SOIL-AMENDING TECHNOLOGY, GRASSLAND FARMING, AND
NEW ZEALAND ECONOMIC DEVELOPMENT:

A STUDY OF THE ORIGINS, APPLICATION, AND IMPLICATIONS
OF AN INNOVATION STREAM IN NEW ZEALAND AGRICULTURE

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ABSTRACT

This dissertation explores the role of soil-amending technology in the development of New Zealand's agricultural sector. In a survey of the evolution New Zealand's farming systems it is shown that the use of soil amending emerged from a set of circumstances whereby the utilization of grassland farming methods was favoured by the development of refrigerated marine transport and governmental policy which fostered the formation of small, family farms adapted to more intensive livestock production whose produce refrigerated ships could deliver to the British market.

The relative shortages of capital and labour in this institutional structure led to the introduction of labour-saving technology which promoted grassland-based farming systems. The need to develop and maintain consistently high levels of quality produce, particularly in dairying, entailed the investigation of British agriculture's soil-amending technology. Its successful adaptation and adoption, favoured by its highly divisible labour and capital demands, was a key element in stabilizing the small farm structure as it successfully boosted agricultural productivity and enabled other innovations based on highly productive plants and animals to enter the farming systems. The perfection of mechanical distribution methods from tractors to ground-spreading vehicles and aircraft allowed this technology to be extended from the lowland plain dairy and fat-lamb farms into more rugged terrain areas producing wool and store stock.

An agricultural focus to scientific research was a feature supported by government in the establishment and funding of organizations investigating ways to increase and improve agricultural output. Successful research and development brought improved plants and stock which benefited from soil amending through the addition of soil nutrients and trace elements and the control of soil acidity. Concern with the study of pasture as an ecosystem was a basic factor in the advances made. Pedological investigation and the adaptation of foreign research findings especially after 1945 induced rapid increases in livestock output as better distribution methods facilitated the use of the technology devised. Continued economic growth was the outcome of this expansion of output.

The comparative stability of the British market was a central element in the production environment in which such technological

development occurred. The ability to focus attention on a small range of produce for which demand continued to increase through much of the 1890-1960 period meant that New Zealand producers could benefit substantially from improvements of those innovations adopted. Research activity too could be concentrated, so maximizing relatively limited capital and personnel resources. Later deterioration of that market's stability has led to increasing uncertainty and a search for new strategies in production, marketing, and economic planning.

Government has been a central factor in agriculture's development through policy decisions and supporting research, and has become increasingly involved as its role in regulating the economy has grown. Its part in the production environment within which soil-amending technology developed has strongly influenced the pattern of that development.

Noting the relevance of this combination of factors is essential to the geographic study of New Zealand agriculture as a concluding review of a selection of such studies reveals.

PREFACE

This dissertation grew initially from an interest in the utilization of aircraft in New Zealand agriculture for fertilizer distribution. Investigation into the creation and evolution of this technology began to point to a continuity in the use of fertilizer rather than a marked change occasioned by the application of aircraft. The attempt to understand the progression in the use of fertilizer in New Zealand farming systems prompted a review of its evolution. Such an historical approach was productive in that it began to furnish a number of insights into the interaction between the farming systems created and the technology employed therein. Soil amending, the use of substances to alter and improve the productive properties of soils, appeared as a technology basic to the development of productive grassland. The grassland basis of production was a prime characteristic of the farming systems present.

The utilization of grassland developed in the particular capital and labour supply situation found in a small country specializing in animal product output for a market half a world away. The concern with soil amending emerged in the evolution of New Zealand farming systems from extensive to more intensive forms subsequent to transport technology innovation and a program of legislation which stimulated change in the institutional structure of farming. The production environment was apparently a factor in the development of soil-amending technology. The latter's association with dairying in particular appeared to demonstrate how technology could both enable a farm enterprise to exist and induce change within it. The extension of this soil-amending technology to the other livestock enterprises during the present century was a major source of the high productivity of New Zealand's agriculture. The use of aircraft could then be seen as but a later phase in the evolution of soil amending--a means of overcoming the slope constraint imposed on earlier fertilizer distribution techniques.

The above consideration highlighted the related role of resource appraisal and cultural values implicit in the decision to employ a certain technology, particularly where it was new. Continued contact with the source areas of the New Zealand farming systems and the emergence of the scientific study of agriculture in one of them, the United Kingdom, evidently facilitated the transfer of information while, concurrently, the local pioneering environment encouraged the testing of the techniques proposed. Adapting foreign research to develop technology of use locally was a pattern which persisted.

Successful innovation resulted in the reappraisal of existing production resources in New Zealand and prompted the extension of new farming enterprises. Such a situation is dynamic as the technology introduced creates a disequilibrium. The attempt to rectify the initial disequilibrium can contribute to disequilibria elsewhere in the system. Innovation is stimulated to offset the production difficulties encountered and take advantage of opportunities presented. As productivity improvement is a possible consequence of such moves to more efficiently employ resources, and economic growth is an outcome of improved productivity, following the Schumpeterian view (Schumpeter, 1928, 377-378), change in technology can be the basis for growth in the economy. From such growth, economic development, a change in the relative importance of the sectors of the economy and in the society in which they operate, is thought to follow. This profound change then influences the resource utilization patterns within the economy. This resource-appraisal consideration is not the central concern of this dissertation, however, and its elaboration is not pursued further.

What is of concern is the effect of technological change. The interaction of technology, resource appraisal, institutional structure and economic change is manifest in both the spatial organization and the distributional patterns of farming systems. Patterns resulting from a particular combination of the above-mentioned elements should be subject to adjustment once change is introduced to any one element in the system and disequilibrium is created. An understanding of any such interaction is basic to explaining existing spatial patterns and assessing the spatial outcome of ongoing change. Identifying changing patterns can indicate some alteration in the relationship of the interacting elements as they influence man's use of land. The analysis by geographers can thus be predictive and diagnostic and so contribute to policy-making.

This dissertation is an overview of the operation of this interacting system of technology, resource appraisal, institutional structure and economic change in New Zealand agriculture with particular reference to the part played by soil amending. The latter technology was identified as one which proved basic to later development by creating a succession of powerful disequilibrium situations. This survey of the ensuing changes provides a framework within which subsequent, more exhaustive studies of New Zealand agriculture can provide a greater understanding of development processes and their spatial manifestation.

The questions addressed in the dissertation are related to the central problems of the soil amending's place in agricultural development in New Zealand and its role in economic change. Why has soil amending been an important technology in the overall development of New Zealand agriculture and how has it played a role in change in the country's economy? It is seen that innovation in transport technology stimulated the evolution of more intensive farming systems and thereby fostered the need for creating highly productive grasslands. Employing soil amending to increase soil-nutrient levels to create and maintain such grasslands was a means to achieve the development desired. The technological response to altered circumstances in the production environment supported the intensification undertaken. In this way emerged a widespread institutional structure in the agricultural sector--the comparatively small, family farm. The labour- and capital-supply characteristics of this structure strongly influenced the production technology utilized and, it is argued, prompted the adoption of grassland technology.

What were the distinctive features of the labour and capital supply of that structure that influenced the nature of the production technology utilized and fostered the use of grassland technology in particular? Both capital and labour were in short supply, so technology not requiring much of either was favoured. The relatively greater shortage of labour meant that labour-saving technology was more favoured even if it proved more expensive to acquire. Accordingly, a direct relationship developed between the demand for labour within a particular farm enterprise and its use of labour-saving technology. Insofar as grassland technology met this demand, it was employed, particularly when both the use of soil-amending technology and the establishment of farm enterprises able to use it were favoured by the physical environment.

What was the consequence in such farm enterprises of focusing attention on the technology utilized? Would they serve as a source of technological information to other enterprises? If so, grassland technology could be improved and disseminated in relation to the importance of the farm enterprise most dependent upon it. This would be one possible answer to the questions of how the agricultural focus of inventive activity has been maintained and how the results have been spread throughout the farming community.

What is the relationship between technology and the institutional structure of an economic sector? While technology, on the one hand, may play a part in the emergence of an institutional structure, on the other, its development can also be abetted and directed by the same structure, so constraining the pattern followed. What were the consequences of the relationship in New Zealand? Inventive activity was centred on biological concerns related to agriculture. The resultant innovations furnished a basis for increased productivity in that sector as well as for growth in the economy as a whole. Creating institutions active in research as well as in the dissemination of the findings of that research stimulated innovation on the farm and, consequently, these institutions may be viewed as having served a growth-promoting function.

What has been the role of government in the development of agriculture? Creating and supporting the research institutions noted above is but one instance of government's involvement. With greater reliance upon governmental intervention to counter the effects of economic crises, the government's participation in decision-making, especially in the allocation of resources within the economy, has become more important to the development of the various economic sectors. Thus the role and significance of agriculture in the national economy was dependent on government policy. This is evident in the recourse to legislation before the turn of the century to promote the small farm as one of the basic elements of New Zealand agriculture. Furthermore, linkage with other economies through international trade and dependence on foreign markets has become increasingly related to governmental decisions. A weakening of the demand-induced growth effect of the British agricultural produce market, for instance, spawned a re-examination of the trading links. To what extent is the relationship between national economies influential in the economic development process and can it be an explanatory factor in the nature and extent of such development?

Has dependence upon the British market proved significant in agriculture's development? Where once the nature of that market featured in New Zealand agriculture's continued productivity improvement through providing a measure of stability in the production environment, the market's capacity to absorb the increasing output generated by the effective use of technology diminished. This change created a situation where the basis of New Zealand's economy came under continuing review. Has the change led to an adjustment of the economy to new circumstances? The response of the New Zealand economy is of concern here as the productivity improvement in agriculture has occasioned economic growth; yet the attainment of economic development as suggested in economic theory remains in doubt. An appreciation of the technological and institutional factors important to growth and development can provide insight of value in anticipating, and so planning, the course of further economic restructuring.

In light of these considerations the following assertions are examined:

1) Soil-amending technology has been the key element in boosting agricultural productivity because of its importance to grassland farming, and so this technology has played a significant role in agricultural development and in national economic growth.

2) Farming systems based on grassland have developed and focused inventive activity on those key technologies such as soil amending which support them.

3) The introduction and adoption of grassland technology reflected the capital- and labour-supply situations in the altered institutional structure of agriculture after innovation in transport technology occurred.

4) The characteristics of soil-amending technology strongly influenced its adoption and widespread use.

5) In the course of its diffusion from its point of origin an innovation may be modified through its adaptation to a new environmental setting.

6) The adoption of inventions created modifications in production techniques but the institutional structure and the farming

systems in New Zealand agriculture were able to achieve a high degree of stability.

7) Government has played an important part in the diffusion of agricultural technology through its role in sponsoring research and information dissemination and through the strong effect on resource allocation decisions occasioned by its greater involvement in the economy.

8) Change in the stability of the trade pattern has had a direct effect on the promotion of productivity improvement in agriculture, on the stability of the institutional structure of the agricultural sector, and on the relative importance of the various sectors of the national economy.

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The thrust of the questions put forward in the preface indicates the importance of the past in present patterns. In order to deal with questions emanating from this historical perspective consulting documentation about the New Zealand economy and the agricultural sector was essential. Data on both these wide topic areas were assembled largely from government publications and from analyses by authors in a number of disciplines. In the following sections the scope, continuity, and reliability of the various data series pertinent to the study are discussed whenever difficulties became apparent. The utility and shortcomings of the available data series are considered and observations made about the constraints imposed on the present inquiry by the limitations of statistical series at certain levels of aggregation and measurement.

DATA AND DATA SOURCES ON SOIL-AMENDING TECHNOLOGY

New Zealand's soil-amending technology involves the application of chemical fertilizer, lime, and trace elements to boost soil productivity. This concern is reflected in official statistics. Data on the use of chemical fertilizers on grassland have been published annually since 1926-27 in the *Agricultural Statistics*[1]. Only for the first three years of reporting was an attempt made to indicate the areal extent of soil amending using dung. It was realized that the practice of year-round, outdoor grazing led to the deposition of dung in situ. The farmer controlled the quantity spread in a pasture by adjusting the frequency and intensity with which his stock grazed, not by collecting and spreading dung. The difficulty of obtaining the latter type of data led to an emphasis on inorganic treatment.

The three soil-amending practices recorded annually were: the use of the chemical fertilizer of any type on its own, the use of lime on its own, or a combination of the two. Although some attempt to differentiate the type of soil-amending practice was made, this was not done consistently until 1932. The quantity of fertilizer and lime employed was not recorded in the agricultural statistics between 1930 and 1948, a serious omission as the rate of application by type of treatment cannot be assessed during this period of change. As this rate can be varied over a given surface area, measures of soil-amending practice using acreage data only may not be strictly comparable from year to year should some factor affect application rates. Although the comparison value is limited, the acreage figure[2] does measure the extent to which the decision was made to employ this particular technology. Changes evident thus indicate either an adjustment in the use of the technology as a whole, or a modification of the way it was employed. It was on this basis that an analysis of variance of the use of soil amending was undertaken. Changes in the data collection areas necessitated the reconciliation procedure noted in Table 8.3 to re-create common areas in order to effect some statistical analysis. The statistical divisions used are shown in Map 7.1[3]. A further problem arises from the change in 1971 of the period for which data are recorded. Long-term studies have become increasingly handicapped by both of these changes unless the effects can be measured, so allowing some weighting procedure to be used in analysis.

Fortunately, there are other sources on the quantities of soil amendments available over time. The application rate on a national scale can be determined by combining domestic production and imports, as exports and re-exports have not been sufficiently large to be noteworthy. Domestic production of limestone and rock phosphate has been recorded annually since 1917 in the *New Zealand Official Yearbook*[4] as part of quarrying activity. The quantities of imports prior to 1921 have been issued in the *Statistics of New Zealand*[5] and those since 1921 recorded in the *Trade and Shipping Statistics - Imports*[6]. Data in the *External Trade Statistics - Imports* supplement to the *Monthly Abstract of Statistics*[7] for the July-December period of the years since 1962 have been used to convert the figures from June to December years[8] to make the series as consistent as possible. Differences in the detail of the figures recorded does pose some problem with the lower volume fertilizer imports. The methods used to rectify the problem are noted in the tables involved. McCaskill (1929) tabulated a full record of imports and domestic production from 1867 to 1921, so allowing the series to be extended back to the period when soil amending was initiated. However, corrections to this series were made after a check of the source of this data, *Statistics of New Zealand*, revealed errors made in transcribing figures. Since the area on which amendments were applied was not recorded, an analysis of actual application rates is not possible but a generalized view of the emerging national pattern of usage was attempted by using the application rate per area of improved land.

Rather than attempting to trace domestic production of chemical fertilizers, as data for the period prior to 1926 are not available from government or company sources[9], the conversion factors available in the *Fertiliser Statistics*[10] were employed to convert quantities of imported and domestically produced chemical fertilizers to equivalent quantities of plant nutrients. The resultant series allows the trends in chemical fertilizer use to be traced in relation to the findings of scientific research on the operation and nutrient requirements of pasture ecosystems. The effect of science on the usage pattern appears in the changes in trend noted. The lack of precision concerning imports for December years prior to 1914 precluded the extension of the series prior to that date. Organic fertilizer production from domestically produced materials and the number of associated production plants was traced through using *Statistics of New Zealand* and *Industrial Production Statistics*[11]. These sources also provided information on the number of chemical fertilizer and lime-production plants in operation[12].

The reduction in importance of organic fertilizers caused by the extension of chemical fertilizer production capacity after World War I meant that their contribution to grassland technology was increasingly limited. As there was also some difficulty in obtaining conversion factors for the nutrient components to accord them with the data available for chemical fertilizers, organic fertilizers have not been included in the synopsis of soil amendments used.

The publication of *Fertiliser Statistics*[13], begun in 1950, is a valuable source of information concerning trends in production and the problems encountered year by year. The use of either June and December years in the series limits the usefulness of the published data because of the comparability problem created. However, the series do provide a source of information on aerial application of fertilizers which is supplemented by annual reports in *Civil Aviation Statistics*[14]. The aerial topdressing data in the *Agricultural Statistics* permit a comparison with other application methods in terms of the rate of application and the area treated. Only in 1963 in the latter source is the large role of ground-spreading vehicles recorded separately. This is a curious oversight, the more substantial documentation on aviation perhaps reflecting greater governmental involvement in that service industry.

The use by the Civil Aviation Administration of provincial districts for licensing aerial operations and so for recording data, rather than the land districts or statistical areas used by the Department of Agriculture means that the direct comparison of information is limited. For example, as the Auckland Provincial District encompasses the entire northern half of the North Island, differences in aerial techniques employed between regions within that district are not observable. Similarly, the smaller provincial districts in the South Island, Nelson, Marlborough, and Westland have been grouped in published sources, and detail is lost. The use of common data collection areas by the Ministry of Transport and the Ministry of Agriculture and Fisheries where statistical information overlaps so closely as in the case of aviation operations carried out for agricultural purposes would facilitate the study of these operations. Sharing a common time period would also be advantageous in this regard as Transport has switched from March to December years while Agriculture and Fisheries has switched from January to June years. The latter change has at least brought the agriculture and fertilizer production years into line, so facilitating statistical analysis.

DISEQUILIBRIA AND COMPLEMENTARITY IN TECHNOLOGY

In the above discussion of sources, soil-amending technology is viewed as operating in isolation. It is noted that the adjustment of soil fertility is used to boost plant production in order to increase animal production per unit area. The introduction of animals and plants capable of more efficient utilization of available soil nutrients served to boost the benefit derived from such technology. The development of each technique often served to stimulate some other technological innovation.

Both evident resource depletion and customary use, as noted by commentators on agricultural development (Smallfield, 1947a, 1947b; King, 1947a), facilitated the use of soil-amending technology. The first reason came about in response to falling productivity which induced a search for means to overcome a declining income situation. Other options at that time included moving onto unexploited land to tap its natural fertility; adjusting the type of production to the new fertility level, and withdrawing from production completely. Any and all of these options were available to an individual producer. Tracing the development of each entails examining: the rate of adoption of soil-amending technology through the quantity of amendments imported and the acreage treated from the sources noted earlier; the amount of land brought into production and allowed to go out of production, and the number of holdings. The use of the number of holdings is based on the assumption that 'one man, one farm' remained an adequate description of the structure in farming. Although usually adequate for the purpose here, the continued assumption that this pattern has continued creates certain problems in the study of adoption. All the above data are taken from the series in the *New Zealand Official Yearbook* and from the *Agricultural Statistics*, supplemented by additional data for the nineteenth century from the volumes of the *Census of New Zealand*[15] and *Statistics of New Zealand*. Averaging the data for five year periods is employed to smooth the trends over time by reducing the effect of annual variations within a lengthy series. As data are not always available for the full five years, the best average possible was calculated and the number of years employed recorded in the table. As data collection improved following World War I, the information for the 1920 to 1970 period is nearly always complete. Single-year data are also used to outline trends over the shorter time periods involved in some chapters.

The above-mentioned losses of both productive land through reversion and decreased number of holdings indicated a failure to overcome the soil fertility problem. This difficulty is more readily observed once the amount of land in production had stabilized, thereby removing the opportunity, on a large scale, to move onto previously unexploited land. The use of technology is seen as inducing improvement in the manner in which increments in soil fertility are utilized. Equally, it has an enabling role in laying the base from which other aspects of grassland technology could develop. By noting the sequence of developments which occurred in New Zealand, one can indicate the operation of this disequilibrium situation. What becomes evident is the order in which technological developments occurred and were presented for general use.

Farming statistics present data on some of the associated technology: the number of tractors on farms, the area in grassland, and the amount of grassland cut for hay and silage. The number of tractors employed, however, may not reflect widespread adoption since the number of farms using them is not indicated. The possibility of more than one tractor being used on a holding is so ignored. Recording the number of farms or farmers reporting the use of machinery and techniques would facilitate adoption and diffusion studies. Accordingly, commentaries on developments by scientists employed in grassland research, particularly, Levy (1959, 1961b), Lynch (1967, 1972), Sears (1962a, 1962b, 1963), and Smallfield (1970) are used to gain insight into developments. Articles appearing in the *Journal of Agriculture*, the *New Zealand Fertiliser Journal*[16], *New Zealand Agricultural Science* and the *New Zealand Geographer* are other useful sources as are papers presented at farmers' conferences held at Massey Agricultural College (later University), Lincoln College, and the Ruakura Experimental Station, or at meetings of the New Zealand Grassland Association and the New Zealand Geographical Society. Full historical treatments of agricultural production such as Evans (1969) and Department of Agriculture (1950) have been infrequent but the work of Belshaw (1936, 1947), Cumberland (1944), Cumberland and Hargreaves (1955, 1956), Evans (1956, 1960), Gould (1965, 1976), Hargreaves (1960, 1963, 1965, 1966), McCaskill (1929), Philpott (1937), Robertson (1939), Smallfield (1970), A.B. Ward (1973), and A.H. Ward (1975), contain particularly helpful discussions of trends which emerged in the periods each dealt with. The reports of Royal Commissions investigating agricultural problems are further sources of such information.

SOURCES OF INVENTION AND INNOVATION

The sources cited above provide additional material on the origins of local institutions concerned with invention and innovation. The fact that researchers such as Levy and Smallfield, were also engaged in popularizing the application of grassland technology means that there is often ample expression of the methods followed, and of the findings and usefulness of the research.

The establishment of institutions for research marked an important phase in the progress of technological development in New Zealand. Government sponsorship meant that their evolution is documented in the annual reports of the associated government departments. The Department of Agriculture's *Annual Report*[17] proved particularly useful. Reports of the Air Department[18] and of the Department of Scientific and Industrial Research furnish further detail. The funding of these institutions by government and the activities in which they engaged provide an indication of both the economic linkages seen as important within the country, and the influence exerted by government in regulating the course of economic adjustment which ensued. Accordingly, governmental sources[19] do provide references to much of the development which occurred, especially in the early, less fully documented phases. Finally, articles in the *New Zealand Fertiliser Journal* outline events related to fertilizer production and usage from the mid-1950s on, and the agricultural periodicals cited earlier provide further information on the sources of invention and innovation.

INSTITUTIONAL DEVELOPMENT

Following the development of the institutional environment in which change occurred is necessary in assessing the pattern of that change since institutions do direct the use of resources in the economy (Davis and North, 1971). In the course of colonization the cultural and institutional heritage of the home country was adapted into an institutional structure suited to the requirements of the new settlers. In developing its own economic institutions, New Zealand society has, through governmental activity, determined the relative importance of the sectors of the economy. The degree of promotion through the provision of production resources and protection from disturbances such as external competition, evince various attitudes to the various sectors. The works of Blyth (1974), Condliffe (1915), 1959, 1963), Gould (1972), Lloyd Prichard (1970), Scholefield (1909), Simkin (1951), Sutch (1966, 1969) dealing with New Zealand's economic history are particularly important in this area. From their work can be drawn an outline of the nature of the production environment in which innovation decisions concerning technology were made. Their discussions cover the earlier institutional developments and are supplemented by the range of background papers for the economic conferences of the 1960s.

ECONOMIC CHANGE

Data summarizing the progress in production in the agricultural sector are available for the nineteenth and early twentieth centuries from the *Statistics of New Zealand*, from the *Census*, and from the *New Zealand Official Yearbook*. The annual summary of agricultural statistics furnishes further detailed data after 1921[20].

Quantity and value figures for categories of agricultural products were collected from various editions of the *New Zealand Official Yearbook* and from the *Trade and Shipping Statistics*. The *External Trade Statistics*

-*Exports* supplements to the *Monthly Abstract of Statistics* for the July-December period from 1962 to 1970 and the *Export Statistics* were used to continue the series of December years throughout. The importance of the various farm enterprises and the proportion of agricultural exports to total exports is calculated from this data. Condliffe (1915) and Simkin (1951) in particular provide most useful analyses of the data for the period to 1914.

From the relationship between land use and the livestock which provided the main exports it is seen that the carrying capacity of land has been increased with the extension of grassland feeding practices and the concurrent use of soil amending. Although the increases in the production of livestock cannot be totally ascribed to soil amending (many other practices were also entering the agricultural systems) reliance is placed on an association between scientific observation of the role of soil fertility and evidence to that effect. This is discussed in the chapters dealing with grassland research.

The contribution of increased production to economic development is assessed from the works of economists and economic historians dealing with this topic. Blyth (1961, 1974), Gould (1972), Lane (1976), Lane and Hamer (1973), Philpott (1963), Rosenberg (1968), Sutch (1966, 1968a, 1968c), and Westrate (1959), have been concerned with this question in the post-World War II period. The recession of the late 1950s and the emergence of an industrialization policy led to a number of studies on past and expected changes in the economy. The observations therein, when viewed in the light of the work of economic historians and economists concerned with general patterns of economic development, became the basis of one of the central considerations of this dissertation. Economic growth in the form of increased production which soil-amending technology made possible, was not found to be readily translated into shifts within the economy of production patterns or new resource deployments which would have marked economic development.

ORGANIZATION

As the principal thesis involves innovation in soil-amending technology and the impact of that innovation on the structure of the agriculture sector and thence on the economy as a whole, the dissertation is organized so that the next three chapters set out a framework interpreting innovation and change, and subsequent chapters recount the development of soil-amending technology in New Zealand within that framework. The structural adjustments following the development of a grassland technology based on soil amending serve to show the effects of economic specialization arising from a focusing of inventive activity. A concluding chapter outlines the implications of this thesis to the study of agricultural geography in New Zealand.

The specific organization is as follows. In Chapter 1 the place of soil-amending technology in New Zealand agriculture is introduced along with the concept of its place as a innovation in contributing to growth in the economy. The influences conditioning the emergence and retention of soil-amending technology are also presented as a guide to the main considerations of the dissertation.

In Chapter 2 the process by which an idea is translated into technology is traced. It is argued that with the development of new technology, further decision-making processes are set in motion which can lead to its application to economic production. Subsequent adjustments to the pattern of factor utilization to rectify the disequilibrium created are considered with a view to identifying the impact of those adjustments on the economy as a whole.

Chapter 3 is concerned with the occurrence of technological change within the agricultural sector. Though this sector is similar to others in the economy, there are important differences which relate to the pattern of technological change. The organizational structure, the biological focus of production, and the large part played by the natural environment are the principal constraints which have caused technological change in agriculture to lag behind that in other sectors. Nonetheless, agriculture is seen to play an important role in economic growth and development, and the basis for this is examined.

In Chapters 4, 5, and 6 the New Zealand example is developed to trace the emergence of grassland technology. From British and Australian experience when put to use in the new environment came a variety of practices which formed the basis of a number of viable extensive farm enterprises. With the advent of refrigerated marine transport in the 1880s came change since meat and dairy exports could be undertaken. The institutional structure of agriculture altered with the creation of smaller farms. The concern with improving output was translated in a situation of labour and capital shortage into a farming system dependent upon year-round, outdoor grazing to minimize labour and building costs. Soil amending became an eminent concern as it came to be seen as fundamental to the more intensive use of grassland over the following decades. Institutions geared to farmer education and agricultural research were established by government as it sought to foster more intensive agricultural enterprises and improve social welfare.

The outcome was a body of research focused on agricultural problems which brought a reassessment and improvement of the biological materials being utilized. The results provided an important productivity boost which sustained New Zealand's attempts to channel consequent economic growth into more diversified economic development. The greater application of mechanical power to farming greatly aided the dispersal and utilization of the grassland technology so created.

Chapter 7 links the framework with the New Zealand example in demonstrating how the development of the agricultural sector, as influenced by the use of soil-amending technology, has followed the theoretical pattern of adjustment to technological change culminating in economic development. Economic growth in the agricultural sector is studied to see what role soil-amending technology has played. A synthesis of the patterns, using a range of economic and agricultural production data, provides a number of insights into the agricultural sector in New Zealand and its place within the national economy. The fundamental importance of institutions both developed within the sector and furnished to assist it are noted. Government's role in particular is seen.

The focus of this dissertation on the particular role of technological change has played in the evolution of New Zealand farming systems leads, in Chapter 8, to observations on the problems inherent for the geographer in studying a dynamic situation. The New Zealand case presents particular difficulties in that it contains elements of change within a comparatively stable production environment. Observing spatial process and organization then becomes a challenge. The utility of a structural approach to define the changes occurring is then shown. The perspective provided is used to reappraise previous arguments of geographers on the nature and distribution of farming systems in New Zealand and to emphasize the importance of understanding change processes in order to provide information of use in the further development of the New Zealand economy.

FOOTNOTES

1. This title has varied as follows: 1921-22 - 1948-49 *Statistical report on the agricultural and pastoral production of the Dominion of New Zealand for the season [given].*

   1949-50 - 1950-51
   Statistical report on the agricultural and pastoral production of New Zealand for the season [given].

   1951-52 - 1952-53
   Report on the agricultural and pastoral statistics of New Zealand for the season [given].

   1953-54 - 1966-67
   Report on the farm production statistics of New Zealand for the season [given].

   1967-68 - 1969-70
   Report on farm production statistics for the season [given].

   1970-71
   Agricultural Statistics 1970-71.

   In the text reference is usually made to *Agricultural Statistics* unless a particular season is mentioned, in which case *Agricultural and pastoral statistics* or *Farm production statistics* is used as appropriate.

   The first year of the season date is used as a January year is used (footnote 8). Thus 1921-22 includes eleven months of 1921 and that year alone is usually used in the text.

2. Throughout the text the British measurements employed during the period of study have been retained. The metric equivalents are given below:

   1 mile = 80 chains = 1,609 metres
   1 acre (ac.) = .4047 of a hectare
   1 ton (2,240 pounds) = 1,016 kilograms
   1 hundredweight (cwt) = 0.05 of a ton = 50.8 kilograms

   Decimalization of currency in July 1967 was based on
   £1 = $2, 1s. = 10¢, 6d. = 5¢.

3. The sources of these boundaries are McLintock (1960), Town and Country Planning Branch (1968), and Local Government Commission (1976). McLintock (1960) was used as the base for all maps and for the locality information presented.

4. This title has changed as follows: 1892-1960 *The New Zealand Official Year-book*, 1961- *New Zealand Official Yearbook.* It has been abbreviated to *NZOYB.*

5. This title has varied as follows:

   1853-72 *Statistics of New Zealand*

   1873-1906 *Statistics of the Colony of New Zealand*

1907-20 *Statistics of the Dominion of New Zealand*
Statistics of New Zealand has been used in the text and tables.

6. This title has varied as follows:

1921 *Statistical report on the trade and shipping of the Dominion of New Zealand for the year [given]* .

1922-26 *Statistical report on trade and shipping in the Dominion of New Zealand for the year [given]* .

1927-32 *Statistical report on trade and shipping in the Dominion of New Zealand, [year given].*

1933-44 *Statistical report on trade and shipping of the Dominion of New Zealand, [year given]* .

1945-48 *Statistical report on trade and shipping of New Zealand*
1950-51 *for the year[s] [given].*

1949, 1952-61 *Statistical report on the external trade of New Zealand for the year[s][given].*

1962 *Statistical report on the external trade of New Zealand for the six months January - June 1962.*

1962-70 *External trade of New Zealand July - December [year given].*

7. Abbreviated to *MAS*.

8. The term June year refers to annual tabulations for the period starting 1 July and ending 30 June. A December year is the usual calendar year ending 31 December. Also found in New Zealand statistics are the March or fiscal year ending 31 March; the April year, ending 30 April, used in recording sheep production; and the January year, ending 31 January, for other agricultural statistics from 1896 to 1971, except for 1911 when a census in March was used.

9. Communications from the Economics Division, Ministry of Agriculture and Fisheries; and Kempthorne, Prosser and Co. Ltd., the company in question.

10. PLANT NUTRIENT CONTENT CONVERSION FACTORS

	Kind of fertilizer:	Plant nutrient content percentage:
i)	nitrogenous	N (elemental nitrogen)
	ammonium sulphate	21
	ammonium nitrate	34
	sodium nitrate (natural)	16
	sodium nitrate (chemical)	17.5
	calcium nitrate	20
	urea	46
	other (unspecified)	25

ii)	phosphatic	P_2O_5 (available phosphoric acid)
	superphosphate	35
	other concentrate	45
	basic slag	21.5
	guano	23
	raw rock phosphate	38
iii)	potassic	K_2O (water soluble potash)
	potassium chloride	60
	potassium sulphate	40
	oxide potash salts	30
	other (unspecified)	50

Source: *Fertiliser Statistics* (1975, Table 15)

11. This title has varied as follows:

    1921 *Statistical report on the industrial manufactures of the Dominion of New Zealand for the year 1921-22.*

    1922 *Statistical report on the industrial manufacture of the Dominion of New Zealand for the year 1922-23.*

    1923-30 *Statistical report on the factory production of the Dominion of New Zealand for the year [given].*

    1931-40 *Statistical report on the factory and building production of the Dominion New Zealand for the year [given].*

    1941-51 *Statistical report on the factory production of the Dominion of New Zealand for the year [given].*

    1952-61 *Report on the industrial production statistics of New Zealand for the year [given].*

    1962 *Report on statistics of industrial production for the year 1962-63.*

    1963 *Report on statistics of industrial production for the production year 1963-64.*

    1964-69 *Statistics of industrial production for the production year [given].*

12. The mapping of lime plants was not undertaken as the number producing agricultural lime could not be determined. Chemical fertilizer plant locations were taken from McClintock (1960) and issues of the *New Zealand Fertiliser Journal*. Railway locations and closure dates were derived from Gandar (1973), Leitch (1972), McClintock (1960), and Lloyd Prichard (1970).

13. This title has varied as follows:

    1950 *Fertilisers; a statistical review from 1940-41 - 1950-51.*

    1951-59 *Fertilisers; a statistical review of the [given] fertiliser year.*

1960-63 *Statistical review of the fertiliser industry in New Zealand.*

1964-73 *Statistical review of fertilisers in New Zealand.*

1974, 1976-77 *N.Z. Fertiliser Statistics.*

1975 *N.Z. Fertiliser Statistics.*

Fertiliser Statistics has been used in the text.

14. This title has changed as follows:

1960 *Civil aviation statistics.*

1962-73 *New Zealand civil aviation statistics.*

The year ending 31 March has been used until 1972 when the December year came into regular use. The 1971 statistics are available for both March and December years. This title has been abbreviated to *CAS.*

15. This title has varied as follows:

1867-71 *Census of New Zealand.*

1874-96 *Census of the Colony of New Zealand.*

For full titles see the bibliography. *Census of New Zealand* is also used for all subsequent census publications.

16. Abbreviated to *Fert. J.* in references.

17. Abbreviated to *ARDA* in references. The year referred to is that ending 30 March, e.g. 1908-09 is given as 1909.

18. Abbreviated to *ARAD.*

19. Included are the *New Zealand Gazette,* (given as *Gazette* in the text) *Statutes of New Zealand,* (given as *Statutes* in the text), *Appendix to the journal of the House of Representatives* (abbreviated to *AJHR*) and *New Zealand parliamentary debates* (abbreviated to *PD*).

20. In line with the New Zealand Government Printing office *Style Book* the following symbols are used in all tables

..	figure not available
--	amount too small to be expressed
—	nil

CHAPTER 1

SOILS, AGRICULTURE, AND SOIL-AMENDING TECHNOLOGY IN NEW ZEALAND: A PRELIMINARY FRAMEWORK

Soil amending[1] is the key to the pre-eminent per capita productivity[2] of New Zealand's agriculture[3] (Moran, 1974, 124). The country's soils, having evolved in conditions of geological instability, are youthful and varied in nature (Daly, 1973, 11). Moreover, they often lack natural fertility and are commonly deficient in minerals (Moran, 1974, 125). Recognizing the part played by these edaphic limitations to agricultural productivity has been a fundamental step in the creation, intensification, and refinement of the nation's grassland ecosystems[4] for over a century.

To a large extent initial decisions made in the formative years of colonization strongly influenced the strategies pursued to establish grassland ecosystems. With colonization and frontier expansion came the diffusion of the European concept of farming before the peculiarities of the New Zealand environment were appreciated. Australian experience in extensive grazing enterprises[5] based on European grasses and stock provided a useful pattern to follow. Accordingly, sowing land to pasture became the practice. However, the deterioration of the grasslands soon posed significant problems for the early farmers. As long as the area of occupied land could be extended, production could be maintained by expansion alone. In the late nineteenth century, as the limits of the frontier were being reached and enterprise changes became possible, more attention began to be paid to increasing the productivity of the land.

Matching plant requirements and soil fertility was seen as the key to the production process (Smallfield, 1947a, 169). It was first held that the plants employed should be altered to suit existing soil-fertility levels. Only later was it suggested from the work at the Rothamsted and Cockle Park experimental farms in Britain that increasing these levels could sustain the ecosystems seen as most productive from European experience. This technology[6], accordingly, was applied to improve soil-nutrient levels. Effort came to be devoted to unravelling the essential features of the biological system involved to increase the effectiveness of soil-amending techniques. The option of seeking plants demanding lower soil-fertility levels was not pursued as vigorously and so contributed less to existing production techniques (Filmer, 1955, 12; Corkill, 1971, 12, 14). Only with the appearance of limitations in the prevailing ecosystems by the 1960s was interest in the above option renewed (Daly, 1973, 25).

The principal grassland ecosystem which emerged was based on perennial ryegrass and white clover, which 'from North Cape to Stewart Island give a uniform appearance to nearly 9 million hectares of sown pastures' (Daly, 1973, 21). Its characteristic flourishing grass growth stems from the legumes present, principally clovers, which supply the nitrates needed through their symbiotic relationship with nitrogen-fixing soil bacteria. Thus, if the nutritional requirements of the clovers, are met, man can exploit this system and obviate the need for nitrogenous fertilizers. As clovers prefer neutral soils, liming soils with too high an acidity level is a first step in successfully establishing this ecosystem. Furthermore, the calcium in lime favourably affects the formation of the root nodules where the nitrogen-fixing bacteria reside, so contributing to a greater supply of nitrates (Brady, 1974, 435). While requiring the same nutrients as other pasture plants, legumes have a particular need for phosphate (Brady, 1974, 456). The general deficiency of this mineral in New Zealand soils was the principal limitation to be overcome by soil amending. The recognition of the relation of lime to phosphate uptake, the role of trace elements in plant nutrition and the importance of the leguminous component to the pasture sward were to follow.

The utilization of land for pasture had become a feature of New Zealand agriculture by 1861 when 70 percent of the area of improved farmland was so employed (*Statistics of New Zealand*, 1861, Table No. 51). By the early years of the twentieth century this figure had risen even higher, and to 1970, remained in the 88 to 90 percent range[7]. The types of pasture land have varied in their character, distribution and productivity. The climate, soil, and relief could not all be managed to achieve the uniformity of pasture type desired. For example, of the 8.5 million hectares of sown pasture, some 4.5 million are found on unploughable slopes (White, 1973, 261). The attractiveness of the steep slopes is an outcome of the limited supplies of flat and undulating land of the anticipated profitability of grazing. Forest, fern, and scrub were cleared from hill country and steep mountain slopes. The difficult relief was a major obstacle to soil amending, however. Signs of declining land productivity appeared (Gould, 1976, 19; Gibbs, 1974, 174-175); yet a solution to the general problem of ensuring adequate soil fertility was not found quickly. Many decades of continuing experimentation were needed before significant success was achieved but this success was spectacular. The distinguished scientist, Sir E.B. Levy (1955, 9), has claimed that the 'inimitable grassland climate' was 'linked with soil fertility and with plants and animals that can exploit to the full the potentialities of our [New Zealand's] climate.'

A first step in this linkage of climate, soil fertility, plants, and animals was the replacement of indigenous grasses with more productive exotics. The use of these more demanding grasses depleted fertility and prompted a search for ways to maintain fertility to sustain them (Levy, 1970, 48). The technique of amending the soil through the addition of nutrients and the control of acidity was a critically important development.

The effects of this technology are complex, involving the biological and biochemical processes through which soil and plants interact to create feed for animals. These interactions can be regulated by the distribution of appropriate chemical and biological materials it was being discovered in Europe at the time of New Zealand's colonization by Britain. The techniques developed were incorporated into the technology which came to be used to overcome the newly encountered production difficulties. The transmission of this information to farmers, and the organization of institutions to research it and further develop it for use in the New Zealand environment were important in the creation of appropriate farming practices. The concern with the technical aspects of soil amending entailed the development of suitable mechanical spreading devices and of management techniques. The use of both played a key part in the emerging farming systems. The application of these techniques reflected a reappraisal of the production potential of the land itself.

Soil amending was more than just a means of linking livestock production with climate potentialities. In sustaining the grassland economy, soil-amending technology may have altered the course of New Zealand's economic development. Many factors served to perpetuate the grassland underpinning of the economy, to the disadvantage of the non-agricultural sectors. The high fertility demands of the ryegrass-white-clover pasture, the most productive type (Levy, 1970, 70), were met by an unswerving commitment to improving soil fertility, rather than by exploring the alternative strategy of creating grasses with lower fertility demands. The faith in soil-amending technology had important ramifications. It became a focal point for inventive activity, encouraged a long-term stability in agricultural patterns, and facilitated the continued dominance of the agricultural sector. The success of these supportive trends further confirmed the faith in soil-amending technology and, when abetted by a combination of external and internal factors, constituted a conditioning influence on the search for and receptivity towards improvements in soil-amending capability.

THE FRAMEWORK

This dissertation considers the introduction, adoption, adaptation, and generation of soil-amending technology in New Zealand. The conceptualization of soil-amending techniques as innovations, embodying the application of knowledge to production, and of the rounds of adjustment following their adoption as technological changes, provides a basis for tracing the incorporation of soil-amending technology into New Zealand agriculture. Employing a framework embracing the related notions of economic growth and economic development[8] allows the exploration of the ways in which changing technology enables and induces productivity improvements and introduces entirely new approaches to productive activity. The former bring about growth in the form of scalar changes, while the latter stimulate development through the process of restructuring economic relationships. The causality of the relationship between technological change, growth, and development is thus a central concern of this dissertation.

The interconnection between technological change in agriculture and economic development can be usefully discussed by reference to economic production theory. Conventionally, the idea of a production function[9], where interdependent factors of production are used in combination or as substitute or complementary factors, provides a conceptual device for describing growth adjustments that ensue from technological change. The application of this concept at different levels of aggregation can help to identify critical aspects which characterize much technological change.

Changing technology often improves the productivity of both tangible production factors (labour, natural resources, tools, and other capital goods) and intangible production factors (according to Kendrick (1973, 11), 'the stock of productive knowledge incorporated in the labour force and in non-human instruments of production, or disembodied as in the organization of production'), so leading to a reassessment of the mix of factors employed in achieving a particular production level. The improvement in productivity of one or more of these factors can also be utilized to achieve higher production levels.

Soil-amending technology has been employed to directly enhance the productivity of the land resource, thereby increasing total agricultural production. The application of this technology has further indirect effects through the need to invest more capital to achieve full benefit from the improved performance of the land resource. As the application of capital often entails further application of labour, so the application of new technology can induce substantial adjustments of the production function in addition to expanding the production frontier. With labour, through its limited supply, being an expensive commodity in New Zealand, production systems have been developed which are capital- rather than labour-intensive. This is the basis for the high per capita productivity in agriculture initially mentioned. The steady expansion of output following the application of soil-amending technology, and the adjustments in the production function have ensured the dominance of the agricultural sector in the national economy. The effective utilization of resources in that sector has probably resulted in a disproportionate flow of factors of production to that sector. The durability of the ensuing national economic structure has been enhanced by this channelling of resources into one sector.

The principal thesis of this dissertation is that the innovation stream associated with advances in soil-amending technology has been responsible for the emergence and the continuation of a highly productive grassland ecosystem. The stability of the agricultural systems based on grassland over at least the past fifty years is almost paradoxical in that a priori argument suggests many reasons why New Zealand agriculture might have undergone pronounced structural change, particularly in light of the introduction of increasingly complex technology and of changing, often adverse, external circumstances. One issue addressed in this dissertation is the stability of the structural organization of New Zealand agriculture. Is this stability reflected mainly in the nature of the agricultural system itself, especially in the use of grassland; in the character of soil-amending technology; or in the political and economic system which constitutes the wider environment of agricultural activity?

Exactly how and why New Zealand farmers came to utilize the scientific knowledge of Europe embodied in soil amending is an intriguing question. Clearly they were motivated and able to learn about scientific findings. They adopted and adapted new technology incorporating the advances of science. Cultural values must have encouraged experimentation with new techniques. The existing capitalist ethic led farmers to undertake enterprises which would be economically viable and then to improve the profitability of those enterprises (Watters, 1965, 190). Identifying opportunities to increase profitability by increasing production resulted in the introduction of technological change into agriculture and in new appraisals of the production possibilities of the land.

What is more difficult to determine is just how soil amending became established, how this and other new but related practices were employed, and how the farming enterprises and agricultural systems were able to incorporate the benefits of these technical advances. In attempting to unravel the implications of soil-amending technology the context of its adoption cannot be ignored.

The present state of development is dependent upon its historical context. The cultural approach to the dispersion of agricultural innovation as developed by Sauer (1970) in relation to plant and animal domestication provides a basis for examining the historical context of the systems created in New Zealand. The British background of most of the early settlers (Table 1.1), together with Australian production experience, furnished the basis from which agricultural systems were derived in the new environment. The initial wool enterprise based on extensive grazing certainly followed the pattern operative in New South Wales from 1814 (Clark, 1949, 157; Jeans, 1972, 90-91). As only a small proportion of the migrants had agricultural experience, they imitated and adapted a successful pattern which became the norm until later economic and technological changes altered the production environment (Clark, 1949, 156-157). British-derived agricultural techniques gained greater importance only in the later

TABLE 1.1

BIRTHPLACES OF THE NEW ZEALAND EUROPEAN POPULATION 1858 - 1901

	Percentage of the Population Born in:								*Total Percentage:*	
Year	*England*	*Ireland*	*Scotland*	*Wales*	*British Isles*	*Australia*	*Other British Dominions, etc.*	*Other Lands*	*Not New Zealand Born*	*New Zealand Born*
1858	39.9	7.7	13.4	0.4	61.4	2.4	2.1	2.6	68.5	31.5
1861	36.5	8.9	15.7	0.5	61.6	2.6	1.9	6.0	72.1	27.9
1864	34	11.8	18	0.6	64.4	5.5	1.8	4.4	76.1	24
1867	30.0	12.8	15.9	0.6	59.3	5.2	1.7	4.5	70.7	29.3
1871	26.2	11.6	14.4	0.5	52.7	4.8	1.6	4.5	63.6	36.5
1874	24.9	10.1	12.8	0.5	48.3	4.5	1.0	5.2	59.0	40.9
1878	25.7	10.6	11.6	0.4	48.3	3.9	0.9	5.0	58.1	42.0
1881	24.3	10.1	10.8	0.4	45.6	3.5	0.8	4.5	54.4	45.6
1886	21.7	8.9	9.5	0.3	40.4	3	0.7	4.1	48.2	51.9
1891	18.7	7.6	8.3	0.4	35.0	2.6	0.6	3.3	41.5	58.6
1896	16.6	6.6	7.2	0.3	30.7	3.1	0.5	2.9	37.2	62.8
1901	14.5	5.6	6.2	0.2	26.5	3.5	0.5	2.6	33.1	66.8

Note: Totals not equalling 100.0 percent are due to rounding error.

Sources: 1858 *Statistics of New Zealand* (1858, No. IX).

1861-1871 *Census of New Zealand* (1871, No. 12).

1874-1901 *Census of New Zealand* ([for years shown] , Birthplaces of the People).

nineteenth century when more intensive use of grassland became feasible (Clark, 1949, 384). By then British agricultural systems were viewed as the most advanced in Europe, and the New Zealand colonists remained strongly culturally related to Britain even though almost half of the population was New Zealand-born (Table 1.1). Imitation occurred; yet, Clark (1949, 157) has noted:

> When they [the English farming methods] were applied, ..., they were always modified by the inherited equipment of animals and plants introduced by the early regime [extensive grazing], as well as by the natural physical equipment of the area (often modified by this regime over half a century), and by its peoples' rapidly established habits of thought and action.

Thus, adaptation of borrowed technology has been an important process in the development of New Zealand's farming systems.

CONDITIONING INFLUENCES

In exploring the emergence and retention of soil-amending technology, it is helpful to keep in mind several conditioning influences which, although varying in magnitude and effect through time, have played a vital role in shaping the eventual patterns of agricultural production. These conditioning influences are:

1) The historical context in which technological change has taken place.
2) The pattern of information transmission and its effect on adoption.
3) The perception of the need to change existing agricultural systems.
4) The perceived ramifications of innovation.
5) The role of complementary technology in innovation diffusion.
6) Structural change and sectoral interdependence as outcomes and sources of technological change.
7) The role of government.
8) The occurrence of economic growth and development.

An introductory discussion of each of these influences highlights how they have conditioned the utility of soil-amending technology.

Historical Context

The modification and replacement of indigenous ecosystems with the introduction of European farming methods has been noted as a fundamental step in determining New Zealand agricultural practice. Pioneering involved a process of experimentation with more familiar technology in an unfamiliar environment (Moran, 1974, 123). The setting proved conducive to invention and innovation[10]. In the formative stages of the farming system, the organization of production was approached anew in the absence of an established, formal institutional structure.

The development of an indigenous institutional structure of itself provided some direction to the further development of the economy. Later, as further changes in technology appeared, the same structure served to direct any changes that took place. It has been argued that the New Zealand farming systems prior to 1950 had been established between 1880 and 1920 (King, 1950, 69) and that the patterns of the late 1960s were actually an extension of those of the 1930s (Cumberland, 1968, 9). These observations suggest that the farming systems have enjoyed a long-term stability in spite of the occurrence of a number of significant changes in technology and in markets.

The technological changes and shifts in markets point to the wider historical context affecting New Zealand. The growing complexity of world technology seen in the growing concern with biological as opposed to mechanical processes (Parker, 1972, 66) has had implications for New Zealand agriculture. The range of equipment and processes available has greatly broadened and has encouraged experimentation in new areas. New Zealand's strong, traditional trading tie with the United Kingdom and its former colonial status may well have conditioned the nature, direction, context, and transmission of change in the economy generally, and in the agricultural sector in particular. The change of this pattern has broadened possible sources of change.

Information Transmission and Adoption

The pioneering agriculturalist participated in the innovation-decision process described in Rogers and Shoemaker (1971, 102). Each producer judged his own success and that of other producers in gauging which methods had proven most successful. Such individual initiative was stimulated in New Zealand through the lack of development of a supportive community framework in the colony's early planned settlements (Watters, 1965, 192). Because of the individual nature of decision-making, information was transmitted first by fellow producers and later was augmented by government and private sector agents. Imitation occurred readily (Stephens, 1965, 52). This pattern follows Rogers' innovation-decision model as interest was high initially because of an awareness of difficulties in the pioneering situation (Rogers and Shoemaker, 1971, 128). New techniques were readily employed as part of the experimentation phase of adoption. Farmers were greatly concerned with finding and implementing viable farm enterprises, and then improving their performance using the technology available.

Perception of the Need to Change

The harsh reality of finding that existing grasslands would not support the desired livestock enterprises and the associated stocking densities heightened the drive to find any means to secure an adequate return on committed investment (Hill, 1965, 44; Stephens, 1965, 59). The adherence to the capitalist ethic had certain implications for the type of production units which emerged, and meant that farmers as owner-operators were interested in opportunities to develop and improve production of saleable commodities.

While local knowledge was of immediate and, perhaps, primary concern in problem-solving, the knowledge developed outside New Zealand was also considered. Opportunities for the transfer of knowledge through trading links in the British and Australian markets (Lloyd Prichard, 1970, 67) facilitated this transmission of ideas. As Great Britain, the home of many migrants to New Zealand, was emerging as a centre of agricultural research in the nineteenth century (Hadfield, 1952, v), a stream of new knowledge was forthcoming. The general literacy of the population (Table 1.2) and the absence of cultural differences provided the opportunity for New Zealand farmers to exploit quickly the new ideas presented.

TABLE 1.2

DEGREE OF LITERACY AND PERCENTAGE OF FARMERS IN THE NEW ZEALAND EUROPEAN POPULATION 1856-1901[a]

Year	*Percentage:* *Unable to Read and Write*	*Able to Read Only*	*Able to Read[b] and Write*	*Percentage of Farmers*
1856	24.8	13.6	61.6	..
1858	25.2	11.3	63.5	7.4
1861	22.3	9.0	68.7	7.5
1864	20.1	7.2	72.7	7.0
1867	21.4	7.2	71.4	8.6
1871	23.3	7.5	69.2	8.0
1874	23.8	8.1	68.2	11.6
1878	23.7	6.8	69.5	11.6
1881	23.1	5.6	71.3	11.2
1886	21.2	4.8	74	11.3
1891	18.8	4	77.3	10.9
1896	16.5	2.9	80.6	11.9
1901	15.3	2	82.8	11.6

Notes: *a* The comparison of the figures on illiteracy and on the percentage of farmers could indicate that farmers formed a substantial portion of the illiterate population and so were unable to utilize written information. However, Condliffe (1933a, 171) has pointed to the interest of early farmers in education and provides an indication of their literacy. He suggests that later small farmers were more limited in this regard but they were able to obtain verbal advice from Department of Agriculture instructors after 1892.

b Totals not equal to 100.0 percent are due to rounding error.

Sources: i) Degree of Literacy

1856 *Statistics of New Zealand* (1853-56, No. 5A).
1858-1901 *Census of New Zealand* (1901, Education of the People at Successive Censuses).

ii) Percentage of Farmers calculated from:

1858 *Statistics of New Zealand* (1858, No. 4).
1861 *Statistics of New Zealand* (1861, No. 12).
1864 *Statistics of New Zealand* (1864, No. 15).
1867-1871 *Statistics of New Zealand* ([for years shown], No. 14).
1874-1901 *Census of New Zealand* ([for years shown], Occupations of the People).

Methods: From 1858 to 1886 the occupations listed as 'primary' represented those in agricultural and pastoral pursuits only. Calculating the percentage of the total population represented by those working in farming and pastoral occupation established this fact.

From 1891 to 1901, the calculation was made by adding the number listed in the agricultural and pastoral sub-orders and then finding the percentage of the total population. In 1896 this involved adding males and females working in each occupation sub-order first.

Perceived Ramifications of Innovation

An innovation stream, involving the application of a number of inventions from various areas of science yet all related to the increase of productivity from pasture land, followed from the perception of needed improvements. Farmers were clearly inexperienced in maintaining the European-derived grasses and soil fertility (Hadfield, 1952, 3). British experimentation at Rothamsted had shown that soil fertility levels could be increased through the addition of nutrients in the form of chemical fertilizers. Accordingly, the procedure first proposed (Clifton cited in Smallfield, 1947a, 169), that of more extensively using indigenous grasses because their fertility demands more closely matched the level available in the soil, was not widely pursued. Soil fertility was improved by soil amending to boost the yield of the fodder crops which supplemented grass production.

The effects of this innovation were major in entailing further substantial changes in the existing production system (Hollander, 1965, 195). New livestock breeds were developed, and the farming system altered to include rotational use of land. The further major innovation of topdressing, that is the application of soil amendments directly to grassland, reduced labour demand because it diminished the need to frequently renew pasture by ploughing and reseeding. The increased herbage yield over a longer period was also found to reduce the need for supplementary fodder crops, again reducing labour input, except in areas where climate limited adequate year-round grass growth. This practice became the basis for the development of a distinctive grassland technology. The farmers who employed it became innovators and generated further invention as experimentation continued and other needs were identified. This interaction between innovator and inventor is a key feature in technological change (Rosenberg, 1969, 21).

Significantly, it was found that the soil amendments applied throughout the country varied in their effectiveness in improving pasture production. Research began to consider where and why the various mineral deficiencies were to be found. Phosphate deficiency was the first widespread problem to be recognized and soil amending practice focused it. Extensive experimentation by government agencies and by farmers led to the identification of specific regional phosphate requirements. Adaptation of an institutional framework through which to stimulate such research was a vital step in creating the agricultural systems which later emerged. Continued work within these institutions provided many of the inventions which generated later technological change in grassland utilization.

Using lime as a soil amendment was seen as a minor innovation, one not entailing substantial change in the existing production system, because its effect varied widely with soil type and its role in improving herbage yield was not as quickly understood. Though the scientific knowledge concerning the importance of legumes in adding nitrates to soils had emerged by the mid-nineteenth century, the application of this knowledge took longer to develop. Strains of grasses which would derive most benefit from this ecosystem had to be identified to make the clovers' contribution more important. The isolation of truly perennial strains of ryegrass was a major invention by New Zealand plant scientists (Smallfield, 1970, 66). Permanent pastures of perennial ryegrass benefiting from abundant nitrates produced by clovers growing in nutrient-rich soils at the proper level of acidity were the basis for further livestock production innovations which fostered New Zealand's high levels of farm productivity. The pattern for this farming system had been established in the nineteenth century but all of these elements of grassland technology only converged and became nationally significant in the 1930s. Accordingly, the substantial rise in output and in intensity of land utilization from the use of this technology can be seen from this period on.

