic regimes, with man imposing his influence over all. It is mainly from this ecological standpoint that the subject is discussed and developed.

B. THE IMPORTANCE OF HILL LAND IN THE FARMING ECONOMY OF NEW ZEALAND.

At this stage some justification (more specific than that voiced in the prologue) for studying hill land improvement may be necessary. The question inevitably arises, - why be concerned about the improvement and management of the nation's hill land?

Given that the wealth of New Zealand depends on the production of primary goods, the more intensive is the use of the land the greater will be the national wealth.

In this connection the relative areas of hill country and flat or rolling country are important. Aitken (1950) puts the proportion of land under the 600 foot contour at less than one quarter of the land surface.

Of the 43.1 million acres of land under occupation in 1946-47, the apportionment of areas between hill and flat or undulating land was as follows (Farming in New Zealand, 1950):

Surface sown pasture (mainly on hilly or mountainous country)	...	11,000,000 acres
Tussock and other native grasses (mainly in South Island hill country)	...	13,900,000 acres
Total		24,900,000 acres

On this basis about 58% of the occupied land is pastoral hill country, and this takes no account of 4,700,000 acres of fern, scrub and secondary growth which covers much potentially productive hill land.

Belshaw (1936) observed that a large part of the 24 million acres of occupied but uncultivated land consisted of light hill country, well suited to extensive grazing.

From these estimates, something between 55% and 58% of the occupied land in New Zealand would seem to be pastoral hill country, and a further 10.9% - much of it hill country - is under fern, scrub and secondary growth.

From the point of view of area alone, the hill land

of New Zealand is seen to be important, but its importance in the economy of the nation is to be found in other reasons, the chief among which are the following.

I. As a Source of Store Stock and Fat Lambs.

The organisation of the low ground fattening farms of the nation depends upon a regular, annual supply of store lambs and cast-for-age ewes from the hills. Without this supply much of the fattening pasture on the lower country would require to be used for the maintenance of purely breeding flocks, with a concomitant decline in the number of sheep and lambs fattened.

The average number of fat lambs sent to the freezing works annually is between 11 and 12¼ million, representing about 175,000 tons of meat. In 1946 - 47 the export value of New Zealand mutton and lamb was £17,397,000, or over 17% of the entire national income. (Primary Production in New Zealand, 1948). The basis of this trade is the store lamb and the cast-for-age ewe from the hill country.

Smallfield (1947) estimates the number of replacement ewes which must be brought from the hill country into the fat lamb producing districts of the North Island as follows:-

Region	Estimated replacement ewes which must be acquired from other regions.
South Auckland	35,000
Waikato	300,000
Central Plateau	35,000
Taranaki	60,000
Manawatu	125,000
Total	555,000

This table does not show the replacements available locally from nearby hill country, nor are the number of replacements required in the South Island lamb fattening districts indicated. Now, according to Hamilton (1947) approximately 6,000,000 lambs pass through freezing works in the North Island each year. It would seem, therefore,

either that a large number of replacement ewes must be moved over short distances (from hill to fattening districts) within the regions set out above, that considerable numbers of store wether and cull ewe lambs are transferred from the hill country annually (for which no statistics are available), or that many easier hill country properties are able to fatten a considerable proportion of their own surplus lambs. This latter proposition is probably more true of North Island hill farms than of those in the South Island.

It seems impossible from the figures available to sort out the relative importance of each of these factors, but this in no way detracts from the role played by the hill country in supplying the major portion of the breeding and store stock from which more than 11,000,000 fat lambs are produced annually.

It has been suggested to the writer by Coop (1951) that this present dependence of the fat lamb and mutton industry upon store and breeding stock drawn from the hills may in the future be much less. The argument is that by pasture improvement, and by increasing lambing percentages through the application of better knowledge of the physiology of the reproductive processes, it will be possible so to increase the productivity of the low ground that much of the hill land may be allowed to go out of agricultural use, while at the same time allowing the national output of mutton and lamb to be maintained at the existing level.

The desire to improve low ground productivity is wholly admirable and may in some measure be achieved, but there seems no reason why such improvement should not lead to an increase in national earnings rather than to an abandonment of hill land - provided the hill land remains economically productive. The present high prices for the products of the sheep farming industry should provide an incentive for carrying out hill land improvement so that this class of land may be moved further from the position of economic marginality which has been one reason for its deterioration in the past.

II. As a Source of Wool.

In 1946 New Zealand exported 365 million lbs. of wool, having a value of £26.6 millions (N.Z.) and forming over 26% of the national income from all exports. In 1950, with wool prices considerably inflated, of a total Dominion income of £194,588,000, no less than £84,589,000, or 43%, came from the sale of wool (Meat and Wool, 1951). Again, apportionment of this sum between hills and low country is not practicable, but the proportion derived from the hill country is undoubtedly the major one.

Not only is the hill country important as a source of wool, it is important as the source of that high quality Merino and Half-bred wool which commands the highest prices. This may partially be demonstrated by quoting the price index of greasy wools sold in various districts in New Zealand. (Monthly Abstract of Statistics, 1950)

Base (100) = Average price in all districts combined for 1945-46.

District	1945-46	1946-47	1947-48	1948-49	1949-50
Auckland	96	113	148	154	244
Hawke's Bay	96	116	151	158	239
Wellington	97	114	154	153	228
Canterbury	110	151	230	240	325
Otago and Southland	102	130	190	186	277
New Zealand	100	124	174	177	260

This reflects the sustained heavier demand, and consequently greater price, for the finer quality wools of Canterbury and Otago.

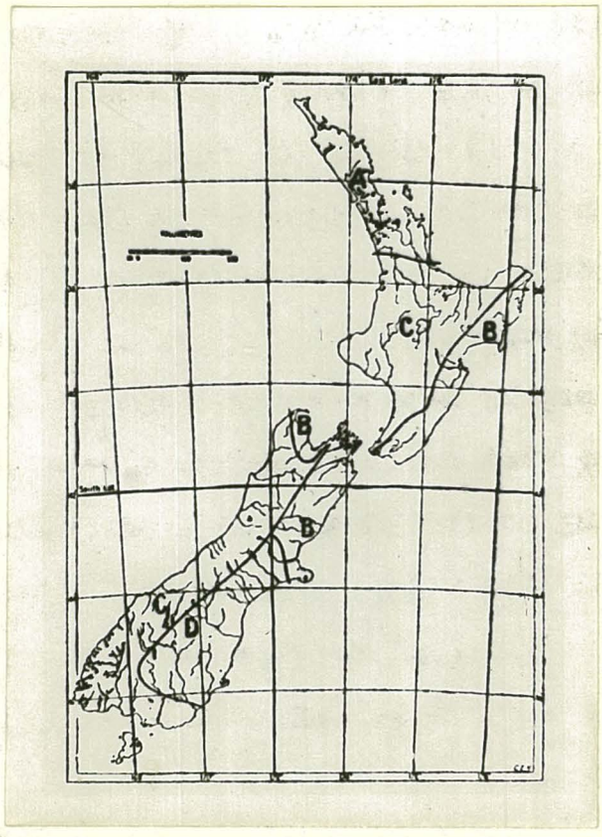
III. As a Source of Employment.

The manpower used directly in the hills as shepherds, musterers, drovers, in shearing and scrubcutting gangs is important in itself, but the indirect employment caused by the farming of the hill lands is probably even more so. The labour involved in the transport, preparation, freezing and shipment of fat lamb and mutton, in the transport,

scouring, grading, auction and shipment of raw wool, or its conversion into the manufactured product within New Zealand, in the supply of goods and services to those working on and farming in the hills owes its livelihood to a thriving hill farming industry.

IV. As a Source of Water and Silt.

If a rainfall and a topographical map are superimposed it will be seen, as would be expected, that the rainfall is heaviest in the hill country - usually from 60 to over 100 inches per annum. Heavy rainfall in these areas, if not adequately controlled, may devastate many acres of fertile, low-lying country by flooding and silting. This is most likely to occur where the hills are inadequately covered by vegetation, when run-off is rapid, and erosion severe.



Map I. Climatic Areas in New Zealand.(Kidson,1936).