The greater application of electrical and mechanical power to farming in this period was a contemporary development improving labour productivity in dairying and wool production. The move to replace horses with tractors gathered momentum, enabling available manpower to be deployed more effectively in soil amending and grass conservation. The wider use of the latter technology in hay and silage making led to a notable reduction in fodder crop and root crop acreage. The constraint of relief on soil amending resulted in farm-enterprise-related patterns of adoption and usage. Dairy and lamb-rearing farms located on flat to undulating land benefited first from soil amending as available equipment could be readily utilized there. Only after World War II did haulage contractors specializing in lime cartage undertake to adapt their trucks to spreading other soil amendments more efficiently and more widely than could most farmers. This change extended the area which could be effectively covered. Still, this set of innovations was minor in that they improved the efficiency of soil amending in an existing agricultural system.

It took the adaptation of the aircraft to bring this same technology to the sheep rearing and wool enterprises situated on hilly and mountainous land[11]. Manual broadcasting was not sufficient to reproduce the effect of heavy topdressing. Agricultural aviation for pasture topdressing was, then, a major innovation developed in New Zealand. As aerial topdressing was accompanied by aerial sowing of seed of higher-yielding pasture plants, the lowland types of grassland were extended to the slopes and contributed to greater wool and meat production from the mid-1950s as the technique was more widely adopted and the number of sheep rose.

An altered evaluation of the land's production potential is evident from the change in patterns which emerged. Farm enterprises previously found on the lowland areas such as lamb rearing were able to penetrate easier hill country so altering the extent of stock movement from the store-stock farms to the lowlands, to name but one feature.

The increased herbage yield induced a number of major innovations in sheep farm management. There was an increase in fencing for greater control of grazing, a practice found subsequently to increase production on its own. Stock management techniques emerged which enabled fuller use to be made of available herbage. A greater number of minor innovations appeared such as the use of clovers (other than white) better suited to drier and shadier hillsides to sustain grass growth, and the improvement of secondary-growth control as the feasibility of maintaining pasture was demonstrated.

Similar possibilities resulting from the ability to carry larger numbers of livestock existed in the lowland farm enterprises so inducing innovations in stock and pasture management, and in production facilities. For example, a dairy farmer was able to run more cows using this grassland technology but milking more cows entailed the use of more efficient milking equipment to keep labour input at the previous level. As farming systems utilized production systems varying both in method and in intensity, the impact of the change in technology was not spread through them equally. Those undergoing little change found the degree of change needed to fully exploit the major innovations greater than those in which change was ongoing and induced smaller, more frequent adjustments.

The adoption of one innovation, as seen above, may entail a number of subsequent adjustments. Being able to identify the extent of change necessitated by a particular innovation often influences the producer's adoption decision (Snodgrass and Wallace, 1964, 127). The greater the change seen as required, the less readily adoption occurs. Similarly, the perceived difficulty of implementation in terms of cost or effort and the amount of readily observable benefit are directly related to the rate of adoption. Hence, minor innovations, in requiring less substantial change to the existing system, should be more frequent.

A seemingly simple technique such as the application of chemical fertilizer and lime can be seen to be major, once the changes induced in the production system have been evaluated. The study of these changes proved to be the focus of much scientific research and furnished additional invention in the form of more productive plants. Further, this research altered soil-amending practices following the detection of further mineral-element deficiencies, an examination of their role in livestock production, and the study of phosphate retention. Though these aspects of scientific research represent important contributions to productivity, they are of minor importance because they reinforce an existing production system.

Complementary Technology

The effectiveness of one innovation can be altered by others which promote its utilization. The view of Rosenberg (1969, 10) that advances in technology create disequilibria which induce further invention and innovation to correct it, is most useful in understanding this relationship. For example, the use of chemical fertilizers was limited until effective mechanical means of distribution were created. Moreover, machinery designed for this purpose was not applicable in all farming regions due to the constraints of relief and inadequate mechanical power. Thus the available soil-amending technology was not evenly applied to New Zealand's agricultural systems. This created a situation where structural change was not necessarily occurring in a uniform manner and the rate of adoption varied throughout the agricultural sector. The available pool of knowledge and technology becomes an important consideration in evaluating the potential effectiveness of a particular innovation in creating change within a production system (Solo, 1966, 92-93). The linking of technologies can become a major innovation in its own right, as in the application of aircraft to soil amending.

Structural Change and Sectoral Interdependence

The introduction of major technological change is expected to lead to structural change in a production system. The alteration of the production function leads to a new mix of inputs and a consequent increase in production necessitates some amplification of the existing structure to deal with it. Soil amending, as a major innovation, involved agriculture in substantial production increases and a greater reliance on production inputs from the secondary sector. However, the broad structural pattern of the sector based on family farms has survived (Smit, 1975b, 104). Such a situation raises the possibility that the farming system accommodated an amplification of production following technological change, because capacity at the farm level had been underutilized (Smit, 1973, 16).

The alteration of an economic structure through technological change can be felt in other sectors of the economy where linkages have developed. One sector may rely upon another to provide the necessary inputs to implement new technology as in the case of farmers relying upon chemical manufacturers for fertilizers. Where the performance in the supplying sector is not felt to be adequate, operators may succeed in entering the sector.

The linkages between the agricultural and manufacturing sectors of the economy need not be direct but may be organized through tertiary sector firms whose function is the co-ordination of the flow of goods and services between the other sectors. Where an imbalance in the number of producers in each sector inhibits communication, such firms offer an important link, often serving as agents of change, and become essential elements in the institutional structure of the economy (Symons, 1972, 70-72). In New Zealand, LeHeron and Warr (1976,1) have observed that the growth of export-oriented agriculture was:

> supported by a network or related servicing industries, i.e. stock and station agencies, agricultural machinery

> suppliers, meat freezing and exporting companies, dairy processing companies, woollen mills, road and rail haulage.

Such agribusiness[12] firms have had an important role in agricultural development in supplying organizational and managerial skills, technical expertise, and capital to farmers. These firms have undertaken innovations beyond the means of individual farmers. For example, the New Zealand and Australian Land Company, a proprietary firm, played a great part in the settlement and development of the South Island through training farmers in apprenticeship on its holdings and in creating more suitable breeds of livestock (Palmer, 1971, 608, 435). Furthermore, it was instrumental in initiating frozen meat and butter shipments and in opening markets for this produce (King, 1947b, 566-567; Palmer, 1971, 437). Butter and cheese factory development was strongly encouraged and financed by such interests (Palmer, 1971, 524-525) often at times when competing, co-operatively owned firms were unable to invest (Philpott, 1937, 102). Subsequently, dairy co-operatives became sufficiently strong to displace proprietary firms and 'The risks taken by the earlier proprietaries and their courage in supporting the dairy industry in periods of at least doubtful future potential were steadily forgotten' (Ward, 1975, 11).

In other farm enterprises the proprietary firms have remained and still exert influence on agriculture through the farm functions they have taken over (LeHeron and Warr, 1976, 1). The policy of reducing farm size according to the 'one man, one farm' concept decreased the farmers' capacity to muster capital and labour so increasing their dependence on external sources for both. This inadequacy of capital and labour remained a characteristic of New Zealand farming into the 1960s and was criticized as being a major impediment to productivity improvement (Sears, 1963, 244-245). Research into farm enlargement in Northland pointed to the critical importance of capital availability in the decision to leave or stay in farming, and in the capability of remaining farmers to increase production through expansion and intensification (Smit, 1975a, 163). Supplying capital is a strong link in the close relationship between agribusiness firms and farmers, and one whereby these firms can influence agricultural production.

Role of Government

Government, acting as arbiter in such relationships between sectors of the economy, plays a similar role to tertiary firms in influencing the decisions made within each sector (Tarrant, 1974, 45-46). It also has a direct role in the agricultural sector in New Zealand. These roles depend upon the form of government adopted and the strength of regulatory powers assigned to it. The economic structure which develops typically reflects governmental decisions as much as, or more than, producers' decisions (Duncan, 1973, 140).

Through directing resource allocation government is able to promote the development of one sector in preference to another. This role is clearly seen in ventures bringing land into agricultural production (Stover, 1969; Fielding, 1965a; Fielding, 1965b), in the stimulation of the growth of dairying (Philpott, 1937), and in the promotion of producer boards responsible for marketing (Evans, 1969). Further, it has created and funded the institutions for research into agricultural production problems. The failure to extend similar involvement to the manufacturing sector until quite recently is one factor explaining the continued dominance of agriculture in the New Zealand economy.

The decision that government should be involved in formulating the institutional changes required to buffer the impact of external change on the economy added another dimension to the role of government. The institutions created could and did alter the production environment of agriculture. The activity of government needs to be assessed carefully when any review is made of producers' decisions about technological and structural change.

Economic Growth and Development

The occurrence of economic growth and development may introduce a new pattern of resource availability. The change of the relative cost of production resources can act as a further stimulus to the entrepreneur's normal quest for means of reducing costs and to his adoption of technology to that end (Salter, 1960, 43,44). Fellner (1961, 308) suggests that where such innovation occurs it becomes 'adjusted reasonably well to basic resource positions' because of the individual firm's market situation. Thus, where labour has become scarce as in the course of economic growth, a preference for labour-saving, as opposed to capital-saving, innovation appears even though both could be employed effectively.

Likewise, demand changes following the increase in secondary- and tertiary-sector employment can prompt change in the agricultural sector aimed at either increasing output for a larger market or maintaining output in spite of a reduced labour supply. Both of these changes can introduce a reassessment of existing technology in agriculture -- the first step in the innovation process.

The structure of New Zealand's agricultural sector has been notably stable but production has increased greatly. The situation in which production increases but does not promote change in behavioural modes as expressed in social structures, cannot strictly be called economic development (Dunn, 1971, 9). Can the agricultural sector in New Zealand be seen to have experienced growth without experiencing development, even though technological change has occurred? This point raises some problems since technological change, a key component of the productivity increases which contribute to economic growth, can be a necessary condition of development. Should technological change occur without engendering economic development, then the relationship may no longer be valid. The effects of technological change within the economy would need to be reassessed.

Such a situation emphasizes the importance of the accurate measurement of the effect of technological change upon productivity. It has been considered that this effect may have been overstated in past assessments of economic growth (Gould, 1972, 297). Examining the soil-amending technology introduced into New Zealand agriculture against such a background provides some insights into this general problem.

FOOTNOTES

1. Soil amending is used to describe the application of soil amendments, that is, 'any substance such as lime, sulfur, gypsum, and sawdust used to alter the properties of a soil, generally to make it more productive.' Fertilizers are included in this term in this text, though the term is more generally applied to the other materials noted (Brady, 1974, 594-595).

2. Productivity is used in the sense of output per unit of input (Olmstead, 1970, 40).

3. Agriculture is the 'purposeful tending of crops and livestock' (McCarty and Lindberg, 1966, 204). Cropping and livestock production are frequently referred to as 'agricultural and pastoral' enterprises in New Zealand sources.

4. The ecosystem is 'a functioning, interacting system composed of one or more living organisms and their effective environment, both physical and biological' (F.R. Fosberg, 'The island ecosystem', 2, cited in Stoddart, 1965, 243). The agricultural systems can accordingly be seen as 'distinctive types of man-modified ecosystems' (Harris, 1969, 134-135).

5. The enterprises 'consist of crops, grasses (sometimes classified as a crop) and livestock products' (Morgan and Munton, 1971, 23) generated in a farming system.

6. Technology, when defined as 'the discipline and body of knowledge as to the application of science to production' (Phillips, 1971, 160), is clearly the link between the two areas. Techniques are the practical crafts employed in production (Ziman, 1976, 146), and technological change is some change in the techniques of production (Strassmann, 1960, 16).

7. The full series of figures is presented in Table 7.4.

8. Economic development is a diversification of economic activity away from primary activity, towards industrial and services sectors, (Gould, 1972, 2). It is usually associated with economic growth, 'an increase in aggregate product, either total or *per capita*' (Robinson, 1972, 54) but need not be so, as is shown later.

9. The production function is an expression summarizing the range of possible commodity outputs which given collections of factor inputs can generate, given the existing state of technology (Gill, 1973, 4).

10. Invention is the combination of new and existing ideas (Norris and Vaizey, 1973, 22); while innovation is the application of invention to production (Strassmann, 1959, 2).

11. Hill country and high country in New Zealand parlance.

12. Agribusiness is defined as 'the sum total of all operations involved in the manufacture and distribution of farm supplies and inputs;

production operation on the farm; and the storage, processing and distribution of farm commodities and items made from them' (Davis and Goldberg, 1957, 2).

CHAPTER 2

TECHNOLOGY, TECHNOLOGICAL CHANGE, AND ECONOMIC DEVELOPMENT

The assertion that innovation in soil amending has had a major impact on the economic structure of New Zealand through its effects on farm structure and the channelling of research activity, leads to a consideration of the innovation process itself in this chapter. Sketching the causal connections between invention, innovation, improvement, and technological change leads to a description of how these interrelated events can constitute a vital component of the process of economic growth and development. It then becomes possible to understand in later chapters the process whereby soil-amending technology emerged in New Zealand and became implicated in the pattern of economic development.

THE CONTEXT OF TECHNOLOGY

This view of the linkage between technological change and economic development owes much to the writing of J.A. Schumpeter on the role of innovation in economic history. Schumpeter (1934, 68) stated:

> development consists primarily in employing existing resources in a different way, in doing new things with them, irrespective of whether those resources increase or not.

Such innovation possibilities are a necessary condition of economic development but are not sufficient in themselves, in Schumpeter's view, since entrepreneurs must be present to implement any such innovations (Schumpeter, 1934, 74-75). Nonetheless, as is seen later in the New Zealand example, technology exacts changes in terms of closer planning of production over longer periods, greater commitment of capital, more specialization of production and manpower, and a restructuring of organization (Galbraith, 1968, 20), and so, can be at the heart of change in the economy.

As technology is often used to define the productivity of an economy, then, changes in technology are likely to alter the productive base of that economy (Freeman, 1974, 20). As 'an increase in aggregate product, either total or per capita', (Robinson, 1972, 54), defines economic growth, the productivity boost imparted by technological change can be of paramount importance. Improvements in the economic operation of production can lead to social and structural changes which are symptomatic of economic development (Mundlak *et al.*, 1974, 102). The relationship between them need not be direct though. The changes generating economic growth may not be sufficient to generate the changes needed to attain economic development (Robinson, 1972, 63).

Technology, although an initiator of change, is also a response to it (Galbraith, 1968, 20). Technology is a reflection of the general development of knowledge and is also a measure of the capacity and willingness of people to implement such development in production. An idea must prove both practical and practicable before it can lead to technological change. In the transition from idea to application an assessment is made of both potential cost reduction and output increase. The relative contribution of an innovation may be considered as either major or minor, according to the extent of technological change which follows its application. A technologically simple innovation may have far-reaching impacts upon the existing technology and the structure of the economy and so be major in its effect. Soil amending through topdressing pastures is seen to be an excellent example of such an innovation.

THE SEQUENCE OF TECHNOLOGICAL CHANGE

Technological change does not occur in a single step. It stems from a sequence of events which are outlined below.

Invention

Invention develops from an insight whereby a new possibility occurs in combining old and new knowledge and from the embodiment of this possibility in some rudimentary form (Norris and Vaizey, 1973, 22). Invention's occurrence, as seen in technological change, is the outcome of either the growth of the body of knowledge, the demand for a means to reduce particular economic costs or the overcoming of particular shortages of production-factor inputs (Strassmann, 1960, 16).

In the former situation, often described as the science-push thesis:

> The growth of the body of science conditions the course of invention ... . It does this by making inventors see things differently and by enabling them to imagine more

> different solutions than would otherwise be the case. (Schmookler, 1966, 200)

This inspiration may be accidental or irrational, making invention a largely unpredictable occurrence (Schmookler, 1966, 199).

In contrast, the demand-pull thesis accords little importance to irrational processes:

> 'invention is largely an economic activity which like other economic activities is pursued for gain,...'. (Schmookler, 1966, 206)

The economy signals the appearance of cost or production problems and thereby focuses inventive activity through offering a reward to the inventor who overcomes them (Wells, 1972, 6). Communicating the existence of such problems is as fundamental to attracting inventors to deal with them as it is essential in providing the pool of information from which ideas are drawn (Ziman, 1976, 90). The establishment of communication links between inventors and entrepreneurs is needed to accelerate the inventive process within a society (Parker, 1972, 64). The accumulation and consolidation of practical knowledge by producers can occasion an interest in the explanation of the processes employed. This eventuality leads to a scientific approach to technical problems and more communication with researchers (Ziman, 1976, 146).

Pred states that the importance of communication lies in 'the technological disequilibrium in the production process' which 'stimulates new inventions which, in turn, give rise to others' (quoted in Hudson, 1972, 151). Disequilibrium, where some element in production technology retards the application of some innovation, is seen to have 'continually directed the application of some competent personnel to the solution of problems of obvious practical importance ' (Rosenberg, 1969, 11). The sequence of inventions becomes compulsive as inventors seek to restore a technological equilibrium. Demand-pull is a powerful force in directing attention to particular disequilibria and setting off, through demand for improvements in related productions, a sequence or stream of inventions which can condition the technological environment of production (Wells, 1972, 25). Stages of production preceding that in which an innovation has occurred may be affected by an increased demand for their output. This demand induces cost-reducing, quantity-increasing innovation. In succeeding states of production, in a form of feedback, innovation is induced by the reduction of supply costs relative to the quality of inputs (Strassmann, 1960, 16). The consequent technological change in either stage or in both stages, can have an effect on the industry in which invention first occurred. The more interrelated the industry in which an invention and subsequent innovation occur is with other industries, the greater the effect of that invention on the economy as a whole.

Whereas the science-push thesis tends to make invention too inexplicable, the demand-pull thesis is too mechanistic in minimizing the role of individual effort and that of chance (Mansfield, 1969b, 165). Actual inventions 'represent the intersection of sets of (scientifically) possible and (economically) desired inventions' (Gould, 1972, 337). The level of knowledge tends to act inversely on the cost of inventing. The engineering practice of the time, the knowledge of materials, mechanisms, and natural processes and properties are the elements which the inventor assembles in his mind in finding a solution. Entering a new field of knowledge may demand an expansion of that knowledge and increase the cost of the desired result. Working with established knowledge that is better understood can keep costs down (Mansfield, 1969b, 165-166).

The cost of the activity may be reduced if inventors are grouped into institutions such as universities and research and development laboratories (Ziman, 1976, 2). In such settings, the conjunction of 'mind, problem and will to solve' (Scherer, 1970, 352) and the juxtaposition of workers from varying fields of research[1] stimulate the combination of knowledge which is at the heart of invention. The enhanced experience available to the individual and the scientific approach are harnessed to create circumstances more favourable for invention. The research and development organizations so established have steadily accounted for a greater proportion of invention because the rate of invention has tended to increase with a growing dependence upon science rather than upon individual experience, skill, and intuition (Gould, 1972, 337; Hamilton, 1973, 22).

This new technical knowledge is the basis upon which the set of techniques available in production is altered and the dynamism of technology established (Norris and Vaizey, 1973, 22). The present state of an economy is the product both of the past, in being derived from inherited capital stock and past investment and technique decisions, and of the future, in reflecting expectations about new techniques, variations in factor prices and new demand conditions (Salter, 1966, 266-267). As social conditions are similarly established, the alteration of either can 'induce men to make inventions which somehow enable them to benefit from or ameliorate untoward consequences of the altered conditions' (Schmookler, 1966, 199) .

Innovation

What may follow invention is innovation:

> the first decision to alter the routine of production, when funds were staked on an untried novelty, when new technical knowledge was applied on a commercial scale . (Strassmann, 1959, 2)

The emphasis in innovation is on commercial exploitation as some organization of markets, capital, labour, and materials is required in implementing an innovation (Strassmann, 1959, 7). In the innovative stage, entrepreneurs in commercial firms undertake the work with the profit motivation of attempting to satisfy a demand they perceive (Wells, 1972, 8). Though initially the objectives may be scientific, non-commercial, and call for little expenditure, later, the concern for production costs and potential sales leads to the reduction of the role scientific people have to play as large amounts of risk-capital are expended (Gould, 1972, 347). This risk-capital expenditure is used as a factor explaining the location of entrepreneurs in markets demonstrating strong demand for a product innovation (Wells, 1972, 6).

The commercial orientation of innovation has led Scherer (1970, 350) to suggest it is the end phase of the process of development occurring through time. The first phase is invention; the second, the development of the invention; the third, the testing of it; and the fourth, the marketing of it.

As the phenomena of invention and innovation can be distinct, the application of an invention can well lag behind its discovery (Hollander 1965, 26). At this stage the high degree of uncertainty present in the decision-making process may lead to an interruption of direct development sequence. The likelihood of such interruption is so great that an 'innovation chain' linking basic research with innovation and economic growth is viewed as 'improbable because it presupposes that there is no dependence between the intensity or occurrence of technical development (innovation activity) and the economic conditions in an industry' (Haeffner, 1973, 19).

Social conditions can also play a role in disrupting an automatic progression. Public concern over the results of work in a particular field could discourage some researchers directly through some demonstration of opinion and indirectly either through the suspension of funds from public sources for that type of research or through legislative prohibition.

The decision to innovate relies heavily on the production environment. Before an innovation begins to look technically and economically viable, further invention varying in degree of difficulty of creational magnitude may have to occur to support the proposed innovation (Scherer, 1970, 352). This is a form of the feedback noted by Strassmann (1960, 16). The value of an awareness of developments in other fields of endeavour through information dissemination increases because the solution to problems in the development of one innovation may be found in other inventions and innovations (Ziman, 1976, 209).

Development

Economic viability prompts the entrepreneurial investment decision which permits development, 'the lengthy sequence of detail-oriented technical functions' (Scherer, 1970, 350), designed to ready an invention for commercial utilization. The proven utility of the innovation generally reduces uncertainty in the decision-making process, but there remain the problems of working out the invention in detail, perfecting it, and assessing the return expected from its sale. Substantial costs may still be involved at this stage' especially if technical uncertainties arise (Ziman, 1976, 208). Product innovations may be less difficult to develop than the process innovations needed to manufacture these new products (Freeman, 1974, 105). The interplay between invention and new findings is still likely to occur as the technology utilized is constantly evaluated under production conditions (Strassmann, 1959, 10). This interplay is important to invention as 'invention may follow some research findings but it has usually arisen in the process of developing some other process' (Norris and Vaizey, 1973, 23). Interaction, therefore, can prove critical in redefining the environment in which an innovation occurs and thereby altering the entrepreneur's decision to proceed with its development.

Improvement

When the innovation is being utilized in production at a significant scale, problems may appear that prompt further development. This may be initiated and partly undertaken by production personnel. The improvement stage is a manifestation of learning through experience in the repetition of some activity (Gould, 1972, 359-360; Norris and Vaizey, 1973, 164). One expects that much minor technological change, i.e. a development that is though 'relatively simple by men skilled in the pertinent arts' (Hollander, 1965, 195), originates in this manner. Existing techniques may be altered more or less continuously under the test of minimizing production costs. The cumulative effect of these minor changes may be greater than that of major technological change (Hollander, 1965, 196). This view is supported by Arrow (1962, 157) who suggests that not only new technology but the more effective application of existing technology can be used to adjust a production function. Hollander (1965, 205), moreover, has suggested that the minor changes are dependent upon major changes as the former would become exhausted without the occurrence of the latter.

Support for this idea is found in Arrow's observation that cumulative investment is a better measurement of experience than output. The rate of output tends to become constant after some innovation has occurred, an indication that the rate of learning is subject to diminishing returns. As capital is rarely replaced by exactly the same sort of capital, new technology is embodied in the new capital introduced and so, the production environment changes and a stimulus to learning occurs (cited in Norris and Vaizey, 1973, 196).

A technical progress function provides a conceptual framework in which the rate of growth in the productivity of labour working on new equipment may be related to a constant rate of investment, output per man increases but with diminishing returns. This concept assumes an exogenous, constant flow of ideas so that increasing the rate of investment permits the exploration and application of more ideas. As all ideas are not equally productive, the function implies that those with the greatest potential for productivity increase tend to be exploited first. This relates well to the idea that the simplest inventions, those most obviously boosting production, are created first (Parker, 1972, 63). An increase in the occurrence of invention shifts the curve upwards, an indication that any growth of investment leads to a more rapid rate of growth of labour productivity from the use of new capital.

Where such learning occurs in a technologically dynamic economy, new technological developments may also be stimulated (Arrow, 1962, 157; Hirsch, 1969, 37). The more time which elapses between planning output and producing the last unit, or the greater the planned volume of output, the more opportunities one has to incorporate new technological knowledge into the production process (Hirsch, 1969, 37). Either innovation or improvement could occur. Such learning is ongoing and occurs with any newly adopted practice. Hence:

> Unless major inventions come thick and fast, which is often unlikely from the very nature of the scientific field in question, it is probable that a substantial part of overall productivity gain will come from the gradual improvements going on continuously between the discrete major innovations. (Gould, 1972, 358)

This source of productivity gain is important since:

> in a competitive system a substantially new process will be introduced when, but only when, it promises a discernable reduction in total costs below those of existing (improved) processes. (Gould, 1972, 358)

Improvements altering the composition of the production function would be introduced first to take advantage of any difference in factor costs which is perceived as being significant (Gould, 1972, 363). Particular market needs and production situations can lead to the adaptation of technology to meet them. The process might involve only minor improvements featuring low uncertainty (Freeman, 1974, 196-197). Likewise, the operating environment of the activity system has a strong influence, for:

> the fact that improvements are often in some degree specific to a particular plant or to a pattern of factor and resource availability peculiar to a particular region means that they often cannot be transmitted, as basic techniques can, from one environment to another. (Gould, 1972, 360)

The specificity of any improvement has to be carefully assessed before it is made available to other producers. The particular importance of this consideration to agricultural production is taken up in the following chapter.

THE IMPORTANCE OF TECHNOLOGICAL CHANGE

The range of technological solutions has expanded as scientific enquiry has moved from the study of mechanics to more complex studies of matter and natural forces. These solutions are then incorporated into available technology once sufficient enabling invention has occurred (Parker, 1972, 70). The broader the range of problems being tackled and solved, the more likely a variety of inventions will enter the body of technology at a given time. With adequate communication, effort in one field of activity can be minimized by utilizing inventions developed elsewhere both directly in production and indirectly as a complement to other inventions.

The state of technology sets the basic levels of cost and productivity around which the economy operates. In the absence of invention in an area of the economy, some lag in development may occur. The effect of the lag may be reduced by resource mobility to compensate for the failure of invention, as this is the basis of the production function concept. Nonetheless, economic resources are not perfectly mobile and not perfectly substitutable. As this applies to the knowledge of techniques, a succession of problems has to be overcome in the development of technology to achieve the highest possible productivity levels in the economy.

Technological change results in a shift in the production function (Lave, 1966, 5). With changes in technology the usefulness of resources can be reassessed and new combinations employed. The usual effect of this shift is a quantitative rise in production because more output is available per unit of input. Also likely are changes which may result in higher quality output per unit of input (Snodgrass and Wallace, 1964, 217).

The measurement of the former has been found to pose fewer problems than that of the latter (Gould, 1972, 295) and so has enjoyed more use as a frame for in assessing the effects of technological change on productivity. The shift could conceivably create both more and better output; yet this poses a more complex measurement problem. Hollander's study of cost-reducing technology indicated that in many instances, technological change designed to reduce per unit production costs had the secondary effect of permitting an improvement in quality which in turn gave rise to further reductions in per unit cost (Hollander, 1965, 200). The reduction of per unit cost could be dependent upon first altering the nature of the product itself. Whatever the case, productivity, the measure of output per man-hour, has been enhanced.

Kuznets (1967, 81) had indicated one major problem in assessing the role technological change has played in productivity improvement. He used the term, 'the large remainder', to describe whatever effects could not be directly ascribed to capital and labour inputs in shifting the production function. This residual category encompasses technological change, improved resource quality, and changed production arrangements.

This approach has been criticized on the basis that the aggregate inputs of capital and labour may not have been measured adequately; therefore, any influence they might have is assigned to the 'residual', usually called technological change. True changes in technology, best indicated by innovations, do not include other possible contributors to the production function shift--movements away from or towards the production frontier, economies of scale, or unknown factors (Gould, 1972, 299). The contribution of technological change is overstated in such a situation.

Schultz (1971, 8) argues that improvements in the quality of the factors of production play a 'real and large part in productivity change'. The level of education achieved by the labour force is given as an example of a qualitative change whose effect, while not measurable, does form a part of technological change (Gould, 1972, 297). Attempts by scholars such as Becker (1964) to quantitatively assess the importance of education in increasing productivity have been criticized. Gould (1972, 309-310) notes:

> it perhaps seems questionable whether any simple scheme of counting increments of schooling and relating these to the growth of product by a crude formula really meets the complexity of the case.

Such criticism does not deny that changes in technology have been important. The problem lies in the ability to gauge what improvements can be made in capital and labour so that their technical attributes can be altered and so acted upon in new ways as technology changes. Schultz (1971, 11) and Norris and Vaizey (1973, 134) indicate that investment is the mechanism through which these alterations occur.

THE ROLE OF CAPITAL

Equally important to such an argument is the definition of capital. When capital is defined as 'the stock of produced or man-made means of production consisting of such items as buildings, factories, machinery, tools, equipment, and inventories of goods in stock' (Gill, 1973, 14), then it follows that technology forms an intrinsic part of capital. It is perhaps less obvious that the skills used in employing capital can be part of capital. Schultz (1971, 11) considers that new techniques themselves when developed and put to use are a form of capital. While not all authors would agree on the utility of the analogy between human skills labour and a production good (for example, Chamberlain, 1967), the close relationship between production goods and production techniques is demonstrated. Hollander has suggested that the direct contribution of capital to productivity increase has been understated in that some level of the technology available is embodied in capital and cannot readily be treated as a factor on its own. Any measure of input capital not taking into account the changes over time of such features as the effectiveness of plant and equipment in use, and the improvements which have occurred in machinery, overemphasizes the residual value of technological development and underestimates the contribution of the capital itself. Existing stocks of capital, those in which investment has already been made, are labelled 'old' on this basis. Short-run economic progress can be based on the application of existing technology (Freeman, 1974, 20). Subsequent technical progress will not be included in this capital without some change occurring first.

It is with subsequent investment that a new stock of capital is acquired, thereby embodying newer technology which has more flexibility to meet new production techniques (Dunn, 1971, footnote 2, 14). When technological change requires investment in plant and equipment, the two activities interact to increase productivity. This increase is not so much a result of increasing the quantity of capital stock as of replacing the older, less adaptable stock:

> The rate at which new technology may be used, and/or new resources used, and/or new uses made of old resources will depend to some degree on the amounts of existing capital and its age. (Thomas, 1964, 204)

Where new stock is not acquired, the competitive position of an industry or firm tends to deteriorate as capital ages without renewal (Thomas, 1962, 69). The part played by investment in improving productivity is highlighted by this observation.

Although the pressure to produce as efficiently as competitors may have a role to play in creating obsolescence (Singer, 1971, 62), it remains uneconomic to scrap capital as long as operating costs fall short of price, no matter how technologically obsolete a technique is (Gould, 1972, 346, 350). An additional factor retarding the use of new technology may be any high levels of investment in terms of both the production goods and the training of the labour force required to undertake a new activity (Snodgrass and Wallace, 1964, 127). Accordingly, the composition of various factors costs has a significant role to play in prompting the decision to incorporate new capital. For example, greater labour availability at decreased cost may enable older capital to remain economically competitive with newer but more expensive capital.

In periods of rapid technological change it may be expected that new capital will be superseded by some superior alternative, and so the decision is made to delay replacement of old capital until the degree of change can be assessed against the cost of entering the market for new capital (Hollander, 1965, 132). The frequency of changes necessitated by rapid technological change may make production insufficiently profitable. Thus, some attempt is made by all firms to extend the duration of use of capital thereby preserving existing investment (Freeman, 1974, 153). A final factor inhibiting capital change is the managerial perception of the rate of technological change. Entrepreneurs have to be aware of possible opportunities to improve their return by replacing old capital with new and must feel reasonably sure of their capacity to employ this new capital. Learning, once again, appears as a factor in technological change, this time at the end of the innovation process.

ADOPTION

Once innovation has occurred, knowledge of its creation diffuses to potential users who decide upon its utility. Putting it to use spreads the technology more widely and broadens the technological environment, thereby increasing the possibility of invention being derived from it. This decision to employ an innovation is a 'mental process through which an individual passes from first hearing about an innovation to final adoption' (Rogers, 1962, 17). A potential adopter becomes aware of the existence of an innovation and may be prompted to acquire more information and so enter the second or 'interest' stage. The resistance of the adopter has to be overcome by sufficient, effective information (Brown, 1969, 194) to persuade him to evaluate the innovation through some trial before he puts the innovation into productive service and imitates the innovator.

As products of an expressed need, innovations should be readily accepted by those expressing the need. Nordhaus (1969, 18) also points out that the indivisible nature of an innovation should facilitate its spread as any firm can acquire it at almost no marginal cost unless it is protected in some way, by a patent for example.

The rapid spread of an innovation does not always occur, however, as barriers can be imposed. Kuznets (1959, 31) has stated that any move in the innovation chain can be blocked. Haeffner's (1973, 22) three parameters representing the need for an innovation: function, environment, and economy, can be used to indicate the difficulties which are encountered. The innovation may not perform as expected. Regional differentiation may arise on this basis as an innovation which functions successfully in one set of conditions may fail in another. Griliches (1957, 511) noted this feature when he demonstrated and explained the lag between regions in the use of hybrid corn. It has been recognized that an invention's importance can be a function of how well it suits the production environment where it will be utilized as well as of its own attributes (Schmookler, 1966, 198). Likewise, market knowledge becomes as necessary to innovation as technical knowledge (Freeman, 1974, 165). Some combination of social, socio-economic, and political factors may make potential adopters resist change in any form. The extent to which an innovation is radical, calling for major changes in the social, economic, and political framework of the community may play a part in the adoption decision. An innovation radical in terms of the technology employed, yet fitting into an existing pattern of production may be more readily accepted than one which involves a substantial alteration of that pattern but employs more conventional technology.

Such a phenomenon deserves careful consideration when one is attempting to determine which innovations, if any, are more likely to be resisted. As innovations may form a stream, resistance to any one may lead to an interruption which causes a reduction in efficiency (Kuznets, 1959, 29). A problem which arises here is the detection of any shift of the frame of reference being applied by the innovation agent and potential adopters. At one point in time there is probably a diversity of frames over a given industry or within a given area (Kuznets, 1959, 112). Uniform adoption, in that case, becomes unlikely. Measuring the causes of such variation as expressed in spatial terms can be in the realm of geography as Hägerstrand (1952; 1966; 1967) demonstrated.

The use of innovations can involve high levels of capital investment in both physical and human capital. New capital has the advantage of being more flexible than old capital in that it is not invested already and can be applied more readily to meet the needs of the adoption of the innovation. The type of cost affected also has a role to play (Snodgrass and Wallace, 1964, 239) as variable costs can be reduced by reducing output while fixed costs continue to occur regardless of output levels. Accordingly, an innovation requiring capital outlay which results in higher fixed costs may be adopted more slowly than an innovation whose costs can be cut more rapidly in a changing market situation.

The rate at which adoption occurs influences the rate and amount of economic growth in a given period of time (Thomas, 1962, 72). Because of the obstacles to be overcome in meeting the new situation, entrepreneurs must have the talent and skills and the incentive to overcome them, along with good communication. The potential users who judge the possible changes required in the new situation must be responsive; otherwise they dismiss the innovation out of hand (Kuznets, 1959, 32).

In summary, unless the resistance created by any of the three factors noted above is overcome, technological knowledge is unlikely to be translated into economic development. If the resistance is not evenly spread throughout a social system there can be some regionalization of the use of new products and/or processes. In turn, one set of producers becomes able to enjoy whatever competitive advantage the innovation has to offer and are able to profit by it. Where this advantage is translated into structural change in the economy, the innovators can direct inventive activity to their technological difficulties and extend their situation of advantage within the economy.

THE ROLE OF TECHNOLOGICAL CHANGE IN ECONOMIC DEVELOPMENT

The translation of technological change into economic development relies upon the capacity to create new modes of behaviour and social and cultural change within the economy as it experiences growth. This growth should be sustained, that is, both irreversible and long-lived (Gould,1972, 1). While the exact definition of those terms is considered to be difficult (Supple, 1972, 19), the characteristic changes are better defined. In general there is an increase in the scale of social structures present in the activity system and an increase in the quantitative levels of the activity systems. An increase in existing quantities of resources of the same quality may be employed in the same structures to expand the output of the same products. Growth, then, can occur through the acquisition of unexploited, free resources such as an enlarged labour force or newly acquired land, or the opening of new markets, any of which may allow the 'aggregation of existing behavioural modes'. (Dunn, 1971, 9) The increase in productivity can occur through a change in inputs in type and/or in quality. New production methods or a new industrial organization may be employed. The resulting output may also be changed in that there may be more of it, and it may be of a new type or of a higher quality (Schumpeter, 1934, 66). Technological change is implicit in the creation of these new products and processes, so reflecting

> the application of new knowledge to the solution of economic problems. They [changes noted above in goods, production methods, markets, sources of raw materials, and industrial organization] represent changes <u>within</u> a given aggregate preference structure, not changes of that structure [defined as the social and cultural value systems]. (Robinson, 1972, 57)[2]

It is noted, however, that 'changes in the volume of resource input may well have had indirect effects on efficiency and hence on the growth in per capita product ' (Kuznets, 1967, 82). Short run economic growth must rest, accordingly, on economic development over the long run; however, there may not be a perfect correlation within a finite time span (Dunn, 1971, 8-9, 10).

Another possibility is the occurrence of technological change which alters the technical structure. This can result in:

> new (social and political) institutional structures such that potential profits are high. Thus technological change leads to tension which is worked out by entrepreneurs who initiate changes in the technical and institutional structures through investment. (Robinson, 1972, 62)

The above-mentioned tension is defined as:

> present perceived potential profit arising either from the present economic and preference structures or from changes in those structures in ways that are perceived to be feasible and desirable. (Robinson, 1972, 61-62)

Accordingly, it not only represents a perceived gap between what is desired in the preference structure and what could be produced by the best economic structure but also implies elements of uncertainty as some tension must be perceived to be operative. The importance of the entrepreneur in perceiving the gap and of information flow in aiding perception are indicated in this tension concept.

The tension concept relates to the disequilibrium concept of technological change. Where equilibrium, or balance, exists in an economy or in technology, change is not generated because tension is minimized. The emergence of change in a structure, as in the case of soil amending in the technological structure of farming in New Zealand, disrupts the equilibrium to a degree determined by the intensity of the tension produced. Imbalance is the outcome until sufficient, seemingly appropriate adjustment takes place. This may come in the form of changes in the structure or of changes in other structures to resolve the perceived tensions. Economic development is one possible outcome (Robinson, 1972, 63). As this tension involves both economic and preference structures, economic development is related to social change:

> changes in activity levels and their supporting capital structures require changes to be made in the stocks of physical and human capital. (Dunn, 1971, 22)

Such changes may be necessary to the incorporation of both old and new behavioural modes into the economic structure (Dunn, 1971, 24). Such changes may alter the aggregate preference structure so causing tension and contributing to further growth. With new products and processes altering the demands made for production factors, the worth of these inputs is reassessed and adjustments of capital and labour inputs accompany the structural changes which occur during economic development. The working out of past tension in the economic structure contributes to ongoing change. Because learning may be a consequence of such change, it is not surprising that the economic and social changes may not occur simultaneously. Commonly, changes in the institutional framework of the economy tend to lag behind those in the economy itself (Islam, 1974, xvi). Over time the interaction between the economic and preference structures is reduced as major changes in the economy are worked out.

The lessening of tension derived from structural change and the linking of structures leaves technological change as the principal tension source in developed countries. This view of the leading part played by technological change in developed economies is supported by other economists (Kuznets, 1967, 81; Galbraith, 1968, 71). Even in the process of development, technological change is vital:

> the growth of factor productivity is associated most significantly with scientific progress and technological change which have been both the cause and consequence of structural changes that have altered so dramatically the composition of output and the occupational distribution of the labour force. (Johnston and Kilby, 1974, 42)

With development, the physical and human resources used in production are improved; the institutions and preferences, reflecting the society in which they are found, are altered; and the technology being utilized is changed.

It has come to be recognized that change in the economy is dependent upon some unbalancing of existing structures (Streeten, 1963, 671). Growth theories have varied in the degree of imbalance and the structure or structures to be unbalanced. Unbalanced growth theory relies upon the inducement effect of substantial investment in one sector. Linkages in the economy then transmit growth by inducing investment (Myint, 1960, 126). The investment tension is worked out by structural change if market forces are sufficiently powerful to effect this transmission and co-ordination of the structural change has been adequately planned (Streeten, 1963, 671).

In balanced growth theory, the emphasis is on the provision of a number of investment projects which, in being carried out simultaneously, provide for the interdependence of firms and of sectors (Johnson and Kamerschen, 1972, 278). As investment is geared to stimulating the complementarity of markets for final goods, the need for co-ordination and the structuring of an investment package is primary (Streeten, 1963, 671). Balanced growth as an aim not a method of economic growth is advocated (Nurkse, 1961, 279), though there is concern that in creating an equilibrium situation, the tension for further growth would be absent (Hirschman, 1958, 66). The thesis of Robinson (1972, 67) that technological change is the main basis for economic change and of Gould (1972, 337) that the pace of technological change is accelerating, lead one to suspect that attaining balanced growth is difficult indeed.

This argument on economic development and the part played by technological change is derived from the work of a number of theorists and observers concerned with identifying a pattern to be followed in promoting development. In this dissertation, the argument is the *a priori* basis for assessing the impact of technological change associated with soil amending in New Zealand. The changes in the economy anticipated from that major technological change appear to diverge from the pattern suggested. The agricultural basis of the New Zealand economy suggests that the pattern of technological change in agriculture may be a determinant of development.

FOOTNOTES

1. Research is "the accumulation of knowledge by systematic observation, deliberate experimentation and rational theory." (Ziman, 1976, 3)

2. The structures referred to in the text are defined as follows:

   (1) technical structure:

   'a technical production function or a set of such functions relating outputs to inputs and so describing the state of human knowledge or technology effectively applied to the problems of production'.

   (2) institutional structure:

   'the social and political institutional system in which the economy operates'.

   (3) economic structure:

   'the entire factor-demand and product-supply side of the economy defined by the technical and institutional structures'.

   (4) preference structure:

   'the social, cultural and political value system of a society including any external constraints or interdependencies that affect the product-demand and factor-supply functions'.

   (Robinson, 1972, 58-59).

CHAPTER 3

AGRICULTURE, TECHNOLOGICAL CHANGE, AND ECONOMIC DEVELOPMENT: INTERRELATIONSHIPS

In the preceding chapter the part technological change may play in the process of economic development was examined. Here the role of such change in the agricultural sector is considered. Although that sector shares characteristics with other sectors of the economy is differs in many respects. It is held that in many instances these differences may alter the patterns connected with technological change. The scale of agricultural operations and the biological focus of agricultural enterprises together determine both the rate and the type of technology which has been introduced. The technical problems in agriculture arising from the great diversity of the production environment and the related specificity of the innovations made, and from the difficulty in formulating the theories of genetics and life processes, created a lag in development in that sector (Parker, 1972, 75). Significant progress in understanding plant nutrition and crop fertilization, for example, only began in the period between the mid-nineteenth and early twentieth centuries (Tisdale and Nelson, 1970, 14). The transition of inventive activity from areas largely benefiting industrial productivity to the chemical and biochemical areas benefiting agriculture is a recent event. The path of agricultural development has been affected by this delay as has the path of economic development, given the role of the agricultural sector in such development.

THE AGRICULTURAL SECTOR: ORGANIZATION AND LIMITATIONS

So far we have proceeded without concern about the characteristics of agriculture as an industry. It has been assumed that agriculture operates as an industry and that all industries behave alike. Certainly agriculture shares processing activities, mechanization and the application of scientific techniques with secondary industry and can be regarded as being closely related to industry. Thus, its diversified activities, may be agglomerated into one homogeneous agricultural industry (James, 1971, 16, 17).

The organizational unit of production, the farm, is thus a firm within the industry, and the farmer is the manager of that 'farm firm' (Metcalf, 1970). In that capacity he acts as an entrepreneur in organizing production. Since it is his task to identify and act upon opportunities to make a profit, a willingness to take risks in order to obtain an economic return from the capital and labour invested in the farm is an expected behavioural pattern (Habbakuk, 1971, 39). In this regard he does not differ from decision-makers of firms in other sectors of the economy.

Historical interaction with other sectors in the market has committed agriculture to growth if not to development (a distinction made in Chapter 1, footnote 8). The quality of the resources on the farm have had to be upgraded to maintain increasingly important demand pressures made upon producers. Growing population and improved transport technology have made the world a source of virtually unlimited, aseasonal demand for an individual farmer's production. The existence of an export market often allows agricultural output to greatly exceed domestic demand (Lewis, 1956, 280). Export demand requires both high and consistent levels of production, a requirement that often results in quality improvements in the farm products sold (Gould, 1972, 97). Innovative activity to this end has received ready rewards so that production emphasis on those products bought abroad has developed. Over the last century science and technology have been progressively applied to the agricultural production process. The farmers' increasing business orientation has made them more responsive to the economic pressures applied from the other economic sectors (James, 1971, 28-29). In short, agriculture, in most developed nations at least, has been led into the modern industrial pattern of employing science-based techniques as the highly urbanized, industrialized societies expanded (Rutherford *et al.*, 1966, 31).

However, adjustment is not very rapid in the sector:

> In agriculture, immobility, inadaptability and inflexibility are more pronounced than in industry. The industrialist can, within a reasonably short space of time, adjust his output and his organization to external fluctuations, and is hence more dynamic and more adaptable than the farmer ... He [the farmer] is unable to take immediate advantage of altered technical processes, nor can he quickly readjust his productive pattern to changes in tastes, fashion or habits. (James, 1971, 16)

Immobility

Once settled on the farmer decides what to produce there given the anticipated cost-price ratios for the various kinds of products he chooses to raise. It is less likely that he will move to land suited to the type of production he envisages. The latter decision is more akin to that made by a manufacturer seeking the best location for his particular product (McCarty and Lindberg, 1966, 207). This difference accounts for the comparatively greater immobility found in agriculture.

Inadaptability and Inflexibility

The inadaptability and inflexibility stem from 'old capital' and the small-firm structure. Farming is hampered by an accumulation of old capital not only in equipment with specialized functions but also in skills and management techniques learned over time. Boserup (1965, 25) has observed that established systems of land use can retard the adoption of new technology unless change in both coincides. Farming tends to be seen as a way of life even though it has moved to being basically a business. This recognition of farming as a business in New Zealand has led to a decline of interest in farming as an occupation and a growing labour cost in order to compete with the attraction of employment in other sectors (Franklin, 1967, 9). Adjustments have occurred but social conditions are a limitation to change (Rutherford *et al.*, 1966, 47). In addition, a strong reliance remains on existing methods to meet the expected set of conditions characterizing the natural environment (Mellor, 1967, 21).

The small-firm structure of the industry poses problems for technological innovation just as it can in manufacturing (Mansfield, 1969a, 110). While the entrepreneur is able to link market and technological developments quite effectively, when faced with increasingly complex markets and technological developments, he may be less able to cope on his own. His experience gained through practice may prove of little benefit in evaluating technology that embodies increased scientific content (Freeman, 1974, 28). Minor improvements may be generated through non-specialized knowledge gained, but major innovation is unlikely to occur. As a result, the resources needed for the translation of an invention to an innovation are frequently lacking unless professional experience is added to capital and opportunity (Freeman, 1974, 194-195). One outcome is a slowing of innovation diffusion as many individuals must make decisions before the industry as a whole benefits (Morgan and Munton, 1971, 19).

Attracting capital can pose a problem as the small firm offers a larger risk factor but without capital the opportunity to improve productivity is reduced. Accumulating this capital is cited as a result of economic development but it is also a cause (Kaldor, 1970, 339). Without it, the agricultural sector lags behind in economic development.

In this production environment which is further complicated by the seasonality of the biological cycles employed (Duckham, 1963, part III), production is variable and it is the attempt to cope with this variability which has created varying degrees of inflexibility. Once a successful pattern has been found which satisfies the operator's demands with a reasonable degree of certainty (Morgan and Munton, 1971, 30-31, 36) he is unlikely to wish to change it without substantial external pressure, more than would be the case with the industrialist (Mellor, 1967, 21).

Increasing Input Dependence

The attempt to control this variability is important in the demands of the agriculture. The scientific thinking and technological progress featured in the nonagricultural sectors is sought by the agricultural producers. Acquiring information and adopting production processes and products utilized or developed in the other sectors are means of enjoying that progress (Gould, 1972, 87). Tapping resources from other sectors can result in supply pressure on the producers who use them for their own benefit. Increased supply comes as a consequence of the associated intensification of production from inputs with high marginal productivity. Individual operators who adopt cost-reducing, output-increasing techniques can have a correct response as they seek to spread their fixed costs over a greater volume of production (James, 1971, 31). This is the process labelled as the modernization of the agricultural sector (Mellor, 1967, 26); yet it creates problems for the sector as a whole through stimulating excess production (Woolmington, 1971, 22).

The sectoral interaction extends beyond the acquisition of physical resources. Management and production techniques appropriate to the new production function are employed. Internal economies of scale and a greater efficiency of resource use follow (Rutherford *et al.*, 1966, 37). However, the opportunity to so modernize may be widespread and the number of adopters sufficiently large to create a substantial and continuous increase of physical output. When aggregated, this increase may tend to exceed demand so the farmers' income position worsens relative to the incomes in the non-agricultural sectors (Southworth and Johnston, 1967, 8).

The dependence on the non-agricultural sectors can provoke cost problems for farmers. The expansion of the industrial sector contributes to greater input costs for agricultural activities as the capital goods have a more elastic supply (Mellor, 1967, 26). The higher industrial production costs may be passed along to a sector which comes to rely on them for its prosperity. More capital is required to acquire capital goods incorporating new technology which would boost productivity. The scale of operations, the location of production, and the choice and combinations of farm enterprises all have to be reassessed in light of the modernized environment in which the commercially orientated farmers find themselves (James, 1971, 38-39). Their reassessment may prompt innovative activity to cope with a range of economic problems: low farm incomes, structural inefficiency, a cost-price squeeze, over-supply, and inefficient marketing (James, 1971, 10). It certainly accounts for the developments in organizational methods, decision-making processes, and mechanics of production:

> 'Mechanized, high-powered, complex tool systems using extensive energy applications through time, with intensive applications in specialized tasks but relatively low volumes of human energy' becomes a way to describe the methods involved in many agricultural enterprises. (Spencer and Stewart, 1973, 543)

The farmer also turns to institutions to overcome the innovative difficulties of his operation. Government, for example, is usually able to establish the organizational infrastructure needed for research and development work. Pioneering work can be carried out for the industry in pilot projects, so allowing farmers to imitate successful technology. In effect, the farmers are in a better position to imitate since overhead expenditures are reduced by not engaging in research and development work (Freeman, 1974, 272). In not participating directly in the innovation process, however, the farmer may be unable to comprehend the science behind the technology and so fail in effectively utilizing the technology. An increase in the rate of technological change accentuates the problem in making a wider range of techniques available from which to choose increasing uncertainty about the best combination and in allowing more innovative competitors to develop an advantage using the new techniques.

It is considered that the imitative firm succeeds better when the pace of technological change steadies. The firm is then able to become more efficient in utilizing the technology in production usually to achieve scale economies (Freeman, 1974, 273). This suits the goal of the farmer attempting to spread his fixed costs over a larger production and sales volume through intensification. The technological changes required result in the accumulation and use of much greater quantities of new capital and the substitution of capital for labour (by mechanization) and land. Such changes enable the farmer to undertake a wider variety of land-use practices in order to obtain greater output per unit of input (Rutherford *et al.*, 1966, 133).

The dependence of the farmer on other sectors' innovative capability means that the extent of their inventive activity on his behalf is directly influenced by the agricultural sector's importance to them as a market. Its relation to other sectors is limited in that, as a primary sector, its output is seldom input for some preceding stage of production (Franklin, 1969b, 29). Much of its output is consumer-oriented, hence its degree of interrelatedness is limited and less subject to induced technological change than basic capital-goods industries (Strassmann, 1960, 21).

The introduction of innovation in agriculture is slowed where it is not the focus of development as greater rewards are offered for inventive activity in other sectors. This situation is viewed as normal:

> Whenever technological change is the same or greater in agriculture ... than in the production of basic capital goods, [this sector has] either benefitted from more scientific advances, or [it has] increased the pace of applying already available science. (Strassmann, 1960, 21-22)

Intervention through government action can be used to offset this imbalance to achieve the above-mentioned conditions should the agricultural sector retain sufficient political, if not economic, importance.

Reliance on Biological Systems

While sharing a given set of economic, political, and social systems with the manufacturer the farmer is much more directly concerned with biological systems. His dependence on them may be reduced through scientific and technological advances but physical conditions and biological constraints directly influence his total output (Morgan and Munton, 1971, 16). Hence the farmer tends to work within a framework of probable yields and possible prices. The element of uncertainty so introduced tends to lead to production responses for an expected range of conditions. This goal is the control of as many inputs, animal, vegetable, and mechanical, as possible in a farm enterprise system in an attempt to control output. Though the farmer may not succeed in maximizing his income, he tries to keep it above some minimum level. Such a strategy provides for risk minimization. Indeed, his approach may be one less concerned with producing profit than with deriving satisfaction from the farm operation (Metcalf, 1970, 38). A mixture of all three motives is likely to be the case.

Though some natural forces are beyond the farmers' direct control, he is able to manipulate the outcome of many life processes such as breeding. Agriculture's involvement with these very processes has slowed its technological advance. As life processes are fundamental to the production of crops and livestock, and the operation of these processes was investigated by science later than that of machines, it is not surprising that major technological change in agriculture occurred more recently in agriculture than in manufacturing (Parker, 1972, 75). Technique, in fact, sometimes preceded observation, deliberate experimentation, and science, and so, did not benefit from the 'systematic rational theory' that is the mark of the scientific research approach (Ziman, 1976, 35, 3).

The involvement of a large number of parameters is a major handicap in investigating life processes. One parameter's contribution to a process may be isolated in an experiment, but assessing that contribution when further interacting parameters are introduced may be difficult indeed. Until statistical methods were developed to assist in assessing such problems, experimental work in determining and explaining exactly what had occurred was retarded. Lacking adequate theory, scientists found controlling the experimental situation to achieve reliable results a serious problem. Though advances were made and techniques applied to agricultural production, failure was high and the practical results were not always employed fully. The farmer could achieve similar results with his practical experience and so did not come to rely confidently on suggestions made by scientists unable to do much better.

For example, the idea of improving animal performance through breeding was a well-known technique by the late eighteenth century, yet the predictability of the outcome was not great until the 1820s (Ziman, 1976, 32). New breeds were developed, but the understanding of how this occurred was limited. In plant breeding the same handicap was met. The need to repeat trial-and-error procedures frequently slowed progress. The discipline of science developed and, hand in hand with increased literacy (Fussell, 1972, 182) research proceeded more systematically and more rapidly. However, the degree of success in productivity advance remained behind that achieved elsewhere in the economy. Agriculture was no longer the focus of attention of science it had been in the eighteenth century but a subsidiary activity. The opportunity to employ capital was 'prodigiously' expanded not by increased land supply but by 'mechanical inventions and the growth of metallurgical and engineering knowledge' (Galbraith, 1968, 54). Science, in accord with the demand-pull view, was attracted to the fields of mechanics and materials (Parker, 1972, 170). Inventive activity dealing with life processes, the core of agriculture, was to come much later. Genetics only re-entered agricultural technology in a practical way about 1950 after a century of developing theory (Ziman, 1976, 35). Thus, one element in changing technology was absent. Accordingly, possible consequent changes in land use were retarded (Boserup, 1965, 23).

Specificity of Production Environment

An offshoot of the multivariate problem is that of the specificity of results from any practical trial of biological material.

The diversity of environment means that productivity improvements made on one particular firm in learning about the operation of a particular innovation can be unmatched in another location. Knowledge and tools created in one farm environment may not be suitable elsewhere without substantial modification, thereby making the extent of their application more varied than in manufacturing and transportation. The advantage of using a particular innovation can be limited indeed and no general improvement in productivity result from its adoption. The individual producer is thus obliged to run his own experiment on each innovation to test its worth on his farm--a situation demanding opportunity, time, labour, and capital. The benefit perceived needs to be large to attract interest. Further, the more innovations offered at any one time, the less the chance that any subsequent one might have to be tested once one is being investigated.