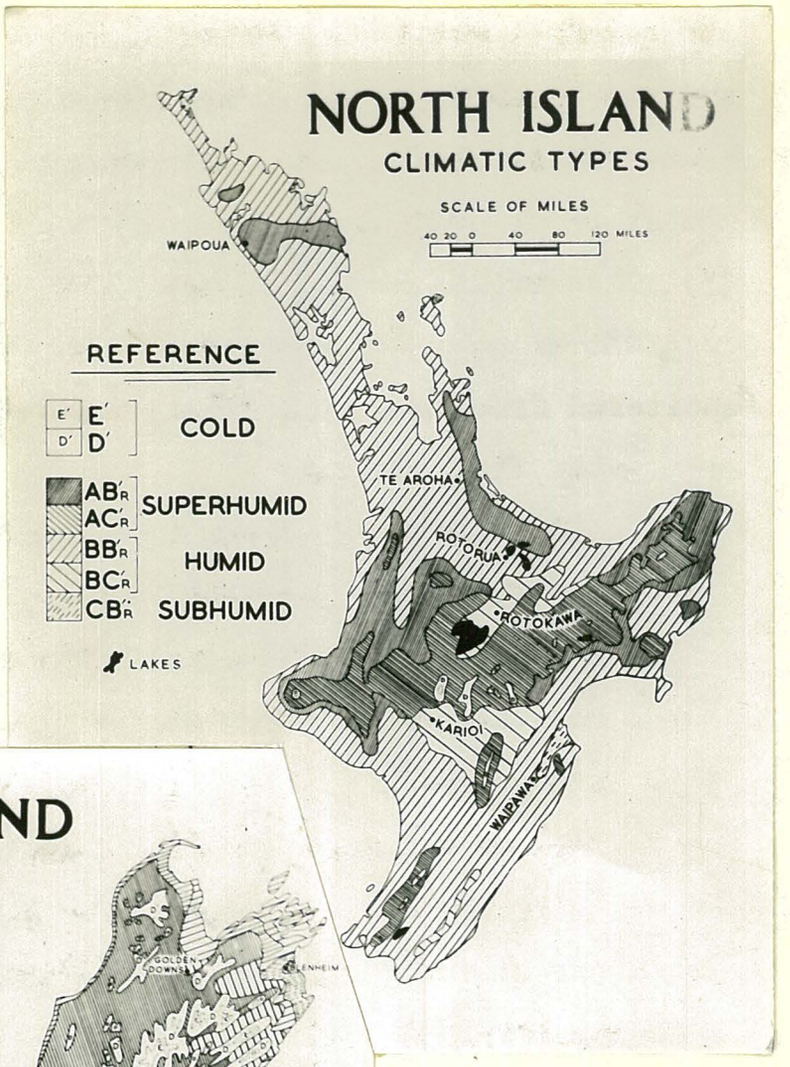
C. A CLIMATOLOGICAL CLASSIFICATION OF HILL LAND IN NEW ZEALAND.