The ease with which such experimentation can be conducted would certainly influence the readiness to adopt technological innovations. This specificity problem accounts for a slowing of the overall rate of economic development in this sector and is partly responsible for the 'regionally uneven way in which Western economic growth affects a country' (Rutherford *et al.*, 1966, 137), since the distribution of earth resources can vary at the farm, regional, and national scale. Much geographic study has been devoted to explaining such patterns.

The importance of farming practice and farm enterprise based on these resources to the innovation diffusion process is being uncovered (for example, Walton, 1973, 10-11; Chambers and Mingay, 1970, 207; Jones, 1968). Identifying the pattern of diffusion and the barriers indicated by uneven distributions is a contribution geography can make to agriculture through linking 'spatial and other aspects of human behaviour' (Gould, 1969, 69).

THE PATTERN OF TECHNOLOGICAL DEVELOPMENT

Learning by doing is a continuous source of experimentation in agriculture. Although the results of this work may not be susceptible to a scientific formulation, progress made is transmitted and methods are imitated. Farmers breeding livestock pass on not only news of successes (hence the importance of literacy as agricultural publications transmit information widely) but also any advance embodied in the stock itself. Success in profitably exploiting a particular farm enterprise can also be imitated and some expertise acquired in each of the enterprises attempted.

Invention in biochemical processes occurred early in agriculture as indicated by the development of the use of chemical fertilizers. From seventeenth and eighteenth century studies in plant structure and nutrition, early nineteenth century scientists, having confirmed the nature of soil elements, theorized that plant production would eventually exhaust soil fertility (Fussell, 1972, 180). This fertility level could be enhanced by the introduction of these elements back into the soil. Where farmers had come to understand this principle in connection with animal manures, vegetable matter, and even urban refuse (Kerridge, 1967, Chapter V) science indicated the possibility of achieving the same end using other substances (Chambers and Mingay, 1970, 64). Bone-dust became the first of these 'artificial' fertilizers to be used extensively in Britain (McCaskill, 1929, 36).

Demand for fertilizer was attendant upon a major innovation, the rediscovery of the ancient practice of growing fodder crops to enhance crop production (Fussell, 1972, 182). During the seventeenth century in England it was noted that the use of turnips benefited subsequent crops as did the use of legumes, particularly clovers (Jones, 1974, 69-70). Turnips were introduced into the crop rotation pattern as in the Norfolk four-course system, and clovers were established in pastures. The requirements of these plants, neutral soil and adequate fertility levels, stimulated an awareness of liming and fertilizing practices. The concern with fodder crops was a break with past practice (Fussell, 1972, 153).

A further development led to a greater appreciation of the value of animal manures. Feeding the fodder crops to the greater number of animals which could be carried on farms led to an increase in the supply of manure available. In turn, the deposition of this manure led to better crop yields. Land productivity could be improved by employing a natural cycle but labour productivity was also greatly increased (Boserup, 1965, 109-110). Consequent mechanical invention provided means to harvest the increased output (Fussell, 1972, 45).

These discoveries preceded the scientific understanding of what was occurring, nevertheless they were put to practical use. The experimentation of Lawes in treating phosphate rock to create a readily soluble phosphate that could be absorbed by plants to stimulate growth was complete by 1842 (McCaskill, 1929, 7). Commercial production of the material began shortly thereafter, initiating a new fertilizer technology in agriculture. It was subsequent to this period that Lawes himself undertook to investigate the action of phosphates through field testing (Jones, 1974, 205). Invention does not need to proceed on the basis of prior scientific knowledge. Science served as a stimulus, but where it lagged in its capacity to discover knowledge, experience proved a more useful tool. As argued in the previous chapter, invention can push science to uncover a fuller explanation of the reasons why an invention works.

The concern with life processes did not overwhelm the pattern of technological development one would expect from Parker's thesis. At an early stage mechanical power was applied to agricultural production to increase productivity. The use of reapers and tractor engines in the mid-nineteenth century, the development of seed drills, hay mowers, and milking machines all attest to the concern for improving production methods by employing the engineering expertise available at the time. Farmers were able to apply their practical experience to the invention of machinery as little scientific research was required. Once more complex matters were involved, the farmers' influence was reduced. Innovation in agriculture became more the responsibility of institutions and other sectors than that of the agricultural sector itself, and, accordingly, came to reflect advances made in other sectors more than the increase in the knowledge of the farmers. This lag situation was prejudicial to the adoption of innovations whose application was ill-understood. The movement of technology to biochemical processes (Parker, 1972, 75) without compensatory improvement in farmer education made the development of such a situation inevitable.

Coping with biologically based problems posed particular problems for farmers. The scale of expansion which any individual can undertake is limited. Diminishing returns make increases in the intensity of production uneconomic at some point. Except for a limited number of products which can be organized in a factory type of production agricultural producers can only expand horizontally by putting a greater acreage into production (James, 1971, 17). The extent to which this is possible depends on land-tenure practices. In the case of a large number of producers tending to oversupply the market, each farmer seeking to better his own position through the application of productivity-boosting techniques. Their bargaining power, vis-à-vis the comparatively few processors to whom they increasingly sell their produce, is reduced (James, 1971, 32). It also means that the economies of scale become difficult to achieve, so the possibilities open to manufacturers are not always present in agriculture.

Economies of scale are missed not only through the operation of diminishing returns but also through the seasonality of production. The diversity of operations which must be carried out at distinct times during the year limits the opportunities for specialization, and for mass production and processing which flow from it.

Not only the fixed costs but also the variable costs can be subject to a time-lag which is held to be more prominent than in the secondary sector of the economy (McCarty and Lindberg, 1966, 206). The seasonality of production can mean that the implementation of adjustments to the production function can take up to a year or more. Rapid readjustment becomes difficult so much so that on occasions there may be a demand for products which cannot be immediately satisfied. Shifting production to meet this demand can lead to an oversupply and lower prices than expected, or to investment in an enterprise from which demand could just as readily switch away. This shortcoming of the farmer's ability to be dynamic and adaptable has already been noted. The attempt to cover a number of such contingencies could lead to sub-optimal production in the enterprises concerned. This is inefficiency in economic terms yet it may be the farmer's best response to the conditions he perceives as operative beyond his farm (Metcalf, 1970, 34).

THE ROLE OF AGRICULTURE IN ECONOMIC DEVELOPMENT

Concern with the state of the agricultural sector is a consequence of the importance of agriculture within the economy. As the sector which initially affords most employment and consequently generates most income, agriculture must undergo development to sustain development in the other sectors (Mellor, 1967, 21). Agriculture's contribution has been separated into three parts: product, market, and factor, though these three branches are not strictly separable in reality (Kuznets, 1965, 238). Technological change in agriculture insofar as it results in sectoral growth, can lead to economic development through the linkages noted by Hirschman (1958).

Product Contribution

Growth in agricultural production takes place to satisfy the demand of a population growing as the economy develops. The adoption in Europe of the technique of soil fertilizing using leguminous fodder plants has been ascribed to such an increase in population (Boserup, 1965, 39). Although international trade can supply part of this demand, an intensification of agricultural production generally occurs as prices rise. Capital accumulation, a source of funds for investment, follows (Mundlak *et al.*, 1974, 102), and the need to intensify production triggers considerable innovation in the agricultural sector (Lewis, 1956, 276; Kuznets, 1965, 28).

The resultant production increases lead to surplus food supplies, or surplus labour, or both. These conditions can turn the terms of trade against the agricultural sector especially when the rate of increase of its production exceed that of the population. Where trading connections have developed for agricultural produce, an overemphasis on exports can lead to increases in productivity to the point where the exports are available on terms more favourable to the importer, the more industrialized country. Income can fall, discouraging investment and innovation (Lewis, 1956, 288, 277). Only development and growth in the other sectors to offset these surpluses can prevent such a situation of stagnation. Not surprisingly, the interdependence of the economic sectors is highly important in regulating the development of any and all of them (Mundlak *et al.*, 1974, 103; Thorbecke, 1969, 4).

Market Contribution

Such a condition highlights the agricultural sector's place as a market. Opportunities are created for other sectors to grow by selling their goods and services to agricultural producers, and for the economy as a whole to participate in international trade or other international economic flows (Johnston and Kilby, 1974, 44; Papi, 1966, 77). The product contribution of agriculture becomes increasingly important. Typically, the agricultural sector is the first able to earn sufficient amounts of foreign exchange to promote overall economic development (Islam, 1974, xv). The foreign exchange earned by the sale of agricultural products in foreign markets, or the saving made by the substitution of local produce for imports, can determine the import capacity of a country, and, in turn, the amount of access it has to other technologies (Thorbecke, 1969, 5).

Nonetheless, the development of the other sectors, with a consequent increase in their own trade, makes it possible for the agricultural sector to operate more efficiently as a producing unit. That sector becomes more specialized and commercialized, and uses its products more effectively as a consuming unit (Kuznets, 1965, 246). The labour shortages which tend to occur in the agricultural sector as development occurs elsewhere make this inevitable (Gould, 1972, 84). Through this mechanism, industrial inputs embodying new technology are able to enter the agricultural sector and contribute to its development.

However, the advantages accruing to the agricultural sector decline relative to those in the other sectors because of their attainment of economies of scale and their accumulation of the skills embodied in labour displaced from agriculture. Hence, the importance of agriculture to the total output of a developing country tends to decline and its share of total exports to drop (Kuznets, 1965, 248-249). This is regarded as the typical pattern of economic development, although there are unfavourable effects on necessary capital formation when other sectors overshadow agriculture:

> If agriculture stagnates, the capitalist sector cannot grow, and capitalist profits remain a small part of the national income, and savings and investments are correspondingly small, (Lewis, 1956, 277).

The development of an adequate agricultural infrastructure must be associated with this market development to facilitate not only production but also distribution of goods. Through this association the agricultural producer comes to rely on external agencies to promote development within his sector of the economy. There is certainly some level of infrastructure which is a necessary, if not casual, condition to the development of that sector (Wharton, 1967, 113). As development occurs in the sector, the infrastructure becomes increasingly important, especially that part concerned handling and distributing produce (Islam, 1974, xix), and can be adapted to serve the needs of other sectors.

Factor Contribution

The final contribution stems from the way in which capital and labour resources from the agricultural sector are eventually transferred to other sectors as production factors once the intensity of agricultural production has increased sufficiently (Boserup, 1965, 118). Capital flows into agriculture in response to its effort to meet domestic and external demand. This capital is then transferred to the other sectors by such flows as investment and taxation. The level of demand and the pattern of saving and investing are social aspects of economic development as they influence the rate and level of technology adopted by the agricultural sector (Mellor, 1967, 26). Labour migrates from the agricultural sector as productivity increases release people for employment in other sectors (Livingstone, 1971, 236). The degree of skill possessed is quite important, for the more skilled the labour force, the more adaptable it is in the work in the other sectors.

As implied in the explanation of the market contribution, productivity in the agricultural sector has to be in step with the other sectors, rising to accommodate such changes as the release of capital and labour for the development of those sectors (Gould, 1972, 101). Indeed, as technology advances and specialization increases, the complexity of the economy grows, making the interdependence of agriculture and the other sectors more pronounced (Southworth and Johnston, 1967, 1). The adverse effect on the rate of technological change resulting from a limited interrelatedness with other sectors of the economy is reduced (Strassmann, 1960, 16). Agriculture becomes more responsive to change as a preceding stage in capital goods production but the increased output which follows has been shown to pose a difficult problem for farmers. Nonetheless, agriculture can be the basis for national wealth in being efficient. New Zealand is cited as an example of just such a situation (Meier and Baldwin, 1966, 400).

SUMMARY

Given the possibility of realizing the contributions noted above, agriculture appears as the starting point for the process of economic development. The reasoning in Chapter 2 indicates that implementing technological change can bring about economic development. Technological change in agriculture should do as much, yet in this chapter, the particular characteristics of agriculture are shown to have a retarding effect on the development sequence. Elements of uncertainty concerning price and yield are pronounced (Metcalf, 1970, 32) and the sequence of invention has not favoured this pattern. Agricultural productivity rose first through sharing in the mechanical invention which marked industrialization. The rapid extension of the area of cultivated land in the nineteenth century reduced the need to boost land productivity by mastering life sciences. The application of known techniques and genetic materials in newly settled lands provided the output required while improved transport methods brought the produce to the growing European market (Grigg, 1974, Chapter 4). Advances in agricultural science, as evinced in the emergence of British high farming and soil amending, did occur in response to scientific curiosity and the increased demand for livestock products. These advances did not initiate economic development, however. Indeed, further increases in agricultural productivity were in large part dependent upon further invention in manufacturing (Parker, 1972, 76). It has been considered that on the world scale: 'Only from the 1930s and indeed ... in the last thirty years' have farmers generally adopted the techniques of 'modern scientific farming' apart from the mechanization of harvesting (Grigg, 1974, 55). Technological change is viewed as slower in agriculture than in manufacturing and so, development is seen to have lagged. Hence, economies based on agricultural production can be expected to be less fully developed.

The combination of assertions in the preface and the framework presented in Chapter 1 have required the presentation of the background information, theory, and concepts concerning innovation, technological change, and economic growth contained in Chapters 2 and 3. Pointing out the particular problems of agriculture in relation to innovation and technological change, while noting its importance to economic growth and development, leads to the presentation of the development of agriculture in New Zealand in the three following chapters.

CHAPTER 4

THE CREATION OF GRASSLAND FARMING SYSTEMS

In the 80-year period from the initiation of European colonization to the early 1920s was laid the basis of New Zealand's economy, as it was then that the nation's farm enterprises were developed and the primary importance of grassland was established. The farming systems devised by the pioneers were to have a lasting effect on subsequent systems worked out in the light of social, economic, and technological changes.

EARLY SETTLEMENT 1840-1860

The pioneer settler faced the problem met by any innovator; for, having established the need or opportunity to alter the production environment, he was obliged to evaluate the potential of that environment in terms of the resources at his disposal. Where he succeeded, the pattern became fixed in the landscape and in the relevant structures of the economy.

The concepts and precepts brought by the nineteenth century settlers of New Zealand originated in Western Europe and the British Isles, though the Australian experience of some was a conditioning factor. Settlement was geared to the production of European colonists who became farmers in the 1840s and 1850s (Condliffe, 1963, 19). Initially they were faced with finding cultivation methods to ensure their survival. The missionary settlements established after 1815 could have provided some information based on their agricultural experience but this source was evidently not tapped by the later colonists (Hargreaves, 1966, 39). Production techniques had to be developed for whatever farm enterprises were found to be worthwhile. Hargreaves (1963, 49-50) presents some of the methods employed in Taranaki. Suitable institutional structures to foster whatever type of development was envisaged were also needed. Models for such structures to guide settlement were available from previous colonial experience but the challenges to farming offered by this new environment were hardly known. Although the temperate nature of the climate led to a duplication of English agriculture practices, these were soon found inappropriate (Gould, 1972, 88). Labour shortage alone impeded the adoption of English farming systems (Hargreaves, 1966, 106). The unfamiliar physical environment made experimentation with crops and adaptation of farming methods and equipment necessary (Rutherford, *et al.* 1966, 142, 163). Until the 1850s it was held that local agricultural experience was insufficient (Hargreaves, 1966, 117). With their survival assured, the settlers undertook a more careful evaluation and exploitation of the natural and man-induced ecosystems in the early 1850s (Hargreaves, 1966, 121).

Farm Enterprises

It is suggested that two developments occurred on this basis. The first was mixed agriculture, largely of a subsistence character on small farms, to supply family needs and those of the local market in the small urban settlements--dairying is an example of such an enterprise (Hargreaves, 1965, 121). The proportionately large area of cropland in the 1840s (Table 4.1) reflects this concern with subsistence. The second was the large, commercially oriented, pastoral holdings for wool production (Hearn and Hargreaves, 1974, 68). Although the need for the former type of enterprise was based on necessity and would have been a relatively familiar practice for those from British agricultural backgrounds, the emergence of the latter type of pastoral enterprise amounted to copying the successful pattern developed earlier in eastern Australia (Jeans, 1972, 90-91, 97-101 *passim*).

As in New South Wales, the pastoral enterprise begun in New Zealand relied upon Merino sheep (Cumberland, 1944, 204). A connection with the Australian type of enterprise was obvious. The original stock in both the North and South Islands came from Sydney (Hill, 1965, 44; Stephens, 1965, 53). Some of the pastoralists themselves came with the intention of establishing a farming system similar to that in New South Wales (King, 1947a, 243). In the Canterbury settlement the shepherds were engaged from that area (Stephens, 1965, 53). Close contact was maintained between the breeders in Australia and their New Zealand counterparts (Miller, 1950, 136).

The development of both farming systems involved the evaluation of the land's productive potential: on the crop-producing farms soils were evaluated and on the pastoral holdings the native grasslands. In both instances the evaluation took some time. The limited natural fertility of the soils and the need to amend them were

TABLE 4.1

NUMBER OF HOLDINGS; AREA OCCUPIED, AND PRINCIPAL LAND USES (THOUSANDS OF ACRES) 1843-1920

Year	*No. of Holdings*	*Area Occupied*	*Area Improved*[a]	*Sown Grass and Clover*	*Hay and Silage*	*Green Fodder and Roots*[b,c]	*Crops Threshed*[d,e]	*Grain Crops for Fodder*[f,g]
1843	..	..	2.8	0.6	..	..	2.1	..
1848	..	..	14	5.4	..	..	8.6	..
1851	..	..	29.1	15.6	..	2.1	9.2	..
1856	..	..	110.1	79.2	..	1.8	21.1	..
1861	..	..	226.6	158.1	..	5.7	49.6	..
1864	..	..	382.6	272.1	..	8.3	82.5	..
1870-71	10,211	22,633.7	1,140.3	776.1	34.3	14.5	222.5	..
1873-74	15,883	24,426.7	1,651.7	1,181.4	43.6	24.1	264	22.2
1880-81	24,124	26,845.5	4,768.2	3,556.9	54.1	257.2	586.8	51.2
1885-86	31,763	28,169.8	6,668.9	5,465.2	40.3	338.2	538	83.5
1890-91	38,083	31,867.5	8,462.5	6,966.2	44	406.5	703.3	134.7
1895-96	..	..	10,698.8	9,285.2	96.8	460.7	674.8	171.6
1900-01	62,786	34,911.6	12,636	11,081.9	68	538	721.3	201.7
1905-06	69,942	37,167,4	14,114.9	12,525.5	80.7	610.6	648.8	247.7
1910-11	73,876	40,238.1	16,154.2	14,214.7	62.6	675.7	719.9	319.2
1915-16	77,229	41,386	16,984.2	12,747.8	95.8	819	593.1	440.5
1920-21	84.076	43,546.8	18,159.8	15,912.8	161.8	745.6	441.6	431.4

TABLE 4.1 (Continued)

Notes:

a Recorded as area cropped to 1867 but includes sown grassland, later recorded as area cultivated though much grassland unploughed (Table 4.6)

b All 'other crops' i.e. not grain or pulses to 1864 and so overstates acreage

c All green and root crops included except potatoes from 1867 to 1887; only turnips, rape, mangolds, beet, carrots, and onions to 1916; turnips, mangolds and green fodder only from 1917

d All grain crops recorded to 1867; wheat, oats, and barley only to 1887; pulses included from 1888

e Grain crops fed-off, cut for chaff, hay or ensilage, or not harvested not included in total after 1869

f Includes oats for green fodder only until 1901

g Calculated for all grain and pulse crops from 1901

Sources:

1843-48	Calculated from *Statistics of New Zealand for the Crown Colony Period; 1840-1852.* (1954).
1851	*Statistics of New Zealand* (1858).
1856	*Statistics of New Zealand* (1853-56).
1861-64	*Statistics of New Zealand* (for years shown).
1871-74	*Statistics of New Zealand* (1874); *Census of New Zealand* (1871).
1880-85	*Statistics of New Zealand* (1887).
1890-95	*Statistics of New Zealand* (1895).
1900-10	*Statistics of New Zealand* (1910).
1915	*Statistics of New Zealand* (1915).
1920	*Statistics of New Zealand* (1920).

recognized by the 1870s but crops yields were high enough without this extra expense, so soil amending was not widespread (Hargreaves, 1966, 263, 264). The ploughing of tussock grassland to intensify its use became common in the 1870s (Hargreaves, 1966, 254-255). In the North Island, settlers were confronted with the need to cut, burn, and surface sow bush and fern land. The practice was probably copied from the Maoris (North American experience could have contributed too) but even though established by the 1850s (Smallfield, 1946, 543; Hargreaves, 1966, 124), it did not enable rapid occupation of the land to occur. In the South Island, ploughing the turf and fern root proved a problem, given the livestock and equipment available (Forrest, 1964, 25).

The pastoral enterprise was established in the non-forested areas where the ecosystems necessitated a much lower investment of labour and capital for an immediate return (King, 1947a, 243) when compared to the struggle to bring bush and fern land into production (Johnston, 1961; Hargreaves, 1963, 53). Accordingly, they were set up more rapidly than the farms based on arable cropping (Miller, 1950, 136). The greater extent of suitable land in the South Island led the extensive sheep farmers (runholders) there from early settlements in the North Island (King, 1947a, 244). Pastoral licences modelled on Australian practice (Condliffe, 1933a, 150) provided leasehold tenure after 1852 (Evans, 1969, 24) and in four years almost all the available land in the Canterbury Plains, Otago, and Southland was occupied by settlers, many of them coming directly to the South Island (King, 1947a, 244, 245).

Although speculation in leasehold land meant that not all the area was occupied, (Hargreaves, 1966, 403) the rapidity of land occupation remains remarkable. The speed of occupation often meant that holdings were understocked despite a 350 percent increase in sheep numbers in the 1861-71 decade (Table 4.2). This problem was only overcome by the late 1860s when most readily utilizable land in the South Island was being grazed by sheep (Hargreaves, 1966, 299; King, 1947a, 254).

Indigenous ecosystems were adapted to grazing by oversowing European grasses in tussock lands and by ploughing. Exotic resources were substituted for indigenous ones (Price, 1963, 95). From the 1840s on there are references to the laying down of English grasses,

TABLE 4.2

NUMBER OF PRINCIPAL LIVESTOCK 1843-1920

Year[a]	*Sheep*[b]	*Dairy Cows*[c]	*Other Cattle*[e]	*Horses*
1843	10,382	..	4,049	448
1848	84,908	..	22,584	1,991
1851	233,043	..	34,787	2,890
1856	990,988	..	91,928	9,243
1861	2,761,383	..	193,285	28,275
1864	4,937,273	..	249,760	49,409
1870-71	9,700,629	135,168	301,424	81,028
1873-74	11,704,853	142,450	352,467	99,859
1880-81	12,985,085	226,819	471,818	161,736
1885-86	15,174,263	279,136	574,222	187,382
1890-91	17,865,423	206,906[d]	582,013	211,040
1895-96	19,138,493	276,217	771,684	237,418
1900-01	20,233,099	372,416	884,264	266,245
1905-06	20,108,471	517,720	1,293,216	326,537
1910-11	23,996,126	633,733	1,386,438	404,284
1915-16	24,788,150	750,323	1,667,168	371,331
1920-21	23,285,031	1,004,666	2,134,557	337,259

Notes: *a* Enumeration in various months from 1843-1890; January 31 used from 1895 except 1910 when as *b*.

b Sheep recorded on April 30.

c Breeding cows until 1891; only dairy cows in milk thereafter.

d Number of breeding cows 280,711.

e Total cattle until 1871.

Sources: 1843-48 Calculated from data in *Statistics of New Zealand for the Crown Colony Period; 1840-52*.(1954).

1851 *Statistics of New Zealand* (1858).

1856 *Statistics of New Zealand* (1853-56).

1861-64 *Statistics of New Zealand* (1864).

1871 *Census of New Zealand* (1871).

1874 *Census of New Zealand* (1874).

1880, 1895-1920 *Census of New Zealand* (1881); *NZOYB* (1930, Statistical Summary).

1885-90 *Census of New Zealand* (1891).

though not in every region (Hill, 1962, 100). The low carrying capacity of the tussock grasslands of the South Island as compared to that of the more familiar pastures in Britain, and the lack of suitable natural grasses in the North Island quickly led settlers to consider the use of such a procedure (Clark, 1949, 353; Hargreaves, 1963, 56). The wetter climate was a deterrent to sheep farming using merinos which readily utilized native grassland. The importation of English breeds which fared less well on native grasses prompted the sowing of English pasture plants (Hargreaves, 1966, 156). It is estimated that the carrying capacity of the land was tripled by this simple procedure (Gould, 1976, 19). Hay was also cut as the difficulty in overwintering stock was gradually realized (Clark, 1949, 354). Haying was a popular practice because of its simplicity and relatively low labour input (Hargreaves, 1966, 260), but records of the extent of grassland cut are not available until 1869.

At an early stage European precepts were operative in spite of the capacity of the indigenous ecosystems to support some forms of agriculture. In 1843 approximately 665 acres were in sown grasses in the main European settlements of the Crown colony but by 1851 this figure had risen to 15,589 acres. The area of cropland in the same period rose from 2,100 acres to 9,200 acres (Table 4.1). The importance of grassland emerged early in New Zealand's farming systems as within a decade its acreage exceeded that of all other crops combined. The livestock enterprise developed with similar rapidity. Between 1843 and 1851 the number of sheep increased from over 10,000 to just over 233,000, the number of cattle from about 4,000 to nearly 35,000, and the number of horses from nearly 450 to almost 2,900 (Table 4.2). The great increase in sheep numbers demonstrates the prime importance of that enterprise in this period.

Entrepreneurial Development

A critical role was being played by the entrepreneurship of the runholders. It was they who were largely responsible for the commercial orientation of the colony's agricultural production. They did not remain within the framework of the agriculturally oriented Wakefield settlements with their relatively expensive land and small-farm structure (Hill, 1962, 93). Using their own initiative and capital from whatever source would lend it, these men rented land, purchased sheep, and went into the production of wool for export. There was a ready market in Britain and the product was unlikely to perish in transit--the problem which restricted the export of meat and dairy products for many years. Both adventure and a quest for personal profit have been cited as motivations of the sheep farmers (Stephens, 1965, 59). The Australian squatters in particular:

> brought to New Zealand not only money and stock, but, what was more valuable, experience in extensive sheep farm management. They had unlimited faith in the squatting system and great contempt for the freehold and small farm ideas in New Zealand. (King, 1947a, 243)

Their aim was certainly not the re-creation of a pre-industrial, rural, English society as was that, apparently, of the Wakefield settlements (Hearn and Hargreaves, 1974, 68). Instead, earning a satisfactory level of income was their concern. The absence of markets for mixed farming product directed them to wool production (Belshaw, 1936b, 4). Decisions concerning the use of production factors were assessed according to capitalistic motivation. The plants and animals which were essential inputs to the production of saleable output were reviewed critically. One would expect such an evaluation procedure from entrepreneurs entering a new environment which, although similar to that known in Europe and Australia, differed in production possibilities. There was certainly some transfer of their cultural and economic heritage as there were attempts at first to duplicate British production patterns in sheep farming just as in arable farming. Indeed, it is stated that it was the 'benevolent habitat' which prevented the 'early errors' from leading to failure (Hill, 1965, 39). The economic concerns heightened an awareness and interest in changing technology. Evaluation occurred following the adoption of new techniques and equipment.

Watters (1965, 190) has suggested that the social, political, and cultural situation of the period favoured the rise of these farmer capitalists. The greater belief in the importance of individual endeavour, the increasingly favourable status of the entrepreneur (traditional elements in British society were eroded by the rise of industrialism), and the appreciation of economic considerations at the expense of non-economic considerations all contributed to the commercial orientation which developed in New Zealand's agricultural sector.

More significantly, however, the settlers arrived at a time when the technological perspective of the age was widening. Much faith was being placed in the benefits the application of science and technology would bring (Perkin, 1971, 12-13). It was noted in New Zealand that the early 1840s settlers were eager to adopt labour-saving mechanical devices (Hargreaves, 1966, 146-147). Certainly, new appraisals were being made of known resources and new resources were being discovered as the impact of empirical science was more widely felt. In the unfamiliar environment of New Zealand the colonist felt it necessary to be both self-reliant and aware of the experience being acquired by his fellows. Those occupying the land could succeed through their own efforts, and tended to begin on much the same footing. Smallfield (1946, 539) thought that:

> The settlers wanted land with a clear title and freedom to develop their farms along the lines they though best.

In view of this, the failure to develop a supportive society in the settlements would only have enhanced the value of the effort of the individual to achieve success (Watters, 1965, 192).

The comparatively low entry threshold, in monetary terms, made it possible for labourers earning high wages through the scarcity of labour (Lloyd Prichard, 1970, 62) to aspire to holding land. Small family farms rapidly became typical of all New Zealand settlements (Hargreaves, 1966, 108). This development along with the presence of large pastoral holdings meant that the Wakefield settlements never emerged in the pure form envisaged (Hargreaves, 1966, 120). English farming would not be the pattern of New Zealand farming. The development in the colony itself of facilities associated with the 'complex apparatus of high capitalism' already familiar in Britain, in addition to the creation of an institutional framework modelled on that of the homeland, were important factors in the creation of an environment favourable to the establishment of farming entrepreneurs (Watters, 1965, 190). Money was made available for investment in the development of land and stock (Lloyd Prichard, 1970, 85). The entrepreneurial interests were also represented fully in the representative parliamentary government instituted in 1852 using a property-based franchise (Lloyd Prichard, 1970, 65-66). By 1856 executive responsibility to the legislature had been confirmed (Webb, 1940, 7), thereby giving the runholders a powerful means of determining the institutional structure of the colony.

The existence of an efficient public administration service relatively free of corruption and of a land-tenure system which served to stimulate investment were two other significant social inventions (Lewis, 1956, 177). They both came to New Zealand, the first through the imitation of the British competitive entrance, merit-based model (Webb, 1940, 74), and the second through the creation of long-term leasehold and freehold tenure systems which guaranteed the occupant of the land a virtually free rein to develop his property as he saw fit in the time perspective he held.

In this period of settlement institutional stability was achieved by duplicating the institutions of the home country. Deliberate innovation was not undertaken but the early settlers were able to influence the development of institutional structures, and created an acceptable political and economic framework to support their activity (Webb, 1940, 405). A measure of institutional imbalance arose, however, because those undertaking new enterprises at a later stage found it necessary to cope not only with environmental obstacles to their innovation and inherent economic difficulties but also with an institutional structure not designed to accommodate their particular needs.

Information and Information Sources

The pastoralists did not produce entirely for domestic markets. The small population, still under 100,000 in 1861 (*Statistics of New Zealand,* 1861,No.1), was a stimulus to seeking external markets. Trade became established quickly and remained centred on overseas markets principally in the Australian colonies and in Britain for both exports and imports (Lloyd Prichard, 1970, 56). Of great importance was the development of channels of communication which enabled producers to learn of trends in both those markets and of changes in production techniques which could affect them. In this fashion information transfer broadened their sphere of knowledge. The popularization of scientific discovery, a major development in Britain (Ziman, 1976, 114, 116), was carried to New Zealand. Founding universities and scientific societies paralleled the British and Australian models. As English agricultural techniques were being re-evaluated in the light of new discoveries, and new techniques were being developed, the New Zealand farmers learned about such changes. England, indeed, was seen as a centre for advanced agriculture by the end of the eighteenth century in its concern with fodder and root crops and crop rotation (Fussell, 1972, 182).

Of particular importance were the discoveries concerning the operation of the pasture ecosystem being developed. The early colonists did not have much information available, as the experimental work on the rôle played by soil nutrients in plant growth was only developed in the 1830s by men such as the German scientist, Liebig. His book on agricultural chemistry was first published in 1840 (McCaskill, 1929, 7), so the dissemination of information on the value of soil nutrients was still in an early phase. In fact he only suggested the idea of treating bones with sulphuric acid in that year before the British Association for Advancement of Science in that year (Sauchelli, 1965, 2).

Experimentation on the benefits of developing phosphatic fertilizer was still in an early stage. Although the use of bone-dust had grown to provide phosphate to the soil, Lawes in England, like Liebig in Germany, had only just begun experimenting with the use of sulphuric acid to render the phosphates in bone more soluble and so more readily available for uptake by plants (Miller, 1947, 29). The process of creating soluble phosphate from rock phosphate, Lawes' major contribution, was only patented in Britain in 1842 and commercial production of this superphosphate begun in 1843 (McCaskill, 1929, 7). The direct application of ground rock phosphate was also being advocated as increasing quantities were found in Europe. Liebig in 1857 confirmed the work of Lawes in showing that an acid treatment of the mineral would work as effectively as it did on bone (Waggaman and Easterwood, 1927, 18). This process was adopted rapidly and displaced the use of bones once further sources of rock phosphate were discovered. This innovation was very new when settlement began in New Zealand. Experimentation to determine the exact benefits on permanent grassland of differing manuring substances, including superphosphate, was not undertaken until 1852 when Lawes began work at Rothamsted (Miller, 1947, 29). Hence, information concerning the utility of this fertilizer would have been quite limited for those leaving Britain. The modern pattern of research and development occurring prior to innovation was not evident in this instance. The commercial application of the discovery preceded a more extensive knowledge of the benefits of the product involved. Industrial science had not yet fully emerged as science 'moved lock, stock and barrel, into the universities' (Ziman, 1976, 66, 57). Until universities became involved in agricultural research, farmers had few sources of new scientific information. Nonetheless, in New Zealand, fertilizing crops using guano was attempted to a limited extent by 1856 (Hargreaves, 1966, 266). The information available was leading to experimentation in the local environment.

AGRICULTURAL DEVELOPMENT TO 1882

The sale of wool to foreign markets and the sale of stock to new farmers had promoted agricultural growth from the early 1850s to the early 1860s, making New Zealand seem the best suited of the Australasian colonies for pastoral production (Lloyd Prichard, 1970, 85-86). It became the mainstay of the colony's economy while mixed farming expanded slowly (Hargreaves, 1966, 196). Sheep numbers increased almost twelve times between 1851 and 1861 and then more than quadrupled between 1861 and 1874. The increase in cattle numbers slowed to two-and-a-half times in the latter period from double that rate in the 1851-61 period. The rate of increase in the number of horses showed an even greater reduction from a ten times to a three-and-a-half times increase (Table 4.2). The latter trends reflected a growing stability of production as more land was occupied and run to sheep. The limited local market became oversupplied with meat. The production of tinned meat from the meat-preserving plants built in the 1870s (includes all those plants shown in Table 4.3 prior to the introduction of freezing plants in the 1880s) proved unsuccessful initially (Hargreaves, 1966, 322-323). The number of plants declined in the early 1870s but rose again to 1881 (Table 4.3). Nonetheless, disposing of surplus stock remained a problem. Plants to boil down carcasses for tallow emerged in the 1870s but trade in that product was not lucrative (Hargreaves, 1966, 323). The rising number of sheep

TABLE 4.3

SOURCES OF SOIL AMENDMENTS (NUMBER OF PLANTS) 1867-1920

Province or Provincial District	*Type of Establishment:* Year												
	1867	1870	1873	1878	1881	1885	1890	1895	1900	1905	1911	1916	1920
Meat-processing Plants[a]													
Auckland	—	—	1	1	4	8	7	5	7	8	8	11	11
Hawke's Bay	—	2	1	4	5	6	6	4	2	3	4	4	5
Taranaki	—	—	—	2	3	2	3	2	2	4	3	2	4
Wellington	—	7	1	9	9	7	8	5	5	5	4	7	10
Marlborough	—	4	—	5	9	4	3	1	1	1	1	1	1
Nelson	—	—	—	—	—	—	—	—	—	—	1	1	1
Westland	—	—	—	1	—	—	—	—	—	1	—	1	—
Canterbury		5	2	6	7	5	6	4	4	6	7	5	7
Otago	—	3	5	4	3	12	10	9	13	9	6	9	7
Southland	—	1									7	4	5
New Zealand	—	22	10	32	40	44	43	30	34	37	41	45	51
Boiling-down and Manure Plants[b]													
Auckland	1	1	1	3	6	1	1	8	8	10	6	8	14
Hawke's Bay	—	—	—	—	—	—	—	3	3	2	2	3	4
Taranaki	—	—	—	—	1	2	—	3	3	3	4	1	5
Wellington	—	1	—	—	2	—	1	5	5	5	6	6	8
Marlborough	—	—	—	—	—	—	—	—	—	—	—	—	2
Nelson	—	—	—	—	1	1	—	1	—	—	3	1	2
Westland	—	—	—	—	—	—	1	—	1	—	1	—	1
Canterbury		—	1	1	4	3	3	2	1	2	2	10	8
Otago	—	—	1	4	3	—	3	6	6	8	2	5	11
Southland	—	—									7	—	7
New Zealand	1	2	3	8	17	7	9	28	27	16	33	34	62
Lime Plants[c]													
Auckland	—	—	4	12	7	8	7	10	6	5	4	5	9
Hawke's Bay	—	—	—	5	1	2	—	—	—	1	1	1	1
Taranaki	—	—	—	1	—	—	—	—	—	—	—	—	—
Wellington	—	—	—	1	2	2	2	1	1	—	2	1	1
Marlborough	—	—	—	3	2	1	1	—	—	—	—	—	1
Nelson	1	—	—	3	1	2	4	1	2	3	1	2	4
Westland	1	—	—	1	1	1	—	—	1	1	—	—	1
Canterbury		—	3	4	4	—	1	1	—	1	1	—	—
Otago	1	3	7	4	5	8	6	1	5	9	8	7	4
Southland	—	—									—	—	2
New Zealand	3	3	14	34	23	24	21	14	15	20	17	16	23
Chemical Plants[d]													
Auckland	—	—	—	1	1	2	2/1	3/1	2/1	2/1	4/1	6/1	3/1
Hawke's Bay	—	—	—	—	—	—	—	—	—	—	—	1	—
Taranaki	—	—	—	1	—	—	—	—	—	—	—	1	—
Wellington	—	—	—	—	—	—	1	—	—	3	3	4	2
Marlborough	—	—	—	—	—	—	—	—	—	—	—	—	—
Nelson	—	—	—	—	—	—	—	—	—	—	—	—	—
Westland	—	—	—	—	—	—	—	—	—	1	—	—	—
Canterbury		—	—	—	—	2/1	2	—	1	1	2	5	1
Otago	—	—	—	1	1	2/1	3/1	4/1	5/1	10/1	4/1	7/1	1/1
Southland	—	—									—	—	—
New Zealand	—	—	—	3	2	6/2	8/2	7/2	8/2	17/2	13/2	24/2	7/2

TABLE 4.3 (Continued)

Notes: Below are the headings used in the statistical sources:

a 1870-81 comprises boiling-down and meat-preserving works.

1885-90 comprises boiling-down, meat-freezing and preserving works.

1895-1920 comprises meat-freezing and preserving works only.

b 1867-73 bone-manure manufactories only.

1878-81 bone-cutting mills only.

1885-90 bone-mills only.

1895-1911 comprises bone-mills and boiling-down works.

1916-20 as headed.

c 1867 lime kilns.

1870-85 lime works.

1890-1916 lime- and cement works.

1920 lime crushing or burning and cement-making.

d Chemical works used throughout and presented in regular face type. Known chemical fertilizer plants (McCaskill (1929) is used as the source) are shown in italics. Wellington and Canterbury were centres of chemical production but did not become the sites of fertilizer production as did Dunedin and Auckland.

Sources: 1867, 1920 *Statistics of New Zealand* (for years shown).

1878-81, 1895 *Census of New Zealand* (for years shown).

1870-73, 1886-90, 1900-05 *Census of New Zealand* (for year following the years shown).

noted earlier depressed stock prices from the mid-1860s--a boon to North Island runholders who readily acquire large flocks for us in controlling secondary fern and scrub growth on newly cleared land (King, 1947a, 253). The absence until 1881 of boiling-down plants in the North Island provincial districts except for Auckland (Table 4.3) indicates the shortage of stock and the outlet provided by meat-preserving plants there. Cropping was introduced to provide an income supplement to the returns from wool and tallow which fell in the later 1860s and dropped more severely a decade later (Lloyd Prichard, 1970, 111-112, 161).

It is certain that the interplay between environment and technology brought change to both. The extensive form of pastoralism, though remaining largely adaptive in terms of the pasture utilized, entered a more intensive, manipulative phase with the introduction of European grasses and clovers to replace some native grasses and tussock, between 1861 and 1871 (Hargreaves, 1966, 299). Although this form of pastoralism did undergo some change, the development of an intensive pasture ecosystem would not have occurred without an external stimulus to change. As long as wool, tallow, and hides were the only viable pastoral exports--dairy exports remained generally insignificant in value and volume (Hargreaves, 1965, 127)--the need to intensify production was not discernible (Miller, 1950, 141). The comparatively low return per unit of volume output did not encourage an intensification of production to increase supply. This transition arose after substantial increases in demand.

The gold rush of the 1860s constituted an unexpected, new, local market which led to an expansion arable farming (Belshaw, 1936b, 6) evident in the sharp acreage increase in the grain crops between 1856 and 1864 (Table 4.1). The large-scale cereal production enterprise emerged and became export-oriented. It grew rapidly, particularly as:

> after 1878 when the boom conditions of the 70s ended ... extensive cereal production became more profitable than extensive sheep farming on the tussock grasslands of the plains. The invention of drills and reapers and binders came at a most opportune time, enabling a rapid change-over from wool to cereal production to be made on suitable country, notably in Canterbury. (King, 1947a, 253)

Imports and locally produced machinery met the demand created

(Hargreaves, 1966, 382-383). The New Zealand farmers' use of labour-saving machinery, similar to that in Australia and in North America where labour was also in short supply (Hargreaves, 1966, 462) dates from this period when there was a significant increase in the area under cultivation (Table 4.1) notably in the lowland tussock areas of the South Island (Hargreaves, 1960, 7). Cropping grain became a stage in the conversion of land to pasture since several years of cultivation were required to aid the formation of a good grass sward and prevent the regeneration of native vegetation (Gould, 1976, 4-5). The area of sown grass also expanded fairly quickly through this period (Table 4.1) because of the use of better grass seed mixtures containing more clover (King, 1947a, 253). The capitalist ethic was well rewarded in such circumstances:

> worthwhile profits could be made by taking a few successive crops of wheat or oats from land rich in nitrogen from the droppings of the stock which had been pastured on unploughed tussock for several decades, and on which for a few years excellent yields could therefore be obtained. (Gould, 1976, 5)

Both large-scale and small-scale farmers benefited but the scale economies of the large holdings prompted production increases there (Cumberland and Hargreaves, 1955, 105). The need for soil fertility improvement would not have been immediately obvious, nonetheless, it was recognized:

> 'our future progress in agriculture depends on the facilities offered for obtaining manure [fertilizer] with which to restore to our soils the elements of plant foods which are now being removed from them by cropping, ... it [the supply of fertilizers] will tend to hold in check the exhaustion to which our soils are liable if we continue to follow in the steps of other new countries such as America and Australia.' (*New Zealand Country Journal*, 1882 cited in Scott, 1947, 365).

Recognition did not lead to immediate remedy. The tussock lands' fertility, for example, was appreciably reduced (Cumberland and Hargreaves, 1955, 106).

Fertilizer Usage

For the New Zealand farmer, information about soil amending was available through perusal of journals such as that of the Royal Agricultural Society, personal contact with recent migrants from

Britain, or visits to the home country. Awareness of advances in agriculture such as soil amending and the borrowing of them has been noted (Brooking, 1972, 30). For example, Liebig's work on soils and soil testing was published in New Zealand at this time but interest in pursuing the work and in soil amending had not advanced much by the 1870s despite its earlier use (Hargreaves, 1966, 264, 267). On a missionary farm in 1825 the problem of soil exhaustion had been noted and the application of fertilizer undertaken (Hargreaves, 1966, 13). In the 1830s the use of crops for green manuring, the spreading of dung, and the spreading of lime obtained by burning seashells were methods recorded to improve grain production in some mission farms (Hargreaves, 1966, 47). Some awareness of the growing soil-amending technology being developed in Britain was evident but its adoption was slower with a slow expansion of mixed farming. Whereas guano and rock phosphate had been marketed in Britain as early as the 1820s (Royal, 1967, 24) the first recorded shipment to New Zealand was landed in 1867 (Table 4.4). Hargreaves (1966, 266) has noted that this material was available for sale earlier. The practice simply predated the documentation of the imports. Although this first recorded shipment of 459 tons was classed as 'guano' it is considered likely that the material was rock phosphate (McCaskill, 1929, 13). At that time 'guano' was used a generic term for fertilizing material just as 'manure' continued to be in New Zealand until approximately the middle of this century. Occasionally, real guano, the nitrate-rich marine bird droppings, were imported but the cost was high and the supply unreliable (McCaskill, 1929, 11).

The use of fertilizing material developed little through the 1860s and 1870s (Table 4.4) despite the absence of opposition to the use of chemical fertilizers by a conservative tradition favouring animal manure. Farmyard manure was not available in a situation where animals were not penned. Notwithstanding the construction of a small bone-crushing mill at Warkworth (North Auckland) in the 1860s (Royal, 1967, 27), local supply remained limited. The high cost of imported bones was a further deterrent to the extension of soil amending (Miller, 1947, 21).

TABLE 4.4

TONNAGE OF SOIL AMENDMENT IMPORTS 1867-1920

Year	*Bone-dust*	*Guano and Rock Phosphate*	*Unenumerated*[a]	*Total*
1867	..	459	..	459
1870	..	57	..	57
1875	..	1,074	..	1,047
1880	3,187	346	151	3,684
1885	3,702	3,441	1,087	8,230
1890	3,713	6,308	3,208	3,229
1895	7,722	5,341	3,577	16,640
1900	6,799	9,935	12,103	28,817
1905	13,580	5,619	26,954	46,153
1910	11,315	10,941	52,980	75,236
1915	9,372	39,159	78,875	127,406
1920	5,527	55,805	67,011	128,343

Note: *a* Includes all other fertilizers. Table 4.7 indicates that superphosphate was the principal type recorded in this category.

Sources: 1867 *Statistics of New Zealand* (1867).

1870 *Statistics of New Zealand* (1971).

1875-1910 *Statistics of New Zealand* (for years shown).

1915-20 Calculated from *Statistics of New Zealand* (for years shown).

Fertilizer Production

An early phase of fertilizer production had its origins in the need to deal with the by-products of wool exports, the sheep. Old sheep were slaughtered and their carcasses boiled down for the tallow since the local market for meat was oversupplied and the market for replacement sheep was reduced as land had become more fully stocked (Hargreaves, 1966, 322). An organic fertilizer was sometimes made from the remains (Miller, 1950, 141). A number of these plants had developed in the 1870s (Table 4.3) in or near the major ports closest to the large areas of occupied land. These plants were not often financially successful, however, and so their output was limited even as the meat industry expanded in the 1880s (Table 4.5). Concurrently, there was some attempt to create a meat-preserving industry but it did not succeed as an operation (Miller, 1950, 141). Its output of fertilizer was not recorded separately (Table 4.5). Occasionally, bone-mills were established to process the remains of the carcasses from the meat-preserving plants for organic fertilizer and bone-dust. The number of such mills rose from two in 1870 to eight by 1878. There were located mainly in Auckland and Otago Provinces (*Census of New Zealand,* 1871, No. 31; 1878, 347). Canterbury seemed undersupplied with such facilities with only one plant at Timaru, given the concentration of meat-preserving plants (Table 4.3). The lack of concern for fertilizers in the grain cropping of the area as noted above by Gould, would seem to be borne out by this situation. Still, it was at this plant in 1878 that methods of steaming and crushing carcasses to manufacture bone-dust were implemented successfully to make a more usable product (McCaskill, 1929, 85). This material was used as a fertilizer on annual crops as had been the practice in Britain and the Timaru plant prompted the establishment of similar plants (Hudson and Scrivener, 1937, 373). The use of bone-dust was recorded in Taranaki in the 1870s:

> 'old settlers find that farms carved out of forest do not yield as they did in the past and in obedience to stern necessity include bonedust in the programme of operations' (*New Zealand Country Journal,* 1877 cited in McCaskill, 1929, 127-128).

Local production of chemical fertilizers did not begin until the following decade. These plants followed the same locational pattern in being associated most often with meat-freezing plants (Callaghan

TABLE 4.5

TONNAGE OF ORGANIC FERTILIZER PRODUCTION 1885-1920

Year	*Bone-Dust*			*Other Fertilizer*		
	Boiling-Down Plants	*Meat-Processing Plants*	*Bone-Mills and Manure Plants*[b]	*Boiling-Down Plants*	*Meat-Processing Plants*	*Bone Mills and Manure Plants*[b,c]
1885	2,575		1,033	..		1,850
1890	2,703		1,647	..		
1895	1,018	3,230	2,253	670	1,536	
1900	2,309	4,205	2,017	462	5,259	
1905	914	4,956	6,676	163	6,247	
1910	990	5,366	16,723	—	4,845	
1915-16[a]	4,291	1,830		52,374	22,202	
1920-21[a]	22,938			35,284		

Notes: *a* Year ending 31 March.
b Included with boiling-down plants after 1910.
c No further organic fertlizers noted after 1885; recorded as 'manure only' from chemical plants.

Sources: 1885 *Statistics of New Zealand*, 1886, Part IV, 293, 283.
1890 *Statistics of New Zealand*, 1891, Part IV, 333, 331.
1895 *Statistics of New Zealand*, 1896, Part V, 420, 415.
1900 *Statistics of New Zealand*, 1901, Part IV, 407, 401.
1905 *Statistics of New Zealand*, 1905, Part IV, 465; *Statistics of New Zealand*, 1906, Part IV, 473.
1910 *Statistics of New Zealand*, 1911, Part VI, 565, 547.
1915 *Statistics of New Zealand*, 1916, v. III, 91.
1920 *Statistics of New Zealand*, 1920, v. III, 93.

and Peren, 1936, 246).

GRASSLAND FARMING 1882-1920

Though the 1870s were a critical period in New Zealand's agricultural development because of the experimentation of both large and small landholders to find new, viable farm enterprises or new markets (Hargreaves, 1966, 469, 471), it was in the 1880s that developments in progress were complemented by a number of changes which altered the existing agricultural production pattern. The many new settlers attracted in the 1870s had been converting additional areas of land to production, so increasing the total output. This trend, however, held the prospect of oversupplying the existing markets despite their growth and keeping down already depressed prices. Wool, the export fluctuating most in price, was not the basis on which to build the colony's economy (Simkin, 1951, 39).

Transport Innovation

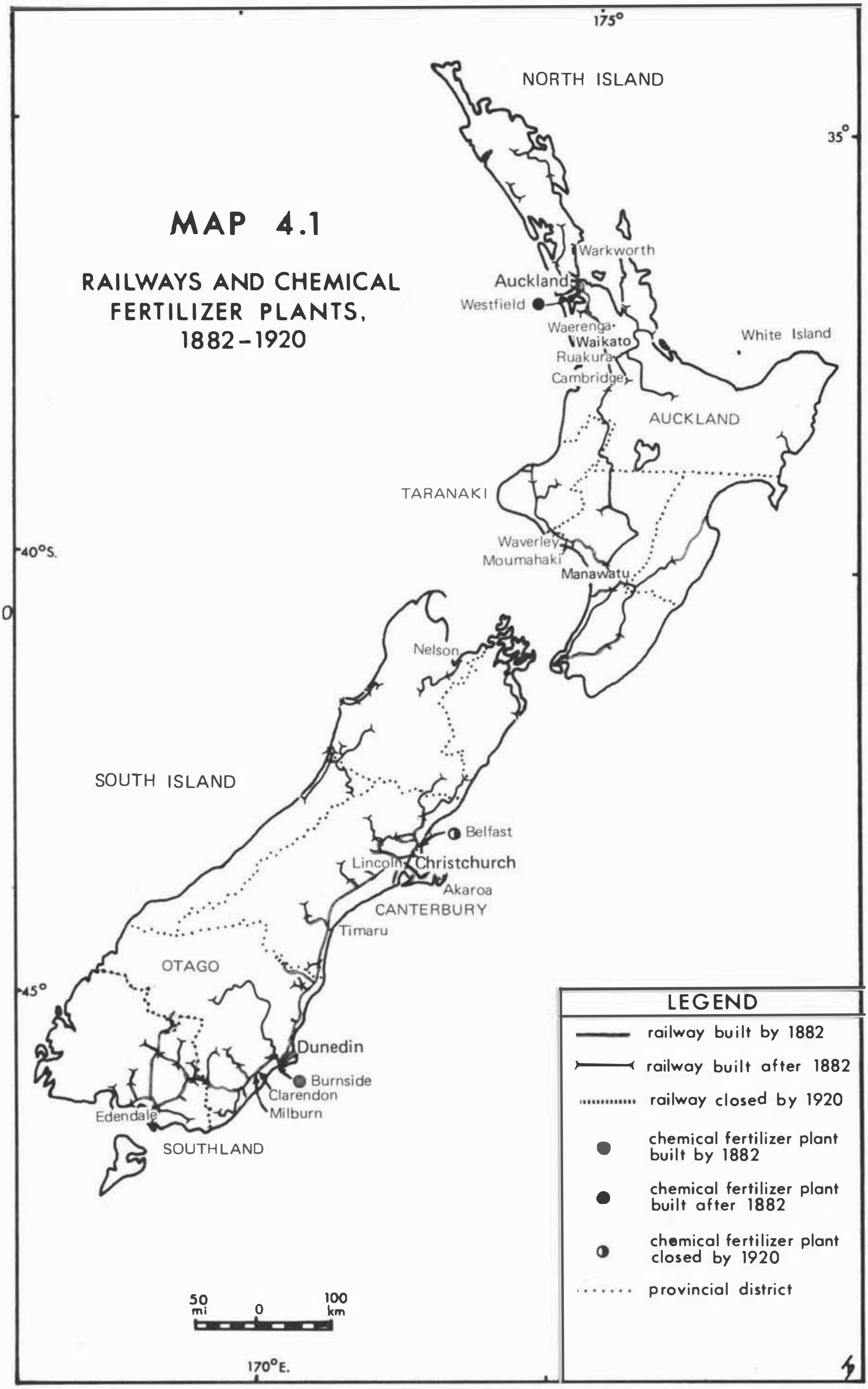
This adverse situation was averted with the introduction of an innovation, refrigerated marine transport. It initiated a major change in the composition of exports. The ability to sell sheep meat in the British market was demonstrated in 1880 by shipments from Australia--the culmination of invention began in the 1850s (Robertson, 1939, 11-12). This experiment was imitated by the shipment from New Zealand to London in 1881 of frozen sheep carcasses and butter (King, 1947b, 567, 569). A large firm, the New Zealand and Australia Land Company, was intimately associated in this experiment to find a way to more profitably dispose of its sheep (King, 1947b, 567). Its managers in New Zealand were endeavouring to open new production opportunities using their knowledge of the British market. Meat demand was growing because of rising real income based on generally higher wages and population increase (Jones, 1974, 199-200). Domestic production could not meet the demand imposed by a doubling of meat consumption so not only were foreign supplies sought but also a price increase occurred which enabled the greater transport cost and risk factors to be defrayed (Jones, 1974, 198-199, 200). The success of the New Zealand frozen-meat shipments revived the Australian industry which had lapsed following its first attempts (Scholefield, 1909, 127).

For the New Zealand sheep farmer the return per animal dramatically increased as meat, a more expensive product than wool, was marketed through the channels being opened. Even though it had been a large land company which had been responsible for the introduction of refrigeration because of its financial ability to assume the risks of experimenting with the new machinery involved, and capacity to organize the trade, the higher return made it feasible for many small farmers to make more intensive use of small areas of land to earn a living (Scott, 1947, 367). They responded by increasing sheep numbers to the turn of the century (Table 4.2). The entry threshold to farming had been lowered but entry necessitated the implementation of efficient organization to keep production costs low as the larger producers had already discovered (Condliffe, 1933a, 161-162).

Closer Settlement

The 1880s witnessed an intensification of land utilization (Gould, 1965, 133). Through political action, pressure was exerted on the large runholders to make way for closer settlement of the land. The policy of opening opportunities for land holding had begun in 1877 with a Land Act designed to stem the acquisition privileges of larger landholders (Evans, 1969, 28). This measure accompanied the efforts of the Vogel ministry to back up land settlement and immigration policy through such important steps as developing the country's infrastructure by the construction of railway lines and roads (Lloyd Prichard, 1970, 132). The railways constructed before 1882 were an outcome of this policy (Map 4.1). Also important was the centralization of land laws through the abolition of the provincial governments in 1876 (King, 1947a, 255). These measures had some effect as the number of holdings increased by over 10,000 between 1874 and 1880 but slowed with the onset of economic depression (Table 4.1). However, Gould (1965, 134) holds that the results of this policy were not much in evidence until the 1890s. Certainly the total numerical increase is greater with just over 17,500 new holdings being formed between 1890 and 1895.

While attempts to create smaller farms by legislation continued through until 1894 (Lloyd Prichard, 1970, 133), the coincidence of a period of depressed prices for the primary products also played a role in forcing the sale of parts of the larger estates to aspiring farmers.


MAP 4.1
RAILWAYS AND CHEMICAL FERTILIZER PLANTS, 1882-1920
175°
NORTH ISLAND
35°
Warkworth
Auckland
Westfield
Waerenga
Waikato
Ruakura
Cambridge
White Island
AUCKLAND
TARANAKI
Waverley
Moumahaki
Manawatu
40°S.
Nelson
SOUTH ISLAND
Belfast
Lincoln
Christchurch
Akaroa
CANTERBURY
Timaru
OTAGO
45°
Dunedin
Burnside
Clarendon
Milburn
Edendale
SOUTHLAND
50 mi
0
100 km
170°E.
LEGEND
railway built by 1882
railway built after 1882
railway closed by 1920
chemical fertilizer plant built by 1882
chemical fertilizer plant built after 1882
chemical fertilizer plant closed by 1920
provincial district

On occasion, revenue from land sales enabled some intensification to be undertaken on the large properties as well (Gould, 1970, 26). Later, price increases for primary products in the late 1890s helped to consolidate the dispersion of farm ownership (Gould, 1965, 133), and encouraged the spread of the more intensive livestock enterprises--fat-lamb rearing and dairying (Miller, 1950, 142). With this trend came a reduction of average farm size as is shown later.

The development of dairying too was dependent on the advent of refrigeration. The amounts of butter and cheese exported within two to three years after 1882 equalled the total volume exported in the preceding 1853-1881 period (Hargreaves, 1965, 128). As this enterprise required less land than other forms of production it facilitated the government's plans for closer settlement (Smallfield, 1947a, 167). The small farmers who had maintained themselves at a subsistence level were finally able to enter a profitable enterprise. Dairy cow numbers rose most rapidly from 1890 to 1905 and continued to increase to 1920 while sheep numbers fluctuated (Table 4.2). Though requiring less capital than sheep farming, dairying did require more labour. The dairy men were further hindered in attempting to overcome the poor quality of both their production facilities and their stock by a lack of even the smaller amounts of capital required (Smallfield, 1947a, 167). The quality of dairy product transport lagged behind that of the lucrative meat trade and slowed the industry's growth until the early 1890s (Robertson, 1939, 113). Co-operation in manufacturing provided the pooling of resources which facilitated the great expansion of dairying from the 1880s to the 1920s as the export trade grew (Ward, 1975, 11) and mechanization improved productivity (Condliffe, 1933a, 163). With these developments dairying became the economic basis of the small holdings (Hargreaves, 1966, 473).

Extension of Grassland

Whatever the combination of causes, the result was a wholesale assault on the existing ecosystems in the conversion on freehold properties, to crop and/or pasture production (Duncan, 1962, 173-175). It was in the 1880-1910 period that the area of improved land quadrupled (Table 4.2). Some further tussock lands were ploughed and sown to grass in the South Island but the main expansion occurred in the North

Island where forests were felled and burned, and grass and root crop seed down in the ash among the remaining tree trunks and stumps (Cumberland and Hargreaves, 1956, 71, 60). A colossal amount of human effort was devoted to the creation of farmland, and the effort expended increased after the late 1860s once the Maori uprisings had been quelled and access had been improved (Johnston, 1961; Petersen, 1965, 69-70). Often enough the effort to clear land was other than a consequence of economic considerations. Gould (1976, 11) describes the irrationality of many settlers' actions:

> there is much evidence of a literary and biographical character that pioneers were often haphazard in their calculation of, or perhaps indifferent to, the profitability of the work of breaking in and improving land.

Once the land had been wrested from its native vegetation, there remained the problem of how to develop it to prevent its reversion to a less productive state. However, improvement remained less important than the extension of grassland acreage until 1914 (Smallfield, 1947a, 169). Experience gained in earlier periods provided some answers; innovation provided others. The rapid increase is evident in the doubling of sown grassland acreage in the 1890-1910 decade (Table 4.1).

The extension of sown grassland proceeded rapidly as the land was not always ploughed before sowing. The ratio of ploughed to unploughed sown grassland was seldom less than 1. The acquisition of land involved its rapid conversion to grass so in the periods of expansion the ratio declined. From the 1890s the extent of oversowing without ploughing increased markedly (Table 4.6). The reversion problem remained serious though the data are limited. Also noteworthy is the fact that the acreage of native grassland remained substantial, exceeding the area sown until the later war years (Table 4.6).

Selection of Pasture Plants

In the 1850s seed mixtures had been formulated which proved sufficiently successful to encourage their continued use in the 1880s. Grasses of English origin were sown along with clovers and root crops such as turnips, the concept of all-grass production being viewed as dangerous (Hargreaves, 1965, 124). Ryegrass found favour early with most farmers and Dutch white clover was introduced by 1871 (Miller,

TABLE 4.6

TYPES OF GRASSLAND (THOUSANDS OF ACRES) 1876-1920, AND RATIO OF PLOUGHED TO UNPLOUGHED SOWN GRASSLAND 1876-1910

Year	*Tussock and Native Grasses*	*Fern, Scrub, and Second Growth*	*Sown Grassland:*[a] *Ploughed*	*Unploughed*	*Ratio*[b]
1876-77	..	..	998.6	1,214.1	1.23
1880-81	..	..	1,568.6	1,988.4	1.27
1885-86	..	..	2,793.3	2,671.9	0.96
1890-91	..	..	3,250.5	3,715.7	1.14
1895-96	..	..	4,254.9	5,030.2	1.18
1900-01	..	..	4,425.7	6,656.2	1.50
1905-06	..	..	4,779.7	7,745.7	1.62
1910-11	..	..	5,000.2	9,214.5	1.84
1915-16	16,704.1	..	14,623.6		
1916-17	16,154	..	14,971.7		
1917-18	16,029.2	3,131.4	15,448.1		
1918-19	15,625.5	3,393.9	15,801.6		
1919-20	14,892.1	3,722.4	16,125.3		
1920-21	14,993.4	3,771	15,912.8		

Notes: *a* Not including area cut for seed, hay, or ensilage.
b Ratio calculated from sources given below.

Sources: 1876-80 *Statistics of New Zealand* (1881).
1885 *Statistics of New Zealand* (1887).
1890 *Statistics of New Zealand* (1895).
1895 *Statistics of New Zealand* (1900).
1900-10 *Statistics of New Zealand* (1910).
1915-20 *Statistics of New Zealand* (for years shown).

1947, 25). This pattern followed earlier British developments of mixed cropping when the value of feeding root crops to stock had been established and their role in breaking up soil had been realized (Chambers and Mingay, 1970, 55). The importance of legumes in pasture for fertility improvement had been noted in England and the whole concept of ley (permanent pasture) husbandry had been introduced there by the late sixteenth and early seventeenth centuries (Jones, 1974, 69-70). The reason for its contribution was not discovered until the late nineteenth century, however. It has been suggested that this imitation of English experience was unfortunate because:

> many of the Dominion's subsequent difficulties with surface-sown country might have been lessened if almost total reliance had not been placed on perennial ryegrass and white clover in the early sowings. (Smallfield, 1946, 544)

The degree of success which could be achieved in New Zealand was an unknown and this led to experimentation with the types of species. A wide variety was employed--it was noted in the South Island alone that 92 species of exotic grasses were found (Clark, 1949, 349). Though some of these species were introduced accidentally through the use of undressed or poorly dressed seed mixtures, many were tried deliberately to see which types would be most productive. By the late 1870s little seed was imported as local production was found to be adequate (Hargreaves, 1966, 259-260). The advantage of using ryegrass and cocksfoot became apparent in the 1850s and the benefit of having white clover was also noted (Clark, 1949, 354-355).

Arable-Grass Rotation

Rotational usage of pasture with cereals and fodder crops was accepted by the 1870s as its superior productivity had been observed (Clark, 1949, 355). The rapid growth in green-fodder-and-root-crop and grain-crop acreages in the 1870s shows this trend (Table 4.1). However, it had taken some time to develop because a stable market for its produce was absent. Farmers grew what was saleable as long as yields remained adequate and, even if those fell, could use fresh land (Hargreaves, 1966, 269). Following British practice did not make sense until markets were opened. This farming practice persisted into the early 1900s as the norm on ploughed land (Smallfield, 1947a, 169). The fact that grain crops produced higher yields when spelled with grass had already convinced cash crop producers to sow crop land to grass and raise some stock as a subsidiary enterprise. Frequently crops were used as sources of fodder, and increasingly so at the end of the period (Table 4.1). The fertilizing of crops must have contributed to the subsequent improvement of pastures (Miller, 1947, 21). The growing market for meat significantly furthered the trend as it was not until the development of the frozen-meat trade that rotation of cereals, fodder crops, and pastures became really profitable (Scott, 1947, 365).

The rotational use of land was a familiar practice in Britain. The use of arable-grass rotations such as the Norfolk four-course, which relied on a close-knit cycle of fodder, grain, and pasture for the production of beef, mutton, wool, wheat, and barley, was well established (Kerridge, 1967, 32). The element introduced by the mid-1860s was the recognition of the relationship of manure to increased production. Greater livestock production could be achieved through increasing the output of root crops in particular from arable farms. The greater quantities of dung created served to enrich the soil, so raising the productivity of the farm for both livestock and grain.

In some areas, Cheshire for instance, there was a move to permanent pasture employing drainage and bone-dust fertilizer to raise their productivity (Jones, 1974, 197, 203). The value of the fertilizers developed by Lawes for the root-crop component was gaining recognition in this system of 'high farming'. Of great importance to the spread of their use was the completion of a rail network which permitted the quick and inexpensive transport necessary (Jones, 1968, 20, 22). The extension of the rail network in New Zealand prior to World War I (Map 4.1) offered the same prospect. The major obstacle to the system was the climatically related problem of an insufficiency of high-quality pasture to meet the needs of livestock all year round. As a result, there was only a limited move in the better grass-growing areas to employ permanent pasture and finish stock for market using supplements such as oilcake (Jones, 1974, 201).

This developing pool of knowledge was accessible to settlers coming to New Zealand, so much so that the rotational use of land was employed even by the many settlers less experienced in agricultural production (Clark, 1949, 358). This technique was used by settlers in the 1850s in eastern Canada (Mahaney and Ermuth, 1974, 119), and given the similarity of origin of the people involved, it can be assumed that comparable techniques were employed in New Zealand. The knowledge that leguminous crops benefited the production of cereals would have spread in such a fashion. The means of the transmission of such concepts were similar, in that farmers in New Zealand, like those in Canada, formed agricultural societies to discuss and compare the effectiveness of differing techniques employed (Mahaney and Ermuth, 1974, 118-119; Smallfield, 1970, 46). In New Zealand such organizations pressed for the establishment of a government department to deal with agriculture in the 1880s (Brooking, 1972, 28). In 1877 the Canterbury Agricultural Society had published the *New Zealand Country Journal*, the first purely agricultural periodical to appear and present information of relevance to New Zealand farming (Hargreaves, 1966, 464).

In New Zealand the value of the root crop for fattening stock, came to be recognized and the cultivation of rape and soft turnips undertaken for this purpose in the 1870s (Hargreaves, 1966, 388). This increase accounted for much of the rapid rise in supplementary fodder crops (green and root crops) seen between 1871 and 1881 (Table 4.1). The suitability of the South Island for the production of these crops contributed to its earlier agricultural development (Miller, 1950, 141). This use of fodder crops led to more scientific farming including the use of fertilizers and crop-rotation methods (Condliffe, 1963, 236). The increase in livestock production, particularly in lamb fattening, following the introduction of refrigeration boosted the acreage of supplementary fodder crops (Table 4.1). Oddly, hay production was replaced by root crops (Table 4.1) despite the increased availability of machinery for haying (Hargreaves, 1966, 262). Only during World War I did haying increase markedly.

Mechanization

The process was facilitated through the advent of more powerful and efficient machinery. Of importance for cropping was the arrival of the seed drill to replace the older broadcast sower, and to these drills could be added 'manure' boxes enabling seed to be sown along with chemical fertilizer (Evans, 1956, 5). Machines developed in Britain, Canada, the United States and Australia were imported and local production was well under way in the 1880s (Evans, 1956, 3). Over 200 such machines were produced annually in the colony by 1891 (*Census of New Zealand*, 1891, Appendix B, xxi). It was seed drills which were first used for fertilizer spreading in the Waikato (Miller, 1947, 29). This is a strong indication of the pattern of fertilizer usage which developed at this stage, and it is a pattern which was maintained into the mid-1900s (McCaskill, 1929, 5). Even though the topdressing of pastures had begun by that point, the importance of it in terms of the relative quantity of soil amendments used did not alter until the 1920s (Holford, 1936, 169).

Soil Amending

Soil amending had developed in conjunction and with the extension of cropping and with local and external production of soil amendments. In the years to 1920 the meat-freezing plants supplanted the boiling-down plants as sources of supply of organic fertilizer (Table 4.5). Bone-mills were more widely established in conjunction with these plants to produce the bone-dust used widely on annual crops (McCaskill, 1929, 85). Domestic production only began to be outpaced by imports by the mid-1890s (Tables 4.4 and 4.5) as the acreage of fodder and grain crops began to reach its maximum (Table 4.1). In 1880 bone-dust was being imported from Australia and the United States and until the mid-1890s, often rivalled the quantity of guano and rock phosphate imported (Table 4.4). However, its high cost, increasing scarcity, and the risk of anthrax infection contributed to its decline (Miller, 1947, 31). The importation of bone-dust tapered off in the early 1920s when it was realized that other forms of phosphate fertilizer were more efficacious (McCaskill, 1929, 38). An adulteration problem persisted so the Manure Adulteration Act, 1892 was passed to provide vendor guarantees of contents and a testing facility to resolve disputes (Brooking, 1972, 53; *Statutes*, 1892, 276-278). Government determined to assist soil amending by providing some guarantee of product quality.

The Waikato was the first area in which soil amending by top-dressing (the distribution of soil amendments without cultivation) of pastures occurred (Holford, 1936, 168). The stimulus for this activity was the Cambridge Farmers' Club. At one of its meetings in 1880 a member presented an address on the cultivation of grasses in which he mentioned the Rothamsted superphosphate trials of Lawes (Miller, 1947, 27). This knowledge alone is not thought to have prompted the use of topdressing on pastures:

> the historical record reveals that their [the Waikato farmers'] remarkable joint effort which overcame the difficulties of Waikato farming was forced on them by circumstance. ... The Cambridge settlers developed topdressing partly because they had heard of the Rothamsted experiments, but mainly because they had to. (Miller, 1947, 19)

Soil, climate, and market factors combined to make intensive grassland farming the basis of the farm enterprise and topdressing using phosphatic fertilizer was needed on soils which would not naturally carry milk-producing pastures.

The technique of pasture topdressing remained local, largely because it was:

> regarded with derision by those who had no need to do it and with shame by those who did. (Miller, 1947, 27)

Testing methods were inadequate and hindered the diffusion of the technique; yet, its use became associated with the spread of dairying, particularly in this area of the Auckland district (Miller, 1947, 29). The low returns for animal products which remained until the early 1890s retarded investment with the result that 'the top-dressing wave, therefore, moved very gently over the landscape in the early years', a view supported in Smallfield (1970, 46), and even by 1909 was but being 'practiced on a moderately wide scale in the Auckland Province' (Holford, 1936, 168). Price rises from the late 1890s are claimed to have promoted facilities and the purchase of fertilizers (Smallfield, 1947b, 271) but the lack of statistical information concerning fertilizer use eliminates a closer examination of the spread of the technique until the late 1920s.

The concern for the maintenance of soil fertility was being communicated nonetheless. Farmers had direct experience with land reversion, a problem of substantial proportion, as it was found that the high-fertility-demanding sward of English clovers and grasses could not be maintained on inferior soils (Gould, 1976, 8-9). By 1900 the carrying capacity per acre and butterfat production were not high on existing grassland (Smallfield, 1947b, 270). Production depended on the cultivation of root crops to provide supplementary feed (Dairy Industry Commission, 1934, 13). Stock numbers on unploughable land:

> before the days of fertilizers to induce clover growth, ... were rarely large enough to provide the amount of nitrogen enrichment required for continued health growth of the established sward. (Gould, 1976, 21)

The result was:

> The national average increase in the number of stock units per acre was brought about only because the rate of formation of sown pastures was sufficiently rapid to offset and more than offset the deterioration which occurred on each separate type of grassland, both exotic and native. (Gould, 1976, 19)

At this stage, research into correcting the problem centred on finding suitable grasses with lower fertility requirements to create permanent pastures on poorer land (Smallfield, 1947a, 169). The move to improving soil fertility on such grassland had not yet occurred.

SCIENTIFIC INVESTIGATION OF AGRICULTURE

Scientific advice was developing in New Zealand itself as, by the 1870s, the need for a scientific approach to agriculture and the inapplicability of the information available from abroad had become evident (Hargreaves, 1966, 463). Its development and dissemination was due to the establishment of a number of institutions and programs to assist farmers.

Teaching Institutions

The emphasis on education which was developing in Britain (Perkin, 1972, 290-302 *passim*) was brought to the colony. A tertiary level of education was introduced and in 1872, as part of the Canterbury University College, a School of Agriculture was established with 100,000 acres of land set aside by the Provincial Council for its endowment (Wallace, 1891, 162). However, the buildings at Lincoln were not completed until 1880, when 16 students were admitted. The number of students never rose above 41 and by 1888 had returned to the 1880 level (Wallace, 1891, 162). A Royal Commission was instituted in 1888 to make inquiries into conditions and make recommendations for their improvement. The aim of raising the standard of technical education of farmers' sons had not been met because of the high fees charged. The second aim of conducting experiments was 'not carried out to any great extent for lack of money' (Wallace, 1891, 163). These aims were met subsequently and the opportunity for practical education expanded when the Department of Agriculture undertook to give instruction to young farmers on three of its experimental farms in the North Island (*ARDA*, 1912, 92).

A fortunate development at Canterbury Agricultural College (usually referred to as Lincoln College after its location) was the appointment in 1880 of W.E. Ivey as its Director. An interest of his was the investigation of fertilizers. In fact, he is thought to have introduced superphosphate to New Zealand by importing 15 tons of Lawes' brand in 1881 for experimental work (Evans, 1969, 200; McCaskill, 1929, 41, 104). There was local recognition of the need for fertilizers to prevent soil nutrient exhaustion and, at the Canterbury Agricultural College, Ivey's successors promoted the use of fertilizers, superphosphate in particular, on wheat crops (Scott, 1947, 365).

Dairy Instruction Service

In addition those at the College, instructors had been appointed since 1883 to assist in the agricultural sector. Initially they only provided information on dairy-factory design and operation (Philpott, 1937, 48). The Agricultural Branch of the Crown Lands Department was organized in 1886 specifically to assist dairying and as well as fruit production (Brooking, 1972, 29). Then the instruction service was expanded to become both practical and permanent in 1889. Dairy associations, dairy-factory managers' conferences and the establishment of a journal on dairying industry problems were the outcome of the instructors' efforts (Philpott, 1937, 73). Schools of one month's duration were also instituted in 1895 in both islands but a permanent school was not founded (Philpott, 1937, 93, 105). Farmers were presented with ideas derived locally and with those adopted from abroad at a very early stage in the development of New Zealand dairying (Duncan, 1933, 5). Before 1881, such government encouragement was 'reluctantly taken' (Hargreaves, 1966, 464). The prospective economic significance of intensive livestock production brought a new attitude.

Experimental Farms

The concept of experimental work was impressed upon the Government when in 1892 a separate Department of Agriculture was formed and based on the concept developed in Britain and North America (Brooking, 1972, 29). Little formal experimentation had been undertaken previously for the agricultural and pastoral societies did not have the funding needed (Hargreaves, 1966, 463). Experimental work was encouraged at the Moumahaki Experimental Station set up in 1894 near Waverley in the North Island. With encouragement from agricultural and pastoral societies, field trials were organized using various fertilizers in various combinations on various crops to learn which proved most successful (McCaskill, 1929, 106; Evans, 1969, 201). This work was developed principally after 1900 with the field-trial program being expanded to cover 600 plots in 1908 (McCaskill, 1929, 108). Additional experimental farms were acquired in the North Island to broaden the areas of investigation by including different soil types and different farm enterprises (Evans, 1969, 201). It was at the farm at Ruakura in 1904 that topdressing trials using basic slag were initiated (Holford, 1936, 168).

This trial was prompted by the Waikato Farmers' Club under the auspices of the Auckland Agricultural and Pastoral Society. Here was an indication of the interest of area farmers in the technique and in the experimentation undertaken. Waikato farmers came to treat topdressing as seriously as Southland farmers treated liming, and they obtained an economic advantage over their competitors in Taranaki, Manawatu, and Southland (Miller, 1947, 31). The results of the experimentation, issued in a Department of Agriculture report in 1908, initiated interest elsewhere and prompted a change from Waikato mixture (equal parts of bone-dust, superphosphate, and guano) to basic slag as the preferred topdressing material (Miller, 1947, 31, 27). Other pasture topdressing trials were carried out at the Waerenga and Moumahaki farms, with the trial at the latter designed along the lines undertaken at Cockle Park in Britain (*ARDA*,1908, 330, 367, 349). The transmission of information on research methods and findings from Britain was evident in this work. The importance of basic slag as a fertilizer was supported by the Waerenga trial, but the results at Moumahaki were viewed as disappointing (*ARDA*,1908, 331, 368). Differences in soil resources were thus becoming recognized.

Research on Grasslands

Although the growing grassland basis of the country's agriculture was clear, it was only in the first two decades of the century that a systematic study of the country's pastures and pasture plants was begun by scientists (Smallfield, 1947a, 167). The formation of the Department of Agriculture provided the institutional framework within which a number of scientists concerned with agriculture could work and could communicate their thoughts both to other scientists and to the public.

B.C. Aston, Chemist to the Department of Agriculture, from 1899 encouraged the search for sources of phosphate and appealed for the institution of a field trial program (Smallfield, 1947b, 275). This program was begun with groups of farmers on the west coast of the North Island in 1908 (*ARDA*, 1908, 320). The Fields Division was organized by E.C. Clifton to include experimental work on large experimental farms before 1916 (Smallfield, 1970, 2). The experimental-farm work was loosely integrated into the research and instructional services which were the main work of the Department. This integration brought about the gradual establishment of an instruction service based on the transmission of accurate information--a basic element in improvement in farming (Smallfield, 1947b, 275). From 1905 on, through this network, Clifton advocated the use of topdressing as a means of improving annual pasture production and giving pastures a longer life (Smallfield, 1947a, 169). In addition, A.H. Cockayne was engaged as an assistant biologist in the Biology Section and through his concern for the development of pasture plants by plant breeding, helped to lay the foundation for work in seed testing and grasslands research (Evans, 1960, 4, 5).

The publication in 1910 of the *Journal of the Department of Agriculture* [from 1913 *Journal of Agriculture*] was an important step in disseminating the views of these men and attracting attention to work being done (Evans, 1960, 4). Information previously published only once a year in the *Annual Report* became available on a monthly basis and at a lower cost. The value of information dissemination was seen by the authorities in the Department of Agriculture and they undertook an active campaign to gain subscribers. By 1912, 7,000 farmers were receiving the *Journal of Agriculture* and it was being distributed to libraries, teachers 'engaged in agricultural instruction', and exchanged 'for the publications foreign Departments of Agriculture and for the reports of workers in the field of agricultural science' (*ARDA*, 1912, 135). Furthermore, the work prepared was the basis for the writing of textbooks dealing with New Zealand conditions specific. These books replaced those foreign texts whose ideas were not always applicable (Smallfield, 1947b, 275).

The utility of the experimental work was questioned in that no overall assessment of the results obtained was made until that by Hilgendorf in 1926 (Evans, 1969, 202). The lack of experience by farmers in applying the sustaining trials scientific methods for more than one year and the inadequacy of statistical techniques to deal with multivariate problems reduced the certainty with which conclusions could be applied (Evans, 1969, 201, 202). The value of using soil amendments was not fully recognized by World War I (McCaskill, 1929, 109). Still, the use of fertilizers did increase (Table 4.4). Whereas in 1890 over 13,200 tons were imported, in 1910 the total had risen to almost 75,300 tons (Table 4.4) of largely phosphatic material, with superphosphate being the dominant kind in quantity (Table 4.7). The generally rising trend continued into the war years (Table 4.4).

The increase in use corresponded with an increase in the number of field-trial plots. In 1912 some 400 farmers laid by 5,205 plots (*ARDA*, 1912, 87) and in 1915 the number of plots reached 10,000 (Evans, 1969, 202). McCaskill (1929, 10) observed:

> The interest of farmers in the use of fertilizers had certainly been aroused but there seems to have been no attempt to arrive at general conclusions.

Root crops, and green fodder crops were treated in this way until the World War I period as they were needed for supplementary feeding in the meat and dairying enterprises. Research into obtaining high yields from them was important to offset the greater cost of production (Smallfield, 1947a, 175). The investigation of topdressing by these trials, 'probably did much to popularize top-dressing these [in the North Island] ... . In any case top-dressing rapidly became an established practice in all dairying districts' (McCaskill, 1929, 118), but principally the Waikato and Taranaki.

The rise of the dairy industry resulting from the introduction of suitable marine transport and the availability of a series of techniques to boost production levels and quality control, also

TABLE 4.7

TONNAGE OF PHOSPHATE IMPORTS 1907-1920

Year ending 31 March	*Bone-dust*	*Basic Slag*	*Super-phosphate*	*Rock*[a]	*Ephos*[b]	*Other*	*Total Phosphates*	*Total All Soil Amendments*	*Phosphate Percentage*
1907-08	9,637	1,980	15,248	8,637	—	1,474	36,976	40,859	90.5
1908-09	9,143	4,321	21,910	12,030	—	2,177	49,581	56,355	87.9
1909-10	12,177	5,013	25,228	6,088	—	3,764	52,270	60,967	85.7
1910-11	11,058	8,670	27,442	15,963	—	871	64,004	72,099	90.1
1911-12	10,799	16,227	32,567	22,050	—	1,105	82,768	94,296	87.7
1912-13	9,281	20,133	32,964	25,033	—	1,453	88,764	100,601	87.2
1913-14	6,578	30,350	41,582	22,093	100	1,105	101,808	114,214	89.1
1914-15	7,966	29,385	54,190	23,983	—	1,527	117,051	130,599	89.6
1915-16	10,059	10,339	58,013	39,366	2,026	3,045	122,848	134,002	91.7
1916-17	10,386	6,660	31,962	24,993	8,614	751	83,366	95,170	87.6
1917-18	6,363	10	37,157	37,037	11,225	676	92,468	92,236	99.2
1918-19	3,468	—	21,400	31,351	—	200	56,419	57,350	98.4
1919-20	6,272	2,759	15,842	38,861	15,000	825	79,759	80,833	97.0
1920-21	4,440	10,823	40,731	70,208	10,810	1,033	138,045	142,357	97.7

Notes: *a* Rock phosphate.

b Rock phosphate imported from Egypt.

Source: McCaskill (1929,55).

prompted a greater use of soil amendments--the use of pasture topdressing in particular. It was estimated in 1912 that topdressing accounted for 40 percent of the use of imported fertilizer (McCaskill, 1929, 130). The trend to employ fertilizers was certainly growing not only in the North Island but also in the South Island, even though the emphasis in the research had been in solving the pasture problems encountered in the former island.

The management of grassland began to be examined as topdressing was practiced. Initially, hay fields were treated but soon, fields used principally for grazing were also included in the topdressing program. The results of the treatment encouraged the adoption of other management practices such as the harrowing of animal droppings to give a more even distribution over the fields, the utilization of heavier stocking to achieve shorter pasture growth so encouraging greater clover persistence and the subdivision of the farm into smaller fields--the basis for rotational grazing which would promote a greater utilization of the pasture growth created by topdressing (Miller, 1947, 31).

By 1904 the demand for bone-dust in the Auckland district was greater than the supply and led to the supplementary use of animal superphosphate (McCaskill, 1929, 130). Another mineral phosphatic fertilizer, basic slag, a derivative of the Bessemer method of steel manufacture, had been introduced into New Zealand in 1891, only six years after the early investigations of its usefulness as a fertilizer by Wrightson and Munro in England (McCaskill, 1929, 39). Its use increased rapidly to 1915 (Table 4.7).

Another experimental station, Cockle Park, had been established in 1896 on the lines of Rothamsted to evaluate the utility of basic slag (Miller, 1947, 29). Experimentation again followed the commercial distribution of the fertilizer. However, there were innovations in the techniques employed. Liveweight gain was used for the measure of grassland production so that the quality of the herbage produced, not just its quantity could be assessed. Many of these advances can be ascribed to the growing appreciation of the interaction between livestock and grassland.

The use of animals led to the closer evaluation of the role of heavy stocking in promoting grass growth. This phenomenon was already known, being the basis of British 'high farming', but the effect was now measured. Similarly, the need for close grazing to prevent the weakening of clover growth was found through observation of the legumes in the experimental plots (Miller, 1947, 30).

The role of the plants in grassland production came under closer scrutiny. In 1886 Hellriegel and Wilfarth in Germany had discovered the role of clovers in fixing atmospheric nitrogen. In the Cockle Park experiments it was confirmed that clover had an important part in promoting livestock weight, when decided increases occurred where white clover was introduced into the sward (Miller, 1947, 29). Furthermore, the experimenters engaged in this work contributed their observations on the importance of the plant strains present in the sward. Persistent white clovers were acquired by utilizing seed from old, established pastures only. The selection of leafy, persistent grasses was emphasized, and it is noteworthy that New Zealand strains of ryegrass and cocksfoot were employed (Miller, 1947, 30). The grassland potential of the colony was being recognized by scientific research in Britain. Communicating such information was a key role of British science in the grassland technology of New Zealand.

SOURCES OF SOIL AMENDMENTS

The advance of scientific agriculture and the growing recognition of the need to develop soil fertility brought the growth of a soil amendment production industry.

Fertilizer Production

The meat-packing plants, using blood-derived mixtures, at first supplied the local market with almost all of the its nitrogenous fertilizers. Blood manure and blood-and-bone would account for most of the production labelled as 'other' in Table 4.5. It was not until 1889, however, that plants were planned in which use was made of process by-products (McCaskill, 1929, 86).

In 1880 the government was made aware of the need for phosphate fertilizer to be manufactured in the colony itself. The Colonial Industries Commission created in August, 1880 received a submission from E. Prosser of the Kempthorne, Prosser and Co.'s New Zealand Drug Co. Ltd. (hereafter referred to as Kempthorne, Prosser and Co.) of Dunedin stating the need for local production of sulphuric acid:

> For agricultural manure alone its sulphuric acid's manufacture would be of immense value to the future agricultural interests of the colony, as it becomes a necessity to keep up the fertility and productiveness of the soil. (Colonial Industries Commission, 1880, 82)

This view was supported by a submission from a local producer of sulphur exploiting the White Island deposits (Colonial Industries Commission, 1880, 127).

The Commissioners were sufficiently impressed to recommend that a bonus be offered to the first local manufacturer of sulphuric acid as it 'enters so largely into various manufactures and artifical manures' (Colonial Industries Commission, 1880, 12). In February 1881, this bonus of £500 per annum for three successive years was offered to the local manufacturer who, using machinery based in New Zealand produced 'not less than 50 tons of sulphuric acid of good marketable quality' (*Gazette,* 1881, 227) and this bonus was collected by Kempthorne, Prosser and Co. in 1882). Production had begun at the Burnside chemical plant near Dunedin, and as an adjunct to the acid manufacture came the local production of superphosphate in 1881 (*Fert. J.,* 1955c, 8). The initial production was not sophisticated as 'the machinery used consisted of wheelbarrows and shovels with hoes used as mixers' (*75 Years of Life,* 1954). By 1885, at this plant and at another company's set up in 1882 at Belfast (Scott, 1947, 365), 424 tons of superphosphate were produced. (*Statistics of New Zealand,* 1886, Part IV, 283, footnote). There were four other chemical plants in the colony at that time (Table 4.3), but no note was made of their entering this trade. They may, however, have accounted for some of the 1,850 tons of 'artificial manure and bonedust' produced by chemical plants in 1885 (*Statistics of New Zealand,* 1886, Part IV, 283, footnote).

Bone-mill operators apparently undertook to produce some superphosphate, presumably using bones, as had been the pattern earlier in Britain; for, in 1890, bone-mills produced 43 tons of this product. The chemical plants produced 599 tons in that same year and it was the last recorded output from the bone-mills. In fact, the chemical plants produced 1,003 tons of bone manure as compared with the bone-mills' output of 644 tons of bone-dust. (*Statistics of New Zealand,* 1892, Part IV, 323, footnote). The chemical plants continued to expand their production to 8,000 tons by 1895 (*Statistics of New*

Zealand, 1896, Part V, 415, footnote). Although this quantity was more than doubled to 18,209 tons for the last recorded year of production, 1905, there was a marked slump to 5,632 tons in 1900. (*Statistics of New Zealand,* 1902, Part IV, 415, footnotes; 1906, Part IV, 473, footnote).

Local production could not keep pace with local demand even though the number of chemical plants increased. Superphosphate was imported from England from at least 1880 (McCaskill, 1929, 41). In the case of Kempthorne, Prosser and Co., a second plant to manufacture superphosphate was built in Westfield, near Auckland, in 1887 to meet regional demand generated there (*75 Years of Life,* 1954). This move certainly indicated a willingness to locate plants where it was felt demand was growing most rapidly. The location of a plant at Westfield indicated the rise of soil-amending practice, including pasture topdressing in the Waikato, as well as the importance of railways to transport this bulky material to consumers. In all cases plants were constructed near major port cities on rail lines (Map 4.1).

Local Production of Phosphates

Local production limitations stemmed, in part, from the restricted local supply of phosphates, apart from that obtainable from the slaughter of animals. Some guano was mined in the late 1880s from deposits found near Akaroa in the South Island but the quantity was limited (McCaskill, 1929, 65). Attempts to locate exploitable quantities of rock phosphate were reported in the same period. The Colonial Analyst located a small deposit in Nelson in 1885; yet it was not until 1896 that the Government undertook to offer a bonus of £200 for the discovery of a suitably rich, accessible deposit able to meet ordinary demands for five years (*Gazette,* 1896, 1251). Despite much exploration by interested parties, it was not until 1902 that the bonus was awarded to R. Ewing for his discovery of the deposits at Clarendon, not too distant from the Milburn lime source (Map 4.1).

Production began there that year and the phosphate was being railed to Kempthorne, Prosser and Co. plant at Burnside. Some was utilized for superphosphate and the rest ground for sale. Some 121,000 tons were produced by 1920 (Table 4.8), but only six years later mining ceased as imports made it uneconomic to continue production and the Clarendon plant was closed (McCaskill, 1929, 67, 68-69).

TABLE 4.8

TONNAGE OF LOCAL ROCK PHOSPHATE AND AGRICULTURAL LIMESTONE OUTPUT 1903-1920

Year	*Rock Phosphate*[a]	*Agricultural Limestone*[b]
1903	4,400	..
1904	2,670	..
1905	5,000	..
1906	6,000	..
1907	5,100	..
1908	5,000	..
1909	10,000	..
1910	9,000	..
1911	10,000	..
1912	10,000	..
1913	11,000	..
1914	9,700	..
1915	7,000	..
1916	7,600	..
1917	5,050	69,861
1918	5,000	86,807
1919	4,000	102,010
1920	5,341	142,252

Sources: *a* 1903-16 McCaskill (1929, 92)
1917-20 *NZOYB* (1919), *NZOYB* (1921-22), *NZOYB* (1924) under entry 'Building and Ornamental Stone'.
Although data in published sources are absent, the total production to March 1916 is given as 102,472 tons (*NZOYB*, 1917, 525). This figure matches McCaskill's above total of 102,470 tons very closely.

b Data not available prior to 1917. The 1917-20 entries from *NZOYB* noted above.

A second deposit was located at Milburn at about the same time but it proved much less productive. Its output was about 6,000 tons of rock over the 1902-1926 period (McCaskill, 1929, 69, 92).

Further offers of bonuses for the discovery of deposits even in New Zealand and in its Pacific territories produced no results by 1917 and so, domestic production of rock phosphate remained small. It was important only early this century when imports were reduced. Production never amounted to more than 11,000 tons in any one year, at a time when 100,000 tons of rock phosphate were imported annually quite often. Imported phosphates were the basis of the New Zealand fertilizer industry. The percentage of phosphates imported (Table 4.7) indicates that this deficiency was regarded as the primary problem to be overcome in soil amending.

Imported Phosphates

Evidence of the link with British soil-amending technology and of its importance is found in the introduction into New Zealand of basic slag. The use of this soil amendment stemmed from the British research noted earlier. Within a decade of the foundation of Cockle Park experiments, basic slag became so widely regarded in New Zealand that:

> Expansion in fertilizer usage in the decade prior to 1914 was based largely on imported basic slag. (Evans, 1969, 201)

The greater superphosphate imports make this point arguable, but basic slag was the material used in the 1904 topdressing trials at Ruakura, following which, its use was recommended in the Waikato. From there the technique spread. The notable increase in imports from 5,013 tons to 30,350 tons between 1909-10 and 1913-14 substantiate this growing usage (Table 4.7).

The use of basic slag presented two problems when World War I began. As the open-hearth steelmaking process had largely replaced the Bessemer process and did not create as suitable a slag, the quality of the material declined (Miller, 1947, 31). Supplies from European sources, France and Germany, were either disrupted by warfare or held back by a hostile nation. What shipping could be scheduled was diverted from carrying such a cargo. Accordingly, availability dropped sharply after 1916 on to the point that none was imported in 1918-19 (Table 4.7).

Other types of imported phosphates, Ephos, the untreated rock phosphate backloaded from Egypt on troopships, and superphosphate were substituted until restricted supply also affected them after 1917-18 (Table 4.7). It is thought that the inability to use basic slag promoted the use of superphosphate (Smallfield, 1970, 47) though the data in Table 4.7 show its earlier popularity. It came to be realized through this experience that superphosphate was generally 'the most effective type of phosphatic top-dressing manure' (Holford, 1936, 169). It will be shown that although the importation of basic slag did recover, local production of superphosphate became increasingly important in the later 1920s. The innovation-decision process for the farmer continued despite some supply-enforced difference in the types of fertilizer available. The use of basic slag persisted even though its price rose above that of superphosphate, a fertilizer found at least as effective (Holford, 1936, 171).

The supply of imported superphosphates grew from their introduction in 1880 to the end of the period. The source of supply did change with Britain becoming less important as the industry developed in nearer production countries. Australia began superphosphate export in 1883 and became the main source of New Zealand's imports. By 1918 the quantity imported from that source exceeded 34,000 tons. Japan, which had entered the New Zealand market in 1903, became the second most important supplier during World War I with the restriction of British supplies (McCaskill, 1929, 42).

Rock phosphate had been imported since 1868 from a variety of sources. The quantities imported, though not great until the late 1870s, were indicative of a rising availability. The growth of British and Australian interest in rock phosphate following its use in superphosphate production in the late 1850s led to an exploration of many potential sources in the Indian and Pacific Oceans (outlined in McCaskill, 1929, 28-33). New Zealand benefited from this in supplementing limited local sources. The working of the Ocean Island deposits by 1900, and of those on Nauru after 1907 created a steady supply of rock (Ellis, 1935, 106, 139).

Lime Production

Of great importance to soil amending in New Zealand was the local availability of agricultural lime. Use of lime is recorded as a long-standing practice (Hargreaves, 1966, 267-268) but it was only in 1880 that the Milburn Lime and Cement Co., a large-scale producer, was established in Southland (King, 1958, 115) and began to provide burnt lime to local farmers for use on the heavy Southland soils. It is suggested that local Scottish farmers may have been somewhat familiar with the practice as it had been carried out in areas such as Perthshire (Evans, 1969, 5) but it is not thought that they initiated the practice's widespread use.

Extensive liming was tried in 1890 for agricultural purposes as a means of overcoming declining production a decade after the settling of dairy farmers on the Edendale Estate of the New Zealand and Australian Land Company. Milk supply had to be maintained to make its cheese factory a profitable venture (Saxby, 1950a, 139; King, 1947b, 567). Having undertaken the liming trials, the company encouraged farmers to adopt the practice by supplying lime free or to the value of a farmers' rent (King, 1947b, 567). There was a restriction in the availability to farmers through the high cost of shipment by rail, hence, areas of utilization were located near the sources of production (Evans, 1969, 5). The extension of the rail network (Map 4.1) assumes further importance in explaining the diffusion of this soil-amending practice. The concentration of lime plants in Auckland and Otago (Table 4.3) would suggest these were the source areas. However, these plants did not necessarily produce agricultural lime. Their inclusion in Table 4.3 only serves to demonstrate possible sources of supply.

That government recognized the need to broaden the use of lime when in 1894 it undertook to subsidize the rail freight charges of lime and 'animal manures [organic fertilizers] ' (noted in *PD*, 1894, 587-588). However, in the South Island the Milburn Lime and Cement Company, because of its virtual monopoly, proceeded to increase its price by the amount of the subsidy (mentioned in *PD*, 1895, 388 and *PD*, 1898a, 17). Farmers were not yet receiving full benefit from the subsidy. It was only in 1898 that the decision was made to fully subsidize rail charges on loads of more than 6 tons for a distance to 100 miles (Smallfield, 1950, 82). However, a similar reduction for fertilizers was rejected (*PD*, 1898b, 568) despite the discovery of the beneficial association of applying superphosphate together with lime. Nonetheless, this association encouraged the use of liming as the use of topdressing spread in the 1900s (Todd, 1950, 323). Soils used for farming crops were those usually treated (Saxby, 1950a, 139) as was the case with chemical fertilizers.

The number and the distribution of lime-processing plants (Table 4.3) indicates that potential production was fairly widespread but there is a lack of information on the quantity of agricultural lime until 1917. Compared to phosphate production, lime quarrying was much more important and continued to expand its output to 1920 when over 142,200 tons were produced. This quantity exceeded fertilizer imports by 50 percent.

The railway subsidy was maintained through to 1947 and, therefore, provided a stable element in the production environment. With the Department of Agriculture's increased interest in the use of lime in the World War I period it is not surprising to see that an important acreage was already being treated by the late 1920s when statistics became available.

SUMMARY

In the period from colonization to the early 1920s agricultural production in a new environment was established. From subsistence farms and sheep runs grew an animal-products industry of major importance to the country. The environment was explored and exploited in order to make profits for individuals. The range of European (primarily British), Australian, and North American farming experience was open to the settlers of the 1860s. The initial, successful imitation of enterprises based on this experience constrained agricultural development and allowed an equilibrium to be reached. It was short-lived. Refrigerated marine transport introduced tension. It became possible to escape from a long period of depressed wool prices by entering into more specialized farming enterprises (Sutch, 1966, Chapters 4-6; Sutch, 1968d). The focus on grassland farming diverted attention away from other economic sectors (Sutch, 1968a, 182). Arable cropping had been an alternative to wool production but it too was displaced in the period of change. Wool and grain production had generated a concern for soil-fertility decline, but methods to combat it were not employed.

The possibility of shipping meat and dairy products substantially modified pastoral production. It led to the dominance of the small-family-farm structure and to rates of stocking at an intensity which would improve soil fertility once sufficiently high-yielding pastures could be established. Attention was directed on the production capability of grasslands as opposed to the more traditional concern with crop yields. This transition took place through the concern with improving supplementary fodder crops. These crops were essential to the early production system in enabling farmers to overwinter large numbers of animals and fatten stock for market. The new enterprise created organic manure on a greater scale and this coincided with a more scientific approach to the problems of improving agricultural production. The institutional framework within which these same developments had occurred in Britain was duplicated in New Zealand by the late 1890s and permitted them to be undertaken in a new setting.

Adoption of the use of chemical fertilizers proceeded to the point where several local companies were encouraged to enter production on a large scale by 1921, whereas, in the 1880s, only two had started small-scale production. New approaches, such as pasture topdressing, were undertaken in an important way from the early 1900s to the post-World War I period when the lack of phosphatic fertilizers created considerable concern (McCaskill, 1929, 132). Evidently, farmers had become aware of the loss of production which followed from not applying soil amendments (McCaskill, 1929, 127). This awareness was not confined to crop production. It extended as well as to pasture production. The limits of pastoral farming on easily developable land had been reached by 1914 (Smallfield, 1947b, 278), so more effort could be expended in maintaining the recently created grassland. The carrying capacity of pasture land was not improved until nearly the end of the period, however. Only then did the more widespread use of topdressing improve the quality of pastures and lengthen their growing period (Smallfield, 1947b, 270).

The awareness of pastoral production problems also extended to scientists embarking upon a more rigorous investigation of means to improve New Zealand's agricultural productivity. The experimentation of the years to 1916, when the Department of Agriculture's field trials were ended, served more as a method of popularizing soil amending than of uncovering the reasons why various practices did or did not aid production. The complexity of the biological problems was still hindering technological advance through the retardation of science-based invention. It is this issue which is pursued in the next chapter.

CHAPTER 5

THE INTENSIFICATION OF THE GRASSLAND FARMING SYSTEMS

By the early 1920s the essential elements of grassland production had been established. A rising volume of meat and dairy-produce exports was the basis of the grassland farming system which enabled labour and capital inputs to be held at relatively low levels (Cumberland, 1948, 48). The emergence of stability in the farm enterprises is evident in the export-produce types in which there was little change once dairying was established. The tension engendered by the long depression and the transportation innovations of the late nineteenth century were being worked out quickly in the economic and institutional changes in the agricultural sector. In the newly expanded dairy industry, for example, proprietary control of processing had largely given way to control by co-operatively owned factories (Philpott, 1937, 397). Furthermore, the rate of increase in the number of farm holdings and in the area of improved land had slowed as the area occupied reached its limits (Table 5.1):

> By 1920 the bulk of the land which could be developed by a farmer with his own resources and labour had been occupied and since that date [up to 1950] there has been little variation in the area occupied. (King, 1950, 70)

Price slumps induced farmers to increase production and reduce costs (Dairy Industry Commission, 1934, 13). The technological changes initiated by scientific advances were ongoing however. Experimentation with plant species had occurred to develop ryegrass and clover swards but pasture management still required ploughing and the use of supplementary fodder crops to provide sufficient winter feed. The use of soil amending in applying fertilizer and lime had developed but the practice of topdressing grassland was not yet widespread other than in North Island dairy districts. The application of chemistry and the development of biological research to improve agricultural production was yet to come. It is the creation of grassland technology to resolve the tension continuing in the technical structure which is traced in this chapter. The application of this technology produced tension through the effects of the growth of out-

TABLE 5.1

NUMBER OF HOLDINGS; AREA OCCUPIED AND PRINCIPAL LAND USES (THOUSANDS OF ACRES) 1915-1949

Year	*No. of Holdings*	*Area Occupied*	*Area Improved*	*Sown Grass and Clover*	*Hay and Silage* [a]	*Green Fodder and Roots* [b]	*Crops Threshed*	*Grain Crops for Fodder*
1915-16	77,229	41,386	16,984.2	12,747.8	95.8	819	593.1	440.5
1919-20	81,592	43,473.1	18,004.8	16,315.3	117.1	718.6	371.8	341.2
1920-21	84,076	43,546.8	18,159.8	15,912.8	161.8	745.6	451.3	431.4
1925-26	85,734	43,606.8	18,583	16,840.7	224.7	738.1	309.6	267.2
1930-31	83,816	43,239.6	19,006.9	17,254.5	442.6	686.4	390.6	295.6
1935-36	84,547	43,282.1	19,671.6	17,496.1	576.9	665.5	381.9	306.3
1940-41	86,373	43,888.3	19,906.6	17,737.6	575.1	637.6	397.5	252.9
1945-56	86,239	43,080	19,967.2	17,955	483.5	633.3	324	142.4
1949-50	90,290	43,158.3	20,228,4	18,192.3	630.5	692.4	299.7	130.7

Notes: *a* Includes lucerne.

b Excludes potatoes, onions and other green fodder and root crops.

Sources: 1915-19 *Statistics of New Zealand* (for years shown).

1920 *Agricultural Statistics* (1921).

1925-49 *Agricultural Statistics* (for years shown).

put resulting from the greatly increased intensity of land utilization. Changes occasioned by the policies followed during World War I were the immediate environment of this new technology, so it is these changes which are noted first.

POSTWAR CHANGES IN MARKETING

With the end of World War I came the end of the guaranteed market in Britain for New Zealand's agricultural produce but the importance of that market persisted (Duckham, 1932, 105). The competitive situation was restored and the rapid release in 1919 and 1920 of produce retained under the Commandeer to capture high prices provoked a brief but sharp depression in 1921-22 when the prices decreased for all agricultural commodities (Fig. 5.1). Dairy produce enjoyed a brief boom as its export value exceeded that of all others in 1921 and was second only to wool in 1922 (Buchanan, 1935, 6). The outcome was a:

> great expansion of the dairying industry, and of butter production in particular, ... due mainly to the rise of the Auckland dairying districts. ... This development was almost inevitable, but its occurrence at this particular time, and the speed at which it was carried through, are direct results of the abnormally favourable price position for dairy products, and especially butter, in the last few years of the period (1914-22). (Buchanan, 1935, 6)

Earnings from wool and sheepmeat production were less favourable as they dropped during the war years and then fluctuated markedly (Lloyd Prichard, 1970, 248, 293). Overstocking of sheep had occurred during the war as a result of reduced slaughtering occasioned by a lack of shipping and of storage space (Robertson, 1939, 52). Reducing the surplus stock evident in the rising number between 1916-1919 led to a marked fall in numbers beyond 1920 (Table 5.2) to a low of 22.22 million in 1921-22 (*Agricultural Statistics*, 1970, Table 1). The rising price of meat to 1921 and the desire to sell wool before the release of 'commandeered stocks' provided an incentive for the increased slaughtering (Buchanan, 1935, 6). Additionally, production is thought to have suffered through the shortage of manpower to thoroughly work the cultivated area or extend the occupied and improved area (Buchanan, 1935, 5-6) though the area of native grassland decreased by one million acres (Table 5.3). Reversion of land to less

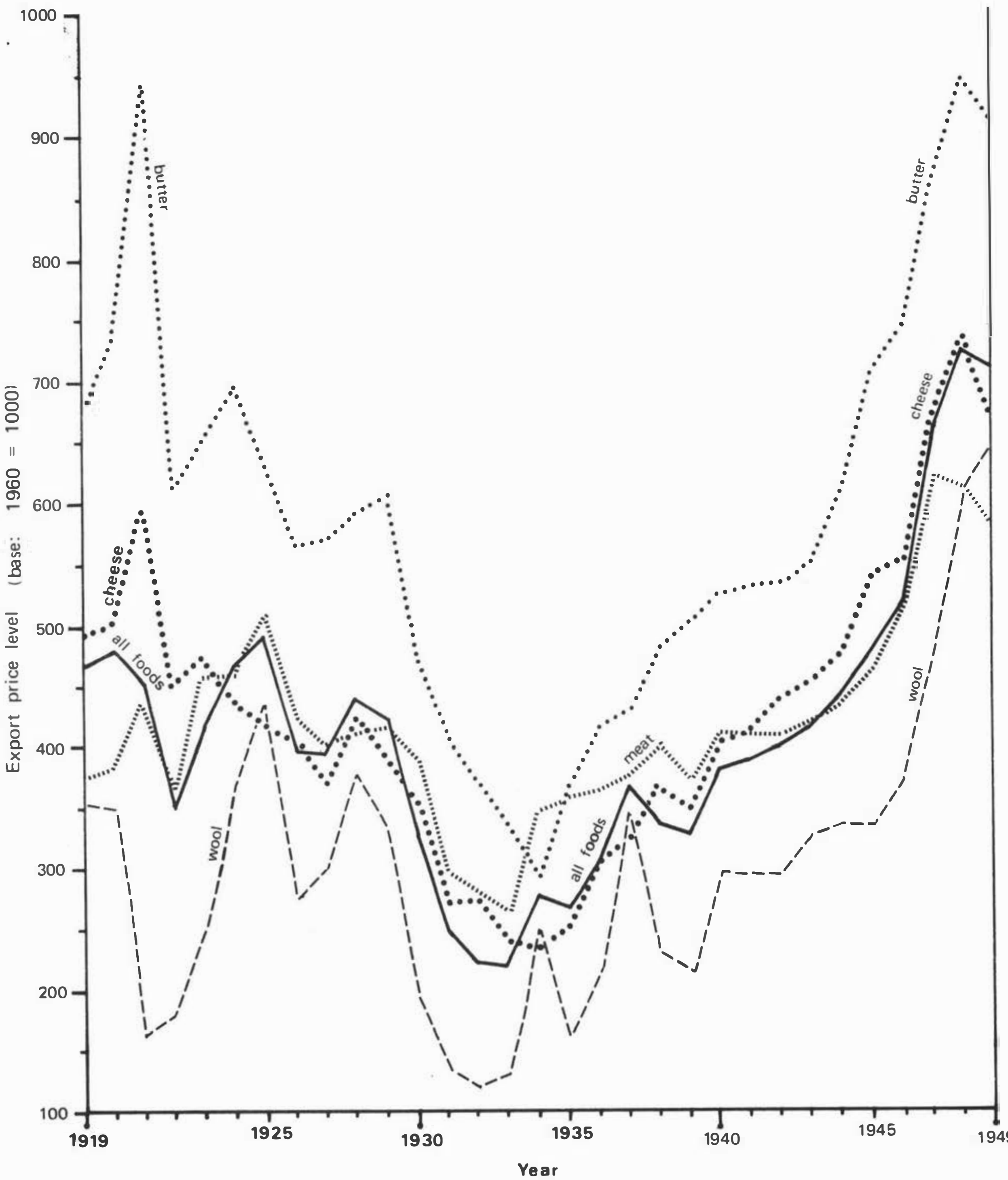


FIG. 5.1 EXPORT PRICE LEVELS 1919 - 1949

Source: *External Trade Statistics*, 1969-70.

TABLE 5.2

NUMBER OF PRINCIPAL LIVESTOCK 1915-1949

Year	*Sheep*	*Dairy Cows*[a]	*Other Cattle*	*Horses*
1915-16	24,788,150	750,323	1,667,168	371,331
1919-20	23,914,506	782,757	2,319,188	346,407
1920-21	23,285,031	890,220	2,249,003	337,259
1925-26	24,904,993	1,181,441	2,271,045	314,867
1930-31	29,792,516	1,499,532	2,580,993	295,743
1935-36	30,113,704	1,823,358	2,430,720	276,170
1940-41	31,751,660	1,779,603	2,796,270	266,066
1945-46	33,974,612[b]	1,661,944	3,004,838	216,335
1949-50	33,856,558	1,850,089	3,104,817	194,877

Notes: *a* Dairy cows in milk only.

b 1945 figure not available, 1944 figure used.

Sources: 1915-19 *NZOYB* (1930, Statistical Summary).

1920-49 *Agricultural Statistics* (1970,Table 1).

TABLE 5.3

AREA OF UNIMPROVED GRASSLAND AND REVERTED LAND (THOUSANDS OF ACRES)
1915-1949

Year	*Tussock and Native Grasses*	*Fern, Scrub, and Second Growth*
1915-16	16,704.1	2,733.3 [a]
1919-20	14,892.1	3,722.4
1920-21	14,993.4	3,771
1925-26	14,298.6	4,165.6
1930-31	14,124	4,149.7
1935-36	14,242.4	4,205.8
1940-41	13,861.5	4,290.7
1945-46	13,968.3	4,601.2
1949-50	12,929.1	5,221

Note: *a* 1916 figures as 1915 data not available.

Sources: 1915 *Statistics of New Zealand* (1915); *Statistics of New Zealand* (1916).

1919-20 *Statistics of New Zealand* (for years shown).

1925-49 *Agricultural Statistics* (for years shown).

productive plant communities, fern, scrub, and second growth, became marked (Table 5.3).

Though the depression in prices was of short duration, there was much uncertainty about the level of prices from year to year (Fig. 5.1). In 1926 another marked slump occurred for all products except cheese (Fig. 5.1; Buchanan, 1935, Graphs 4-7). These variations stimulated the demand by farmers for government action to stabilize income as had occurred under the Commandeer. The wartime pools and commandeers were associated with higher prices and general prosperity. Accordingly, farmers looked to the control methods of marketing produce to restore those conditions (Condliffe, 1933b, 197). Both meat and dairy products were to be handled by marketing agencies set up in 1922 and 1923 respectively (Evans, 1969, 109, 181). A new institutional arrangement was established as the producer of a commodity sought its control by supervising its marketing, thereby protecting his own interest (Sutch, 1968b, 38). Co-operative arrangements found principally in the dairy industry appear to have had a more widespread influence in inducing other farmers to consider some control in production or marketing in order to achieve better returns. The attempt to corner the British market by the dairying agency proved unsuccessful in 1926 (Buchanan, 1935, 70), but the principle of controlling marketing was becoming established. The government role in supporting such agencies while legislating quality control measures for producer-supervised grading indicated the concern for the promotion of export sales of produce from the agricultural sector.