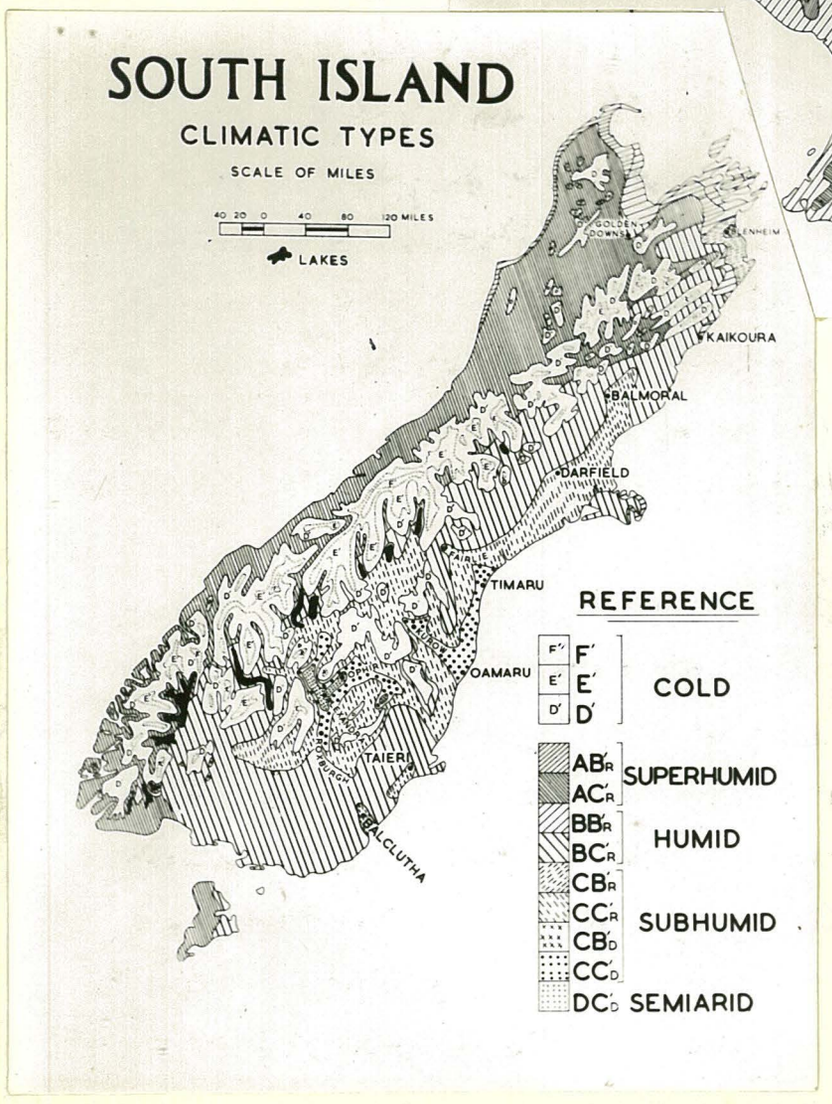
In order to study in some detail a problem of such wide scope and of such great diversity as hill land improvement, it is necessary to subdivide or classify the land into sections such that the country within each section has some basis of uniformity. It is possible to classify the hill land of New Zealand in one or other of several ways - by breed of sheep carried, by purely geological, geographical or administrative boundaries, or by its elevation. However, since this study is primarily concerned with the interaction of animal and vegetation, and since the vegetation of an area is so largely dependent upon the climate of that area, it is perhaps most satisfactory to classify New Zealand hill land according to the climate to which it is exposed. If we first study the effect of climate on the vegetation of each region it will be possible later to study the role which anthropogenic and biotic influences may play in modifying that vegetation.

In common with other countries in middle latitudes, New Zealand lies in the zone of prevailing westerly winds which deposit most of their moisture on the west side of the ranges and produce pronounced föhn effects on the eastern, lee side, reducing the effectiveness of the already limited rainfall on that side. Annual variation of rainfall in New Zealand is controlled by three main factors (Kidson, 1936).

(1) Proximity to the high pressure, low rainfall belt of the sub tropics, which produces on its southern border dry summer and wet winter seasons. The effect of this factor is most noticeable in the northern regions of the country and diminishes southwards.

(2) The effect of the prevailing westerly winds of middle latitudes. These account for the heavy rainfall on the western side of the main ranges. Since the amount of this rainfall is proportional to the flow of the westerly winds,





Maps II & III. North and South Island Climatic Types, based on Thornthwaite's classification. (Garnier, 1950).

Explanation of Climatic Formulae.

D' - Taiga
E' - Tundra
F' - Perpetual frost and snow.

A' - Macrothermal
B' - Mesothermal
C' - Microthermal

A - Superhumid
B - Humid
C - Subhumid
D - Semiarid
E - Arid

r - Moisture adequate at all seasons
s - Moisture deficient in summer
w - Moisture deficient in winter
d - Moisture deficient at all seasons.

the rainfall maximum in October, the minimum in late winter, and the subsidiary maxima and minima in autumn and late summer respectively, are explicable on the basis of the amount of westerly wind.