Government also promoted production through the development of the national infrastructure including:

> the State supply of electricity, ... regulation of internal transport to economise on capital investment and to protect the instrument which had made farm development possible--the railway system. (Sutch, 1968b, 39)

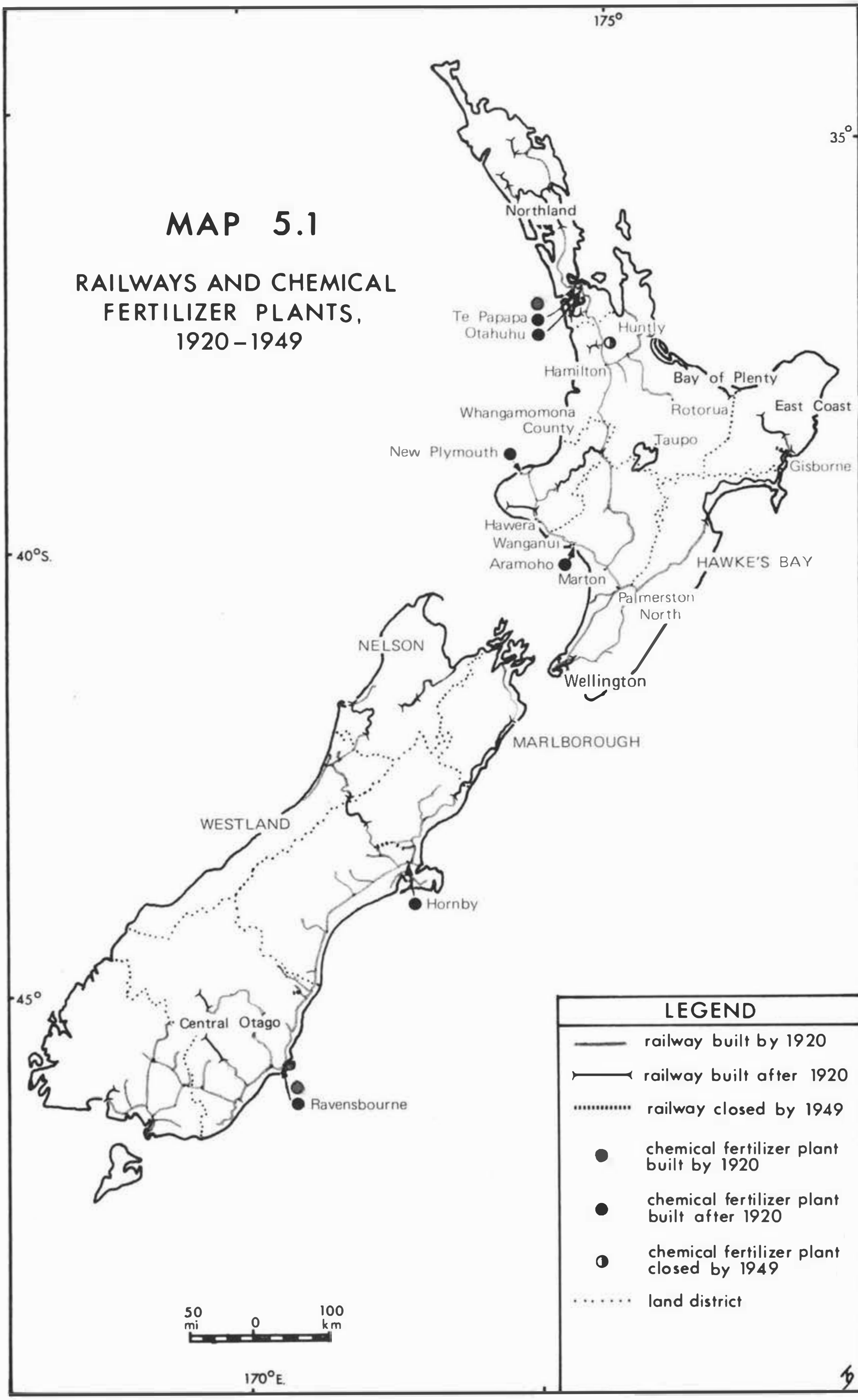
Electrification allowed labour-saving milking and shearing machinery to be introduced. The efficiency and high level of mechanization of livestock production were regarded as particularly noteworthy (Duckham, 1932, 106). Better roads facilitated the extension of motor transport to convey farm inputs and output, and the railways were extended (Map 5.1) allowing traffic in soil amendments in particular to reach more farms. By 1920 in the North Island, only Northland, the Bay of Plenty, northern Hawke's Bay and the East Coast remained unconnected by rail with the main line from Auckland to Wellington. That line's completion before World War I permitted domestically produced fertilizers to be available to lowland farmers. In the South Island, the main extensions brought rail traffic to Central Otago and much of Southland and parts of Westland. However, Westland, Marlborough, and Nelson remained unconnected to the main rail network and so deprived of railborne soil amendments. Coastal shipping in both islands would have carried the bulk of whatever soil amendments were sought given the difficulty and cost of road transport. By 1949 the connections had been completed, the last being the railway to Gisborne. Indeed, some closures had begun, particularly of short branch lines in the South Island.

INCREASING FERTILIZER PRODUCTION[1]

The move by the farmers to control marketing was not their only effort to play a role in controlling their returns. Some also undertook to control production costs in establishing in 1915 a farmer-controlled, though not co-operatively owned fertilizer firm, the New Zealand Farmers' Fertilizer Co. Ltd. The sentiment that the monopoly position of Kempthorne, Prosser and Co. permitted them to charge too much in comparison with their production costs apparently prompted this action. In 1921 a factory at Te Papapa, near Auckland, was completed and in 1926 a second factory began operation in New Plymouth, the first local supply source in the Taranaki dairying area.

The fertilizer market in the immediate postwar period was attractive enough to bring a major firm of stock and station agents, Wright, Stephenson and Co. Ltd. (referred to as Wright, Stephenson) into the industry. Their fertilizer mixing plant was opened in 1921 and a superphosphate unit was added in 1924. Again, production was located near Auckland, at Otahuhu, where imported materials could be landed readily and the Waikato market was readily accessible by rail (Map 5.1).

The largest producer was not inactive in this period. Kempthorne, Prosser and Co. expanded its production in constructing factories at Hornby, near Christchurch, in 1922 and at Aramoho, near



MAP 5.1
RAILWAYS AND CHEMICAL FERTILIZER PLANTS, 1920–1949
175°
35°
40°S.
45°
170°E.
Northland
Te Papapa
Otahuhu
Huntly
Hamilton
Bay of Plenty
East Coast
Rotorua
Whangamomona County
Taupo
New Plymouth
Gisborne
Hawera
Wanganui
Aramoho
Marton
HAWKE'S BAY
Palmerston North
Wellington
NELSON
MARLBOROUGH
WESTLAND
Hornby
Central Otago
Ravensbourne
50 mi
0
100 km
LEGEND
railway built by 1920
railway built after 1920
railway closed by 1949
chemical fertilizer plant built by 1920
chemical fertilizer plant built after 1920
chemical fertilizer plant closed by 1949
land district

Wanganui, in 1926. Thus, it maintained a monopoly position in the South Island and remained the dominant supplier in the North Island. The price structure was not particularly upset by the other competing firms. Fertilizer prices remained stable with locally produced superphosphate selling at £5 11s. per ton.

Farmers still thought this amount excessive and a group operating through the New Zealand Co-operative Dairy Co. Ltd. of Hamilton tried to obtain lower prices for its members. Negotiations with the three North Island producers to obtain the rebates and discounts allowed to merchants did not prove successful, whereupon the company directors threatened to build their own factory and sell fertilizers to members at cost price. The potential loss of clientele led Wright, Stephenson to join with the New Zealand Co-operative Dairy Co. Ltd. in early 1927 to form the Challenge Phosphate Co. Ltd. and convert the firm's existing mixing plant to superphosphate production (Nixon, 1970, 2). Other dairy companies were invited to place orders and so obtain the same rebates and discounts offered to merchants with the added bonus that these could be passed on directly to purchasers. Distribution costs were set at figures below those of merchants and the price was reduced over all the North Island.

These aggressive tactics led the rival companies to announce even lower prices in April of that year. Even though one of the firms was a farmers' organization it acted in conjunction with Kempthorne, Prosser and Co. and received much criticism as a result. The fertilizer 'war' was on and continued into early 1928. The price level set by competitors was so low at £4 2s.6d. a ton of '44/46 super'[2] that the Challenge Phosphate Co. was obliged to try to raise it by 15 shillings to avoid making a loss. The attempt failed as the other companies held firm.

The 'war' appeared to have achieved much from the farmers' and the manufacturers' point of view. Farmers made the most of the low prices as the autumn-topdressing season coincided with the start of the war. The availability of superphosphate at low cost stimulated its use. It was substituted for more expensive basic slag and its production increased. This substitution of a cheaper fertilizer and its wider use helped to establish the benefit of the topdressing technique. The increased demand meant 'permanently increased orders for the manufacturer with consequent economies due to larger outputs'

(McCaskill, 1929, 80). The situation also seemed to have sparked interest in the South Island as the Dominion Fertiliser Co. Ltd. was established in 1929 to build a factory at Ravensbourne, Dunedin, in order to challenge the Kempthorne, Prosser and Co. monopoly there, and also supply the east coast of the North Island. The place of coastal shipping's role is indicated by this decision. Two of the largest stock and station agents in the South Island were appointed selling agents to ensure widespread sales there.

By 1930 there were four firms involved in the local production of chemical fertilizers compared to one in 1920 (Table 5.4). The use of soil amending was being recognized as shown by the increasing use of imported phosphates (Table 5.5). Although it was considered that self-sufficiency in superphosphate production had been achieved in 1922 (McCaskill, 1929, 71), demand increases provided the basis for further extension of production capacity.

FERTILIZER FACTORY LOCATION AND SOURCES OF SUPPLY

The siting of the fertilizer factories (Map 5.1) reflected the demand pattern of the time. The rise of grassland production in Taranaki and the Manawatu regions resulted in the building of a factory at a rail centre near the main port in each of these areas, while the needs of fat-lamb production in Canterbury were met by the factory built at Hornby near Christchurch.

Such port locations, were favoured because of the break of bulk of the imported raw materials, sulphur and rock phosphate, and the need for urban-based labour but points for the distribution of the bulky fertilizers were also chosen by rail. The importance of the rail siting increased when in August 1926 carriage rates for fertilizers were reduced by 40 percent to encourage their further use (*Gazette*, 1926, 2554). The location pattern of fertilizer plants was successful in that it remained static through the period under consideration (Table 5.4). The existing plants remained in production with no new additions made until 1933 when the Ravensbourne factory was finally opened. The output of the other plants noted (Table 5.4) was either very small or not related to superphosphate production (*MAS*, 1929, ix). Their production was also of short duration as one closed in Dunedin in 1929 and that in Auckland in 1932 (*Industrial Production Statistics*, 1929, 1932).

TABLE 5.4

SOURCES OF SOIL AMENDMENTS (NUMBER OF PLANTS) 1920-1949

Provincial District	*Type of Establishment:*						
	Meat-processing Plants[a]						
	Year						
	1920	1925	1930	1935	1940	1945	1949
Auckland	11	12	10	9	10	7	8
Hawke's Bay	5	4	4	3	3	3	3
Taranaki	4	2	2	3	3	3	3
Wellington	10	7	6	7	7	7	7
Marlborough	1	1	1	1	1	1	2
Nelson	1	1	1	1	1	1	1
Westland	—	—	—	—	—	—	—
Canterbury	7	7	7	7	7	10	9
Otago	7	5	5	4	4	7	10
Southland	5	4	4	3	3	6	8
New Zealand	51	43	40	38	39	45	51
	Boiling-down and Manure Plants[b]						
Auckland	14	8	11	12	15	14	13
Hawke's Bay	4	3	2	2	2	2	1
Taranaki	5	4	3	—	—	2	2
Wellington	8	5	5	6	6	8	6
Marlborough	2	2	2	2	2	2	2
Nelson	2	1	1	—	—	—	—
Westland	1	1	—	—	—	—	—
Canterbury	8	5	6	5	6	6	6
Otago	11	2	3	3	3	3	3
Southland	7	—	—	—	1	1	—
New Zealand	62	31	33	30	35	38	33
	Lime Plants[c]						
Auckland	9	7	10	28	24	34	44
Hawke's Bay	1	1	2	4	4	3	4
Taranaki	—	—	1	—	—	—	—
Wellington	1	2	4	3	2	6	6
Marlborough	4	1	1	2	4	3	4
Nelson	4	3	6	6	12	18	16
Westland	1	2	2	2	2	2	2
Canterbury	—	2	5	3	8	9	13
Otago	4	4	5	5	7	8	6
Southland	2	4	4	4	5	8	9
New Zealand	23	26	40	57	68	91	104
	Chemical Fertilizer Plants[d]						
Auckland	1	3	4	3	4	4	4
Hawke's Bay	—	—	—	—	—	—	—
Taranaki	—	1	1	1	1	1	1
Wellington	—	1	1	1	1	1	1
Marlborough	—	—	—	—	—	—	—
Nelson	—	—	—	—	—	—	—
Westland	—	—	—	—	—	—	—
Canterbury	—	1	1	1	1	1	1
Otago	1	1	1	2	2	2	2
Southland	—	—	—	—	—	—	—
New Zealand	2	7	8	8	9	9	9

TABLE 5.4 (Continued)

Notes: Below are the headings used in the statistical sources:

a Meat-freezing and preserving works.

b 1925-45 boiling-down and manure-making works.

1949 comprises boiling-down, glue and manure making establishments.

c Lime crushing or burning and cement making works.

d 1920-25 from McCaskill (1929).

1930-35 chemical fertilizers, refining.

1940 superphosphate and chemical fertilizers works.

1945-49 chemical fertilizers.

Sources: 1920 *Statistics of New Zealand* (1920); McCaskill (1929).

1925-49 McCaskill (1929); *Industrial Production Statistics* (for years shown).

TABLE 5.5

TONNAGE OF PHOSPHATE IMPORTS 1915-1949

Year	*Bone-dust*[a]	*Basic Slag*	*Super-phosphate*	*Rock*[b]	*Guano*	*Other*	*Total*
1915	11,202	11,056	54,250	39,519		516	116,543
1919	6,007	2,350	17,604	42,710	7,906	100	76,677
1920	7,232	11,167	34,410	64,955	9,660	—	127,424
1925	2,951	46,534	500	114,218	10,791	—	174,994
1930	1,020	61,795	25	149,332	10,501	2,070	224,743
1935	30	16,369	—	209,946	27,251	10,005	263,601
1940	171	8,510	—	371,938	24,210	10	404,839
1945	—	—	—	241,345	46	—	241,391
1949	—	42,101	2	440,133	8,330	—	490,566

Notes: *a* Includes bone-char, char-dust, and blood-and-bone.

b Comprises rock phosphate from Pacific Island and North African sources.

Sources: 1915-20 *Statistics of New Zealand* (for years shown).

1925-49 *Trade and Shipping Statistics* (for years shown).

The emphasis on locations near ports shows the failure of local phosphate rock production (Table 5.6) to satisfy demand during the period, and the ability of the manufacturers to obtain less expensive phosphate rock elsewhere. The latter situation was much improved as a result of Germany's defeat in World War I. In 1919 the island of Nauru, a major source of supply, was placed under British mandate and in 1920 Australia, Britain, and New Zealand became joint partners in the British Phosphate Commission, so sharing the phosphate rock output. Although the Nauru deposits had been operated since 1906 by the Pacific Islands Company (later the Pacific Phosphate Company) without interference from German authorities, the source of supply was secured and taken out of private hands. After some initial trials Britain did not exercise its option to take rock from this source. Thus, Australia and New Zealand were able to supply their own industries with the entire output of this high-quality material.

The output from Ocean Island, where deposits were exploited a year before its annexation by Britain in 1901, was also placed under control of the Commission. Accordingly, much of the highest quality phosphate rock in the Pacific was made available to New Zealand at a low, standardized price. The marketing agency aspect of the Commission's operation ensured a steady flow of material as it made purchases from other sources, such as Makatea Island, Florida, and Morocco whenever Nauru or Ocean Island production fell below the level of demand (McCaskill, 1929, 35-36). Furthermore, the Commission acted as a buying and shipping agent for sulphur and nitrate of soda used in superphosphate production (Tait, 1957, 193). This dependence upon one main source of supply was to have severe consequences at a later stage, but in the 1920s and 1930s it provided the basis for the developing chemical fertilizer plants' output (Smallfield, 1947c, 577).

FERTILIZERS EMPLOYED

Despite superphosphate's increasing importance many farmers returned to the use of basic slag, a virtually unobtainable product between 1918 and 1920 (*Statistics of New Zealand,* [for years indicated]; Table 5.5). Basic slag imports increased to exceed those of superphosphate after 1922 (McCaskill, 1929, 21) since increased local production reduced the need for the latter. Farmers in the Waikato and in Taranaki remained convinced from trials conducted in the prewar

TABLE 5.6

TONNAGE OF LOCAL ROCK PHOSPHATE AND AGRICULTURAL LIMESTONE OUTPUT 1917-1949

Year	*Rock Phosphate*[a]	*Agricultural Limestone*[b]
1917	5,050	69,861
1920	5,341	142,252
1921	6,012	123,796
1922	3,128	88,087
1923	2,383	103,566
1924	1,575	138,734
1925	—	134,689
1926	—	122,181
1930	—	204,811
1933	—	191,888
1935	—	288,559
1940	—	593,995
1941	—	728,474
1942	9,241	613,168
1943	19,931	752,603
1944	7,956	903,808
1945	11,047	812,635
1946	200	..
1947	—	1,020,810
1948	—	1,091,299
1949	—	1,100,126

Sources: *a* Under the entry 'Building and Ornamental Stones':

1917 *NZOYB* (1919).
1920 *NZOYB* (1921-22).
1921-22 *NZOYB* (1924).
1923-24 *NZOYB* (1926).
1942 *NZOYB* (1945).
1943-44 *NZOYB* (1946).
1945-46 *NZOYB* (1947-49).

The total produced between 1943-47 using the above data does not agree with the total of 40,887 tons given in *NZOYB* (1951-52). The difference of 7,488 tons is not explained.

b *NZOYB* (for years shown) under the above entry.

period that this fertilizer was more effective than superphosphate. This belief persisted despite assurances to the contrary made by government scientists on the basis of experimental work done at Marton (Holford, 1936, 132). Experiment results did not explain why some differences could be observed; for the isolation of the role of trace elements in plant growth processes had not yet occurred. In addition, the combination of liming and dressing with superphosphate was only being developed as a technique (Kempthorne, Prosser and Co., 1925, 8). The free lime content in basic slag was another advantage of that product whenever it was used on lime-responsive soils (Burnard, 1931, 44-45).

The rising demand for basic slag only declined gradually as supplies became more limited through increased demand in Europe and the replacement of the Bessemer process by the open-hearth method of steel production (Miller, 1947, 31). The latter change produced a product of lower quality, and, with an increased understanding of the operation of phosphatic fertilizers and wider use of superphosphate, farmers turned to the domestically produced fertilizer (Burnard, 1931, 44, 50).

Other sources of phosphatic fertilizer were minor (Table 5.5). Bone-dust imports which rose during the war, presumably to offset the loss of other types, declined from over 6,000 tons in 1919 to just over 1,000 tons in 1930. Similarly, the use of guano began to decline though not as rapidly. Both the local advantages of fertilizer production and the realization of the greater efficiency of using chemical fertilizers were evident in this trend. Likewise, the use of ground rock phosphate fell as farmers realized the slowness of its fertilizing effect due to its insolubility in water (Burnard, 1931, 50). The increasing rock phosphate imports (Table 5.5) for use in superphosphate production demonstrate the industry's rising output.

Also clear was the concentration of New Zealand fertilizer demand upon phosphatic material. Where prior to the war the import tonnage phosphates comprised remained between 85 and 80 percent, in the period from 1918 to 1929 it did not fall below 92 percent (McCaskill, 1929, 55). The dominance of phosphate imports is highlighted by comparing the tonnage of nutrients supplied from imported and domestic fertilizers (Table 5.7). Elsewhere in the world, recognition of the need for nitrogenous and potassic soil-amending materials had stimulated their

TABLE 5.7

FERTLIZERS BY TONNAGE OF NUTRIENTS 1920-1949

Year	*Nitrogen*[a]	*Phosphorus*[b] *Domestic*	*Imported*	*Potassium*[c]	*Sulphur*[a]
1920	466	2,284	24,587	716	4,622
1925	436	—	70,138	5,467	24,802
1930	1,125	—	80,424	2,263	17,131
1935	1,390	—	104,834	4,716	32,244
1940	702	—	113,026	1,015	58,019
1945	473	4,198	130,170	2,304	43,633
1949	1,078	—	178,220	4,156	64,832

Notes: *a* Measured on elemental content.

b Phosphoric acid (P_2O_5) content.

c Water soluble potash (K_2O) content.

Sources: Calculated from:
1920 *Statistics of New Zealand*

1925-49 *Trade and Shipping Statistics* (for years shown).

production; in New Zealand, where soils were principally deficient in phosphorus, these elements played a secondary role in the type of production being adopted by farmers. Potassic-fertilizer imports generally remained under 5,000 tons and were used as supplements to the phosphate mixtures prepared for soils showing this particular deficiency. The quantity employed in any year varied strongly according to economic conditions (Smallfield, 1947c, 579) until their need was more firmly recognized in the period following World War II.

The level of nitrogenous-fertilizer imports remained even lower (Table 5.7). The use of sulphate of ammonia, for example, was found unprofitable despite its decreasing cost (Smallfield, 1947c, 579). The profitable and necessary level of use was unknown, so introducing uncertainty into its use. The nitrogenous fertilizers appeared useful only to promote out-of-season pasture growth but posed problems in suppressing legumes (Burnard, 1931, 60). Their use was to remain limited until further work on pasture plants and pasture management was completed. The nitrogen-fixing action of soil bacteria associated with clovers was already known and its effects were evident in New Zealand in this low demand for nitrogenous fertilizers.

AGRICULTURAL LIME

The soil chemistry aspects of soil amending were under investigation in the research institutions already established. Determining soil acidity levels and identifying levels unfavourable for clover growth had prompted the use of agricultural lime to lower soil acidity. This response was understood and was being put into practice more extensively as the proportion of farmed land in sown grasses continued to increase. The free-lime content of basic slag reduced the need for lime, but liming tended to improve the performance of the superphosphate fertilizers applied and so, the two practices became more widely accepted (Burnard, 1931, 51). This combined use became much more common in the early 1930s and the use of lime only dropped sharply after 1932 (Table 5.8).

Previous regional variations in soil amending on grassland became somewhat more uniform though liming was 'greatly neglected in many districts in New Zealand' (Burnard, 1931, 51). Whereas in the South Island liming occurred before the application of fertilizers, following the practice developed in Southland, in the North Island

TABLE 5.8

SOWN GRASSLAND TOPDRESSED, BY TREATMENT TYPE
(THOUSANDS OF ACRES) 1926-1949

Year Ending 31 January	*Treatment:*			*Total*
	Fertilizer Only	*Lime Only*	*Fertilizer and Lime*	
1926-27	1,409.8	107	4.5	1,521.3
1927-28	1,831.2	118.1	3.2	1,952.5
1928-29	2,531.5	223.4	3	2,757.9
1929-30	2,854.6	359.7	..	2,650.7
1930-31	2,432.4	438.9	..	2,871.3
1931-32	2,067.7	386.6	..	2,454.3
1932-33	1,741.0	103	594.1	2,438.1
1933-34	1,469.5	116.2	663.4	2,249.2
1934-35	1,703.3	146	834.8	2,684.1
1935-36	1,798.7	150.9	932.6	2,882.2
1936-37	2,122.4	176.8	1,027.1	3,326.3
1937-38	2,516.2	189	1,168.8	3,874
1938-39	2,584.6	218.4	1,213.9	4,016.9
1939-40	2,764.3	204.5	1,218.5	4,187.3
1940-41	2,923.4	251	1,475	4,649.3
1941-42	2,324.1	380.1	1,508.1	4,212.4
1942-43	1,574.8	570.8	1,324.4	3,470.1
1943-44	1,471.1	729.7	1,169.2	3,370
1944-45	1,602.9	726.5	1,317.0	3,646.4
1945-46	1,757.8	606.7	1,288.7	3,653.2
1946-47	2,237.3	566.0	1,456.7	4,260
1947-48	2,654.4	548.5	1,481.3	4,684.2
1948-49	2,981.9	584.4	1,496.1	5,062.4
1949-50	3,754.3	589.6	1,394.5	5,738.4

Sources: 1926-46 Smallfield (1950, Table 14).
1947-49 *Agricultural Statistics* (for years shown).

the reverse had been true, following the pattern established in the Waikato (Smallfield, 1947c, 579).

Data on lime usage is available only from 1926 onwards but the trend to covering a greater acreage of topdressed grassland is evident (Table 5.8). Between the 1926-27 season and the 1930-31 season the acreage covered quadrupled. The proportion of grassland treated doubled, rising from 7.0 to 15.3 percent, even while the amount of land sown to grass was increasing. These early data do not strictly separate the area treated with lime only from that also treated with chemical fertilizers. Part of the increase, then, could be a result of greater use of the latter material. However, the similarity of the total acreage of grassland treated between the 1931-32 and 1932-33 seasons (when a more detailed breakdown of type of soil-amending practice became available) would indicate the continuation of a similar usage pattern. The improvement in the performance of phosphatic fertilizers and the recognition of lime's role in providing minerals need for stock health combined to promote its use. Production of limestone did not increase as rapidly however (Table 5.6). From 1926 to 1930 limestone output rose 82,000 tons while the acreage on which lime alone was used in 1926-27 and 1930-31 rose by 332,000 acres. The application rate per acre fell from 1.14 to 0.47 tons. Only in the late 1930s did limestone output rise almost steadily.

SOIL-AMENDING PRACTICE

Comparatively, the grassland acreage treated with lime remained well below that treated with chemical fertilizer (Table 5.8). By 1930, 2.65 million acres of grassland were fertilized. The use of superphosphate exceeded the combined use of basic slag and all other types during the 1926-27 to 1929-30 period (Table 5.9). Unfortunately, the trend cannot be followed as a simplified collecting procedure was invoked at the beginning of the depression which led to only the agreage treated with any chemical fertilizer being recorded.

Fertilizer use on grassland in the late 1920s showed a rapid increase. Between 1927-28 and 1928-29 almost 700,000 more acres were fertilized (Table 5.8). The rising trend continued into 1929-30 with a further increase in treated grassland of over 320,000 acres. This represented 15.7 percent of the nation's area of improved grassland. It has not been possible to find earlier data at the land district or

TABLE 5.9

COMPARISON OF SOIL AMENDMENT USE BY ISLAND IN 1926-27, 1929-30, AND 1949-50: THOUSANDS OF ACRES COVERED, THOUSANDS OF HUNDREDWEIGHTS USED, AND APPLICATION RATE

Type of Soil Amendment	*Year*											
	1926-27				*1929-30*				*1949-50*			
	NI	*%*	*SI*	*%*	*NI*	*%*	*SI*	*%*	*NI*	*%*	*SI*	*%*
Superphosphate												
acreage covered	826	84	159	16	1,454	82	308	18	2,179	86	353	14
quantity (cwt)	2,039	87	315	13	3,538	87	539	13	5,657	91	570	9
rate (cwt/ac.)	2.47		1.98		2.43		1.75		2.6		1.62	
Basic Slag												
acreage covered	252	96	10	4	599	92	52	8	306	96	14	4
quantity (cwt)	730	96	28	4	1,506	93	113	7	969	97	30	3
rate (cwt/ac.)	2.9		2.8		2.51		2.17		3.17		2.14	
Other Fertilizer												
acreage covered	152	94	10	6	365	83	76	17	267	92	22	8
quantity (cwt)	452	94	31	6	878	87	131	13	842	95	46	5
rate (cwt/ac.)	2.97		3.1		2.40		1.72		3.15		2.09	
Lime												
acreage covered	53	49	54	51	214	60	145	40	184	31	408	69
quantity (cwt)	267	34	521	66	805	43	1,075	57	2,482	24	7,876	76
rate (cwt/ac.)	5.04		9.65		3.76		7.41		13.49		19.30	

Note: *NI* denotes North Island, *SI* denotes South Island.

Source: Calculated from *Agricultural Statistics* (for years shown).

provincial level in order to see how fertilizer use spread. Evans (1969, 203) asserts that by 1926 topdressing had become 'Dominion wide', but not all areas benefited. The practice of topdressing was still limited to areas having access to materials and able to be treated using horse-drawn machinery. Sheep farming, even in such areas, lagged behind in soil amending (Nosworthy cited in Kempthorne, Prosser and Co., 1926, 5-6). Although topdressing was developing:

> it had been estimated that, despite the successful propaganda of the Department of Agriculture and of stock and station agents, not more than 5 percent of the sown pastures of the Dominion are annually topdressed. At this rate it would take 20 years to get round all the sown pastures--a rate which at current dressings would hardly counterbalance natural depletion, and would leave inherent soil deficiencies practically untouched. (Stapledon, 1928, 85)

Farmers were still experimenting with fertilizer usage, often not employing the most suitable type (seen in Table 5.9 in the changing percentage of soil-amendment type used) and, with the policy of using 'one cwt. per acre, per year, perhaps' were not applying adequate amounts (Kempthorne, Prosser and Co., 1926, 9). Topdressing 'was practised only where lack of phosphates was proved to be a serious limiting factor in production' (Hudson and Scrivener, 1936, 404). A full assessment of needs and a complete fertilizing program involving lime and potash had not been made by the mid-1930s. It was felt that the success of phosphate application alone was limiting 'the further immediate development of [this] concept of complete manuring' (Hudson and Scrivener, 1936, 404).

The use of various soil amendments on grassland in the North and South Islands showed the marked differences in the amount and type of fertilizers employed and the rate of application of superphosphate and lime (Table 5.9). Farming system differences, notably more sown grassland and dairying in the North Island (Kempthorne, Prosser and Co., 1925, 36), and soil differences account for the variation noted but a continuing steady pattern of fertilizer application rates did appear. The heavier use of lime reflected the greater need seen to adjust soil acidity in the South Island, but the acreage covered rose more rapidly in the North Island to 1930--a trend which continued to 1950. There was some concern expressed at that time that farmers' greater use of lime was an attempt to reduce the use of more expensive fertilizers

(Connell, 1931, 307). With later shortages during and after the war such was certainly the case as the heavy liming rate shows (Table 5.9).

RESEARCH ON GRASSLAND

The rise of topdressing indicated that sown pasture was a central feature of New Zealand's farming systems. Of the total area of occupied land being farmed, sown pasture rose from 36.5 percent in 1920-21 to 39.9 percent in 1930-31. The area in sown grasses rose from 15.9 million acres to 17.3 million acres as scrub land in the North Island and tussock in the South Island were converted to pasture (Smallfield, 1947c, 577). However, sown pasture was far more prevalent in the North Island as a percentage of grassland. With the greater production occurring in the former island it was seen that sown pasture was 'of most economic importance for the Dominion as a whole' (Duckham, 1932, 107). The importance of this feature is seen in the direction New Zealand agricultural research took. Crop production clearly trailed far behind in areal extent as neither the grain and pulse crop acreage nor that of all green and root crops (largely intended for livestock fodder anyway) reached 2 percent of the area farmed (Table 5.1). Cropping was seen as antithetical to topdressing practice (Kempthorne, Prosser and Co., 1925, 47). Consequently, it is possible to accept the statement 'The lineaments of the land use pattern and farming systems were established' (Moran, 1974, 124).

The promotion of grassland farming developed strongly in the period to 1930 through the efforts of people already in the institutions established prior to World War I, and through the efforts of those involved in new institutions founded in the 1920s. The intensity of this effort led to the comment that: 'Research work in New Zealand is concerned almost exclusively with the land and land products' (Belshaw, 1936a, 25). The importance of sown grassland in that research concern directed attention to grassland problems, notably in fertilizer investigations (Hudson and Scrivener, 1936, 384).

Advances in Experimentation

The developmental work on the use of soil amendments was guided by those assessing its physical properties. The work of Ivey of Canterbury Agricultural College and Aston of the Department of Agriculture followed from their background in soil chemistry. Advances in the physical sciences enabled the properties of various fertilizers to be analyzed and the use of the experimental method in field trials enabled researchers to make some assessment of the utility of these materials on particular soils. It was only in 1917 that it was decided to approach the problem of assessing fertilizer-trial results more rigorously by operating a limited number of experimental areas on selected soil types to demonstrate proper techniques. By 1923, seven such areas were being employed in addition to three model farms in the North Island (*ARDA*, 1924, 5, 22). This represented a great reduction in the scale of experimentation, but it was regarded as 'a period of recovery from the previous orgy as well as a time of preparation for the introduction of modern methods' (McCaskill, 1929, 110). Staff numbers remained limited as in 1920 there were only 10 or 11 people in the Fields Division (Smallfield, 1970, 9), imposing a restriction on the amount of work undertaken and the amount of information dissemination. Only in the 1930s did the number begin to grow, and slowly at that, until 1950 (Table 5.10).

Analysis of experiments, however, could be performed more rigorously using the new statistical techniques available. New trials were planned on this basis and previous trials were reassessed. The first such work was done in 1921 at Lincoln College (McCaskill, 1929, 114). The Department of Agriculture did not emulate this approach until 1924 when fertilizer trials on wheat and pasture undertaken by a private body, the Canterbury Soils Improvement Committee, were 'extended and taken over' (McCaskill, 1929, 114). Only in 1929 at the Marton Experimental Station were trials started using intensive research methods which permitted an analysis of the effects of fertilizers on grassland. It was from these ongoing trials that practical fertilizing practices were developed (Hudson, 1954, 13-14).

The tools of analysis were required before a better understanding of the trial results could be obtained. It was necessary for these methods to be taught to existing personnel and for graduates already trained in their use to be engaged by the Department to continue the work on a wider basis. An official system was decided upon in March, 1924, and in January 1925 Dr. Hilgendorf published an article in the *Journal of Agriculture* outlining the methodology involved (Hilgendorf, 1925). This dealt with the first situation, and, as an example of the second situation, A.W. Hudson, a Lincoln College graduate with a

TABLE 5.10

NUMBER OF FIELDS DIVISION PERSONNEL

Year	*Instructors*	*Other Professional Researchers*
1925	15	9
1930	30	11
1935	33	28
1940	62	10
1946	53	20
1950	110	56

Source: Data supplied by P.W. Smallfield in Hudson (1954, 17).

statistical background, was appointed in 1924 to supervise all experimental work done by the Department in Canterbury. In 1927, he became Field Crop Experimentalist for New Zealand, responsible for supervising all field experimental work in the country (McCaskill, 1929, 114-115). Greater scientific training was being directed into the investigation of agricultural production.

Plant Strains

Much of the impetus for this development was provided by men appointed prior to World War I, but they had not been successful in implementing their ideas about further research. A.H. Cockayne, who had pioneered studies of montane grassland, was appointed as an assistant biologist in the Department of Agriculture in 1909. In 1910 he was already indicating the direction in which he thought the department's research should be pointed in writing in the first volume of the *Journal of the Department of Agriculture* (after 1912, *Journal of Agriculture*):

> In New Zealand our grass crop far outshadows all others. ... roughly about 95 per cent of our cultivated land is devoted to the production of feed for our herds and flocks, and 5 per cent to all other crops. When these figures are considered, especially in conjunction with the vital importance of our export trade in animal produce--wool, meat and dairy produce--it is apparent how essential to the national welfare of the country is the improvement of our grass lands and their subsidiary crops. (Cockayne, 1910, 234)

He wanted to see a plant-breeding station established to improve grasses and subsidiary crops, an area less well developed in other agricultural countries. The grass crop needed to be improved to obtain better yields, more drought-resistant varieties and more nutritive qualities. However, prior to 1923 when the Fields Division of the Department was re-established and he, as the Director, was able to co-ordinate and direct its work (Smallfield, 1970, 9), little came of the effort to promote plant breeding of forage crops and grasses. More work was put into seed testing after 1912 but most effort was involved with cereals and was done outside the Department of Agriculture (Smallfield, 1970, 64).

There was a realization of the importance of the plants and animals on which production was based. The work of Gilchrist in Britain had created an awareness of the importance of plant strain in improving production (Stapledon, 1928, 97). Nonetheless, the pastures being so widely established were based on seed which:

> probably varied more in quality, and therefore in value that [than] any other commodity the farmer had to buy. At the same time they [seeds] were, weight for weight, the most expensive of any of his recurring purchases, and for that reason great care had to be exercised in buying. (Evans, 1960, 5)

Farmers trusted their own judgment rather than the voluntary purity and germination tests available from the department laboratory set up for this purpose in 1910 (Smallfield, 1970, 69). Although some progress was made under the direction of E.C. Clifton in the early 1900s, only after 1920 was a more determined seed-testing program instituted based on Cockayne's observations of the situation in the United States. New Zealand was envisaged as an important centre for seed production for the British Empire on the basis of this work (Stapledon, 1928, 106).

Research Institutions

Seed testing was related to the establishment of the Plant Research Station at Palmerston North in 1928, the culmination of Cockayne's many years of effort. The station comprised six sections: agronomy, crop experiments, agrostology[3], mycology, entymology and seed testing with the result that the full Fields Division and the Biological Laboratory staff were working together (*ARDA*, 1929, 36). This arrangement remedied the absence of an institution fully equipped to conduct the plant-breeding work and embody the advances found in strain selection (Stapledon, 1928, 90).

This adoption of a suggestion of R.G. Stapledon, founder and Director of the Welsh Plant Breeding Station (Levy, 1970, xxxi) followed the pattern of imitating institutions established elsewhere. The Canterbury Agricultural College and the Department of Agriculture were nineteenth century examples of this pattern which was followed in the creation of the Department of Scientific and Industrial Research (hereinafter referred to as the DSIR) in 1926. In the latter case, the Secretary of the Department of Scientific and Industrial Research in the United Kingdom was invited to report on the organization and application of scientific research in New Zealand (Riddet, 1954, 4). An institution similar to that in Britain was established and later took over much of the research work being done under the auspices of the Department of Agriculture.

The emphasis on applying research work to agriculture acknowledged New Zealand's economic dependence on that sector and was further borne out by the establishment of a separate Dairy Research Institute (abbreviated to DRI) in 1927 to deal with more specific problems of production improvement (Riddet, 1954, 4). In line with this aim it affiliated the Hamilton and Hawera Laboratories of the New Zealand Co-operative Dairy Co. and Federation of Taranaki Co-operative Dairy Factories (Callaghan and Peren, 1936, 252). A link with industrial production problems was forged. Significantly, the DRI and the Plant Research Station were sited in close proximity to the newly founded North Island agricultural college, Massey. Facilities were shared and staff engaged in teaching, thereby permitting research findings to be diffused to other researchers, academics, and students who could participate in the work being undertaken and learn the methods employed (Philpott, 1937, 278).

A.H. Cockayne, as Director of the Plant Research Station, strongly favoured the maintenance of close connections between research and instruction, and an applied approach to research (Levy, 1970, xxxix). The industry being served could then better understand the results obtained and give some direction to research being pursued. The concern for the research program led him to agree to the transfer of the Plant Research Station to the DSIR as it 'would give added scope and better opportunities for the financing of a sustained research programme than he [Cockayne] could foresee in his own Department' (Levy, 1970, xxxix).

Agrostology and Seed Certification

Although the organizational arrangement was largely imitative in origin, it proved effective in directing research work to New Zealand's particular needs. The key role of grassland in production was recognized in the agrostology work undertaken in 1928 by E.B. Levy. This work was begun in conjunction with W. Davies of the Welsh Plant Station who had been seconded for two years by Stapledon (Levy, 1970, xix) as part of the research co-operation program of the Imperial Agricultural Research Bureaux scheme (Callaghan and Peren, 1936, 293). Following Stapledon's concern with the quality of herbage plants, fundamental research into the ecotypes (strains) available was undertaken. Preceding work done by Cockayne and Levy in identifying the most valuable pasture plants enabled some selection to be made. More concentrated effort could then be applied to those species which appeared most productive. The work of the Agrostology Section beginning in 1929 indicated that 'there were striking and important differences in the commonly used pasture plants, particularly in ryegrass, white clover, cocksfoot and timothy' (Evans, 1960, 15). Research into strain through 1931 was concentrated on ryegrasses, cockfoot, white clover, red clover, subterranean clover, and browntop, and results were published regularly in the *Journal of Agriculture* to disseminate the information gathered. Seed certification centred on but two of these plants, ryegrass and white clover, as they were considered the two most important permanent pasture species. Clover's role in the establishment of productive pasture by furnishing nitrogen to the grasses had been uncovered in the 1920s; hence, its study was of particular importance in developing better pasture (Smallfield, 1947a, 169). Finding a true perennial ryegrass was the major accomplishment of the scheme as it provided the basis for productive, high-quality, permanent pasture (Smallfield, 1947c, 581).

The controversy surrounding its use had been carried to New Zealand from Britain in the 1880s and continued until certified perennial ryegrass was proven worthwhile in the 1930s. Smallfield (1970, 64) notes the reliance placed by New Zealand on British experience:

> At that time [late nineteenth and early twentieth centuries] New Zealand looked to Great Britain for information on farming developments and the ryegrass controversy there was followed with interest here.

While Smallfield (1970, 64) also noted that,

> it does seem strange that ... so much was said, so many opinions put forward and so little investigation work was carried out on the nature and value of ryegrass strains,

it seems less surprising when viewed in light of Parker's thesis that such biologically oriented work would not be carried out prior to the development of appropriate measurement techniques and a greater experience in plant breeding. It is indicated that adoption of new strains developed and certified was not immediate as there was some initial prejudice and indifference (Evans, 1960, 18), but Levy campaigned actively to introduce it using field demonstrations over much of the country (Smallfield, 1970, 66), and so combined the function of researcher and information agent as Cockayne had envisaged. The outcome was more rapid adoption of this particular strain of perennial ryegrass (Callaghan and Peren, 1936, 296).

The capability of rapidly disseminating the best strains was developed through a linkage between organizations concerned with biological material. J.W. Hadfield, an agronomist who had worked on seed certification for potatoes and wheat, was able to set up a scheme to apply the results found (Hudson, 1954, 13). In the 1929-30 season the Department decided to inaugurate a Seed Certification Scheme whereby it would be possible to produce guaranteed seed of a particular pasture plant found beneficial. The aim of the scheme:

> was to produce lines of pure seed of known strain, whose purity, quality and germination capacity would be guaranteed, the use of which would bring about a steady improvement in our pastures with consequent increased carrying. (Evans, 1960, 16)

A distribution organization was established to promote both wider use and greater production of the certified strains. Existing seed-trade channels were used with stock and station firms purchasing stock seed from the Department of Agriculture for commercial production (Irving, 1961, 155). The production potential of Canterbury, where seed dressing had occurred as early as 1870 (*Census of New Zealand*, 1871, Table 31) was exploited in a more effective, scientific manner.

The initial agrostological research approach reflected Cockayne's work as a biologist concerned with ecosystems, for 'he pointed out the scientific interest and far-reaching practical importance of research based on ecological concepts' (Levy, 1970, xxxvi), and transmitted this view to men such as Levy. Stapledon shared this approach of conducting research on pastures in the fields and worked with Levy in Wales in developing this approach (Thomas, 1966, 17). Necessary botanical and chemical studies were then carried out in associated research institutions to resolve problems indicated by work in agrostology. As this linkage was created in the organization of the research institutions, the progress envisaged by such an arrangement was realized. Those interested in the problems of grasslands grouped together in 1931 to form the New Zealand Grasslands Association with the aim of promoting the use of the research discoveries being made (Smallfield, 1970, 108).

Information dissemination to farmers reflected these advances in knowledge as noted in the changes in the editions of F.W. Hilgendorf's *Pasture Plants and Pastures of New Zealand*. Where the second edition simply noted the problems of impermanence in pasture plants (Hilgendorf, 1923, 9) and indicated the wide variety utilized, in the fourth edition the former condition was related to plant nutrient requirements and soil-fertility levels, and the variety of pasture plants noted substantially reduced (Hilgendorf, 1936, 9).

The importance of perennial ryegrass and of grass strain appeared in the fourth edition (Hilgendorf, 1936, 12) and led to a revision of the worth of temporary pasture, a reflection of the pasture management changes which were to occur on New Zealand farms (cf. Hilgendorf, 1923, 72; Hilgendorf, 1936, 76). By the fifth edition, mention of the value of seed certification was included and the eminence of ryegrass underlined (Hilgendorf, 1939, 7-9).

Similarly the importance of clovers was noted in the second edition (Hilgendorf, 1923, 51-52) but further study to extend this culture is first recommended in the fourth edition and the difference in reds and white clover strains recognized (Hilgendorf, 1936, 60-63). The work carried out by Levy, Davies, and Hadfield was being noted and transmitted to the farmers.

Aiding in this transmission process were the instructors of the Fields Division. Their numbers rose, albeit slowly, through the period prior to World War II (Table 5.10) but they were active in arranging fertilizer and pasture plant strain trials for instruction purposes in districts throughout the country (Hudson, 1954, 13). They were able not only to present innovations to farmers but also to report their observations back to researchers, indicating where failure and success occurred and increasing the relevance of the experiments in progress. This role in research was considered significant not only for the contributions made but also in translating research-station findings into practice on a wide range of farms (Woodcock, 1961, 5).

RESEARCH DIRECTIONS

Two lines of research emerged: one based on chemical analysis which was concerned with detecting mineral deficiencies in soil and evaluating the performance of soil amendments, and a second, based on ecological concerns, in which the interrelationships of soil fertility, pasture, and grazing stock were explored.

Chemical

The work of B.C. Aston in providing a remedy for 'bush sickness', a deficiency disease of animals which had limited production in much of the central North Island from the 1880s, exemplifies the first line of research. Aston found in the 1920s that providing stock with limonite could overcome the problem he diagnosed as iron deficiency (Stapledon, 1928, 82-83). Attention became centred on the mineral constituents of pasture as a consequence, thus leading to further discoveries using the research resources available. The value of lime and phosphate fertilizers in stock health appeared through this work, and served to promote topdressing (Burnard, 1931, 51).

Following Aston's work, other researchers in New Zealand and elsewhere found that limonite was not always successful in remedying 'bush sickness'. By 1935 the role of the trace element cobalt had been uncovered and topdressing using cobalt sulphate had been introduced with success (Smallfield, 1947c, 585). Farming then became viable in the pumice lands in the Rotorua-Taupo area (Hudson, 1954, 15). This success led to the further investigation noted in the following chapter.

Concern with mineral deficiencies also led, in 1925, to the first soil surveys in Nelson in 1925, conducted by T. Rigg of the Cawthron Institute (*Fert. J.*, 1956a, 4). The experience gained in the Nelson surveys using reconnaissance methods learned in Britain resulted in Rigg's being asked in 1930 to head a team to define the volcanic ash soils involved in 'bush sickness' (*Fert. J.*, 1960a, 4). Initially this work was carried out as part of the Geological Survey, but the need to link up the soil-survey findings with chemical analysis led in 1933 to the establishment of a Soil Survey Section in conjunction with a chemical laboratory with the DSIR (*Fert. J.*, 1960a, 3). This link emphasized the importance of the relating of soil surveys to the fertilizer-response surveys began by A.W. Hudson in 1931 using the work of farm advisory officers (Woodcock, 1961, 7). The basis for planning soil amending was broadened.

Maps of the soils surveyed began to appear in the mid-1930s and allowed 'advisory officers to investigate soil fertility problems on individual soil types, and a wide survey of fertiliser and lime responsers was soon carried out' (Smallfield, 1970, 56). The bulletins incorporating available knowledge on soils issued by the Soil Survey Section in collaboration with the Department of Agriculture became 'the most important factor in the development of accurate advice for the improvement of soil fertility and consequent raising of the productivity of pastures and annual crops' (Smallfield, 1970, 56). By 1941 a provisional map of North Island soils was issued, although a complete survey was not published until 1953 (*Fert. J.*, 1960a, 4).

Ecological

The second line of research emerged from relating mineral deficiency problems to animal health and plant production. As researchers became aware of the relationship between soil fertility, pasture growth, and grazing stock, they added this approach to the areas of fundamental research into grasslands production. It is evident that this relationship had been exploited in nineteenth century, British 'high farming'. While it was recognized as important by Cockayne and Levy, little research work into the exact relationships involved had been performed. The Plant Research Station's establishment in the late 1930s permitted such work to be undertaken later under the direction of P.D. Sears (Melville, 1954, 20). In this area, pioneering research techniques was as important an aspect as the results actually found. Once it was possible for accurate data to be obtained it was possible to study the interaction of animal, pasture, and soil and assess in production situations the utility of the outcome of plant breeding and soil amending experiments. The work of farm advisory officers armed with such information became more valuable to the farmer.

Soil amending became but one aspect of the production problems studied. Pasture composition and the role of various plants in animal nutrition became important as it was realized that grasses and legumes had different nutritive value. Legumes had a higher mineral content than grasses, and so supplemented the value of grassland. Its application served to stimulate clover growth which led to increased grass growth particularly where pedigree perennial ryegrass strains were sown. More grass enabled more livestock to be grazed and the greater quantity of dung and urine deposited improved grass growth both in quantity and in feeding value (Smallfield, 1947c, 581). The English experience could be repeated in New Zealand once grassland fertility had been improved and stock numbers were increased to the point where their manure output alone would stimulate grassland production. Grazing management was recognized as the method of maintaining a balance between pasture and animal production (Dairy Industry Commission, 1934, 15).

LAND DEVELOPMENT

Attempts to foster closer settlement at the turn of the century had first involved government in land development. Later, soldiers returning from World War I were encouraged to establish new farms. The lack of success in these ventures where the land was found unable to support such farms, prompted the Land Laws Amendment Act of 1929 which established the principle of the state development of land prior to its settlement (Smallfield, 1970, 26). It was this involvement which provided government research workers with a large-scale laboratory in which to test their findings.

In the early 1920s the methods employed to develop scrub land had been found inadequate as the pastures established were insufficiently productive to pay for the cost of their development (Smallfield, 1947c, 583). Reversion of land from pasture (Table 5.3) became a major problem following World War I as soil fertility in recently developed bush land declined under inadequate pasture management, and remedial work could not be undertaken for lack of labour and suitable techniques (Smallfield, 1947c, 587; Smallfield, 1947b, 278).

Stapledon (1928, 78, 86) observed that government would have to be involved in land development as it alone had the large-scale organizational capacity to distribute the fencing materials and the fertilizers held to be the basis for grassland improvement.

Initially, this approach was not taken in land development. The Deteriorated Lands Act of 1925 provided some remedy in funding individual farmer's projects but 'The administration of the Act was not very liberal' (Smallfield, 1970, 36) so progress was slow. Some effect could be seen as the area of fern, scrub, and second growth fell between 1925 and 1930 but only by 16,000 acres in a total of 4.1 million acres (Table 5.3). Many improvements made were lost during the depression when farmers could not maintain the inputs needed (Smallfield, 1947c, 587). Between 1931 and 1936 56,000 more acres reverted, but this marked a slowing of the rate of reversion experienced in the early 1930s.

Surface sowings after secondary burns of scrub, fencing, and topdressing were the methods employed, but soil amending was wasted until the quality of pasture could be assured through the use of certified grass and clover seed. The work done on hill country of topdressing by hand was not complemented by oversowing with white or subterranean clover. It was only the advent of perennial ryegrass seed in 1930 which provided the basis for the government projects in the central North Island under the Land Development Board to begin (Smallfield, 1947c, 583). By 1933 some 70,000 acres of new farm land had been developed, but the depression conditions led to a reluctance to settle on them (Hudson, 1954, 16). The depression made this work more important as urban unemployment rose leading the government in 1933 to begin large-scale operations under the Small Farms Board to settle families on farms where they could provide food for themselves (*ARDA*, 1933, 5).

New methods of creating high-production pastures were developed on these projects where the government was supporting the financial burden. The approach which emerged was not one of gradual fertility development but of adequate cultivation, the sowing of certified seed, and the application of heavy dressings of superphosphate to stimulate strong white-clover growth (Smallfield, 1970, 29). Then, using managed heavy grazing, growth could be controlled and the pasture heavily manured. The pasture-animal relations being explored were found to have important practical application in this work, as were the discoveries concerning mineral deficiencies in New Zealand soils.

Although undertaken somewhat hesitantly and interrupted by the war, the projects became firmly established in the late 1940s as the techniques developed were adapted for use in other classes of marginal land (Hudson, 1954, 16). Improvement could be made as evidenced by the Department of Agriculture's investigations in Whangamomona County of the effects of topdressing country reverting to secondary growth. (Kempthorne, Prosser and Co., 1926, 90-91).

Of greater importance was the fact that individual farmers were learning about the techniques to employ, admittedly on a smaller scale (Hudson, 1937). In 1928 Cockayne had noted that farmers were extending topdressing into hill country but the problem of applying fertilizer by hand was a major handicap (*ARDA*, 1928, 35). Further, without the oversowing of clover, the topdressing of the hills was of doubtful value (Smallfield, 1970, 127). To aid hill-country farmers in breaking in land and maintaining it, Levy (1939, 13) reiterated Stapledon's suggestion that:

> some pooling of the national resources of the country applied by way of subsidy is necessary to help the individual settlers through those difficult and costly breaking-in stages of development.

Nonetheless, private effort did develop. Tracks were constructed over steep hills to reduce the effort of getting fertilizers to points for distribution (Saxby, 1950b, 110). Otherwise inaccessible areas were being dressed by hand-spreading as a result, though not in a regular or intensive way (Hudson and Scrivener, 1936, 371). Equipment was devised for spreading the material, canvas carriers delivering fertilizer through a hose and, after the war, mechanical blowers (Smallfield, 1970, 127; Hamblyn, 1949, 452). There is no record of the extent to which these were used and the area of land treated. Given the amount of labour required to employ these techniques and the shortage of available labour at that time, the coverage could not have been extensive. The lowland areas, where distribution was comparatively easy, remained favoured. Accordingly:

> Topdressing of hill-country, except for almost insignificant areas, was generally considered physically and economically impossible. (Evans, 1969, 205)

Contractors who had embarked on the practice (Holford, 1936, 174) had not had much impact.

Accordingly, in 1947 it was considered that the extension of topdressing into surface-sown hill country still awaited full exploitation. Carrying capacity had been increased using lower-fertility-demanding danthonia grasses and drought-resistant subterranean clover but the full production potential had yet to be realized (Smallfield, 1947c, 579). The volume of pastoral production (wool and sheepmeat) did not reach the level attained by dairy produce until World War II (Table 5.11). The distribution of soil amendments, the enabling element in the creation of the ryegrass-clover sward, had to be improved.

ECONOMIC DEPRESSION 1930-1935: ITS EFFECTS ON AGRICULTURE

In spite of the varying economic conditions in the 1920s, it had still been possible to keep farm incomes fairly constant by increased production and rising efficiency (Duckham, 1932, 106). The depression of the 1930s was another matter for it reduced revenue and research. New Zealand's export earnings were rapidly depressed by the economic downturn in Britain. Wool was the first commodity hit and it was soon noted that sheep farmers were using less fertilizer (*ARDA*, 1931, 5). Dairy produce and, to a lesser extent, meat exports also fell in value to new low levels (Figure 5.1). All prices continued to fall into 1932 when they were under half the 1928-29 level (Table 5.12). Gross farm income was 55 percent of that in 1928-29 (Table 5.13). An index of the price of farm inputs (Table 5.12) shows that the total level in 1931-32, while it fell from 54.7 in 1928-29 stood at 50.2 (1949-50 base level = 100). Farmers were caught in a major price squeeze seen in the reduced terms of exchange (Table 5.12).