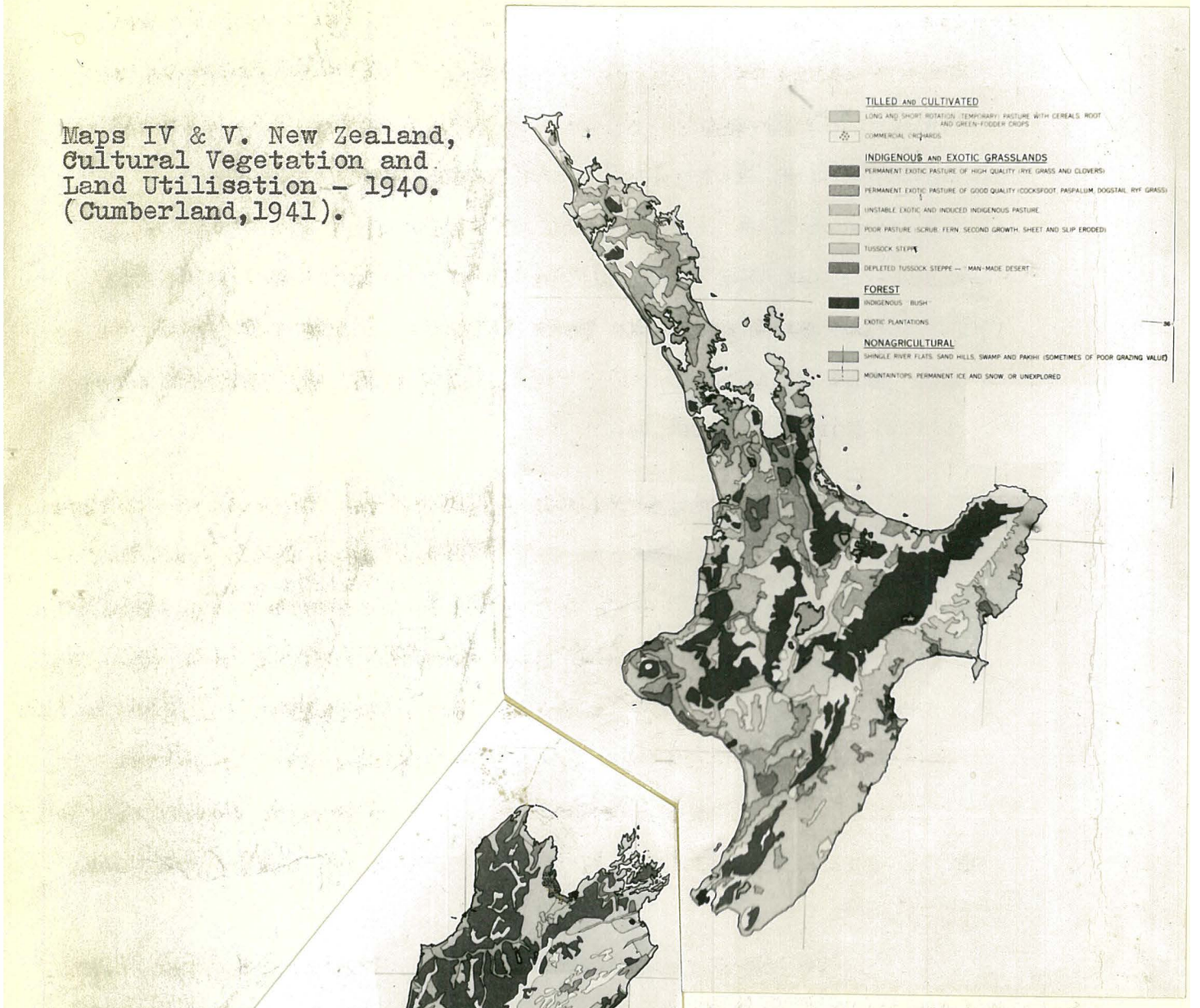
(3) Convection caused by insolation giving rise to summer rainfall of high intensity and short duration in those areas sheltered from warm westerlies, exposed to cold southerlies, and having clear skies.

On this basis alone Kidson divided New Zealand into four major climatic districts as shown in Map I (page 8a). Area A has a summer minimum and a winter maximum of rainfall, as has the northern portion of area B. In area B the total precipitation wanes from north to south and the distinction between summer and winter rainfall diminishes. Area C in the North Island has a fairly evenly distributed rainfall except for diminution in the late summer. The regime of maximum rainfall in October and minimum in late winter, previously explained, operates to its fullest extent in area C in the South Island. Due to factor (3) above, area D receives most of its small amount of rainfall in the summer months.