Production levels did not fall, however. The grasslands technology available, better stock, and improved farm management, it was felt, allowed production levels to increase despite falling fertilizer use (*ARDA*, 1933, 7). The rapidly increased production was regarded as an outcome of:

> The pressure of falling prices since the war, more especially after 1925, stimulated improved farming technique, more particularly in the form of topdressing, rotational grazing, improvement of herds and increased use of machinery. (Belshaw, 1936a, 21)

Topdressed area fell by 509,000 acres from its peak 1929 level to its lowest level in 1934 but that figure was only an 18.4 percent reduction in acreage. The quantity of fertilizer fell only slightly more, 19.1 percent, in the same period (Table 5.14). The output of dairy produce rose while that of pastoral produce remained at the same level as dairy prices fell less than those of sheep-farm products (Table 5.11; Fig. 5.1). The effect of this differential was change in the lowland farming systems. Dairy farmers found it profitable

TABLE 5.11

INDEX NUMBERS OF VOLUME OF FARM PRODUCTION 1921-1949
(1949-50=100)

Year	*Agricultural*[a] *Produce*	*Pastoral*[b] *Produce*	*Dairy Produce*	*All Farm Produce*
1921-22	71.5	50.2	42.3	50.3
1922-23	60.7	50.9	48.0	51.3
1923-24	54.8	53.0	48.6	52.5
1924-25	59.4	54.5	51.3	54.1
1925-26	60.6	52.2	49.8	52.5
1926-27	64.0	53.0	55.0	55.5
1927-28	71.7	62.3	56.2	61.4
1928-29	71.3	64.2	61.5	63.7
1929-30	70.0	67.5	66.7	66.9
1930-31	75.3	64.2	68.4	67.7
1931-32	70.0	64.2	70.9	67.7
1932-33	90.7	70.0	82.1	77.4
1933-34	79.3	74.0	87.2	79.8
1934-35	69.3	73.2	84.6	77.4
1935-36	82.0	75.6	88.9	81.5
1936-37	74.0	78.9	93.2	83.9
1937-38	70.7	82.1	89.7	83.9
1938-39	66.7	81.3	85.5	81.3
1939-40	79.3	79.7	91.5	84.6
1940-41	84.0	90.2	98.3	93.5
1941-42	85.3	89.4	93.2	90.2
1942-43	92.7	85.4	87.2	87.0
1943-44	98.7	86.2	82.1	86.2
1944-45	106.7	91.9	89.7	93.5
1945-46	94.7	91.1	78.6	87.0
1946-47	101.3	89.4	87.2	90.2
1947-48	96.0	93.5	88.9	92.7
1948-49	104.0	91.9	96.6	95.9
1949-50	100.0	100.0	100.0	100.0

Notes: *a* Denotes cropping.

b Denotes wool and meat.

Source: Philpott and Stewart (1958a, Table 11).

TABLE 5.12

PRICES RECEIVED AND PRICES PAID 1921-1949
(1949-50=100)

Year	*Price Index of Farm Outputs*	*Price Index of Farm Inputs*	*Terms of Exchange*[a]
1921-22	51.9	65.3	79.5
1922-23	54.8	56.9	96.3
1923-24	53.5	53.9	99.3
1924-25	62.8	54.4	115.4
1925-26	54.9	54.6	100.5
1926-27	51.7	52.9	97.9
1927-28	53.7	53.9	99.6
1928-29	58.9	54.7	107.7
1929-30	49.9	54.8	91.1
1930-31	35.2	54.3	64.8
1931-32	30.6	50.2	61.0
1932-33	26.9	45.5	59.1
1933-34	34.0	44.9	75.7
1934-35	32.9	44.7	73.6
1935-36	39.5	45.6	86.6
1936-37	48.5	50.9	95.3
1937-38	46.2	57.0	81.1
1938-39	47.1	58.7	80.2
1939-40	48.5	60.4	80.3
1940-41	49.5	60.4	82.0
1941-42	50.8	63.5	80.0
1942-43	53.2	69.0	77.1
1943-44	55.0	72.8	75.5
1944-45	59.9	73.2	81.8
1945-46	60.3	77.8	77.5
1946-47	67.4	82.9	81.3
1947-48	80.6	89.2	90.4
1948-49	84.2	98.5	85.5
1949-50	100.0	100.0	100.0

Note: *a* Price index of farm outputs divided by price index of farm inputs.

Source: Hussey and Philpott (1969, Table III).

TABLE 5.13

GROSS FARM INCOME IN MILLIONS OF DOLLARS 1921-1949

Year	*Agricultural*[a] *Produce*	*Pastoral Produce*	*Dairy Produce*	*All Farm Produce*
1921-22	..	..	..	95.4
1922-23	..	..	..	102.8
1923-24	..	..	..	103.0
1924-25	..	..	..	124.4
1925-26	..	..	..	105.6
1926-27	..	..	..	105.2
1927-28	..	..	..	120.8
1928-29	14.6	71.6	51.0	137.2
1929-30	14.8	58.8	48.8	122.2
1930-31	13.4	37.8	35.8	87.0
1931-32	13.0	28.0	34.8	75.8
1932-33	13.8	29.2	33.0	76.0
1933-34	14.0	49.6	35.6	99.2
1934-35	12.0	44.6	36.6	93.2
1935-36	14.8	55.4	47.8	118.0
1936-37	14.4	79.0	55.8	149.2
1937-38	14.6	68.0	59.6	142.2
1938-39	16.6	61.8	62.0	140.2
1939-40	19.2	62.8	68.0	150.0
1940-41	20.6	75.4	73.6	169.6
1941-42	22.8	74.2	70.6	167.6
1942-43	26.6	74.6	68.4	169.6
1943-44	28.8	77.6	67.2	173.4
1944-45	32.8	91.8	80.6	205.2
1945-46	31.8	87.0	73.4	192.2
1946-47	31.8	101.6	89.2	222.6
1947-48	34.8	134.6	103.8	273.0
1948-49	39.2	139.6	116.4	294.0
1949-50	41.6	200.8	127.8	370.2

Notes: *a* Denotes cropping.

b Denotes wool and meat.

Source: Philpott and Stewart (1958a, Table 8).

TABLE 5.14

ESTIMATED FERTILIZER USAGE IN TONS 1926-1945[a]

Year Ending 31 January	*Straight super-phosphate*	*Other phosphates*	*Blood-and-bone, blood, bone, etc.*	*Potashes, ammonium sulphate, and sodium nitrate*	*Total*
1926-27	187,761	71,814	19,768 [b]	12,648	291,991
1927-28	295,919	66,487	21,331 [b]	8,009	391,746
1928-29	275,488	151,249	24,746 [b]	13,701	465,184
1929-30	299,327	183,555	24,031	18,992	525,905
1930-31	234,220	125,266	25,340	17,814	402,640
1931-32	231,078	97,021	22,556	9,157	359,812
1932-33	307,224	59,480	26,115	10,513	403,332
1933-34	280,418	64,266	24,001	7,490	376,175
1934-35	313,924	25,305	23,021	11,178	373,428
1935-36	331,029	54,895	25,234	15,242	426,400
1936-37	370,178	92,337	25,338	15,027	502,880
1937-38	447,407	120,862	21,676	21,371	611,316
1938-39	461,572	107,291	23,535	21,990	614,388
1939-40	511,570	111,896	26,684	22,461	672,611
1940-41	598,529	58,534	29,846	11,748	698,657
1941-42	418,562	47,563	32,221	4,085	502,431
1942-43	294,935	27,374	34,828	5,194	362,331
1943-44	250,894	128	29,512	4,882	285,416
1944-45	364,926	29,503	29,447	6,339	430,215
1945-46	444,785	26,603	25,000	10,681	507,069

Notes: *a* Serpentine and lime not included.

b Because of alterations in the basis of the Census and Statistics Department's returns, these figures are not strictly comparable with those in subsequent years.

Source: Mouat and Rodda (1950, Table 63).

to employ more labour as the ratio of dairy prices to wage rates rose and production grew rapidly (Philpott, 1963, 24). As dairying became comparatively more attractive to farmers, the number of dairy cows in milk reached a new peak in 1935 after increasing by about 100,000 head per year from 1929 (*Agricultural Statistics,* 1970, Table 1). The number of sheep rose to 30.84 million in 1930, then declined by almost 3.1 million through 1933 to the level closer to that of 1928 (*Agricultural Statistics,* 1970, Table 1) as lamb prices exceeded those of wool prices and encouraged farmers to slaughter a higher proportion of lambs (Philpott, 1963, 25). The number of cattle excluding dairy cows in milk also declined as demand fell (Table 5.2). Nonetheless, the reaction to the slump was still one of attempting to maintain output:

> In order to meet debts the majority of farmers resorted to increased production, working longer hours and stocking to capacity, and in some cases beyond capacity. (Mouat and Rodda, 1950, 279)

Indeed, between 1928 and 1932 the volume of all farm production rose 10 percent though its value fell 37 percent (Tables 5.11 and 5.13). It was regarded as noteworthy that at no time during the depression was there a proposal to restrict production:

> It was felt that such a step would only benefit overseas competition, especially Australian, far more than the rise in domestic prices would be able to compensate. (Brunner, 1938, 53)

The figures in Table 5.11 bear witness to the production effects of this belief. Dairy output was increased steadily from 1929 to 1934 and other livestock production registered an increase, although a lower one from 64.2 to 74.0, the index rising from 61.5 to 87.2 (1949-50 base level = 100). The British market remained open, absorbing most of the country's meat and dairy produce. The percentage of New Zealand's exports to Britain rose as other markets, mainly those for wool were closed (Rosenberg, 1968, 11-12).

Governmental Intervention

Government played a role in attempting to maintain production at this time. In October 1931 a subsidy of 11s. per ton was granted on the production of superphosphate to ensure a continued supply and keep the use of fertilizers at an adequate level (*ARDA,* 1932, 5). The drop in usage of 166,000 tons (32 percent of the 1929-30 total) from 1929-30 to 1931-32 was halted. This subsidy was continued through to the end of June 1936 (*MAS*, 1937, xv) when the Labour Government established fixed prices for superphosphate of £3 16s. 'ex works' in the North Island and £4 2s. in the South Island. It can be seen that these levels were well below the prevailing prices during the 'fertilizer war' of 1926-27. Imported fertilizers were not subsidized as local manufacturing was to be encouraged (Burnard, 1931, 40) and they fell quickly. Between 1929 and 1935 only 325 tons of superphosphate was imported. Basic slag imports dropped from 94,500 tons to 16,400 tons, guano imports fluctuated between 10,500 and 28,000 tons, and other phosphates fell from 59,800 to 11,000 tons in this period (figures from *Trade and Shipping Statistics*,[for the years indicated]). Unfortunately, 1931 and 1936 span the period of depression and recovery, so Table 5.5 is unhelpful in this instance. It is noteworthy that rock phosphate imports held steady to 1931 and rose after 1933, an indication of the continued domestic production of chemical fertilizer. Usage remained above 373,000 tons until the end of the subsidy program. Though this was a lower level of usage than in 1928 it still surpassed the level achieved a decade before, and subsequently, usage increased to 1941 (Table 5.14) and there was a noticeable rise in imports of rock phosphate to meet this demand. The use of organic fertilizers, by-products of the meat and boiling-down industries remained stable during the depression (Table 5.14) though output fell 7,000 tons (Table 5.15). Despite increased output after 1933, usage did not expand and, in any case, the quantity usually represented less than 10 percent of the fertilizer used. Annual crop production, the main use of these fertilizers, though it showed some increase (Table 5.1) particularly in the South Island as wool prices fell (Evans, 1969, 16), did not maintain itself. With the rise of pastoral commodity prices after 1935 (Fig. 5.1), crop acreages, especially those of the major cereals, fell. Oats were less widely grown as motor mechanization entered farming and gradually displaced draught animals, and wheat production fluctuated through the varying market conditions and the attempts to reach a satisfactory price level.

The crisis prompted significant economic intervention by government--the one institution with sufficient resources to stage off collapse--for many farmers were able to stay on the land only through

TABLE 5.15

TONNAGE OF ORGANIC FERTILIZER PRODUCTION[a] 1915-1949

Year	*Bone-dust*	*Blood-and-bone and Blood*	*Other*[b]	*Total*	*Mixtures*[c]
1915-16	6,121	74,576		80,697	..
1919-20	9,644	26,568		36,212	..
1920-21	22,938	35,284		58,222	..
1925-26	6,455	27,863		34,318	..
1930-31	5,452	14,169	16,687	36,308	..
1935-36	4,639	14,144	21,443	40,226	..
1940-41	6,850	18,358	8,545	33,753	..
1945-46	5,544	22,219	2,474	38,542	8,304
1949-50	4,309	22,729	1,104	38,450	10,308

Notes: *a* Combined output of meat-processing plants and boiling-down and manure plants (Table 5.4).

b Blood-and-bone fertilizer from boiling-down and manure plants was evidently classed as 'other' prior to 1949 (cf. 1945-46 'other' total in *Industrial Production Statistics* (1945) with that in 1949-50 shown above).

c Mixtures recorded from meat-processing plants only.

Sources: 1915-20 *Statistics of New Zealand* (for years shown).

1925-49 *Industrial Production Statistics* (for years shown).

a mortgage moratorium (Lloyd Prichard, 1970, 383). A variety of other measures were also introduced to alleviate farm debt and reduce cash expenditures (Sutch, 1968b, 42-43). This marked a change of role for government in the economy in moving away from observation to intervention (Sutch, 1968c, 62).

Government attention was directed not to production difficulties alone. The recommendations of the Royal Commission of 1934 which investigated the financial condition of dairy farmers led to the reconstitution of the New Zealand Dairy-Produce Control Board as the New Zealand Dairy Board under the Agriculture (Emergency Powers) Act (Ward, 1975, 89-90). Production output and all aspects of marketing for export were to come under Board's control with minimum sales prices being established (Evans, 1969, 163-164). In addition, the distribution of butter and cheese in the local market was to be added (Ward, 1975, 95). Plans to implement the scheme were drawn up in 1935 but were not put into effect for with the change of government in 1936 came new legislation, the Primary Products Marketing Act.

This act was modelled on the control boards established in the mid-1920s. The Labour Party had promised to introduce state control to achieve a guaranteed price for farm produce (Condliffe, 1959, 26). Under this scheme, marketing came under the jurisdiction of a Minister of Marketing and the board's remaining functions, related to improving farms' productive capacity, were also subject to his approval. Control was moved from producers to the government (White, 1963, 67). This was an attempt to stabilize farm incomes in assuring a price based on average market prices over a given period, the price of production and a fair return on investment. Surpluses earned were held in a special fund to meet deficits so reducing income fluctuations and ensuring a reasonable standard of living (Lloyd Prichard, 1970, 391). This power was extended to internal marketing of dairy products a year later. Farmers knowledge of the prices by the beginning of the season would facilitate production planning decisions for the year ahead. However, their aim was not so much the stabilization of income as a guarantee against falling prices while enjoying gains from rising prices (Condliffe, 1959, 77). These policies were maintained through the period to 1949, and provided the framework in which production decisions were taken. While producers remained capitalist in orientation, a collectivist solution to the difficulties they had encountered was imposed, with their acquiescence, in a situation of distress. This solution did not meet with widespread approval. Dairy farmers organized a Dairy Industry Council to make recommendations on such matters as the prices being set but they had no direct means of influencing the decision made (Evans, 1969, 188).

Meat producers did not face a similar restructuring of their industry but did operate under quota restrictions after July 1934 (Evans, 1969, 124). The Meat Producers' Board had operated successfully until 1930 when the depression posed particular problems for it. The British market became oversupplied, a situation which resulted in a short-term quota being introduced at the Imperial Economic Conference in 1932. The planning needed to regulate shipping on such a basis proved difficult, and so, longer-term quotas were set up until the end of 1938 (Evans, 1969, 124). Even in this situation of uncertainty:

> The most was made of the possible effect of the restrictions bringing higher prices and, as prices did rise in the latter half of the 1930s, the outlook was not unfavourable until just before the Second World War broke out, when the problem of disposing of increasing quantities of meat and dairy produce threatened to become acute. (Smallfield, 1970, 107).

A guaranteed price structure, however, was rejected by the meat producers (Condliffe, 1959, 76).

It is noteworthy that wool production did not fall into this pattern even though wool exports had been most seriously affected by the depression. Its market remained free prior to World War II with producers selling at public auction through brokers. The guaranteed price concept was also rejected by these producers. Reserve prices could be set, otherwise the price offered in New Zealand or in the markets of the United Kingdom had to be accepted (Evans, 1969, 90-1). Whereas, in this system, prices generally rose to 1929 with small fluctuations, from 1930 to 1933 prices fell sharply (Fig. 5.1). It was not until 1937 that predepression export-price levels were reached again but a decline followed to 1939. Still, prices were buoyant and production rose in response but not as rapidly as in dairying; for the 'hilly and mountainous land' made such a response difficult (Smallfield, 1970, 107). The infrastructure improvements moved more slowly into the wool-producing areas, more rugged areas where access was most difficult.

The response of farmers in areas specializing in certain types of production could be expected to vary according to the rate of recovery enjoyed by that line of production. As only dairy products were included in the guaranteed price scheme, variation in prices received influenced the production decisions of farmers. Sheep farmers having suitable land added dairying to their farm enterprise. The fact that dairy produce prices had fallen less than those for wool and meat (Fig. 5.1) made the greater income from dairying attractive. An additional attraction was the low capital outlay incurred in the change-over (Dairy Industry Commission, 1934, 15). The entry of farmers into dairying tended to create a market glut but the flow was reversible (Condliffe, 1959, 78).

This trend was not entirely disadvantageous in terms of disseminating grassland production techniques. Where dairying had overtaken sheep production in many areas in the early 1920s, the development of a larger lamb market in Britain in the later 1930s and the 1940s encouraged greater production employing the improved grassland-farming techniques made available (Mouat and Rodda, 1950, 284). As fat-lamb producers had undertaken some dairying to earn some income they had been exposed to the grassland-management ideas developed for that enterprise and the co-operative factory system which formed the organizational unit wherein these ideas were spread (Condliffe, 1963, 242). This process was furthered by the advocacy of lamb production on dairy farms to diversify income sources (Dairy Industry Commission, 1934, 50). A greater pool of information and experience was so formed.

RECOVERY AND WORLD WAR 1935-1945

Prices for agricultural produce had begun to rise from 1934 but even by 1940 were still below the 1929 level (Fig. 5.1). Still, the terms of exchange had improved (Table 5.12)--the crisis was ending.

Agricultural Production

The impending war in Europe provided the situation in which production met an assured market yet in 1937 and 1938 the fall of wool prices led the government to introduce exchange-control regulations and import-control and selection measures to prevent the terms of trade from moving too sharply against the country (Ross, 1954, 255). Agreements with the United Kingdom to sell all exportable surpluses for the duration of the war and one season after were welcome, particularly to wool growers. The growers had:

> An assured market at liberal prices [which gave growers] a guaranteed income independent of marketing, shipping and storage problems. Wool production mounted .... (Ross, 1954, 257).

Wool auctions were suspended as the Marketing Department took over the administration of such specified commodities (Condliffe, 1959, 85).

The intergovernmental co-operation continued after the war with the establishment of a Joint Wool Marketing Organization, comprising the United Kingdom, Australia, New Zealand, and South Africa, to dispose of the wool surpluses (Evans, 1969, 94). The operations were so successful that the same price depression which followed World War I (Fig. 5.1) did not occur. Both the volume of produce and income rose to 1949 (Tables 5.11 and 5.13).

The same situation occurred with frozen meat after 1944. Production had increased during the war but shipping problems restricted the amount slaughtered and exported (Condliffe, 1959, 86). It was thought that production curtailment would be necessary to prevent the accumulation of meat, the dumping of which had created the depression of meat prices following World War I. Canning and dehydrating meat served to offset the problem as did provisioning American forces from 1942 on (Ross, 1954, 261).

In 1944 shipping availability improved and Britain undertook to take all surplus meat produced. Incentive was given to boosting production. A long-term contract was negotiated under which the exportable surplus was to be sold to Britain from 1945 to 1948 at increased prices. This was extended by a Bulk Purchase Contract for a further seven years to 1955 (Evans, 1969, 130-131).

For dairy produce a similar procedure was followed under the Bulk Purchase Contract to end in 1955 too. The negotiations were carried out by the Dairy Products Marketing Commission, an agency set up in 1947 to achieve the co-operation between the government and the dairy industry missing in the earlier marketing procedure (Evans, 1969, 190-191). The Marketing Commission was empowered to purchase all butter and cheese and regulate its sale internally as well. In 1948 it was given the ability to control the export of dairy produce other than butter and cheese, as milk powder and casein were becoming increasingly important (Evans, 1969, 191). Where receipts for exports remained steady for the first three seasons during the war, they rose substantially, reaching new high levels by 1949 (Condliffe, 1959, 86).

Fertilizer and Lime Production

The use of soil amendments, which in 1939 'had become the norm for intensive-grassland farms' (Ross, 1954, 246), was seriously disrupted by 1941 as related by Ellis (1948, 60-61). In December 1940, German raiders sank five phosphate transports and later shelled Nauru to hold up supplies to Australia and New Zealand. Delays resulted as loading installations were repaired and ships were organized in convoys for protection. Shipping proved to be a problem as indicated by the problems of meat export, but enough was organized to enable phosphates to be imported from Makatea, the Red Sea area, and Florida to augment supplies. Thus, in 1941, the area topdressed was at its highest level since 1927 (Table 5.8). However, as in World War I, because of supply and shipping restrictions, basic slag became unavailable (Table 5.5).

Japanese entry into the war was more serious as Nauru and Ocean Island were first bombed in December 1941 and then occupied in August 1942. The loading installations were demolished before the occupation, ending this principal source of phosphate for New Zealand until 1946. The 1942 rock phosphate import was 109,500 compared to 255,700 tons in 1941 (*Trade and Shipping Statistics*, 1942). The area topdressed fell by 437,000 acres in 1942, a further 740,000 acres in 1943 and another 100,000 acres in 1944 (Table 5.8). These figures disguise the fact that the use of fertilizers decreased sharply as lime was being employed in its stead (Saxby, 1947, 59). This view is upheld by the greater use of lime on its own in this period (Table 5.8).

The use of organic fertilizers rose as meat production increased to meet war demands increasing by-product availability and as farmers tried any material available but the extra 7,000 to 10,000 tons could not meet the demand (Table 5.15). So great was the need that the long-closed phosphate works at Clarendon were brought back into production but its output did not reach 20,000 tons at its peak (Table 5.6).

Fertilizer rationing was introduced in 1941 to conserve phosphate and sulphur supplies. Available fertilizers were allocated for cropping and any residual amounts after those needs had been satisfied, were available for topdressing (Ross, 1954, 287). The breaking-in of new land was to end and manuring to be delayed and restricted to the most productive pastures (Barclay, 1941,385; Elliott, 1941, 19) as was the policy for government projects (Saxby, 1947, 54). Rationing was established on the basis of previous use levels in 1939-40 and 1940-41, so those farmers already familiar with the use of topdressing were assisted but, they obtained only 28 percent of the average quantity used in those years until 1946-47 when the figure was raised to 67 percent (Saxby, 1947, 56).

The loss of Nauru and Ocean Island led to the attempt to extend superphosphate supplies by mixing in ground serpentine rock, a material available locally in the North Island, at a rate of one part in four. Trials in 1938-39 had laid the basis for the use of this material (*ARDA*, 1939, 23). Researchers reported that the material was as effective as straight superphosphate and lime-reverted superphosphate, contained magnesium and copper as trace elements, and in addition had superior handling and storage characteristics (Elliott and Lynch, 1941, 179, 181). In the North Island, straight superphosphate sales were stopped by government order and 'serpentine super' substituted, whereas, in the South Island, the lack of a sufficient source of serpentine rock resulted in the use of lime-reverted superphosphate (Cockayne, 1942, 193).

From the frequent appearance of articles in the *Journal of Agriculture* between 1942 and 1944 dealing with this topic it is evident that farmers contested this measure in spite of researchers' reassurances that the new product was as effective a fertilizer as superphosphate. Unfamiliarity with the new material, inadequate quality control of its manufacture, and its compulsory use were cited as reasons for the resistance which developed (Wild, 1944, 4). The lack of alternative material led farmers to use it, while relying upon past development of the phosphate level in soils to see them through in the face of declining supplies.

The latter phenomenon was unexpected as it was thought that production levels, particularly in dairying, would fall with fertilizer rationing but they did not (Ross, 1954, 266). The phosphate retention effect in soils was uncovered, as trials at Marton indicated that deterioration occurred four to five years after the complete cessation of topdressing. The partial withdrawal occasioned by rationing served to maintain production during the shortage period. As the area topdressed did not decline as sharply as the supply of fertilizers, farmers used lower rates of application to achieve this effect, the rate in 1941, 0.15 tons per acre, falling to 0.12 and 0.10 tons per acre in 1942 and 1943 respectively before reaching the low of 0.08 in 1944 (calculated from Tables 5.8 and 5.14).

Subsidies by government to fertilizer manufacturers maintained fertilizer costs from 1942 to 1947 at £4 a ton, a price just over the prewar price (Nixon, 1970, 2). The amounts involved grew as production costs increased but were recovered from farmers by debiting the meat-pool and dairy-pool accounts created under the bulk-purchase agreements (Ross, 1954, 288).

This spreading of the costs to most farmers may help to explain the increased interest in soil amending developed during the rationing period. As everyone was charged equally, those who had not used topdressing previously were encouraged to do so. The annual use of fertilizer developed as farmers 'took the opportunity to obtain it [fertilizer]. It was a case of no one wanting to be left out' (Ross, 1954, 286-287).

The wartime fertilizer shortage induced much greater activity in the lime industry as farmers sought to treat their productive land in some way. Where there were 68 lime works in 1940, there were 91 in 1945 (Table 5.4). Output had risen from 594,000 tons to 813,000 tons (Table 5.6). The government remained interested in subsidizing the transport of what was seen as an important commodity in maintaining production. The scientific work establishing lime's importance in promoting clover growth had not gone unheeded.

In 1947 the major cost in lime utilization, its transport from its mine site to the farm, was further subsidized to encourage use on farms more remote from rail transport (*NZOYB*, 1951-52, 386). Roading improvement and extension made subsidizing road transport worthwhile, so that the rail network (Map 5.1) was complemented with the subsidy on road transport from rail depots. Both rail-only and road-only costs were also subsidized (*NZOYB*, 1954, 453). The subsidy for road transport was needed to overcome the shortage of railway rolling-stock, for it was noted: 'Already road transport has had to be used to handle much of the lime used by farmers' (Ross, 1954, 322).

The problem in distributing lime by rail also occurred with fertilizers. A subsidy to cover the difference between road and rail transport costs where fertilizer had to be delivered by road or sea through the railway's incapacity to handle fertilizer at the required time was instituted in the 1946-47 season and only ended in June 1954 (*NZOYB*, 1951-52, 386; *NZOYB*, 1956, 499). The seasonal demand for fertilizer overtaxed existing rolling-stock capacity particularly, in Auckland and Taranaki (*NZOYB*, 1954, 453). As with lime, the building of bulk stores by farmers and contractors and an increase in railway rolling-stock, overcame the seasonal demand and ended the need for this particular subsidization program in the 1950s. Though this subsidy was paid to the Railways Department and not to farmers, it was a necessary measure to cater for the fertilizer demand in these two producing districts.

Although fertilizer demand was strong, supplies of phosphate rock remained restricted following the war. The Japanese did not surrender Nauru and Ocean Island until September 1945 and the installations there had been destroyed. It was not until April 1946 that phosphate shipments resumed, and the rate of shipment remained below prewar levels (Ellis, 1950, 214). More efficient equipment was installed which permitted full capacity to be achieved late in 1949 but New Zealand demand required other remedial measures to be instituted.

Rationing was continued until September 1947 (Nixon, 1970, 2), but local production was not able to reach prewar output until 1950 (Tait, 1957, 196). Little maintenance work had been done in the fertilizer plants during the war as materials had been in short supply. As this situation persisted after the war and coincided with labour shortages the major overhauls needed proceeded slowly. The 1948-49 output capacity at 650,000 tons was 50,000 tons below 1940-41 capacity (Ross, 1954, 322).

The government not only continued direct farm subsidies to maintain fertilizer use, but in addition, basic slag imports were subsidized between 1946 and 1948 while local superphosphate and Heskett basic slag (a heat-treated phosphate) were subsidized to 1949 (*NZOYB*, 1950, 309-10). Despite this subsidization, fertilizer prices increased to more than twice the prewar level as the cost of production rose. In 1947 it was decided to allow the price of superphosphate to reach £10 3s. a ton--a level considered reasonable in view of rising farm produce prices (Nixon, 1970, 2). Farmers on marginal land and those remote from fertilizer plants were disadvantaged by the removal of the rail subsidy on fertilizer carriage and the doubling of transport cost until the introduction of the road transport scheme permitted them to resume topdressing. The strong demand, exceeding plant capacity, persisted despite the price rise. Demand could only have been increased by two successive price reductions in 1948 and 1949 to reach £7 10s. 6d. a ton (Ross, 1954, 322). The importance of assuring delivery of what had become a relatively scarce production input can be appreciated.

Fodder Conservation

The use of soil-amending technology was not the only lesson in production improvement learned under wartime conditions. Concern for improving grassland production without fertilizer had resulted in more attention being paid to full utilization of herbage and the role of supplementary fodder crops. Burnard (1931, 76) noted in 1931 that:

> The whole trend of New Zealand farming during the last decade has been toward more intensive and more efficient management of grass.

The practice of not grazing some fields in the autumn so that the flush of grass growth could be retained for consumption in winter when growth was reduced was one concept which developed by W. Riddet between 1939 and 1949 in an attempt to relate animal needs to pasture production patterns (Lees, 1949, 177).

Such a practice required a new approach to management as it could only be carried where farms were more subdivided into smaller fields and rotational grazing methods were employed (Smallfield, 1947c, 583). The analysis of production needs could be applied to create a rapid increase in livestock numbers. These techniques had been recognized grazing through the reduction of paddock size by carefully planned fencing. However, their use was still being tested under the demands of the wartime situation.

The concern with avoiding the waste of herbage became evident. Stapledon (1928, 81) observed: 'the mowing machine is perhaps the most important of all pasture implements'. Where intensive grassland farming had developed the conservation of fodder as hay and silage increased, as, with fertilizer dressings, pasture-growth control necessitated the use of some conservation method (Smallfield, 1947a, 175). In the Department of Agriculture's *Annual Report* (1931, 19), it was noted:

> most districts in New Zealand have made sufficient ensilage to recognize its value, and the making of silage should now rapidly become a definite farm practice ... where material is available.

The traditional use of annual crops for supplementary fodder declined (Table 5.1), particularly in the North Island (Smallfield, 1947c, 583). British practice was less and less important as a model to follow in both islands (Clark, 1949, 386). The work on strain had improved grassland productivity and the use of fertilizers had boosted production and, thereby, carrying capacity. The technology of gathering plant material and conserving it had been developed and was being put into practice to sustain the livestock numbers which could be carried. The Fields Division of the Department of Agriculture fostered the use of ensilage by providing advice and assistance to farmers and by promoting competitions where instruction on techniques was offered (Burnard, 1931, 26). This upward trend declined after 1933 (*Agricultural Statistics,* 1934), as feeding silage involved more labour than hay. There was some stabilization until 1942 when a labour-shortage situation and the introduction of hay balers occasioned further decline (Table 5.16). Lucerne, on the other hand enjoyed a gradually increasing popularity (Table 5.16).

Whereas with the use of horses the task involved considerable labour and time, despite labour-saving equipment available (*ARDA,* 1932, 19), with the introduction of tractors, much more such work could be carried out (Evans, 1969, 62). However, it is reported that 'In the late 1920s and 1930s, very few dairy farmers owned tractors' (Smallfield, 1970, 52). The ensilage made of crops of maize, millet, sorghum, oats and vetches or lucerne was limited in this period as well; yet, by 1934 the practice was almost universal amongst Waikato dairy farmers (Smallfield, 1970, 51). The use of annual crops for supplementary fodder was less important as a consequence, so the acreage sown remained little affected by the increase in livestock

TABLE 5.16

AREA CUT FOR GRASS AND CLOVER CONSERVATION
(THOUSANDS OF ACRES) 1915-1949

<table>
<tr><th rowspan="2">Year Ending 31 January</th><th colspan="2">Grasses and Clovers Cut for:</th><th rowspan="2">Lucerne</th></tr>
<tr><th>Hay</th><th>Silage</th></tr>
<tr><td>1915-16</td><td colspan="2">95.8</td><td>..</td></tr>
<tr><td>1919-20</td><td colspan="2">166.8</td><td>..</td></tr>
<tr><td>1920-21</td><td colspan="2">161.8</td><td>..</td></tr>
<tr><td>1925-26</td><td colspan="2">224.8</td><td>..</td></tr>
<tr><td>1930-31</td><td>295.3</td><td>114.3</td><td>33.5</td></tr>
<tr><td>1935-36</td><td>453.4</td><td>82.7</td><td>40.8</td></tr>
<tr><td>1940-41</td><td>462.8</td><td>70.6</td><td>41.7</td></tr>
<tr><td>1945-46</td><td>498.1</td><td>56.5</td><td>46.4</td></tr>
<tr><td>1949-50</td><td>494.9</td><td>83.5</td><td>52</td></tr>
</table>

Sources: 1915-20 *Statistics of New Zealand* (for years shown).
1925-49 *Agricultural Statistics* (for years shown).

(Table 5.1).

While the labour scarcity during the war and the lack of top-dressing slowed this development at the core of the 'grasslands revolution', it was not long after the cessation of hostilities that the new pattern was continued. The greater availability of tractors was the key element introduced in the 1940s (King, 1950, 70). Though mowers, and balers were available for use with horses, they still required much labour and time (Evans, 1969, 62). In the 1930s tractors began to replace horses in the arable farming districts but only spread to the North Island dairy farms in the 1940s (Smallfield, 1970, 120). When equipment specially designed for use with tractors also became available, their use grew more rapidly (King, 1950, 70). The provision under Lend-Lease of 7,000 tractors from the United States between 1943 and 1945 (Ross, 1954, 290) spurred development in making the equipment available when supply from other sources was limited. Although the upward trend in tractor numbers was becoming more pronounced, it was not until the 1950s that the greatest expansion occurred (Figure 5.2).

The emphasis on such powered machinery and implements as tractors and milking machines was a consequence of policy:

> The New Zealand authorities had decided in view of shortages of manpower that farmers would have to mechanize to a greater degree. (Ross, 1954, 291)

The horse was being phased out (Table 5.2), and more power was introduced into farming. Track cutting in hill country developed to facilitate the spreading of fertilizer and lime. Agricultural contractors owning specialized heavy machinery 'replaced and added to the number of contractors who used horses' notably in the distribution of soil amendments and so reduced farm labour requirements and some uncertainty (Saxby, 1947, 61). A service industry which had begun to develop prior to the war was now able to expand.

SUMMARY

Cockayne's indication in 1910 of the dominant role grassland would play in New Zealand's agricultural production had been realized by 1949. The intensive exploitation of grassland had been made possible by a conjunction of practical experience and scientific research. The application of this research became 'the sine qua non' of further

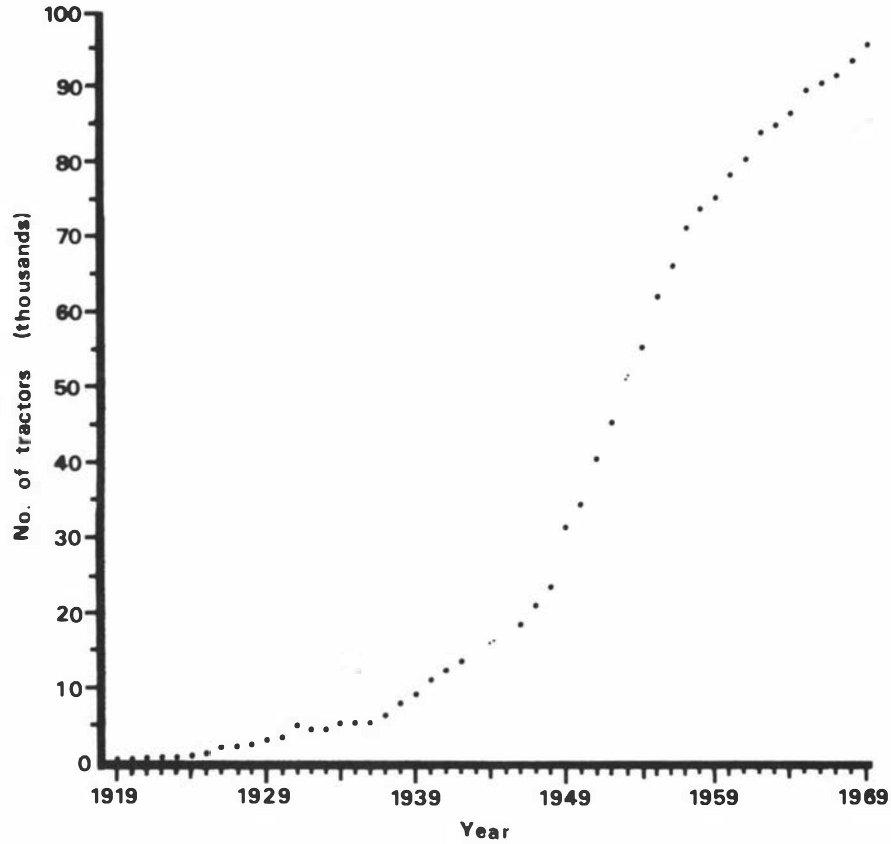


FIG. 5.2 ADOPTION OF TRACTORS 1919 - 1969

Sources: 1919 - 20 *Statistics of New Zealand*, (for year indicated).
1921 - 69 *Agricultural Statistics*, (for year indicated).

progress (Condliffe, 1963, 238). Chemical investigation had pointed out mineral deficiencies in the soil and had identified the role of clovers in furnishing nitrogen for grass growth. Early trials of the soil-amending techniques developed both in Britain and locally, had shown how to overcome phosphate deficiency and excess soil acidity. It was in this period that the application of these techniques by dairy farmers and fat-lamb producers began the cycle of productivity improvement evident in the rapid increase in livestock numbers while the area of improved land stabilized. By the mid-1930s the increased use of chemical fertilizer was regarded as 'one of the most outstanding changes since the war' (Belshaw, 1936a, 27) and the increase in productivity was thought to be due to that very change particularly in dairying (Belshaw, 1936a, 28).

The demands of higher production techniques led to a reassessment of the plants and animals employed. By using a variety of pasture plants in trials researchers had identified the species and strains of grasses and clovers which would give consistently high production. Those strains were then propagated and disseminated through existing seed-trade channels to farmers.

The connection between the biological and chemical sciences was firmly established in agricultural research as the solution of the cobalt-deficiency problem demonstrated. The needs of the proposed, highly productive pasture ecosystem had to be met by knowledge about how to amend soils naturally deficient in essential elements. Soil-amending technology was developed along with the investigation of the soils themselves.

An institutional framework had developed to provide the wide variety of agricultural research demanded. Prior to World War I, the Department of Agriculture, and the Canterbury Agricultural College were the only bodies undertaking research other than farm organizations and the individual farmer. By 1949 there were also a second agricultural college, Massey, the privately-funded Cawthron Institute, the Dairy Research Institute and the Department of Scientific and Industrial Research, all of which gave a broader range of knowledge and contributed a larger body of personnel. New Zealand farming was on a scientific footing, attempting to employ the most beneficial cost-reducing or production-improving techniques being developed in its research centres. Work in other countries was followed closely and links with the British institutions from which the New Zealand framework had been derived, were important in the early phases of grassland technology's development. However, testing was done in New Zealand conditions to assure the applicability of the results. The grassland focus was so reinforced.

New Zealand's economic basis in agricultural production enabled this line of inquiry to be followed with support from both the community and the government. The systems of agricultural production devised to satisfy the British market were further specialized and intensified using the advantages being discovered in grassland farming. This market remained open into the 1930s, so stabilizing economic and preference structures. Though price fluctuations had prompted adjustments to the marketing of some produce, the market demands and linkage were retained. As the production increases sustained in the application of new technology were absorbed in the market and as research results often had immediate application, the discoveries attracted the interest of both the farmers and the producers of the materials to be used. The production of soil amendments, principally lime and superphosphate, increased rapidly and the importation of materials followed suit. Agriculture was becoming increasingly linked with the secondary sector as the use of manufactured inputs increased.

The founding and funding of research institutions was but one aspect of government's support to the agricultural sector. As the sector of the economy developing most rapidly, agriculture was a focus of government involvement. Farming was encouraged by land settlement schemes. The use of new technology was fostered by subsidy programs and the implementation of land development schemes. Where private resources were found inadequate to cope with a crisis, such as land deterioration, economic depression or wartime conditions government intervened, thereby gaining an increasingly important role in directing resources in the economy.

The relative stability provided by the collectivist measures to counter economic and political crises advanced the adoption of grassland technology. Subsidization of manufacture and transport reduced the cost of soil amendments. Policy evolved to assure adequate inputs for grassland technology. Producer returns from the sale of goods were stabilized for dairying initially, and later, for meat. Government undertook to stabilize markets for producers by signing bulk-purchase agreements which linked production to the British market. The basis for continued production expansion was laid through these measures. Reverses through economic depression and war did not serve to stem the advances being made. Institutions to absorb the impact were a critically important development. It appears that the inability to employ the techniques merely served to heighten interest. An upsurge in use followed in each instance, once the supply of materials returned to pre-crisis levels.

Lags in the application of grassland technology developed where enabling invention had not occurred to offset particular problems. Whereas sown pastures were largely being treated, the extension of the techniques into the more difficult relief of the hill country had not been widespread. Mechanization was found to overcome the adverse effect of labour shortage in the dairying and fat-lamb enterprises but it had not yet been applied to soil amending in the sheep farming regions. Tension in the technical structure continued but the pattern of that structure was clear. Grassland farming based on permanent pasture had emerged as the principal agricultural system, one with a capacity for intensification which sustained economic growth in the national economy. In that it served to support the farm enterprises on which the small-farm institutional structure promoted earlier by government was based, soil amending provided a key to sustain existing preference and institutional structures. The success of the economy erected in these circumstances offset the call for economic diversification made when conditions deteriorated in the 1930s. Wartime and postwar demand further delayed the process of change.

FOOTNOTES

1. The account of the growth of fertilizer production is based on McCaskill (1929, 73-81).

2. A superphosphate containing the equivalent of 44 to 46 percent of tricalcic phosphate in a water soluble form.

3. 'The science of grassland construction, management, and utilisation' (Levy, 1970, 359).

CHAPTER 6

THE REFINEMENT AND EXTENSION OF THE GRASSLAND FARMING SYSTEMS

The period from 1949 was one marked by the refinement of lowland plain soil-amending technology and its extension into more rugged sheep farming country. The sheep-farming enterprise had not previously benefited greatly from the discoveries made. Now, with the use of aircraft, mechanization was applied to amend the soils of the steeply sloping country. The success of both changes increased livestock output.

CONCERN FOR SOIL CONSERVATION

Concern for the condition of such country was based on the inability of the pasture ecosystems to maintain themselves there. The high-fertility-demanding swards died out as the nutrients from firing tussock or cutover forest were utilized, leached out or carried away by erosion. Less productive grasses appeared where they were not edged out by secondary growth of scrub and fern or eaten away by introduced animal pests such as rabbits.

Concern about the rate of reversion of cleared land had been expressed by the time of World War I, and the research establishments subsequently set up began to investigate the problem in light of the discoveries being made about the relationship of grass and clover species and soil fertility levels (Levy, 1955, 98, 100-101). The need for amending soils to improve fertility to the point where successful clover growth would furnish sufficient nutrients to sustain an adequate grass cover was recognized. In the 1920s and 1930s some farmers in hill country had begun the arduous task of packing in soil amendments and seed for manual sowing.

Unfortunately the area treated by this method has not been recorded but is unlikely to have been extensive due both to the laboriousness of the task with limited available manpower and to the limited capital available for land development (Smallfield, 1970, 39). It was estimated in 1940 that skilled sowers topdressing at a rate of 2 cwt per acre could cover 15 acres each per day at an average cost of 14s. per acre (£7 per ton). The average rate per man fell to 8 acres per day when the men transporting materials were included in the calculation. Costs could be lower depending upon the type of labour used--hiring a contractor was seen as less expense than employing day labourers, and upon the farm's proximity to a railway station (*Sheepfarmers' Conference Proceedings*, 1940, 11-12).

The practice of topdressing hills varied from farmer to farmer. Where one reported spreading 100 to 200 tons annually, another managed only 20 to 30 tons (*Sheepfarmers' Conference Proceedings*, 1940, 11; B. Moore, 1969, 115). A consistent effort to topdress hill country was absent, and the deterioration of such land was noted. During the war years, as labour became more difficult to obtain, the magnitude of the problem grew. In the immediate postwar years the area in fern, scrub, and second growth continued to rise, reaching over five million acres by 1949-50 (Table 6.1). The inadequacy of the methods employed, the low rate of initial application and the absence of clover oversowing limited the pasture response which could be obtained.

Where the slopes had inadequate vegetative cover there was a greater risk of accelerated soil erosion. The problem was seen in the late 1860s, yet by the 1930s, there were only warnings about it 'but these were few and far between. Those who gave them were usually ignored as cranks' (McCaskill, 1973, 6). High-country farming methods were seen as particularly ineffective in preventing deterioration (Cumberland, 1944, 205). The desire to exploit land outweighed any urge to assess the damage being done, until concern with flooding emerged. The relationship between the damage caused by floods and the denudation of watersheds was recognized, but finding an engineering solution on the lower reaches of the rivers remained more important than implementing soil conservation and watershed management measures in their headwaters (McCaskill, 1973, 13). Severe flooding in the 1930s in parts of the North Island served to focus attention on the seriousness of the problem. The example of the United States, where soil conservation began to be taken seriously following the creation of the 'Dustbowl' in the 1930s, served to motivate people to examine conditions in New Zealand to see what measures, beyond engineering, were applicable (McCaskill, 1973, 17).

There had been little critical evaluation of the extent of soil erosion but by November 1938 sufficient interest had emerged to lead to the establishment of a DSIR Committee of Inquiry. At the time of its report in June 1939 other sources were giving the problem publicity. That month the *New Zealand Farmer Weekly* (60 (15), 3) ran an

TABLE 6.1

AREA OF UNIMPROVED GRASSLAND AND REVERTED LAND (THOUSANDS OF ACRES) 1945-1969

Year Ending 31 January	*Tussock and Native Grasses*	*Fern, Scrub, and Second Growth*
1945-46	13,968.3	4,601.2
1949-50	12,930.7	5,246.0
1950-51	13,112.7	5,245.5
1952-53	13,299.0	5,469
1955-56[a]	13,391.8	5,360.4
1959-60	13,035.5	5,671.7
1960-61	..	..
1962-62	..	..
1965-66	..	..
1969-70	12,373.8	3,617.6[b]

Notes: *a* 1954 figure as 1955 data not available.

b Includes area in flax and rushes.

Sources: *Agricultural Statistics* (for years shown).

article calling for the introduction of soil conservation measures, and in July the *Journal of Agriculture* contained articles (Connell, 1939; Lamont, 1939) indicating the basis of the erosion problem and the value of grass cover and grazing management in limiting it.

Political action to implement soil conservation measures proceeded slowly. Previous attempts to legislate flood control measures in 1929 and 1936 had failed and the onset of World War II directed attention elsewhere. Only in June 1940 was the preparation of another measure concerned with river control begun but the measure did not concern itself with the soil conservation aspect of the problem. Indeed the view of the Minister of Agriculture at the time was that 'In general in New Zealand, erosion per se is not a basic problem calling directly for action' and his Department was more concerned with 'regrassing work in North Island hill country and in the South with investigational work in grassland improvement' (McCaskill, 1973, 22). This view persisted as seen in the report of the Royal Commission on the Sheep-Farming Industry delivered in 1949. It was emphatically stated:

> 'the root causes of erosion are the lack of fertility and rabbit-infestation. ... In fact, the erosion is not due generally to an irremediable characteristic of the land which requires abandonment of farming. Nor does it result from bad farming practices which necessitate spelling of the land control of the farmer. New Zealand is as a whole little threatened by erosion other than river erosion.' (Sheep-Farming Industry Commission, 1949, 42)

Pest control, promoting fertilizer use, and discovering 'suitable highly nutritive, low-rainfall-resistant pasture plants' would set the industry on its way to attaining new production levels (Sheep-Farming Industry Commission, 1949, 43).

Formation of the Soil Conservation and Rivers Control Council

Nonetheless, there was persistent pressure by men such as L.W. McCaskill to integrate flood control and soil conservation measures. McCaskill's experience gained in visiting the United States proved invaluable. In September 1941 a Bill was passed creating catchment districts, each under a catchment board, and the latter co-ordinated and supervised by the central Soil Conservation and Rivers Control Council (abbreviated to SCRCC). This Council first met in September 1942 but found itself without adequate staff and funding. Reports show that:

> After setting up the Council in 1942, the Government of the day left it largely to its own devices, without much help, sympathy, or encouragement to carry out the very vital task entrusted to it. (*Report of Conference of New Zealand Catchment Boards Association,* 1949 quoted in McCaskill, 1973, 29)

The Council was first engaged only in establishing the catchment boards and in taking some stock of the problems with which it would have to deal.

It was fortunate that in 1944 the cause of soil conservation was assisted by the publication of K.B. Cumberland's *Soil Erosion in New Zealand*. This survey assessed regional variations in the extent and nature of the widespread soil erosion in the country and urged a variety of measures dealing with soil conservation. Attitudes to land were criticized:

> There is ... an erroneous idea amongst many agriculturalists and others in this country that New Zealand has attained its food production limit and that maximum agricultural and pastoral output necessarily and inevitably involves losses of soil and fertility. (Cumberland, 1947, 128)

Such was not the case in his view and it was a view publicized by the SCRCC.

This publicity remained the Council's main accomplishment until the immediate postwar period when men and resources became available. In the meantime, the establishment of the catchment boards, with their component of local elected members, served to involve a number of people in evaluating remedial measures. The Manawatu Catchment Board included members of the scientific community centred around the DSIR's Grasslands Research Station. A valuable connecting link between people with a range of experience in dealing with the land was being forged in such a fashion.

THE USE OF AIRCRAFT

It was this ability to seek outside sources of expertise which prompted the SCRCC to consider using aircraft in its work. As early as 1926 a North Island hill-country farmer, John Lambert, had written to his Member of Parliament:

> We have millions of acres of hill land requiring topdressing which can never by done by hand, but it might be worthwhile

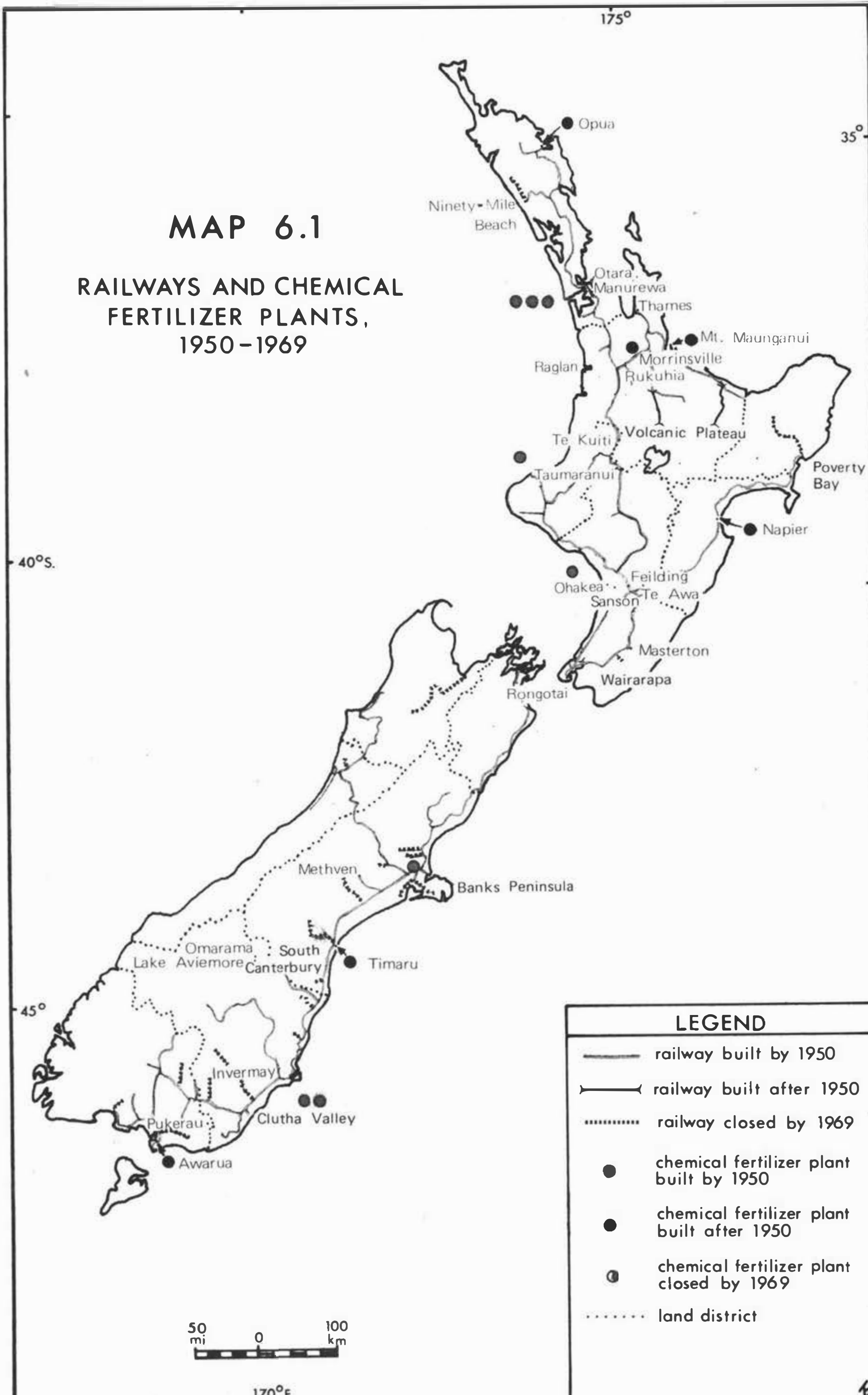
trying from the air. (quoted in McCaskill, 1973, 157)

This statement indicates one farmer's assessment not only of the value of soil-amending techniques being developed but also a realization of the difficulty involved in applying them outside the lowland-plain areas. However, the concept of using aircraft was considered by the Minister of Defence to be impracticable (Alexander and Tullett, 1967, 30).

Early Trials

An awareness of the capability of aircraft was not evident in this decision since the use of aircraft had not developed widely in New Zealand. Whereas aircraft were employed in the United States and Europe for cropdusting and spraying in the 1920s, no incentive to follow this lead appeared in New Zealand. The topdressing materials used on the intensive grasslands were far bulkier than chemical sprays and dusts applied to crops, and the rates of application much greater. In fact, the adequate rates of application were still under evaluation at this time. Indeed, the operation even in the United States remained limited prior to World War II as there were only a few hundred aircraft in agricultural work (Weick, 1959, A-2). There was diversification of the types of work undertaken, however. Seeding and fertilizing had been added to applying pesticides since the early 1930s (Akesson and Yates, 1964, 137). Through experimentation, distribution devices had also been developed (Baker, 1970, 5).

News of such conservation work was carried to New Zealand but was not acted upon immediately (McCaskill, 1973, 157). Sowing seed from aircraft was an idea which occurred to A.M. Prichard, Chief Pilot of the Public Works Aerodrome Services, but his proposals were dismissed until 1939 when he was permitted to oversow a limited amount of lupin seed on sand-dune country along Ninety-Mile Beach (*Fert. J.*, 1956d, 10). This trial was only on a small scale and was only a first attempt to employ techniques developed abroad. Encouragement was not forthcoming. Only in May 1943 was Prichard able to conduct further trials, once again at Ninety-Mile Beach (*Fert. J.*, 1956d, 10). Results were encouraging despite the primitive distribution equipment available and a more sustained effort using a ton of seed was carried out later that year (Alexander and Tullett, 1967, 31-32).


MAP 6.1
RAILWAYS AND CHEMICAL FERTILIZER PLANTS, 1950-1969
175°
35°
40°S.
45°
170°E.
Opua
Ninety-Mile Beach
Otara
Manurewa
Thames
Mt. Maunganui
Raglan
Morrinsville
Rukuhia
Te Kuiti
Volcanic Plateau
Taumaranui
Poverty Bay
Napier
Ohakea
Feilding
Sanson
Te Awa
Masterton
Wairarapa
Rongotai
Methven
Banks Peninsula
Omarama
Lake Aviemore
South Canterbury
Timaru
Invermay
Pukerau
Clutha Valley
Awarua
50 mi
0
100 km
LEGEND
railway built by 1950
railway built after 1950
railway closed by 1969
chemical fertilizer plant built by 1950
chemical fertilizer plant built after 1950
chemical fertilizer plant closed by 1969
land district

Postwar Trials

This work was not expanded as war demands overwhelmed all others. It was not until 1946 that further trials were begun. The material used was not seed but crystalline copper sulphate, a trace element needed to combat copper deficiency. Scientists from the Department of Agriculture's Animal Research Station at Wallaceville wanted to study the effects of this treatment and were able to employ three Public Works Department airmen (A.M. Prichard, A.C.J. Anderson, and J. Frizzell) to spread some 3,300 pounds of crystals over 1,100 acres in the Thames district (Cunningham and Anderson, 1946). Techniques had been improved as specially designed hoppers which included a means to regulate the rate of application were employed. There was no attempt to imitate technology developed in the United States since the 1930s by importing the equipment. The hopper was built by Frizzell (Alexander and Tullett, 1967, 32).

In August 1947 liquid cobalt sulphate was spread on a station near Taumarunui in trials organized by the Public Works Department (Andrews and Prichard, 1947), probably at the instigation of Prichard. Ground control of the spreading was organized and Department of Agriculture officers were assigned to measure the results. The work was most successful and promised a rapid remedy to the 'bush sickness' problem on the central North Island. However, Prichard did not see that the work should be carried out this way:

> Clearly ... aerial topdressing of cobalt sulphate alone would have no application where it is feasible to topdress with cobaltised superphosphate by agricultural machinery or by hand. The possibility of topdressing with cobaltised or ordinary superphosphate by air poses a different set of problems to which the present work offers no direction or direct solution. (Andrews and Prichard, 1947, 505)

He did make one attempt in 1943 to spread fertilizer aerially at Rongotai Aerodrome near Wellington. A low-volume material, granular ammonium sulphate, was used but was found not to spread well. McCaskill (1973, 157) notes:

> It was a pity that this trial, the first attempt in New Zealand to drop fertiliser from the air, should have been carried out with such unsuitable material.

The work in the United States on fertilizer usage went unnoticed it would appear.

Though Prichard may have been discouraged at the prospect of aerial topdressing, others were not. Awareness of the work possibility of aircraft was evidently created through their wartime use. It would have been clear that payloads could be carried anywhere and that realization made possible projects not conceived of a decade earlier. In 1945 Elliott, Saxby, Lynch, and Boot of the Department of Agriculture suggested the feasibility of aerially topdressing this country after a survey in the Poverty Bay area (*Fert. J.*, 1956d, 10). It was further reported:

> In recent years there has been much discussion on the question of aerial topdressing of fertilisers. The matter has caught the public fancy. (Saxby, 1947, 62)

The prospect of performing such work was regarded as less likely than trace element spreading, an activity already demonstrated by 1947, and aerial oversowing, a technique under consideration. In mid-1947, the Poverty Bay Catchment Board approached the Royal New Zealand Air Force (abbreviated to RNZAF) concerning the possibility of airlifting willow poles to an almost inaccessible hill-country station so that they could be planted as part of a catchment protection scheme (McCaskill, 1973, 158). The subsequent drop in June proved very successful, almost as expected, given that the Board had already submitted a conference remit proposing:

> That experimental sowings of seeds from the air should be undertaken upon typical high hill-country where access is not easy (This work should be carried out by the Grasslands Division of the DSIR in conjunction with the Public Works Department). And that the Soil Conservation and Rivers Control Council be asked to sponsor the whole question of these experiments and to include not only seeds but fertilisers in the experimental sowings from the air. (*Report of Conference of New Zealand Catchment Boards*, 1947 quoted in McCaskill, 1973, 158)

The SCRCC's Conservator, D.A. Campbell, was persuaded by the time of the conference in July 1947 to accept such a measure and proceeded to support it enthusiastically. The RNZAF was interested and agreed to co-operate, and the Council itself, in spite of limited funds, agreed to the proposal.

SCRCC Participation

To convert the proposal into action, an Advisory Committee on Agricultural Aviation was formed in November 1947. It became a co-ordinating body of considerable importance in that it came to contain representatives of all organizations to be involved in this aspect of soil amending. These representatives came from the SCRCC itself, the Ministry of Works, the Department of Agriculture, the Civil Aviation Branch of the Air Department, the DSIR, and Federated Farmers. Later meetings included representatives of the RNZAF and fertilizer manufacturers (Campbell, 1956b, 4). Seeding trials were to be carried out by the Aerodrome Services of the Public Works Department as this was Prichard's centre of operation, while fertilizer experiments became the responsibility of the RNZAF.

The seed trials took place at Rongotai Aerodrome to assess the different ballistic characteristics of seeds sown from the air (Campbell, 1948). Then Prichard proceeded with trials in September 1948 on a farm near Gisborne, on a sheep station above Lake Aviemore, and on the Soil Council reserve, Tara Hills, near Omarama (McCaskill, 1973, 159). Though the results were successful, not much enthusiasm developed (McCaskill, 1973, 158).

The fertilizer trials proved more successful from this point of view. The RNZAF was busy adapting a Grumann Avenger torpedo-bomber and its reserve fuel tank for topdressing purposes as no suitable aircraft for this work had been developed anywhere. Controls were created to vary application rates and these were tested at the Ohakea base in September 1948 (Campbell, 1956b, 5-6). The superphosphate first used proved to be too finely ground and drifted too much, so 'hillside super', a more granular type used for distribution on slopes, was employed, and proved more satisfactory (Greenall *et al.*, 1952, 55). The overall results were encouraging enough to prompt a limited experiment in October 1948 on 27 acres of typical hill country. On the property selected near Raglan the Department of Agriculture monitored performance using staff from the nearby newly established Soil Fertility Research Station at Rukuhia (also the site of an aerodrome). Although the fertilizer did not flow properly and this failure led to the covering of the area in several runs rather than one, thereby upsetting the measurement technique (Campbell, 1948, 71), experience was gained in hopper design requirements and in ground-control procedures. The result was:

> these hill trials confirmed the fact that there were no technical problems in satisfactorily distributing fertilizer in bulk from aircraft on hill country. These trials created a tremendous interest in the future prospects ... (Campbell, 1956b, 6)

The original advisory group created in Advisory and Co-ordinating Committee on the Distribution of Fertiliser and Seeds having sub-committees to investigate the aviation, agricultural, transport, fertilizer, and seed sides of the project (Alexander and Tullett, 1967, 36). Following a further trial near Sanson in March 1949 using fertilizer and seed in a modified hopper, a larger scale trial was sought to evaluate the remedies proposed (*Civil Aviation J.*, 1953, 6). The demonstration took place in May 1949 at Masterton, the home of a Wairarapa farmer, L.T. Daniell, who had indicated the difficulties in topdressing by hand in stating: 'I used six pack horses and I am not going to topdress again unless I can use an aeroplane.' (*Sheepfarmers' Conference Proceedings*, 1940, 26). Whereas his fellows laughed at his proposal at that conference at Massey in 1940, at least one academic, A.W. Morton, indicated some support:

> It would appear that this job is one where the flying machine can come to the aid of agriculture, as it has done in other parts of the world, notably U.S.A. and Russia. Topdressing by 'plane would envisage a carefully organised operation under which groups of farmers in a specified locality would agree to have their properties treated at an arranged rate, and would, of course mean the assembling of the fertiliser at some suitable landing ground. This arrangement should appeal to farmers. No trouble about engaging hands for the job, no pack-horses, no cursing wet days, and no worry about deliveries of super. Nothing to do but to pay the Aerial Distributors Unlimited, and watch the grass grow. In all seriousness, the distributors of fertiliser from the air must be carefully considered. The great part of our North Island hill country must be top-dressed to prevent further deterioration, and the task of doing this by hand is one to daunt a Hercules. (Morton, 1940, 28)

It was Daniell who spurred the Council into the demonstration as farmers were not becoming interested rapidly enough in the project (McCaskill, 1973, 159). This trial was to cover 1,008 acres on eleven different properties, so enabling the effect on a wide range of soils, terrain and pastures and farms to be studied. The three RNZAF aircraft used dropped 125 tons of fertilizer and 12 tons of lime in 57 flying hours despite bad weather (Alexander and Tullett, 1967, 37-8).

The results were most satisfactory the Department of Agriculture reported. Although the rate of application was quite variable, a feature ascribed to pilot inexperience, it was concluded that it would not have been possible to achieve better results by any other method (Lynch, 1950, 311). Costs proved acceptable at £15 per flying hour or £7 10s. per acre for transporting and distributing 2 cwt of material for an average distance of 15 miles from the aerodrome. Trials continued until mid-1950s but the success of the operation was apparent by then. Indeed, within a few months of the Wairarapa trial some 200 farmers had applied to have 25,000 acres treated aerially (McCaskill, 1973, 159). By 1955-56 well over three million acres were being so topdressed (Table 6.2). Demand had been created and in a report to the government:

> Strong recommendations were made for the RNZAF to establish a special aerial topdressing flight and service ... . (Campbell, 1956b, 7)

The SCRCC saw topdressing using heavy aircraft as a means to annually treat an area of one million acres of deteriorated hill country and thereby effect soil conservation (Campbell, 1951, 12). This recommendation was not approved.

Private Sector Participation

Whereas those involved in the governmental sphere envisaged agricultural aviation as an activity to be carried out by a governmental service, men already involved in aviation saw an opportunity not to be missed. Airwork New Zealand Ltd. had been founded in 1936 to service aircraft and from this base, its owners, C. Brazier, A.H. Brazier, and J. Frizzell, undertook to modify a de Havilland Tiger Moth (D.H. 82) aircraft by installing a hopper of their own design. This modification was:

> achieved after some months of painstaking experiments and hard work and was finally approved by the Department of Civil Aviation prior to performing the first commercial contract. (Airwork, 1970, 1)

This work was being carried out prior to the demonstration being prepared by the SCRCC. The hopper design was submitted in September

TABLE 6.2

AERIAL TOPDRESSING DATA[a] 1949-1969

Year Ending 31 March	*Thousands of Acres Topdressed*	*Thousands of Tons Spread:*		
		Fertilizer	*Lime*	*Total*[b]
1949-50	48.7	..	..	5.0
1950-51	428.7	..	..	45
1951-52	802.2	..	..	88.9
1952-53	1,376.1	..	..	144.8
1953-54	1,929.5	..	..	203.1
1954-55	2,783.8	..	..	279.0
1955-56	3,853.2	..	..	404.9
1956-57	3,945.6	393.9	34.3	428.2
1957-58	4,159.5	425.5	40.3	465.7
1958-59	3,515.1	368.9	34.2	403.2
1959-60	3,960.9	432.8	41.7	474.5
1960-61	5,241.5	559.7	33.0	592.8
1961-62	5,607.9	597	24.1	821.1
1962-63	5,169.2	591.1	21.0	612.2
1963-64	6,589	705.3	41.5	746.8
1964-65	8,146.3	864.5	58.8	923.3
1965-66	9,437.4	970.9	67.4	1,038.3
1966-67	8,541.7	878.5	58.6	937.1
1967-68	7,030.3	698.8	55.5	754.3
1968-69	7,311.8	717.3	76.3	793.6
1969-70	8,821.3	812.2	87.3	899.5

Note: *a* Figures reported by aerial operators.

b Difference in total due to rounding error.

Sources: 1949-50 *ARAD* (1951, 35).

1951 *ARAD* (1953, 24).

1952-54 *CAS* (1960, 20).

1955-60 *CAS* (1963, 26).

1961-64 *CAS* (1966, 22).

1965-69 *CAS* (1970, 29).

1948, prior to the Ohakea tests, indicating the development of an independent approach to the topdressing question. The flying experience of these men before and during the Second World War must have served to convince them of the utility of the technique. Frizzell's experience on working on a hopper design for the work in the Thames area in July 1946 was transmitted to the private sector where it was further developed and embodied in the Tiger Moth's hopper design.

The firm undertook its own calibration trials in February and March 1949 at Harewood Aerodrome, Christchurch. At first, seed and lime spreading were tested. The firm was persuaded to use superphosphate as it was a better economic proposition being a more expensive yet less bulky material (Alexander and Tullett, 1967, 40). The earliest practical trial had been performed by another pilot, F.J. Lucas, on his brother's farm in 1948. A demonstration was given before farmers in February 1949 at Pukerau in Otago. A few farmers were interested but partners in his firm would not undertake the venture (Lucas, 1968, 76-77). Schumpeter's view of the fundamental importance of entrepreneurship to innovation is borne out.

Support for the idea of aerial topdressing was soon forthcoming from another source. The head of the Agricultural Engineering Department of Lincoln College, A.W. Riddals, demonstrated his belief in the technique following the supervision of the Harewood trials by arranging a meeting between the manager of a large, hilly, farm property on the Banks Peninsula and the operators of Airwork (McCaskill, 1973, 161). This connection of interests led to the first use of aerial topdressing commercially on 27 May 1949.

The results were satisfactory enough for the enterprise to be taken seriously. In an hour's flying, in 300 lb loads, one ton of superphosphate mixed with certified clover and grass seed was spread--a job estimated to have required 14 hours work by a gang of men (McCaskill, 1973, 161). The cost of spreading the 3 tons of material at £5 5s. per ton was considered 'less than half the cost of doing a similar job by hand sowing 10 years previously' (Campbell, 1956b, 7). The figure seems exaggerated in view of the £7 per ton figure cited previously but the cost of aerial application was at least comparable to that of manual application and required much less labour even in its early phase when four men were thought necessary (Woods, 1950, 438). As a shortage of seasonal labour was evident during and after the war, a means of topdressing requiring less manpower was welcome (Ross, 1954, 330). The principal difficulties, the availability of equipment and the cost of the operation, had been resolved (Saxby, 1947, 63).

It took but few jobs for agricultural aviation operators to find more efficient operating techniques. The job of manually loading the hopper from fertilizer bags led C. Brazier to promptly develop a mechanical loader (Airwork, 1970, 2). Although this device proved both inexpensive and serviceable, it was improved by the use of hydraulic rams and a better chassis (Alexander and Tullett, 1967, 41).

By 1950, a major innovation was achieved in developing a bulk loading system. Charges for bags were reduced as was the amount of labour needed to load the aircraft (Robertson, 1962, 4). At this early stage in the industry's growth this innovation proved important as it:

> enabled the fertilizer to be transported, stored and loaded into the aircraft in bulk, which was of course a great advantage to fertilizer companies, carriers, farmers and aerial operators. It [the equipment] enabled the operation to be carried out without the assistance of the farmer who previously had to be on hand to empty the bags of fertilizer into the loader and frequently farm operations were held up (and tempers frayed) waiting for suitable flying weather or while topdressing was in progress. (Airwork, 1970, 3)

The above description gives an accurate indication of the size of the early operations when it is considered that it was applied to the pioneering firm having three aircraft in service. The entry threshold was low as the Tiger Moths were made available from government surplus at £250 each so that:

> An operator could ... start up in business with one or two machines and a cheap loader on a truck and earn big money by distributing 10 to 30 tons of fertilizer per day at a charge of £3 to £5 per ton. (Campbell, 1956a, 7).

This pattern was an immediate result of the efforts of E.A. Gibson, the Director of Civil Aviation, as he envisaged the use of small, privately owned aircraft operating from airstrips on farm properties, as opposed to the SCRCC view that large aircraft in a government-owned concern would provide the service (*Fert. J.*, 1956d, 11). Accordingly, he helped to make surplus New Zealand-built Tiger Moth aircraft available and allowed flying regulations to be adjusted to make this type of flying feasible. With A.M. Prichard, he toured the North Island to convince aero clubs to develop topdressing units (Alexander and Tullett, 1967, 42) and farmers to employ the technique (Rendel, 1975, 72). At least twelve operators (Table 6.3) began in 1949-50 as a result of this tour (*Civil Aviation J.*, 1953, 8).

Formation of the Agricultural Aviation Industry

By the end of 1949 there were five firms with twelve aircraft in operation from five centres: Christchurch and Central Otago in the South Island, and Manurewa, Hamilton, and Gisborne in the North Island (Rendel, 1975, 71). Although there was no direct government involvement in these operations, it is thought that the SCRCC's developmental work and promotional activities were particularly important in stimulating the adoption of agricultural aviation (James, 1966, 12). The attractiveness of being able to continue to fly brought in pilots trained during the war, and so spread the number of firms in operation throughout the country. Their approach to the business was innovative as they sought to improve operating conditions, loader design being one example of this activity. The problems were basically mechanical in nature and so could be solved by individuals with some background in aircraft maintenance. These operators were willing to gamble their capital and their lives to develop this industry (James, 1966, 12)--a degree of risk-taking unlikely to have been permitted in a government-run service. The services of these fledgling firms were either hired out directly or contracted for by stock and station agents who handled fertilizer sales. Early in the development of Airwork's activity, J.C. Paterson of Pyne, Gould, Guiness Ltd. promoted the use of the aerial application, so creating a linkage pattern which was followed elsewhere (McCaskill, 1973, 161).

The growth in the number of aerial operators was rapid, reaching a high of 73 in 1957 (Table 6.3). Rising wool prices (Fig. 6.1) accounted for the availability of risk capital in the initial adoption phase, and a farm-labour shortage for the need to employ some other means of applying fertilizer, lime, and seed, but the underlying cause for the adoption of aerial topdressing must have been a recognition of the utility of employing grasslands technology on hill country. It

TABLE 6.3

NUMBER OF LICENSED OPERATORS AND AIRCRAFT IN AGRICULTURAL AVIATION 1948-1969

Year Ending 31 March	*Licensed Operators*	*Type of Aircraft:*		
		Fixed Wing:		*Helicopters*
		Light	*Heavy*	
1948-49	5	12	—	—
1949-50	12	..	—	—
1950-51	22	..	—	—
1951-52	33	..	—	—
1952-53	39	163[a]	—	—
1953-54	46	204	..	..
1954-55	56	237	..	..
1955-56	59	250	..	..
1956-57	68	262	..	..
1957-58	73	279	..	..
1958-59	69	269	..	..
1959-60	64	248	..	..
1960-61	59	262	..	..
1961-62	59	247	..	..
1962-63	58	255	5	9
1963-64	60	238	5	8
1964-65	60	251	7	10
1865-66	62	284	9	11
1966-67	70	288	10	23
1967-68	65	359[b]	11	34
1968-69	71	332	11	31
1969-70	71	328	10	29

Note: *a* 1952-66 Aircraft available at end of year.

b 1967-69 Aerial work aircraft on the register (1965 figure, 293; 1966 figure, 316).

Sources: Operators-

1948 Rendel (1975, 171).

1949 *Civil Aviation J.* (1953, 8).

1950 *ARAD* (1951, 35).

1951-52 *ARAD* (1953, 24).

1953-70 *CAS* (1970)

Fixed Wing Aircraft-

1948 Rendel (1975, 171).

1952-59 *CAS* (1960).

1960-61 *CAS* (1963).

1962-65 *CAS* (1967).

1966-69 *CAS* (1970).

Helicopters-

1962-65 *CAS* (1967).

1966-69 *CAS* (1970).

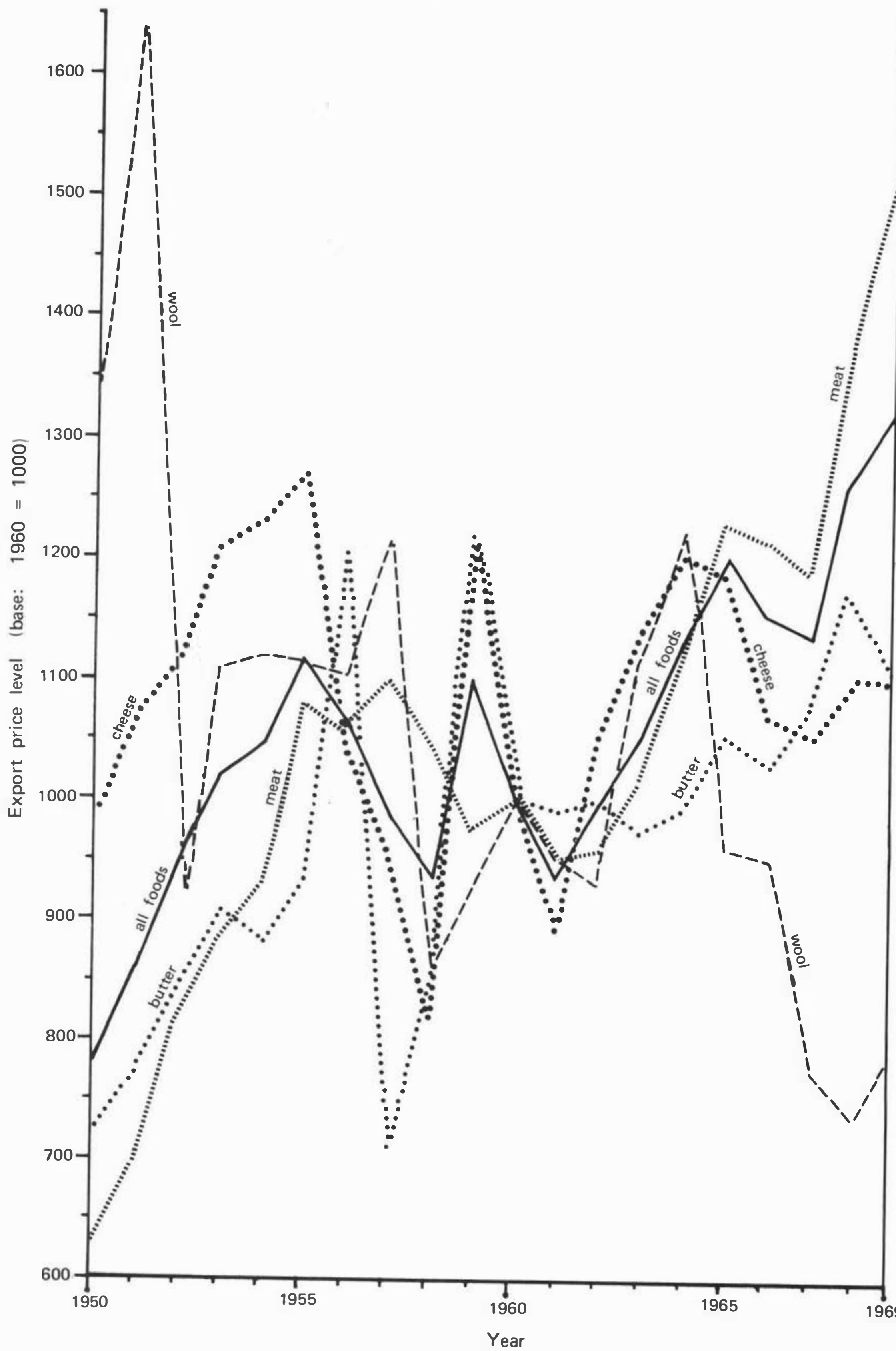


FIG. 6.1 EXPORT PRICE LEVELS 1950 - 1969

Source: *External Trade Statistics*, 1969-70.

was reported that:

> Enthusiastic farmers made airstrips at their own expense and provided assistance for loading the aircraft and often boarded and fed the operators.
> This wave of enthusiastic endeavour swept the country on the crest of a big rise in the price of wool, meat and dairy produce ... . (Campbell, 1956a, 8)

From such sites, 'Under good conditions a plane [Tiger Moth] could cover 250 acres a day at a cost of 50 cents [5s. at that time] an acre' (McCaskill, 1973, 161). Not all farmers supported their enthusiasm with an expenditure in airstrips as they thought the industry was not going to prove viable (Robertson, 1962, 3).

Farmers, did come to realize that limitations to soil-amending techniques in hill country posed by labour shortages and difficult access could be overcome wherever there was both adequate roading to permit the transport of materials within a few miles of the property and an area of sufficiently even ground to serve as a landing strip. Agricultural aviation was able to follow the penetration of higher standard roads being constructed as a result of the growth of motor vehicle transport. In the past, the users of soil amendments relied on rail transport; now truck transport became a substitute, carrying loads to areas once remote from the rail transport network which had achieved its greatest mileage in 1953 (*NZOYB*, 1960, 393). For areas disadvantaged in the use of soil amendments by the absence of rail facilities it became possible to adopt them as rapidly as aerial operators could be found to do the work.

The Government had intervened in 1952 creating a control of the industry through the Air Services Licensing Authority Act which directed operators into building sound businesses (James, 1966, 12). Types of operations and areas of operations were defined for each firm to ensure spreading of the availability of the service and prevent cut-rate competition to stop new entrants into the industry (Rendel, 1975, 72). The industry itself had organized the Aerial Work Operators' Association in 1949 to promote the service and better operating conditions. From 1951, as the Aviation Industry Association, it worked with the Department of Civil Aviation to stabilize the industry (Rendel, 1975, 76) in the period of most rapid expansion of the industry. The area topdressed aerially increased annually by about 50 percent or more from 1951 to 1955 (Table 6.2).

Government regulation in the early postwar period was found to be restricting. The use of helicopters was prohibited on the basis that they were too expensive in requiring dollar payments (Alexander and Tullett, 1967, 73). Regulations controlling civil aviation had not been drafted to encompass the type of flying performed by the aviation firms and the modifications made to their aircraft. The industry association was able to represent the operators as a body and so reduce the time spent by individual firms in dealing with the governmental body.

This work was important as seen in the acreage of grassland treated from the air with fertilizer and lime (Table 6.2). By 1956 this figure represented about 20 percent of all sown grassland and 43 percent of all grassland topdressed. The rate of increase only slowed in 1957 when farm-product export prices as a whole, and wool prices in particular, dropped (Fig. 6.1).

By this time too, the agricultural-aviation industry had begun to stabilize with the change of less than twenty in the number of aircraft employed between 1955-56 and 1965-66 total (Table 6.3). Farmers were interested more in the efficiency of the firm employed. Whereas in the early days of the industry many were willing to invest in a firm to obtain the service and so would overlook some shortcomings, a decade later, the competition was such that proficient and competitively priced service had to be available to retain farmers' custom (James, 1966, 17). Between 1955 and 1959 the amount of material distributed per flight nearly doubled while the acreage treated rose nearly 58 percent (Table 6.4). Improved aircraft could fly longer and faster with more material. The activities of the industry became increasingly diversified in moving away from the distribution of fertilizers, lime, and seed. Larger companies found they had an advantage in having the capital to develop or incorporate innovations such as turbodriven engines for the more specialized aircraft, and superior loader types (James, 1966, 17), but the greater investment entailed meant that higher standards for operating conditions had to be imposed to protect the more expensive equipment. Specifications for airstrips became more demanding and raised the installation and maintenance costs to the farmer. Fewer but better airstrips came to be utilized as a consequence, a condition which improved operating efficiency. By 1954 the aerial distribution costs per ton of

TABLE 6.4

AGRICULTURAL AVIATION EFFICIENCY 1952-1969[a]

Year Ending 31 March	*Amount Distributed Per Flight (cwt)*	*Area Treated Per Flight (acres)*	*Duration of Each Flight (minutes)*
1952-53	4.5	2.1	3.8
1953-54	4.9	2.3	3.9
1954-55	5.2	2.6	3.9
1955-56	7.0	3.3	4.1
1956-57	9.0	4.2	4.1
1957-58	10.0	4.5	4.2
1958-59	10.3	4.5	4.2
1959-60	10.8	4.5	4.1
1960-61	10.9	4.8	4.1
1961-62	11.5	5.2	4.2
1962-63	12.2	5.2	4.2
1963-64	12.3	5.4	4.1
1964-65	12.5	5.6	4.2
1965-66	13.2	5.8	4.2
1966-67	13.8	6.1	4.2
1967-68	14.5	6.5	4.1
1968-69	13.7	6.1	3.7
1969-70	14.7	8.3	4.5

Note: *a* Figures not available before 1952-53.

Sources: 1952-60 *CAS* (1960, 20).
1961-65 *CAS* (1965, 22).
1966-60 *CAS* (1970, 27).

fertilizer spread at a 2 cwt per acre rate had fallen to a level between £1 10s. and £1 14s. in the southern North Island. This figure included fertilizer cost, rail and cartage charges, labour, spreading cost, and interest on the capital invested in the airstrip (*ARDA*, 1954, 32). It is little wonder that farmers were prepared to try the technique at a time when their incomes were high and flocks were being enlarged (Fielding, 1963, 160).

COMPLEMENTARY TECHNIQUES

The role of pasture management in utilizing the benefits to be derived from the use of topdressing and oversowing had been noted. A variety of other complementary farming techniques developed.

Fencing

More effective use of hill-country pasture in particular required greater control of stock and that could only be achieved by better fencing. This concept was highlighted by Suckling's work at the Te Awa Hill Pasture Research Area beginning in 1950. It was found that carrying capacity could possibly be doubled through proper subdivision alone (Suckling, 1965, 9).

Fencing materials, both wire and posts, had been in short supply during the war and remained so following it (Saxby, 1947, 65-66). Prices for wire had doubled the prewar level by 1946 and locally produced posts not only rose in price but also became more difficult to obtain. The result appeared at the time topdressing hill country became practical:

> With fencing costing an average of £400 a mile, many farmers have not been disposed to do any more fencing than absolutely necessary for maintenance purposes. This is a serious matter, for the carrying capacity of many farms would be raised with closer control of grazing, and this can come only from more and smaller paddocks. (Ross, 1954, 293)

In hill country the cost was reported as higher than that cited above, leading to a recommendation in 1949 that new fencing qualify as a capital expenditure for special depreciation for tax purposes (Sheep-Farming Industry Commission, 1949, 117, 127). In 1952 the SCRCC authorized the catchment boards to pay a pound-for-pound subsidy on fencing materials in an attempt to promote grazing management

(Campbell, 1955b, 4-5).

It was recognized that the topdressing and oversowing was largely being wasted without better control of stock to utilize the greater grass growth encouraged. It was estimated that with an aerial distribution of 750,000 tons of phosphate in five years at 5 cwt per acre, three million acres were topdressed, hence:

> The subdivision fencing required to convert normal untopdressed hill-country paddocks to the size required for adequate control of grazing is approximately 1 chain per acre for £10 per acre, making a possible total fencing investment of £30 million necessary. (Campbell, 1955b, 4)

The fencing material necessary for the envisaged 37,000 miles of fences would have required three years' worth of imported fencing wire in addition to posts and battens whose supply was increasingly limited (Campbell, 1955b, 4).

Experiments in the air dropping of fencing materials were conducted by a number by operators and farmers until, 1952, the Director of Civil Aviation organized an investigation by his department. The investigation aimed at establishing trials to see if aircraft could successfully deliver fencing materials to remote locations. The Civil Aviation Administration, the SCRCC, the Department of Agriculture and the de Havilland Aircraft Co. pooled their skills to devise ways in which this practice could be made effective. The experimental program set out was undertaken by the SCRCC between 1954 and April 1955 when a large public demonstration was held to show the results of the work (Alexander and Tullett, 1967, 129-130). Not only were aircraft shown to be able to effectively drop loads of wire and posts, but also a new, lightweight, galvanized-steel posts and battens developed jointly by two manufacturers were demonstrated. The weight per mile of fencing could be reduced from 12 tons to 5 with this system, thereby aiding both aerial operations and those packing the materials in by horse (Campbell, 1955b, 9). Sufficient interest was generated to start a new phase of aerial work. The data provided made its importance hard to assess as the extent of fencing completed is not evident. The data (Table 6.5) only show that demand varied and that the weight of materials was well below that carried for tasks such as poisoning.

TABLE 6.5

AERIAL WORK PERFORMED 1950-1969

Year Ending 31 March	*Top-dressing (acres)*	*Seed sowing (acres)*	*Poisoning (cwt)*	*Fencing Materials (cwt)*	*Spraying (gal)*
1950-51	428,737	16,269	7,134	..	..
1952-53	1,376,118	15,911	26,261	..	28,425
1955-56	3,853,169	50,832	92,338	6,105[a]	374,811
1960-61	5,421,540	76,230	82,396	14,250	1,569,306
1962-63	5,169,210	90,595	115,441	8,639	2,216,112
1965-66	9,200,331	33,748	114,140	9,280	2,795,815
1969-70	8,040,409	248,141	70,280	17,400	4,813,563

Note: *a* 1956-57 figure (first year recorded separately).

Sources: 1950-51 *ARAD* (1951, 35).
1952-55 *CAS* (1960, 20-21).
1960-62 *CAS* (1965, 22-23).
1965 *CAS* (1969, 30-32).
1969 *CAS* (1970, 29-30).

Oversowing

The early work of Prichard in aerial seed sowing for a government department was also taken up by a private flyer F.J. Lucas in early August 1948, when he sowed grass seed on his brother's farm in the Clutha Valley (Lucas, 1968, 73). Later that year he obtained three further contracts for aerial sowing over other properties and dropped 5,300 lb of seed at a cost of £30. In January 1949, he did a much larger job covering 5,000 acres in Methven sowing cocksfoot and white clover seed at a rate of 10 lb per acre. It was a massive job considered 'impracticable' by the Minister of Lands, yet it was completed in less than 43 hours of flying over eight days (McCaskill, 1973, 160).

Experiments with oversowing had revealed problems when seed alone was sown (Campbell, 1948, 76). Pelletizing seed was suggested but was not widely employed (Lindsay, 1961, 6). The practice of sowing seed with superphosphate developed and proved an adequate means of introducing higher quality grasses and the necessary legumes into the pasture sward. This step was needed as it was realized through grasslands research work that:

> The dependence on clovers in pastures for effective responses to phosphates makes oversowing ... mandatory where clovers are not present, and frequently entails the use of lime or molybdenum to ensure their healthy growth. (Campbell, 1955a, 16)

The acreage covered by aerially sown seed was quite variable (Table 6.5). There was an increasing trend but yearly fluctuations in demand were evident. The area covered was far less than that treated with soil amendments.

Pest Control

Lucas was also involved in the initial dropping of rabbit poison from the air in 1948. Again, this activity was first sponsored by a station owner, this one interested in controlling the rabbit population. Because of the success on the several thousand acres covered, the station owner planned to repeat the effort the following year. Very quickly, Rabbit Control Boards engaged pilots to perform this work since it was less expensive than manual applications and could be done much more rapidly (Lucas, 1968, 65). The newly formed agricultural aviation firms found another source of employment which would sustain them until topdressing and oversowing activities became more widely employed. Tonnages rose quickly through the 1950s and only began to wane as the desired effect was achieved in the 1960s (Table 6.5).

The task of rabbit destruction in itself was most important. A Rabbit Destruction Council had been formed in 1947 to invigorate a national campaign as during the war the lack of rabbit shooters and the profitability of selling skins had allowed the pest to proliferate. Nearly 18 million skins had been exported in 1945. Given an estimate that six rabbits consumed as much grass as one breeding ewe, the quantity of skins exported represented a national production loss of nearly 3 milljon ewes (Ross, 1954, 292). The control of rabbits which emerged from this campaign, abetted by aerial distribution of increasingly effective poisons, played a part in increasing sheep numbers. As rabbit control became more effective the amount of work declined (James, 1966, 14), but the extension of the technique to deer and possum control maintained the activity.

Spraying and Dusting

Further aerial operations, trace element spreading, crop dusting and spraying were introduced by Gisborne Aerial Topdressing and by Airwork by 1950 (Bishop, 1952, 118). These activities were more closely related to foreign developments in aircraft utilization but found limited application in New Zealand until the later 1950s. Weed and pest control did not improve productivity as noticeably as topdressing and oversowing, and represented a level of management many farmers had not yet attained. The aircraft used were not particularly suited to this work. Only with the introduction of helicopters in 1955 did the amount of material spread began to increase rapidly (Scott, 1959, 14.1). The rapid increase in volume sprayed shows this trend (Table 6.5). Helicopters were more suited to these tasks and to supply and fence material dropping and they came to dominate these aspects of agricultural aviation (Alexander, 1972, 76). The number of these aircraft remained limited until the mid-1960s when it rapidly doubled from 11 to 23 (Table 6.3). The limited availability could have restricted access to this service over the country.

DEVELOPMENT OF THE AGRICULTURAL AVIATION INDUSTRY

From a small undertaking, the agricultural aviation industry developed rapidly and concerned itself with improving its efficiency and profitability. The success achieved was notable as the average amount spread per flight was increased by almost a further 50 percent between 1959 and 1969 (Table 6.4). Firms were active in finding means to spread a greater tonnage of material without increasing the number of personnel required, thereby, keeping costs low for the farmer (Robertson, 1962, 4).

Aircraft Improvement

Attempts to import aircraft more suitable than the obsolete Tiger Moth--its payload was only 600 lb--were not successful until 1952 when Piper, Cessna, and newer de Havilland models having more power and a larger carrying capacity were introduced. British-designed aircraft were also purchased but did not prove popular (Alexander, 1972, 64). The Canadian-built de Havilland D.H.C.2 Beaver aircraft had a limited appeal. Accordingly, American aircraft became the predominant types. These new aircraft were costly items and did not come to outnumber the Tiger Moths until 1957 (*CAS*, 1960, 19). Load capacities (Table 6.4) increased with the power of the engines utilized and the range of equipment available for use on aircraft developed to give them a wider range of activity.

New Zealand firms benefited as American firms designed aircraft specifically for agricultural work. The agents for Piper and Cessna aircraft were able to import the new models in 1960 and 1966 respectively (Rendel, 1975, 139-140). Developmental work performed elsewhere was embodied in the new designs, and the large output of the companies involved ensured lower cost aircraft with readily available spares.

From being an isolated centre of innovations in this field, the New Zealand agricultural aviation industry was able to show the world what it could offer in holding the first international agricultural aviation show at Palmerston North in 1956. It marked a point at which the exchange of information was facilitated followed by symposia in 1959 and 1964. Techniques developed elsewhere could be assessed through contact with their developers and through some testing in New Zealand. Likewise, New Zealand techniques were transmitted abroad.

Awareness of developments was stimulated by the formation of the International Agricultural Aviation Centre at Wageningen in the Netherlands, which sponsored symposia in 1959, 1962, 1966, 1969, and 1975. However, New Zealand was not always represented at these meetings and only occasionally have New Zealanders presented papers on the agricultural aviation industry (*International Agricultural Aviation Congress Report* for 1959, 1962, and 1966; *Proceedings,* 1971, and 1975).

An important development in this linkage with American aviation was the building of an aircraft, the Fletcher FU 24, designed specifically for use in New Zealand conditions. The concept of creating such a craft was mooted in 1952 by a New Zealander visiting the U.S.A. The idea was followed up by the American firm, Fletcher Aviation Corporation, with negotiations involving a private New Zealand firm and the Civil Aviation Administration who set out the aircraft's specifications. The New Zealand Meat Producers' Board acted as the financial guarantors of the project (Alexander and Tullett, 1967, 58-59). Pilots and maintenance men were questioned about their ideas on the necessary features of a topdressing aircraft and the results, although very varied, did assist in the design work conducted in the U.S.A.

In using American airworthiness standards for the Fletcher, the New Zealand interests were able to speed up development as the American Federal Aviation Administration officers supervising the design and construction of the aircraft made technical knowledge available 'on a scale that the New Zealand airworthiness authorities could never have done' (Rendel, 1975, 75). The link with British civil aircraft standards was ignored, however, and so, New Zealand firms came to favour the use of American aircraft. Even those produced in Australia, were not to threaten numerically the American types. By September 1954 a satisfactory prototype had been built and sent to New Zealand where it earned its Certificate of Type Approved six months later (Alexander and Tullett, 1967, 62). The aircraft were assembled in New Zealand at Hamilton by James Aviation, an agricultural aviation firm emerging as one of the largest, in the country. From assembling the aircraft, James moved to full production after 1966 when the Fletcher project was purchased outright (Rendel, 1975, 75). By then, the Fletcher aircraft, with its 1600 lb payload had become the most widely used for agricultural purposes ahead of either the Piper or Cessna models in numbers and flying hours (Alexander and Tullett, 1967, 63). However, its adoption did take time as in 1956 the Tiger Moth was still the dominant aircraft (*Fert. J.*, 1956d, 12).

The importance of the strong funding and the availability of airworthiness advice is indicated in the lengthiness of development of the one topdressing aircraft designed in New Zealand. An Italian designer working in Australia was invited to design a specialized aircraft by two aviation firms. The venture was begun with capital of only £1,000 and this proved too limited as construction costs exceeded £14,000 (Alexander and Tullett, 1967, 57). Financial control passed from company to company as funds were exhausted but the aircraft, the Bennett Airtruck, was flown in 1960. Its radical design did not meet with immediate Civil Aviation Administration approval so modifications had to be made, to the annoyance of the designer who returned to Australia.

Only one further model of this plane was built before production of the new model, the Transavia PL 12 Airtruk, began in Australia. This model, while successful in New Zealand, was not as widely used as only seventeen such aircraft were registered in 1970 (Rendel, 1975, 74; *CAS*, 1972, 55). The New Zealand-based effort was not as successful as the American-based Fletcher undertaking. The lack of an industrial base and under-capitalization limited diversification.

Loader Improvement

The concern for efficiency in operations also prompted the development of more rapid loading equipment to reduce the time spent by the aircraft on the ground. The developmental work begun by the Braziers was carried on by a number of other companies so that by the time more efficient aircraft were available, more efficient use could be made of them. For example, the Cessna 180, first used in 1952, was able to carry three times the load of the Tiger Moth at 1200 lb of fertilizer and could be charged in as little as five seconds, the total turnaround time being as low as forty seconds (Alexander and Tullett, 1967, 56). The loaders came to be combined with tankers so that with one vehicle operated by one man it was possible to load soil amendments, seed, and refuel the aircraft. Labour costs could be minimized in this fashion as only two skilled men were required on the job, a pilot and a loader operator.

Heavy Aircraft

The initial pattern of topdressing envisaged in the late 1940s--the use of a heavy aircraft carrying a payload of several tons, over distances of up to fifty miles from major aerodromes, did not eventuate until the limitations of the use of small aircraft were realized. Some areas could not be serviced from small strips as road access limited the hauling of fertilizer or no suitable sites for airstrips were located close enough to the area to be treated. However, few areas in the North Island were too distant from an adequate airfield to be untreatable by heavy aircraft (Campbell, 1951, 6).

Such conditions in New Zealand influenced experimental work done in Britain in 1950 using the Bristol Freighter 170. Results, although successful in terms of the application of materials, indicated that an airfield had to be located within forty miles of the job site to make the operation practical (*Civil Aviation J.*, 1953, 9). RNZAF trials with two, smaller, Miles Aerovan aircraft in July 1950 proved them unsuited for the job but they were employed by two South Island agricultural aviation firms (Alexander and Tullett, 1967, 39-40). After this, there was reduced RNZAF participation in work concerned with agricultural aviation. The intention of developing a topdressing service was dropped, and with the limited capital of private operators, heavy aircraft of several tons were not employed.

L. T. Daniell continued to campaign for the use of such aircraft in his position on the Marginal Lands Board (Murray, 1967, 17) and testing was also carried out in New Zealand in March 1954 using the Bristol Freighter aircraft, but it did not result in its being used in agricultural aviation. It was not until 1955 that James Aviation, working with the SCRCC and the Aviation Industry Association, tested the suitability of a Douglas D.C. 3 hired from the government (Campbell, 1956a, 5) for the large-scale job. A new type of loader was built allowing five tons of fertilizer to be put aboard in eight seconds, and so enabling the large craft to take off within three minutes of landing (Alexander and Tullett, 1967, 64). The testing period of eighteen months proved that the plane could manage the job of topdressing areas of hill country previously untouched (Campbell, 1956b, 11).

As a heavy aircraft, the D.C. 3 had a rival. Fieldair Limited, operating in the East Coast region of the North Island, was interested in using heavy aircraft at an early stage. The company was among the first to use the de Havilland Beaver as it could carry one ton of material per flight. In 1954, they undertook to obtain an amendment to their operating licence which would permit the use of a Lockheed Lodestar (*Fert. J.*, 1956f, 21). The public hearings were prolonged, but the result was favourable, with the result that Lodestars obtained from Australia were in operation in New Zealand flying out of Gisborne and Napier in April 1955, while the SCRCC was still testing the D.C. 3's performance and considering the submission to the Air Licensing Authority of a proposal to form a company to operate a Bristol Freighter in the Wairarapa as 'premature at the time' (Campbell, 1956b, 11).

The move to using heavy aircraft did not change the basic pattern of operations. By 1960 only five heavy aircraft were in service, having been pooled by three firms: James Aviation, Fieldair and Rural Aviation to form a company, Airland (N.Z. Ltd.) (Alexander and Tullett, 1967, 97). This consolidation, it was hoped, would permit their use in the most economically practical fashion. It was not an easy matter to put these operations on a profitable footing, the number of heavy aircraft remained limited at ten in 1965 (Table 6.3) when the company became licensed to operate in the South Island as well as in the southern North Island. The Airland grouping did not last, as James Aviation chose to run its own heavy aircraft operations. This change had no great effect on heavy aircraft numbers. In 1969 there were eleven such aircraft in use, all but two, D.C. 3s (Table 6.3). Light aircraft remained the mainstay of the aerial topdressing industry while heavy aircraft provided the service in conditions ill-suited for the former. Co-ordinating operations on individual farms to allow the use of heavy aircraft over extensive areas could be advantageous in reducing application costs, but such a pattern has not yet appeared.

THE GROUND-SPREADING INDUSTRY

The more spectacular agricultural aviation industry has over-shadowed the truck-based industry which, in a similar fashion has extended mechanization and contract services to farm enterprises on sloping land. Whereas in 1949 the prospect of spreading lime from aircraft was seen as unprofitable, the use of trucks for the same purpose in that year initiated the ground-spreading firms (*Fert. J.*, 1957, 7). Stockpiles of lime were established over the year near rural railway stations to overcome the problem posed by the shortage of rolling stock which occurred at peak spreading periods (Warburton, 1962,6). With the extension of the lime subsidy through the Lime Transport Assistance Scheme in 1947 to cover road haulage (*NZOYB*, 1951-52, 386):

> It soon became obvious that the cheapest way of getting this lime sown to a farmer's paddock was through lorries that combined cartage with sowing. (*Fert. J.*, 1957, 8)

The spreading, charge was but a small increase above the normal cartage cost of bulk lime and could be offset by the labour saved by the farmer. The bulk lime did not need to be bagged, an important factor when bags were in short supply, and there was no need for the farmer to have his own topdressing equipment once the logical progression to having fertilizer spread in this same way occurred. This is the trend evident from the mid-1960s (Table 6.6).

Fertilizer spreading was more demanding as the quantity spread per unit area had to be more closely controlled than in the case of lime. Within a year ground-spreading firms were creating devices to control the rates of distribution. The growth of the industry's activity was strongly associated with the development of increasingly efficient hauling and spreading units. By 1957 the trucks used could carry four tons of lime or three tons of superphosphate and pull a trailer bearing twice the truck's load. In ten minutes that load could be discharged at a rate of 1 ton per acre on a suitable field (*Fert. J.*, 1957, 10). The trailer developed by D. Domett of Feilding could also load the truck which hauled it, thereby making the unit that much more efficient.

The service developed was a complement to agricultural aviation in that it treated country on which farmers were more likely to have employed their own equipment. The haulage service was employed by aerial firms thereby saving themselves in their formative stages another capital outlay on trucks and bulk fertilizer and lime stores. These bulk stores were an important development for the service industries in that they permitted firms to ensure continuous service not interrupted by the variable capacity of the railway to supply the needed quantity

TABLE 6.6

SOIL AMENDMENT DISTRIBUTION METHODS 1961-1969

Year Ending 31 January	*Tonnage of Fertilizer Spread:*			*Tonnage of Lime Spread:*		
	By Aircraft	*By Contractor*[a]	*By Farmer*	*By Aircraft*	*By Contractor*[a]	*By Farmer*
1961-62	547,339	650,666		59,754	737,859	
1962-63	541,568	655,792		53,519	667,339	
1963-64	639,200	741,889		81,028	853,883	
1964-65	801,793	449,269	418,031	134,537	825,283	116,115
1965-66	871,693	515,092	407,670	131,167	775,746	141,903
1966-67	903,660	556,623	398,519	118,599	726,644	153,519
1967-68	731,660	550,113	377,316	108,989	574,741	153,821
1968-69	718,554	584,693	376,941	101,234	617,221	148,712
1969-70	816,533	641,974	375,912	119,731	778,734	175,599

Notes: *a* Heading in source 'By Agricultural Contractor'.

b Heading in source 'By Farmer's Own Equipment'.
These are Collectively referred to as 'By Ordinary Means' as opposed to 'By Aeroplane'.

Sources: *Agricultural Statistics* (1962-1969).

of materials at the time required. The labour saving in loading and unloading the material facilitated improvement in operations efficiency for both ground spreaders and aerial operators (Warburton, 1962, 6).

Bulk stores became important over much of the North Island. In the case of the Domett firm, spreading of bulk fertilizer was undertaken in 1950 but had to be discontinued because of the uncertainty of supply. It was not until 1952 with the construction of a store at a railway siding that the service was renewed and, from that point, developed. In the Waikato the introduction of bulk topdressing and bulk storage occurred together in 1953 and both were rapidly extended with the result that approximately 40 percent of the bulk fertilizer employed in the area was handled by bulk topdressing just four years later (*Fert. J.*, 1957, 10). In newly developed areas in the central North Island, heavy demand for the bulk service was thought to be related to the number of returned servicemen for whom land had been prepared since:

> In a great many cases these [the returned servicemen's] are one-man farms, where it is difficult for the farmer to keep up with current work, so he welcomes the opportunity of having this important part of his farm operations done quickly, accurately and at low cost. (*Fert. J.*, 1957, 10)

The advantage of employing a contractor was not wasted on other farmers however, and the service expanded (Table 6.6), particularly in dairying areas where carrying capacity was being increased by heavy topdressing (Clifford, 1966, 28).

The role played by ground spreading cannot be readily evaluated prior to 1964-65 when the figures on soil amending performed by contractors were first separated from those of farmers. Previously, the comparison was with agricultural aviation alone. In terms of tonnage of fertilizer and lime spread, it is evident that the ground-spreading firms have become important indeed (Table 6.6). The aerial distribution of lime has never developed on the same scale as that of ground distribution because of the high tonnage required per unit area (King, 1958, 124). There was some increase in the percentage of work done aerially to 1967-68 as lime was used in a mixture with superphosphate but this fell to just over 11 percent of the total by 1969-70 (calculated from Table 6.6). Being able to apply a heavier volume of soil amendments per unit area on low-relief areas was ground-spreading's great advantage.

In terms of fertilizer spread, the ground-spreading technique advanced on aerial distribution from 1965 on (Table 6.6). Farmers did less of their own spreading as work went to contractors. The trend of decreasing aerial work after 1966-67 may reflect the greater emphasis put on maintaining production on the flatter, more intensively farmed areas which can be treated by truck. At the time of price recovery beginning in 1969-70 (Fig. 6.1), the percentage of aerial work began to recover. The tonnage spread by trucks was greater than the decrease in that spread aerially and by farmers--an indication of the use in at least maintaining the productivity of the areas of lower relief.

Ground-spreading has come to compete with agricultural aviation. The improvements in its vehicles and spreaders have made them able to deal with slopes formerly reserved for aerial distribution (King, 1958, 124). The blower-type spreader developed in the late 1940s came to be used in this fashion (Critchfield, 1969, 62). Trials held in the same period as the aircraft trials proved the method functional although there was little control of the area covered and application rate (Lynch, 1951, 56). Nonetheless, it was reported that this equipment was employed after 1949 (Lynch, 1951, 49) and was linked with the aircraft as an innovation of importance to hill-country improvement (Saxby, 1957, 13), through its use on four-wheel-drive vehicles (Levy, 1961b, 124). However, there is little documentation of such developments in the sources consulted, whereas the aviation aspects have had a good deal of publicity.

THE AGRICULTURAL LIME INDUSTRY

The promotion of lime use following World War II was notably successful as farmers had become increasingly aware of the importance of lime during the war (Saxby, 1947, 60) when it was substituted for unavailable fertilizer. The alteration of the subsidy program in 1947 had the desired effect as the number of lime plants increased through 1951 (Table 6.7) as did the amount of lime produced (Table 6.8). The importance of rail transport can also be gauged (Table 6.8) but the problem of insufficient rolling stock curbed expansion (*ARDA*, 1952, 58). The decreasing use of rail carriage shows

TABLE 6.7

SOURCES OF SOIL AMENDMENTS (NUMBER OF PLANTS) 1945-1969

Provincial District [a]	1945	1950	1955	1960	1965	1969
Type of Establishment: Meat-processing Plants [b]						
North Auckland				5	5	4
Auckland	7	8	7	1	3	3
Gisborne				1	1	1
Hawke's Bay	3	3	3	3	3	3
Taranaki	3	3	3	3	3	2
Wellington	7	7	6	6	6	8
Marlborough	1	1	1	1	1	1
Nelson	1	1	1	1	1	2
Westland	—	—	—	—	1	1
Canterbury	10	9	7	7	7	8
Otago	7	9	4	4	5	5
Southland	6	7	4	5	5	5
New Zealand	45	48	36	37	41	43
Boiling-down and Manure Plants [c]						
North Auckland				10	8	8
Auckland	14	15	18	5	3	3
Gisborne				1	1	1
Hawke's Bay	2	2	1	1	—	—
Taranaki	2	2	2	3	4	3
Wellington	8	6	8	7	6	3
Marlborough	2	2	2	2	—	—
Nelson	—	—	1	1	1	2
Westland	—	—	—	—	—	—
Canterbury	6	6	4	2	2	2
Otago	3	3	4	4	5	4
Southland	1	—	2	2	2	2
New Zealand	38	36	42	38	32	28
Lime Plants [d]						
North Auckland				15	27	24
Auckland	34	42	29	4	3	8
Gisborne				—	—	—
Hawke's Bay	3	4	4	6	7	7
Taranaki	—	—	—	—	—	—
Wellington	6	6	5	3	4	3
Marlborough	3	4	4	2	5	2
Nelson	18	13	6	3	6	5
Westland	2	2	2	2	2	2
Canterbury	9	15	17	17	20	19
Otago	8	6	5	5	4	3
Southland	8	8	12	10	11	11
New Zealand	91	100	84	67	89	84
Chemical Fertilizer Plants						
North Auckland				3	5	4
Auckland	4	3	3	2	2	2
Gisborne				—	—	—
Hawke's Bay	—	—	1	1	1	1
Taranaki	1	1	1	1	1	1
Wellington	1	1	1	1	1	1
Marlborough	—	—	—	—	—	—
Nelson	—	—	—	—	—	—
Westland	—	—	—	—	—	—
Canterbury	1	1	1	1	3	3
Otago	2	2	2	2	2	2
Southland	—	—	—	1	1	1
New Zealand	9	8	9	12	16	15

TABLE 6.7 (Continued)

Notes: *a* By statistical area for 1960-69 (Map 7.1).

Below are the headings under which the number of plants are found in the statistical sources:

b meat-freezing and preserving.

c 1945-50 boiling-down, glue and manure making.

1955-69 vegetable and animal oils and fats.

d 1945-50 lime crushing or burning and cement-making.

1955-69 lime.

Sources: *Industrial Production Statistics* (for years shown).

TABLE 6.8

TONNAGE OF AGRICULTURAL LIME OUTPUT[a]
AND CARRIED BY RAIL 1945-1969

Year	*Quarry Output*	*Carried by Rail*
1945	812,635	..
1949	1,100,126	..
1950	1,259,759	653,733
1952	1,366,651	557,596
1955	1,444,810	575,353
1959	1,011,879	252,351
1960	885,949	264,506
1962	844,354	196,647
1965	1,129,711	192,000[b]
1969	1,010,194	105,000[b]

Notes: *a* Domestic rock phosphate production ended in 1945.
b To nearest thousand.

Sources: *NZOYB* (for years shown).

the impact road transport and the development of ground-spreading equipment had in the period. Areas more remote from lime plants enjoyed a 'substantial increase in the use of lime' (*NZOYB*, 1954, 453), through the subsidy arrangement. To reduce the cost problem, new lime plants were opened in localities previously dependent on long rail hauls. These new locations were probably in Auckland and Canterbury as these were the only districts in which the number of plants increased to 1949-50 and 1950-51 respectively (Table 6.7). Relocations may have occurred where one plant closed while another opened in the same district, but data to substantiate this pattern have not been located.

What was clearly the pattern to 1960-61 was the reduction in the number of plants (Table 6.7). This decrease did not reduce output until the later 1950s but thereafter, total production declined through the mid-1960s (Table 6.8). The discovery that the use of small quantities of molybdenum could reduce lime applications and the introduction of molybdenized superphosphate by 1953 (*ARDA*, 1953, 24) clearly depressed production. Though unfavourable weather was recorded as a reason for the reduction in lime use in the 1955 and 1956 seasons (*NZOYB*, 1958, 52), the trend continued thereafter, an indication that an alternative treatment method had been found. By this time the industry had developed to the point where productivity had improved through the use of modern equipment and modernized production methods to give farmers 'more lime, better quality, at relatively lower prices' (*ARDA*, 1955, 23).

Economic problems after 1957 ended the lime subsidy at the end of November 1959. The Dairy Board had been unable to meet its contribution after 1958 and the Meat Producers' Board announced in November 1959 along with the former body that it would no longer contribute to the scheme (Long, 1963, 12). The Government, accordingly, ended its contribution (*NZOYB*, 1960, 501). The effect on rail carriage of lime was most evident. The amount carried rose in 1959-60 perhaps in anticipation of the subsidy cut, and then fell sharply (Table 6.8). Lime production fell to less than one million tons for the first time since the war as a number of plants closed (Table 6.7).