At a later date Garnier (1950)(i) essayed a new division of New Zealand into climatic zones using Thornthwaite's (1931) method of classification, which takes into account temperature and precipitation efficiency. As Maps II and III, reproduced on page 9a indicate, this method gives a certain refinement to Kidson's classification. Kidson's areas A and B are replaced by climatic types BB'r, BC'r, CB'r and CC'r within the humid and subhumid meso- and micro-thermal, moisture adequate categories. Area C corresponds broadly to climatic types AB'r, AC'r and small portions of BB'r and BC'r in the superhumid and humid, meso- and micro-thermal, moisture adequate range, while Kidson's area D encompasses the types CC'r, CB'd, CC'd and DC'd in the subhumid and semiarid range.

Garnier (1950) (ii) further attempts to emphasise the seasonal variation in climatic type, but for the present any detailed consideration of this work only serves to confuse

Maps IV & V. New Zealand, Cultural Vegetation and Land Utilisation - 1940. (Cumberland, 1941).



The limitations imposed by black and white representation of coloured maps make these two text figures unsatisfactory. It is suggested that reference be made to the original map of Cumberland (1941), or to the grassland maps of Hilgendorf (1935) and Madden (1940).

the picture. The general conclusions which may be drawn from it are, however, of interest. Certain features are common to all seasons. Most significant is the overriding importance of moisture rather than temperature in differentiating the climate of one region from that of another, and the contrast between the wet west coast and the drier east coast in both islands. The exception to this rule is a relatively wet climate in the eastern areas of the North Island in autumn.

In any region in which soils are relatively mature they will tend to have less influence upon their vegetative covering than will those soils which are relatively immature. This is due to the controlling influence of climate upon soil formation, both directly and through the agency of plants, so that with increasing maturity differences in the parent material under any one climatic regime tend to be eliminated and a soil type typical of that climate is formed (Glinka, 1927).

New Zealand hill soils, however, are for the most part immature, and as such will tend to have a considerable influence upon the vegetation covering them. Nevertheless, it is striking to note the broad correlation existing between the climatic zones of Kidson and the vegetation zones as shown in the maps of Hilgendorf (1935), Madden (1940) and Cumberland (1941) (Maps IV and V, page 10a). The refinements in climatic district boundaries introduced by Garnier serve only to emphasise the supreme importance of climate in determining the vegetation covering at least the North Island soils. In the South Island overall climate is again important in determining the vegetative cover, but in this instance certain micro-climatic influences, discussed more fully in a subsequent section, which are not amenable to Thornthwaite's system of overall climatic evaluation play a more significant role.

By comparison of Maps I, II and III on pages 8a and 9a

with Maps IV and V on page 10a it will be seen that the superhumid area of evenly spread rainfall in the North Island (Kidson's area C) encompasses most of the bush, scrub and eroded country, while area B in the North Island, the drier, summer minimum rainfall area, delineates the extent of the major browntop (Agrostis tenuis), Danthonia (Danthonia spp.), hair grass (Aira spp.), sweet vernal (Anthoxanthum odoratum), dogstail (Cynosurus cristatus) and suckling clover (Trifolium dubium) associations.

In the South Island, area B (here having a diminished and more evenly distributed rainfall) encompasses browntop and danthonia associations around Nelson, and passes into a tussock and indigenous grass association extending southwards through Marlborough and Canterbury, merging into the depleted areas of Otago as the drier portions of semi-arid area D are encountered.

It is on this basis, having a common foundation in climate and vegetative association, that a classification of New Zealand hill country will be made for the purposes of this dissertation. Kidson's area C in the North Island will be termed the Wet Hill Country; area B in the North Island, the Dry Hill Country, and areas B and D in the South Island, the Tussock Hill Country.

Such a broad classification necessarily introduces errors and borderline cases, but in the ensuing discussion of the principles involved in the improvement of the hill land in these three areas, this classification seems the only feasible one to adopt. Each area has sufficient homogeneity to justify its being discussed as a separate entity.