A scheme introduced to subsidize lime use on newly developed land, not previously limed (*NZOYB*, 1960, 501), did not induce much greater use until the mid-1960s, when levels of over one million tons were again achieved by a greater number of plants (Tables 6.8 and 6.7). About half the payments made under the program were for government land development schemes (Long, 1963, 12). The recession of the late 1960s reduced consumption, so production levels dropped, although the number of plants did not decrease as greatly as had occurred a decade earlier (Tables 6.7 and 6.8). Lime production was stabilizing as farmers worked out soil needs and used lime more judiciously in conjunction with fertilizers. Soil amending with lime alone decreased while its use with fertilizer remained stable (Table 6.9). By 1958 it was reported that the lime treatment on much flat country had already created suitable soil acidity levels (*ARDA*, 1958, 28). In contrast, hill country had not been widely treated with lime. The development of molybdenized superphosphate in the mid-1950s meant that less lime was needed on responsive soils. The reduction in bulk permitted agricultural aviation to play a more prominent role in lime spreading thereafter (*ARDA*, 1960, 41; Table 6.6).

THE FERTILIZER INDUSTRY

Following the war the domestic fertilizer industry faced a number of challenges which imperilled its already established importance to gross farm output (Philpott and Stewart, 1958b, 27-28).

Production Difficulties

The supply problem in the fertilizer industry had not been overcome by the time the new forms of distribution had been developed. The plant producing Heskett slag at Huntly closed in 1949 after the removal of the wartime production subsidy (Tait, 1957, 195). Production of organic fertilizers remained inadequate even after a 50 percent price rise following the lifting of the price controls (*ARDA*, 1951, 20). The quantity produced tended to vary little (Table 6.10) despite strong demand and so, its role in topdressing can be assumed to have been small (*ARDA*, 1955, 23).

For a period from July 1949 to June 1951 the price of imported phosphate was subsidized 'to redress the wide difference in price between these fertilizers and locally produced superphosphate' (*NZOYB*, 1951-52, 386). As local fertilizer production recovered following the restoration of full phosphate output from Nauru and Ocean Island (Table 6.11), the need for fertilizer imports was reduced as seen in

TABLE 6.9

SOWN GRASSLAND TOPDRESSED BY TREATMENT TYPE (THOUSANDS OF ACRES) 1945-1969

Year Ending 31 January	*Fertilizer*	*Lime*	*Fertilizer and Lime*	*Total Area Topdressed*
1945-46	1,757.8	606.7	1,288.7	3,653.2
1948-49	2,981.9	584.4	1,496.1	5,062.4
1949-50	3,754.3	589.6	1,394.5	5,738.4
1950-51	4,155.9	649.5	1,521.3	6,326.7
1951-52	4,361.2	664.5	1,436.4	6,462.2
1952-53	4,941.7	626.4	1,597.8	7,165.9
1953-54	5,377.4	531.4	1,546.3	7,455.1
1954-55	6,016.7	550.4	1,673.4	8,240.6
1955-56	..	..	..	8,932.5
1956-57	7,191.2	521	1,457.8	9,170
1957-58	7,310	514.3	1,433.3	9,257.7
1958-59	7,174.2	450.6	1,177.1	8,802
1959-60	7,140.2	421.9	1,335.2	8,897.3
1960-61	8,208.6	356.3	1,249.2	9,814.1
1961-62	8,530.1	332.4	1,132.3	9,994.8
1962-63	8,637.5	318.8	985.8	9,942.1
1963-64	9,750.6	382.9	1,257.7	11,391.2
1964-65	10,846.3	392.9	1,606.7	12,845.9
1965-66	11,295.4	365.7	1,439.0	13,100.0
1966-67	11,863.1	347.6	1,405.2	13,615.9
1967-68	10,736.9	325.4	1,167.3	12,229.6
1968-69	11,139.4	339.8	1,179.5	12,658.7
1969-70	11,994.1	408.7	1,563.9	13,966.7

Note: Sums of treatment type not equalling total topdressed are due to rounding error.

Sources: *Agricultural Statistics* (for years shown).

TABLE 6.10

TONNAGE OF ORGANIC FERTILIZER PRODUCTION[a] 1945-1969

Year	*Bone-dust*	*Blood-and-bone and Blood*	*Other*	*Total*	*Mixtures*
1945-46	5,524	22,219	2,474	38,542	8,304
1949-50	4,309	22,729	1,104	38,450	10,308
1950-51	4,063	23,629	1,392	29,084	8,745
1952-53	7,624	22,543	855	31,022	5,276
1955-56	4,150	30,028	809	34,987	6,172
1959-60	5,475	32,910	1,210	39,595	3,090
1960-61	4,313	36,686	1,459	42,458	2,750
1962-63	4,485	39,682	2,810	46,977	2,663
1965-66	4,550	26,200	6,350[b]	37,100	250
1969-70	3,300	26,600	8,400[c]	38,300	900

Notes: *a* From meat-processing plants and boiling-down plants to 1965; thereafter, output from soap-making plants and chemical plants not elsewhere listed also included.

b Includes boneflour.

c Includes boneflour and livermeal.

Sources: *Industrial Production Statistics* (for years shown).

TABLE 6.11

TONNAGE OF PHOSPHATE IMPORTS 1945-1969

Year	*Bone-dust*[a]	*Basic Slag*	*Super-phosphate*	*Rock*[b]	*Guano*	*Other*[c]	*Total*
1945	..	—	—	241,345	46	--[d]	241,391
1949	—	42,101	2	440,133	8,330	—	490,566
1950	—	65,319	1	580,617	267	2	646,206
1952	17	47,102	477	675,428	13,236	267	736,527
1955	—	66,532	7,517	578,474	—	120	652,643
1959	—	25,369	70	469,373	—	305	495,047
1960	—	29,385	—	608,195	—	2,572	640,152
1962	—	21,522	6	593,630	—	4,942	620,100
1965	6[f]	15,915	29[e]	860,951	..	2,968	879,869
1969	2	2,079	161[e]	1,037,390	..	9,995	1,049,627

Notes: *a* Comprises all organic manures including bone-char.
b Comprises rock phosphate from Pacific Island and North African sources.
c Other manufactured phosphatic fertilizers only. Other crude phosphates included with guano.
d Includes bone-dust.
e Total import for June year. The assumption has been made that this represents the full year import as supplementary data for the July-December period to rectify figure are not available.
f Other natural animal or vegetable fertilizer, including guano, landed in June year.

Sources: 1945-60 *Trade and Shipping Statistics* (for years shown).
1962 *Trade and Shipping Statistics* (1962a; 1962b).
1965-69 Calculated from data in *Import Statistics* (for July years containing the years shown and *Trade and Shipping Statistics* (for July-December period of years shown).

the decrease of basic slag imports (Table 6.11). The increasing cost of imports also made superphosphate use more attractive (*ARDA*, 1952, 58) and its use finally superseded that of basic slag (Table 6.11). Demand rose sharply as wool prices increased to 1951 (Fig. 6.1) and accentuated the shortages of raw materials. Rock phosphate imports were returning to prewar levels in 1950 (Table 6.11) and, in 1948, in conjunction with Australia, the New Zealand Government had purchased the rights to the mining of Christmas Island phosphate to assure supply after the anticipated depletion of the Nauru and Ocean Island deposits (*Fert. J.*, 1956c, 11).

More critical to the fertilizer industry in the early 1950s was the worldwide sulphur shortage which limited New Zealand's postwar superphosphate production. Whereas it was estimated that the country would have required 90,000 tons of sulphur to meet its need for superphosphate production of 800,000 tons, only 65,275 tons, roughly the level used in 1949 (Table 6.12), were allocated for 1951 by the Sulphur Committee of the International Materials Conference (*ARDA*, 1952, 57-58). Instead of rationing supplies again, the 'bulking-up' method as used with serpentine superphosphate was employed. Straight superphosphate supplies were discontinued in 1951-52 (Table 6.13) and the choice of fertilizers containing superphosphate restricted to: 'lime-reverted super', 75 percent superphosphate and 25 percent crushed limestone; 'serpentine super', 75 percent superphosphate and 25 percent crushed serpentine rock; and 'super compound', 75 percent superphosphate, 15 percent ground raw Nauru rock phosphate, and 10 percent lime or serpentine (*ARDA*, 1951, 20).

Farmers' familiarity with the serpentine superphosphate during the period of wartime restrictions led to a preference for it, but transport difficulties limited the quantity of rock carried from the quarries near Te Kuiti to North Island factories and so restricted production. Although it was expected that the procedure would lead to a production of 700,000 tons of mixtures (*ARDA*, 1952, 58), the total reached just over 785,000 tons that season (Table 6.13). The exhaustion of this serpentine source by 1956 and the lack of an equally well-sited source encouraged the use of other phosphate fertilizers (*ARDA*, 1956, 23).

The shortage did not last beyond mid-1952, however, (Table 6.12), as rising prices and new technology boosted sulphur production (*Fert.*

TABLE 6.12

FERTILIZERS BY TONNAGE OF NUTRIENTS 1945-1969

Year	*Nitrogen*[a]	*Phosphorus*[b] *Domestic*	*Phosphorus*[b] *Imported*	*Potassium*[c]	*Sulphur*[a]
1945	1,106	4,198	81,630	3,429	51,873
1949	1,078	—	178,220	4,156	64,832
1950	1,333	—	234,741	7,218	62,463
1952	1,756	—	270,120	14,100	79,235
1955	5,519	—	236,809	23,442	127,923
1959	3,209	—	183,978	44,947	88,146
1960	4,371	—	238,594	55,826	133,022
1962	3,670	—	225,545	59,329	104,848
1965	5,509	—	331,929	98,080	184,368
1969	6,810	—	399,914	94,206	193,994

Notes: *a* Measured on elemental content.

b Phosphoric acid (P_2O_5) content.

c Water soluble potash (K_2O) content.

Source: Calculated from:

1945-60 *Trade and Shipping Statistics* (for years shown).

1962 *Trade and Shipping Statistics* (1962a; 1962b).

1965-69 *Import Statistics* (1964; 1968, and for years shown); *Trade and Shipping Statistics* (for years shown).

Method: After 1961 imports were recorded for June rather than December years. The calendar year figures in the table were calculated as follows:

1962 January-June and July-December figures were added.

1965-69 t = year shown; t-1 = preceding year

July-June (t)
- July-December (t-1)
January-June (t)
+ July-December (t)
January-December (t) = calendar year (t)

Using the calculation method above the data for each calendar year could be obtained. As the *Trade and Shipping Statistics* provided a less detailed analysis than the *Import Statistics*, the imports not recorded in the former source were assumed to have occurred in the calendar year. Since these imports were small quantities, the assumption would not have greatly influenced the final results obtained.

TABLE 6.13

TONNAGE OF PHOSPHATIC FERTILIZERS MANUFACTURED 1949-1969

Year Ending 30 June	*Superphosphate:* *Straight*	*Aerial*	*Serpentine*	*Other Primary Fertilizers*	*Total Primary Fertilizers*	*Secondary Mixtures*	*Total*
1949-50	439,091	—	128,262	19,763	587,116	108,470	695,586
1950-51	255,583	—	118,784	270,139	644,506	88,538	733,044
1951-52	6	—	177,291	510,945	688,242	96,852	785,094
1952-53	139,677	—	184,802	277,130	601,609	172,878	774,487
1953-54	377,336	—	177,258	38,702	593,296	216,207	809,503
1954-55	522,977	—	203,910	38,060	764,241	252,140	1,016,381
1955-56	553,977	15,230	178,898	50,207	798,312	287,177	1,085,489
1956-57	447,743	20,316	191,859	31,611	691,529	296,037	987,566
1957-58	394,297	15,664	203,008	27,783	640,752	326,563	967,315
1958-59	318,265	97,273	152,088	29,662	597,288	351,962	949,250
1959-60	267,878	157,455	169,149	30,708	625,190	485,394	1,110,584
1960-61	280,722	202,508	155,962	23,702	662,894	607,287	1,270,181
1961-62	260,369	209,600	142,868	26,587	639,423	562,471	1,201,894
1962-63	305,379	262,194	167,399	26,160	761,132	616,642	1,377,774
1963-64	354,023	344,326	153,473	30,371	882,193	719,443	1,601,636
1964-65	403,225	428,892	146,239	29,950	1,008,306	812,178	1,820,484
1965-66	438,174	434,797	159,331	32,116	1,064,418	883,485	1,947,903
1966-67	461,242	306,010	127,912	30,864	926,028	811,222	1,737,250
1967-68	541,840	187,624	110,121	26,958	866,543	752,740	1,619,283
1968-69	768,463	56,334	114,828	30,587	970,212	876,015	1,846,227
1969-70	817,385	44,232	83,227	31,943	976,787	909,086	1,885,873

Source: *Fertiliser Statistics* (1969, Table 1).

J., 1954a, 22), but the production of straight (pure) superphosphate did not exceed the 1949-50 production level until 1954-55 (Table 6.13). In that season, local production of superphosphate and superphosphate mixtures exceeded one million tons for the first time. The subsidy on imported fertilizer which had been renewed in 1953-54 to cope with the sulphur shortage was accordingly discontinued the following year (*NZOYB*, 1955, 468, 498). Thereafter tonnages remained low (Table 6.11). Sulphur supplies became assured, so permitting the expansion of production along established lines with a phosphate nutrient predominance (Table 6.12). The crisis had prompted the government to seek advice on how to overcome the problem. Sulphur smelting using concentrated Australian pyrites and the construction of new plants to produce phosphate fertilizers not requiring sulphur were recommended, but the lack of pyrites supply, inadequate electricity supply, and a capital shortage operated against the realization of these proposals (*ARDA*, 1952, 58).

The restriction on supply had an effect on the service industry dependent upon it. Campbell (1956a, 8) observed that:

> The immediate and profitable response to 'super' on the better hill country aggravated the shortages prevalent due to low manufacturing capacity of existing works, and this had a steadying influence on the growth of the agricultural aviation industry.

When viewed in light of the number of operators in business and the equipment available to them (Table 6.3), it is likely that some steadying of growth did occur which permitted stable forms of operation to develop. Operational efficiency problems could have been overcome by making available the funds needed for the purchase of more modern aircraft with greater payloads. From April 1954 to February 1956 the Meat and Wool Producers' Boards, recognizing the importance of agricultural aviation, made just such an attempt in offering loans at 3 percent interest on up to 60 percent of the purchase price of new aircraft. A sum of £25,000 was made available for the purchase of 62 aircraft (Murray, 1967, 16). The venture resulted in newer aircraft such as the Fletcher FU 24 being purchased. The Tiger Moths were largely replaced by 1960 when they no longer outnumbered any other single type of aircraft (*CAS*, 1963, 24).

Capacity Increase

The fertilizer production capacity of the country's factories was also expanding. The 1948-49 of capacity 650,000 tons (Ross, 1954, 322) had been increased to 800,000 tons three years later (*ARDA*, 1951, 20). Expansion continued to 1957. For example, Kempthorne, Prosser and Co. extended the production capacity of their South Island plants to 167,000 tons from 132,000 tons between 1953-54 and 1956-57 (*Fert. J.*, 1956b, 18-19) and that of the Aramoho plant near Wanganui to 130,000 tons (*Fert. J.*, 1956e, 20). The capacity of the Dominion Fertiliser Company's plant at Dunedin was increased from 97,000 to 125,000 tons in two years (*Fert. J.*, 1956b, 19). In June 1954 the East Coast Farmers' Fertiliser Company Ltd. plant near Napier opened to serve that area of the North Island. In its first year of operation about 108,000 tons of material were produced and by 1956 production capacity was doubled (*Fert. J.*, 1961b, 14). Complete figures are not available, but the trend was clear.

The Meat Producers' Board was closely linked with the establishment of the latter plant in lending £1,000,000 to overcome the financial difficulties encountered by the organizers of this project. The group responsible had incorporated the company in 1949 but were hampered by shortages of materials and finance until the Board arranged this loan (*Fert. J.*, 1961b, 14). The output of this factory helped to boost New Zealand's fertilizer production over the 1,000,000 ton mark in 1955.

Two similar co-operative ventures were organized in other regions of the country. The Southland Co-operative Phosphate Company Ltd. began operation in September 1958 at Awarua in a plant with a production capacity of 100,000 tons of superphosphate (*Fert. J.*, 1961a, 18). At Mt. Maunganui in the North Island, the Bay of Plenty Co-operative Fertiliser Company Ltd. began production in July of that same year with a plant of similar production capacity (*Fert. J.*, 1964a, 4). The Meat and Wool Producers' Boards again provided funding for the project.

Two privately owned firms, Challenge Phosphate and New Zealand Farmers' Fertilizer Co., joined to build a factory at Morrinsville in the Waikato to serve the growing demand there. Although it was anticipated in 1955 that the 100,000 ton-capacity plant would be completed in early 1957 (*Fert. J.*, 1955d, 18), it was not into production until 1958 operating as the Kiwi Fertiliser Company Ltd. (*Fert. J.*, 1959b, 25). This plant was noteworthy for its reliance on road transport in not being situated close to a port. The use of motor vehicles indicated the desire to be independent of problems associated with rail transport.

Innovation

These plants employed a variety of modern production techniques developed abroad to keep manufacturing costs down while prices were controlled. They also constituted a source of information on innovation for other concerns. The grouping of the research efforts of the companies provided them with the opportunity to jointly assess the efficiency of their production techniques. Older factories were modernized with the use of newer methods of sulphuric acid production and the installation of machinery for continuous superphosphate production (*Fert. J.*, 1954b). The need to expand production provided the incentive to explore new production methods suited to the existing plants. That this expansion was successful can be judged from the 1,770,000 ton production-capacity figure given for 1964 and the plans for further expansion (*Fert. J.*, 1964a, 4). In the next five years only two additional plants were opened, one at Opua in 1965 to serve the rapid land development in Northland and a second at Timaru to serve South Canterbury as the one plant near Christchurch could not supply all the northern South Island (Map 6.1). Although capacity figures have not been published, the continued expansion of output is evident in the rise of the production volume index from 1537 in 1963-64 to 1918 in 1969-70 (1956-57 base = 1,000) (*Industrial Production Statistics*, [for year indicated]). The continued rise in fertilizer topdressing seen in Table 6.9 was being met by domestic output as decreased manufactured-fertilizer imports indicate (Table 6.11).

This industry was well able to meet the demand for fertilizer as indicated by the generally increasing imports of rock phosphate and sulphur (Tables 6.11 and 6.12) and the rising trend in fertilizer output (Table 6.13). The close liaison between the parties interested in fertilizer usage provided the basis for adjusting production types to meet new demands and led to the acquisition of special equipment (Saxby, 1957, 13). The Aviation Industry Association, for example, convinced companies to order granulation equipment. In 1955, the

Ravensbourne plant near Dunedin began to produce a more granular fertilizer by screening out fine materials and incorporating one part of ground serpentine rock in nine parts of superphosphate. The improved flow characteristics facilitated aerial distribution (*Fert. J.*, 1955b, 17; Thom, 1974, 5). Previously serpentine superphosphate had been used for this reason but the improved form was favoured. Output increased markedly from 1957-58 (Table 6.12), and this 'aerial super' was produced at most other plants (*Fert. J.*, 1959a, 24) through the 1960s so stabilizing the demand for 'serpentine super'.

Although granulated superphosphate was developed just prior to World War II, not until it was introduced at no extra cost in 1964 (*Fert. J.*, 1968, 17; Nixon, 1970, 2) did the production of 'aerial super' show any indication of declining. Shortly thereafter its production dropped rapidly with the decline of export prices in 1966-67 (Fig. 6.1). Even after this recession, the production of 'aerial super' did not recover. The use of serpentine superphosphate also declined in this same period to levels similar to those at its introduction almost 25 years earlier (Table 6.13).

External Influences

Needs were being reassessed by interested groups outside the manufacturing industry itself. Those storing and spreading material could indicate the properties they found desirable, the farmers could choose the material which provided the best response in pasture growth, and researchers in the Department of Agriculture and the DSIR could indicate the types of materials needed from a scientific viewpoint. The key decision-making power remained with the users--the farmers.

Government provided inducements to prompt greater fertilizer and lime use but it did not directly intervene in applying soil amendments except on its own land development projects. Price control on fertilizers was maintained until June 1968, so minimizing variations in 'ex-works price' of superphosphate. The only major increase, \$2.85 per ton, occurred in 1967 following monetary devaluation (Warburton, 1974, 3). Subsequent increases were more related to increases in raw-material prices, particularly after termination of the non-profit British Phosphate Commission's operations in Nauru in 1968 when world market prices had to be paid.

From 1962 tax deductions of up to £400 per year for specified land improvements could be claimed in four years subsequent to the work, and a similar special tax concession was offered to hill-country farmers for topdressing expenditures approved by the Marginal Lands Board (Long, 1963, 25; *Fert. J.*, 1963a, 24). The £400 limit was lifted from 1963 and all land development costs could be charged against income to encourage farm development (*Fert. J.*, 1963b, 14).

Apart from the carriage subsidy of the early 1950s there were no subsidies for domestically produced fertilizer and even that measure did not benefit farmers directly. It was not until August 1965 that fertilizer transport was again subsidized as a consequence of the recommendations of the Agricultural Development Council (*Fert. J.*, 1965b, 4). The subsidy rate covered two-thirds of the cost of fertilizer transport when in excess of £1 10s., ($3.00) per ton (*NZOYB*, 1966, 404), so favouring farmers located more than 29 miles from a fertilizer works (Moore, 1969, 10). This program remained in force, and then in 1968 was raised to cover three-quarters of the transport cost when over $2 per ton (*NZOYB*, 1967, 410; 1969, 414), reducing the subsidized distance to 18 miles from a fertilizer plant (Moore, 1969, 10). A further alteration was made in August 1969 to put the subsidy on a mileage rate as had been the case with lime twenty years earlier (*NZOYB*, 1970, 413). In spite of the subsidy, use levels could not be sustained through the 1966-68 recession (Table 6.9) as manufacture declined (Table 6.13) along with the cost of the subsidy--$2,529,000 in 1966-67 compared to $2,280,000 in 1967-68 at about the same cost of $1.42 per ton delivered each year (*NZOYB*, 1971, 415).

This situation proved difficult for those involved in fertilizer production and distribution. As lime and fertilizer were seen as only enhancing production and not as fixed costs, farmers, when faced with a decline in revenue, could choose to reduce or abandon soil amending (Tebb, 1959, 66). As the pattern of autumn application had developed and as the financial year also terminated in this period, it was possible to assess income before making the decision to employ fertilizer and lime (from conversation with a farmer, L. W. Gandar). Production reduction resulting from this decision would be carried over into the following year, when some change could occur to offset the negative consequences of allowing soil productivity to decline.

In some soils, decline would not occur markedly for at least two years if a steady program of fertilization had been maintained previously (Robertson, 1974, 12). Farmers were evidently willing to gamble on this being the case, the reduced extent of soil amending in 1967-68 demonstrates (Table 6.9).

The first major postwar price drop occurred in 1957 and continued to 1959 (Fig. 6.1). Wool production was most strongly affected and as these producers were those most concerned with aerial application on hill country, it is not surprising that a sharp downturn in application took place then (Table 6.2). The immediateness of the effects indicated the high demand elasticity of fertilizer and lime application. The expansion of production capacity continued in the manufacturing industry itself as plant construction was already underway, but full utilization of that capacity did not occur as seen by the decreased output. It was not until 1959-60 that output again reached the same average as in 1955-56 (Table 6.13).

The agricultural aviation companies found themselves particularly hard hit by the reduction in demand. Many suddenly found themselves overcapitalized after purchasing new aircraft to replace the Tiger Moths. The loan program of the Meat and Wool Producers' Boards ceased when it was realized that underutilization could occur. It was evident that aerial topdressing was not yet an integral part of farm operations. Lacking alternate uses for their aircraft some companies left the field, selling equipment and their licences to firms better able to cope as business undertakings. The number of operators had increased to 1957-58, but the following year four operators quit, leading in 1958-59 to the first reduction in the number of aircraft (Table 6.3). By 1960-61 a further ten operators had quit. It is noteworthy that the types of aircraft withdrawn were mainly the Tiger Moths and Austers, the older types (AIA, 1963, 61).

The adoption of newer aircraft having a greater work capacity was encouraged by this recession (Rendel, 1975, 72) and the businesses which followed this course were in a better competitive position as the situation improved. There were fewer, more stable firms left to deal with rising demand (Robertson, 1962, 4). Efficiency of operation was evidently improving as a consequence (Table 6.4). By 1961 the level of work had exceeded that in 1958 with fewer aircraft employed (Tables 6.2 and 6.3). A greater acreage was being treated (Table 6.2), an indication that development of land was once again underway to make up the production loss incurred principally in dairying (Table 6.14). Within five years the amount of improved land in farms exceeded the acreage of unimproved land while the total occupied declined (Table 6.15). By 1966 this became a steady feature of the pattern of land use. Indeed, by 1965-66 the acreage of sown grassland also exceeded the unimproved area (Table 6.15). The outcome in livestock production is evident in the increasing number of animals except for horses (Table 6.16) and the rising farm output index (Table 6.14).

LAND DEVELOPMENT

Government was involved in the land development which had taken place. Its activity was directed primarily by the Department of Lands and Survey as the agency of the Land Settlement Board, and secondarily by the Department of Maori Affairs. These departments were largely responsible for the increase in improved land, and opening of road access in more remote districts (Stover, 1969). From 1941 to 1970 some 3,112,000 acres had been acquired for government land development schemes with the majority of the work having been completed following the Second World War to provide farms for returned servicemen. Only after 1961 was civilian settlement encouraged since ex-servicemen's needs had largely been met. In 1970 there were 1,224,473 acres under development with a further 40,858 acres to be added the following year (*NZOYB*, 1971, 385). The Department of Maori Affairs administered the development of 210,000 acres with further land being developed for it by Lands and Survey--12,378 acres had been so developed by 1970 (*NZOYB*, 1971, 385). All of this Maori Affairs land was located in the North Island. In that island, Lands and Survey projects were concentrated in the Volcanic Plateau and Northland areas where previous efforts at development by individuals had failed. In the South Island, development blocks were situated mainly in Southland and Westland (Symons, 1961; Stover, 1969, 328-329).

Through their link with research organizations, and their ability to call on resources, governmental agencies succeeded in applying newly developed techniques to improve land. However, no research unit was formed to deal with specific land development problems. The early work on topdressing to remedy copper deficiency on Hauraki peat soils was followed by large-scale topdressing of the land develop-

TABLE 6.14

INDEX NUMBERS OF VOLUME OF FARM PRODUCTION 1949-1969
(1949-50=100)

Year	*Grain and Field Crops*	*Wool*	*Lamb and Mutton*	*Beef*	*Dairy*	*All Farm Produce*
1949-50	100	100	100	100	100	100.0
1950-51	107	101	103	107	102	102.4
1951-52	96	107	102	112	102	102.4
1952-53	91	109	101	129	111	107.2
1953-54	102	112	111	114	106	107.2
1954-55	94	121	112	140	104	109.6
1955-56	84	123	118	135	107	112.1
1956-57	105	133	116	136	107	113.7
1957-58	101	134	131	159	116	121.8
1958-59	104	146	144	159	115	126.6
1959-60	126	152	147	163	112	128.2
1960-61	139	158	154	155	117	133.9
1961-62	126	159	162	177	115	136.3
1962-63	151	170	164	187	118	143.5
1963-64	167	167	170	176	122	148.4
1964-65	157	169	171	186	129	152.4
1965-66	170	191	177	188	137	161.3
1966-67	179	191	191	212	137	166.9
1967-68	216	194	199	212	135	171.8
1968-69 [a]	212	195	200	200	137	175.8
1969-70	..	..	..	..	..	..

Note: *a* Provisional figures.

Source: Hadfield (1971, Table XIII).

TABLE 6.15

NUMBER OF HOLDINGS; AREA OCCUPIED AND PRINCIPAL LAND USES (THOUSANDS OF ACRES) 1945-1969

Year	*No. of Holdings*	*Area Occupied*	*Area Improved*	*Sown Grass and Clover*	*Hay and Silage* [a]	*Green Fodder and Roots* [b]	*Grain Crops Threshed*	*Grain Crops for Fodder*
1945-46	86,239	43,080	19,967.2	17,955	483.5	633.3	324	142.4
1949-50	90,192	43,253.9	20,228.4	18,192.3	630.4	692.4	297.4	130.7
1950-51	90,293	43,156.1	20,251.2	18,224	729.3	695.3	280.9	118
1952-53	90,529	43,321.6	19,961.6	17,819.1	877.1	703.9	294	97.7
1955-56	84,705	42,490.6	19,961.4[c]	17,774[c]	1,001.4	877.5[d]	189.4[e]	..
1959-60	76,928	44,018.9	20,702.5	18,549.8	1,009.3	734.1	295.9	67.1
1960-61	73,166	43,666.7	21,152.9	19,017.1	994.3	736.5	330.7	75.5
1962-63	72,293	43,660.4	21,728.7	19,520.5	1,121.8	678	383.2	66.3
1965-66	69,896	43,308.9	22,211.5	19,802.2	1,279.7	702.6	371.2	73.5
1969-70	65,331	43,075.6	23,161.8	20,415.4	1,405.5	598.8	538.9	114.4

Notes: *a* Includes lucerne.

b Excludes potatoes, onions and other green fodder and root crops.

c 1954 figure as 1955 data not available.

d Includes grain crops for fodder.

e Maize threshed not available. Total of 4,320 acres added is the average of 1954-55 and 1956-57 years.

Sources: *Agricultural Statistics* (for years shown).

TABLE 6.16

NUMBER OF PRINCIPAL LIVESTOCK 1945-1969

Year	*Sheep*	*Dairy Cows*[b]	*Other Cattle*	*Horses*
1945-46	33,974,612[a]	1,661,944	3,004,838	216,335
1949-50	33,856,558	1,850,089	3,104,817	194,877
1950-51	34,786,386	1,898,197	3,161,827	183,972
1952-53	36,192,935	1,962,492	3,483,471	158,065
1955-56	40,255,488	1,994,761[a]	3,952,016[a]	139,114
1959-60	47,133,557	1,886,672	4,105,266	104,995
1960-61	48,462,310	1,928,788	4,517,001	..
1962-63	50,190,284	1,997,253	4,693,711	..
1965-66	57,343,257	2,087,869	5,129,851	86,783[a]
1969-70	60,276,111	2,320,636	6,456,696	75,561

Notes: *a* Figure for preceding year used as data not available.

b Dairy cows in milk only.

Source: *Agricultural Statistics* (1970, Table 1).

ment of the contracted firms. Whereas private farmers tended to cut back services in periods of reduced income, government expenditure tended to rise, so giving those firms involved a reliable income. By 1964-65 160,000 tons of fertilizer and lime had been applied, half to lands being developed, and half to land in production (*Fert. J.*, 1966, 6-7). The Director-General of Lands stated with some certainty:

> I think it can be fairly claimed that the use of the contract system has greatly helped the development of the country's agricultural and topdressing industries, and these in turn have stimulated private farm development. (quoted in *Fert. J.*, 1966, 8)

In some areas the principle of renewing contracts with one firm became established, provided the firm's costs did not rise (James, 1966, 14). This policy provided stability of income for the firm involved so giving that firm an incentive to develop cost-reducing techniques to permit that contract to be continued. The technique of offering such work for tender had not provided the same stable production environment. Operators did not usually continue such work for long because the profitability of tendered jobs was kept low by the strongly competitive situation. The outcome was not the development of efficient operations but of ways to 'cut corners' (James, 1966, 14). The contract renewal policy resulted in the creation of effective cost-saving techniques which could be applied elsewhere, albeit at a reduced scale of operations, and the use on privately held land of the equipment acquired by the contracting firms involved.

E.B. Levy argued for the establishment of government- and/or industry-supported land development on privately held land as a means to further agricultural output. He felt that subsidizing fertilizer use was a means to boost income in more difficult country and so keep people in farming (Levy, 1961a, 5-6). Government land development was seen as 'painfully slow' and apt to prove temporary 'if over-reliance on the ultimate individual settler is given once subdivision is effected' (Levy, 1961a, 6). The basis for the tax concessions and later fertilizer subsidies was laid.

Additional benefit came from the location of fertilizer plants in land districts being developed actively by Lands and Survey. Northland's development was retarded until the construction of a plant there because of high freight and application costs (Dudley, 1968, 47-48). The situation in Southland was probably similar. Sufficient demand had first to be generated before the investment in a plant became worthwhile for the three Auckland firms supplying fertilizer to the districts. The project was planned in 1959 but was not completed until 1964. The co-operatively owned plant in Southland was developed more rapidly.

Government involvement in land development included financing private schemes for which funds were not available through normal lending institutions (*NZOYB*, 1971, 386). Under the Marginal Lands Act of 1950, a Marginal Lands Board was established with committees in each land district to approve such funding where it would serve to make marginal land productive (Fielding (1965a) shows the effects in Northland). The program was much less important than its own land development program, for in the twenty years to 1970 an estimated 192,000 acres were grassed under its provisions with only 1,528 loans being approved (*NZOYB*, 1971, 386). Though the various methods of land development were not equally important, the combined result was an impressive increase in improved land, about 2.1 million acres of an overall addition of 3.2 million acres (calculated from figures presented and Table 6.15), based on government involvement.

EXPANSION OF AGRICULTURAL RESEARCH

The research institutions continued the development of grassland technology begun prior to World War II and additional institutions were created to deal with specific aspects of this grassland technology.

Hill-Country Research

Two farms were established to assess the problems of introducing the developed technology into North Island hill-country farming. The Te Awa Hill Pasture Research area was started in 1945 by the Grasslands Division of the DSIR with the support of the Manawatu Catchment Board. E.B. Levy was able to promote this project in his position as Director of the Grasslands Division and Chairman of the Research and Afforestation Committee of the Manawatu Catchment Board (McCaskill, 1973, 89). The aim of the Te Awa project was to increase farming system production by increasing stock carrying capacity through the use of fencing for better grazing management (Suckling, 1965, 7). In addition, the practicality and profitability of recommended soil conservation measures could be assessed.

The second of these farms, the Ruakura Hill Research Station, was established in 1950 by the Animal Research Division of the Department of Agriculture with the aim of improving animal production using orthodox land development methods on deteriorated hill country (*Fert. J.*, 1959c, 3).

Although the approaches were different the goal was common--productivity improvement in sheep farming. Improvements in stock and pasture and improved management of both resulted from the research undertaken and both aspects were proven effective on the hill-country farms of the North Island (*Fert. J.*, 1959c, 6; *Fert. J.*, 1969, 6).

Efforts to establish similar research in the South Island as proposed in the Sheep-Farming Industry Commission Report (1949, 124) did not produce concrete results until 1961 with the founding of the Tussock Grassland and Mountain Lands Institute at Lincoln College (McCaskill, 1973, 133). The Department of Agriculture did not directly enter into South Island hill-country research until 1965 when the Tara Hills Reserve was acquired from the SCRCC. Projects to improve grassland in such country had been initiated in the 1920s but had not uncovered conclusive means of dealing with such land (McCaskill, 1973, 129). Oversowing and topdressing tussock land aerially were becoming regarded as 'feasible methods for pasture improvement' in 1953 when the application of these techniques in the North Island was noted as increasing rapidly (*ARDA*, 1953, 24, 15). Subsequent 'high-country' development was contingent upon the application of such grassland technology (Critchfield, 1969, 60).

It appears that the North Island hill country was awarded a higher priority. Research was centred on its development until means had been found to overcome deterioration of that land. Government research institutions were developed later in the South Island than in the North. Research work was left to Lincoln College and the Cawthron Institute as the Department of Agriculture only opened the Invermay Research Station near Dunedin in July 1949 (*ARDA*, 1950, 25).

Soil Conservation

Those concerned primarily with soil conservation also entered the area of grasslands technology in researching methods to revitalize vegetation on eroding land. Within three years of its creation in 1941 the SCRCC had begun to acquire reserves of eroded land on which to experiment with conservation techniques and demonstrate their effectiveness. Twenty-four soil conservation reserves had been established by 1970 (McCaskill, 1973, 74), though not all remained in operation at that date.

At an early stage both the DSIR and the Department of Agriculture had become involved in the conservation techniques being developed. It was noted above that a catchment board and the DSIR's Grasslands Division had co-operated in creating the Te Awa Hill Pasture Research Area. The work at Te Awa demonstrated the practicality and profitability of soil conservation measures and:

> The fact that the results were available so early was particularly valuable in that they could be put into practice as soon as it was realised that aeroplanes could do a major part of the work. (McCaskill, 1973, 90)

The interrelated nature of soil conservation and grassland improvement was recognized in the integration of the SCRCC soil conservation staff into the Department of Agriculture's Extension Division in 1955 (*ARDA*, 1956, 21). The administration of the soil conservation reserves followed as part of the integration process. The SCRCC found its programs on many reserves to be too extensive for the staff and finance available. Problems which required rapid practical answers were not tackled. However, the administration of the reserves by the Department of Agriculture from 1955 to 1966 tended to result in programs little related to soil conservation (McCaskill, 1973, 99). The difference in objectives led to the administration of all but two of the reserves being returned to the Ministry of Works. The Tara Hills Reserve had already been turned over to the Department of Agriculture and the Wairakei Reserve was obtained as a research area on newly developed pumice land (McCaskill, 1973, 93).

Fertilizer and Soils Research

Fertilizer manufacturers entered the research field in 1950 in collaborating on an equal cost basis with the DSIR in establishing and running a research station at Otara, this in addition to their individual efforts. The New Zealand Fertiliser Manufacturers' Research Association conducted work on fertilizer application and began long-term phosphate trials as part of its agriculturally oriented research. The station also served as an information collection centre on developments in this field outside New Zealand, and concerned itself with product and process innovation as well as fertilizer analysis methods to comply with legislated standards (*Fert. J.*, 1960b, 4, 6). Trace element mixtures, insecticide and herbicide mixtures, as well as methods of maintaining high-quality phosphatic fertilizer using Christmas Island rock were all developed at this centre. A research contract for the improvement of aerial spreading equipment was given to the Engineering School of the University of Auckland as the industry increased its research expenditure from 1967 to 1969 (Rogers, 1967, 10-11).

An important information linkage was established in this way. The fertilizer companies were able to pool their information on production innovation and work in conjunction with the DSIR. Annual conferences to bring those involved in fertilizer work were begun in 1957 (*Fert. J.*, 1965a, 15). In a scheme begun in the late 1950s technical staff from the fertilizer companies were attached to the station to study developments and gain experience in conducting experiments (*Fert. J.*, 1960b, 4). The need to acquire information from and disseminate information to the different organizations involved in the fertilizer production aspect of grassland technology was evident (Rogers, 1967, 11). From 1954, farmers were exposed to developments through the free distribution of the industry's publication *The New Zealand Fertiliser Journal*.

It had become apparent through the work on soil mapping and fertilizer response testing that more needed to be known about New Zealand's soils to make soil amending more effective. Work was undertaken on soil deficiencies by men such as T.W. Walker at Lincoln College. The Department of Agriculture had established the Rukuhia Soil Research Station in the Waikato in 1945. The work of the Agricultural Chemistry Section of the Extension Division was set on a new footing in having both a chemistry laboratory and an experimental area (*Fert. J.*, 1958, 2).

From 1948, under P.B. Lynch's direction, the station expanded its investigational work using trials to observe and measure fertilizer responses in addition to soil and plant analyses. The aim was to furnish the officers of the Extension Division with information of benefit to farmers. The Advisory Soil Testing Service could interpret the results of the research and the findings of the investigators of the DSIR's Soil Bureau to farmers (*Fert. J.*, 1958, 3). Research was also undertaken to develop field tests to detect various element deficiencies. To supplement this North Island work, a similar station, the South Island (later Taieri) Soil Research Station, was established to operate in conjunction with the Invermay Research Station in the South Island.

Other agriculture-related industries also developed research organizations, chemical companies investigated the action of weedicides, insecticides, and fungicides, agents used in grassland technology for pasture management and animal health if not for soil amending. The Primary Producer Boards (Meat, Wool, and Dairy), 'evidently felt the need for research for their own information and guidance in economics and trends in farm production, and in the intricate marketing of our primary products' (Levy, 1961b, 132) and developed research organizations (McMeekan, 1963, 32) as well as furnishing extension services to members (Clifford, 1967). Farmers themselves organized farm improvement clubs, in an effort to learn to apply new techniques (Rose, 1968, 118) and the Federated Farmers' organization undertook some research of its own (Levy, 1961b, 132).

Government Involvement

The absence of research funding directly from the farmers was reflected in the high proportion provided by government (Johns, 1968, 112). Government continued through the period to provide about 80 percent of the funding and played a predominant role in determining national research (Brown, 1975, 48). The limitations imposed by this situation also involved difficulties. The inflexibility of the Public Service salary and grading arrangements hampered the recruitment and retention of capable researchers. The inflexibility of financing and supply arrangement slowed the provision of equipment where needs could not be predicted far enough in advance to avoid delays (McMeekan, 1963, 41). The need to improve employment conditions for scientists continued to be noted (Hamilton, 1965, 10; Johns, 1969, 9).

The reluctance of farmers to finance research was criticized as it was considered to lead government to limit resource allocations to research since farmers, the direct beneficiaries, were seen to be unwilling to contribute. In this environment research personnel felt obliged:

> to woo the farming community by directing work primarily to problems of the present type of farming technology, and often the very immediate problems, even though there are alternative lines of approach potentially far more rewarding, but which would lead to types of farming appreciably different from those used now. (Mitchell, 1967, 48)

Although McMeekan (1965, 6-7) praised the applicability of agricultural research because of its project-oriented approach and its grounding in economic application Mitchell (1967, 48) felt that the development of new technology was less likely when the concern was simply 'the application of good science'. Research came to be used 'to clean up the problems of an existing technology' not to develop new technology in a mutually stimulating situation incorporating producers, processors, and sellers (Mitchell, 1967, 48-49). Concern was expressed that complacency and self-satisfaction were developing (Smith, 1968, 40). McMeekan (1963, 36) had earlier recognized that there had to be some fundamental research to develop new theories and existing theories in order to provide the basis for effective applied work. He noted that New Zealand scientists had not been responsible for developing many of the principles underlying the major achievements in improving agricultural productivity but had taken ideas and developed them and their application. This role was seen as the main contribution of research to the country's economic growth (Johns, 1969, 8), and the practicality of research objectives continued to be emphasized (Smith, 1968, 40; Baumgart, 1969, 152). There is some danger in this situation:

> A highly developed technology has its own form of basic conservatism. Too much science directed too closely to the narrow end of maintaining a particular industry may even be a bar to technical progress. (Ziman, 1976, 179)

However, it was noted that the emergence of new products and increased marketing problems were bound to make research directions less clear and throw up more problems for study. The development of the previous twenty years' research program was seen as 'relatively easy' with 'a reasonable chance of paying off' because of the limited number of significant farm products and farming systems involved (McMeekan, 1963, 37). Problems were more evident because of accumulated experience which also furnished much factual information. The security of markets also enabled expensive, long-term research projects to be undertaken with some security concerning the value of the final pay-off. As this market security decreased, more basic research was thought to be needed to cope with whatever problems emerged. The question became one of direction:

> It should ... be possible to expand research and development in new and desirable areas without sacrificing existing important research, if the major research objectives are sufficiently clear, and the general scale of the scientific effort is in balance with the country's needs and its resources. (Brown, 1975, 48)

The DSIR was reported as broadening its research and then focusing on areas found to be critical, employing more basic research (Baumgart, 1969, 152).

Concern for improving production was evident in the movement to acquire information and develop organizations to produce it but the resulting fragmentation of research was viewed as a waste of quite limited financial, physical, and human resources (McMeekan, 1963, 33). Unplanned duplication of facilities happened when research activities overlapped, and organizational obstacles were erected which inhibited full collaboration on research projects (McMeekan, 1963, 39). The need for a national body responsible for allocating resource priorities and directing available funds was expressed (McMeekan, 1963, 33) but was thought an unnecessary addition to the existing Council of Scientific and Industrial Research (Levy, 1961b, 130). It was contended that although this council had wider responsibilities, it was limited by its DSIR affiliation. It had only limited involvement with other departments such as Agriculture, limited influence on universities and research associations, and non-existent control of private organizations (McMeekan, 1963, 40). The proposals received to create a central body to advise government on establishing priorities, on co-ordinating research programs and acting as an executive body for all departmental research were not endorsed (Moriarty, 1963, 44-45). The existing functions of the Council of Scientific and Industrial Research were to be taken over extended in the newly formed National Research Advisory Council (abbreviated to NRAC) but its role would not be executive or administrative. Advising government on policy formulation for the co-ordination of scientific research and services at a national level and an evaluation of their effectiveness was its brief (Brown, 1975, 46). The question of the unification of scientific research was to be left to the new State Services Commission but no action was taken on it (Brown, 1975, 45).

Agricultural research remained divided between organizations. Levy (1961b, 131) had already expressed his regret that the Department of Agriculture had not been allowed to become 'a highly efficient agricultural research and advisory organization packing into it all the sciences that relate to agricultural production' and McMeekan (1963, 31) had described the organization of research as 'chaotic' and 'overly fragmented' with the separation of agricultural research between the government departments as having 'no scientific or practical justification, and explained only by historical or political grounds within which expediency has been a dominant force'. It was considered that the lack of a link of the DSIR Soil Bureau and Grasslands Divisions and the Department of Agriculture, and the lack of association of either with the university system was 'a grave mistake for the development of soil science' (Walker, 1973, 142).

Nonetheless, co-operation did develop between the various organizations as programs were planned to use the different approaches of the researchers from different organizations (Smith, 1968). The project basis proved a suitable framework for incorporating a number of disciplines into the research to solve particular problems (McMeekan, 1965, 6). Another observer noted the increased co-ordination of research programs between universities and government departments from the 1960s to the early 1970s as the academic research potential was developed through post-graduate fellowships, government department sponsorship of research groups and fellowships, and the granting of research contracts (Burns, 1973, 88) following the pattern recommended in the early 1960s (Hamilton, 1965, 12-13). It was also felt that research was stimulated by competition between the organizations which had emerged (Levy, 1970, 342). The research effort did not suffer in either case unless resources were consumed in too great a duplication of effort, a less likely possibility once the NRAC began to monitor developments. The council was able to 'substantially expand research' (Smith, 1968, 40) even though government did not always choose to follow NRAC proposals (Johns, 1968, 112).

Research Applications and Directions

The research endeavours undertaken prior to World War II continued to develop practical applications and to expand into related fields as the workings of the pasture ecosystem became better understood. The widespread acceptance of the use of phosphatic fertilizers and lime between the late 1940s and 1960 (Woodcock, 1961, 4) brought to light other soil mineral deficiencies which had gone undetected. Molybdenum deficiency was first identified in New Zealand soils in 1945, and was found to be an important limitation on clover production over a wide area (During, 1955, 151). Similarly, the need for or the excess of other trace elements involved in pasture yield and/or animal health appeared. The scope of fertilizer research was noted as becoming both wider and more complex in the early 1950s (*ARDA*, 1953, 14). Magnesium, zinc, copper, selenium, manganese, calcium, boron, and vanadium were all under investigation by the mid-1950s (Adams, 1954; During, 1955).

While some of these problems had been noted in the late 1920s and during the 1930s it was not until this period that sufficiently refined techniques were available to identify the elements concerned. Not only chemical analysis but also statistical analysis were more powerful (Walker, 1961, 85-86). Remedial treatments were readily available as fertilizer works acquired the equipment to mix the minute quantities of a particular trace element needed into the fertilizer applied. As their knowledge of the response to soil amending increased, farmers could evaluate the results of the treatments made and indicate if some imbalance was occurring. The range of treatments available expanded accordingly. The earlier statement:

> because of the success which has attended the widespread use of lime and phosphate, which are undoubtedly the things most commonly needed in this country, there is perhaps a tendency to regard these minerals as the only ones that concern us. This tendency is dangerous if only for the reason that it is well known that as one deficiency is corrected, thus increasing production and the removal of nutrients, another element becomes the limiting factor (Adams, 1954, 37)

was recognized as valid.

Techniques were re-evaluated in light of their effectiveness as determined by the knowledge being acquired. The effectiveness of serpentine superphosphate was questioned as research findings did not substantiate previous results (Karlovsky, 1964, 16). The molybdenum deficiency in North Auckland soils led to the replacement of basic slag and heavy lime dressings by molybdenized superphosphate and light lime dressings (During, 1955, 151). It appeared that the success of superphosphate was related as much to its sulphur content as to its phosphate content (Adams, 1954, 37). The observation of sulphur's utility was first made in New Zealand in 1928, but analytical techniques were not adequate to discern the sulphur-deficiency problem (During, 1955, 155). Early fertilizer trials may often have dealt with more than one type of deficiency with the result that the findings were not accurate (Walker, 1961, 87-88). By 1960 the location of sulphur-deficient soils was regarded by the Department of Agriculture as most important work (*ARDA*, 1961, 32). This finding concerning sulphur made the use of superphosphate important on sulphur-deficient soils covering a wide area. Continued use of basic slag, which contained no sulphur, was seen as an unwise practice as any gain in adding phosphate to promote clover growth was wasted in the absence of sulphur (During, 1970, 122).

The increased intensity of farming led to the appearance of deficiencies not evident in the early stages of land development (*ARDA*, 1953, 14). Potassium levels were depleted by the higher producing pasture species consumed by greater numbers of livestock, particularly in the areas of intensive dairy farming. By 1957 it was considered that the deficiency was widespread and led to greater use of potassic fertilizers (*ARDA*, 1957, 25). During estimated in 1959 that the potassium deficiency was evident on some two million acres and the acreage was increasing (Karlovsky, 1966, 122). By 1966 more than three million acres were being treated with potassic fertilizers. Their greater use in the 1960s is evident in the much greater potash importation (Table 6.11). Of concern was efficient use as costs were higher than for phosphatic fertilizers despite generally decreased costs after 1961 when Canadian potash deposits were brought into production (Roberts, 1967, 92).

The possibility of using expensive nitrogenous fertilizers was considered again for special purpose pasture production (*ARDA*, 1953; 1955) and it was noted that the use of such fertilizers was increasing in the early 1950s but rose unsteadily (Table 6.12). The later 1960s again appear as a period when non-phosphatic fertilizer usage greatly increased, a trend supported by a rapid decrease in nitrogenous fertilizer costs while phosphate costs rose. It was pointed out that:

> The fertiliser price relationship on which New Zealand established its present pasture technology is being turned upside down. The ryegrass-clover technology is based on relatively extravagant use of phosphate to manure clover and hence substitute for expensive bag nitrogen, that paid handsomely. (Mitchell, 1969, 10)

Reliance on the ryegrass-clover technology was regarded as a limitation in moving to more intensive types of production relying on nitrogen application (Mitchell, 1969, 12-13). Grasslands research also indicated the need for more investigation into the relative efficiency of 'clover' and 'bag' nitrogen (created by legumes and man-applied respectively) as the former type presented problems of a less than ideal seasonal growth pattern and animal distribution pattern (Corkill, 1969a, 14). The calculation of nitrogen input from import figures to illustrate the rising trend is somewhat misleading, however, as some of the nitrate of soda was used in sulphuric acid production. Of the remainder most was used on crops rather than on grassland (Riddell, 1968, 14). The 'clover' nitrogen supply was seen as an adequate source. This view could explain why domestic production was not begun. All nitrogenous and potassic fertilizers were imported and mixtures made with locally produced phosphates.

The research into fertilizer use was important for phosphatic types as well, for new fertilizers came onto the market (Roberts, 1967, 91-92). It had been noted under wartime fertilizer rationing that production had not decreased proportionately. Accordingly, the view was advanced by 1954 that fertilizer quantities could be reduced by more discriminating use based on an assessment of need through adequate soil testing (*Fert. J.*, 1955a, 7). The phosphate retention of soils came under investigation by I.L. Elliott and J. Karlovsky and led to a greater understanding of the interrelation between the rate of phosphate topdressing, pasture production, and soil phosphate levels (*Fert. J.*, 1964b, 12). The effect of halting fertilizer application could be evaluated on the basis of the results obtained from this work, thereby giving the farmer the basis on which to make a decision on the level of input use in given economic conditions. The rate of phosphate application could be varied by the level of production required from soils with varying fertility levels. This procedure enabled the farmer to use fertilizer to maximize the resulting production increase by selecting the areas of greatest response (Karlovsky, 1961, 149). The decision made was shown to be more critical with more intensive production as greater grazing pressure was applied to available feed at higher stocking rates so causing production to decline more rapidly. The World War II experience wherein production did not decline markedly was not valid in the post-war situations because of the increase in livestock numbers (*Fert. J.*, 1967, 7) although it was held that even higher numbers were possible given the increase in fertilizer use (Karlovsky, 1966, 115). The rise in fertilizer application (Table 6.6)and in livestock numbers (Table 6.16) can then be regarded as directly associated phenomena.

Other nutrients were also investigated on this basis so that recommendations for the use of sulphur and potassium were developed to enable farmers to economically assess their use of fertilizers over a wider range of materials (Robertson, 1974, 13-14). The changing technology of fertilizer production and findings concerning pasture nutrient needs combined to provide:

> a challenge for agricultural scientists to reassess New Zealand's fertiliser needs in light of the rapidly changing economics of fertiliser application. (Roberts, 1967, 92)

Soil Surveys

The accumulation of such empirical knowledge tended to outstrip the knowledge about the soils on which the results were to be applied (Walker, 1961, 86). The relation between identifying and mapping soil types, and using the information in agricultural research was evident in the 1930s, shortly after the DSIR had begun soil surveys (Lynch, 1972, 8). A.W. Hudson, as Crop Experimentalist to the Department of Agriculture, began a fertilizer response survey in 1931 so taking advantage of the newly available information (Woodcock, 1961, 7). P.B. Lynch (1972, 8) noted:

> The completion of a district soil survey was the signal for a series of experiments to define fertilizer needs and general agricultural value of the soils described and mapped. Soil survey publications often carried a description of the agricultural potential of the soils and usually defined their fertilizer requirements and other features of agricultural significance. This

information was based on research planned according to soil pattern.

Field trials were increased in number by the Extension Division first to locate soils having particular deficiencies and then to test proposed remedies. The inadequacy of previous work in view of the new discoveries made became apparent. The chemicals required and the quantities employed to make most economical use of them were investigated through the period. The soil-testing service was expanded and became involved in developing more efficient testing procedures (*ARDA*, 1954, 16).

By 1956 all of New Zealand had been covered at a reconnaissance survey at a four miles to the inch scale giving soil types down to areas of 200 acres (Gibbs, 1956, 128). This work 'enabled best land use to be predicted with great accuracy and scientific discoveries to be applied with great rapidity' (Fieldes, 1969, 172). There was some variation in the regional coverage, however. Results of the work in the North Island were published in 1954 but general survey of the South Island did not appear until 1968, even though the more intensively farmed areas had been covered much earlier and the early results published in atlas form (Soil Bureau 1954, 1962, 1968a). The results of basic soil research by the Soil Bureau over the 38 year period to 1968 were published in the three parts of *Soils of New Zealand* (Soil Bureau, 1968b). The significance of soil properties assessed in that work was furthered by the publication of a guideline for farmers on soil types and soil amending, *Fertilisers and Soils in New Zealand Farming* (During, 1967).

The attention paid to practical problems meant that solutions could by 'rapidly extended throughout the country in terms of soil groups and soil units' with the result that it was suggested:

> Dissemination of the findings of soil research and related agricultural research has ... been basically responsible for the dramatic increase in productivity in the period since research was expanded since the depression. (Fieldes, 1969, 172)

Work in the field moved from comprehensive soil mapping to description and classification, and then to studies of soil changes under management (Fieldes, 1969, 172).

For the latter work more detailed survey work was undertaken at a one mile to two miles to the inch scale giving soil types of at least fifty acres in extent, with some intensive farming areas being surveyed to give soil types of at least five acres (Gibbs, 1956, 128, 129).

To complement this work and provide the basis for national soil amending work, the mapping of trace element deficiencies, the first project of its kind in the world, was begun (*Fert. J.*, 1960a, 5). Mapped results appeared as early as 1962 and were the basis of the *Soil Bureau Atlas* (Soil Bureau, 1962). Maps of other important elements and revised editions of those previously studied were added until 1967.

In conjunction with the mapping, soil-forming factors and processes were studied to gain a better understanding of the occurrence of nutrient deficiencies. Although this work developed slowly, explanations which enabled deficiencies to be predicted and remedied did emerge (Walker, 1961, 87). This 'widening and extension of the work of the Soil Bureau' was seen as necessary 'for its profound influence on plant, animal and human health' (Woodyear-Smith, 1963, 19) and enabled the research effort to shift to determining the quantity of major plant nutrients needed to maintain desired levels of plant and animal production (During, 1972, i). However, such a shift meant more extensive and more complex field trials (Saunders, 1969, 20). The growing need for trained soil scientists in the early 1960s led universities to develop more specialized soil science programs and to enter into new research programs (Healy, 1973, 161-162).

Future work was aimed at solving:

> the problems of successive limitations to production for each soil class in the most economic manner with a view to increasing ultimate potential and reducing costs of production as speedily as possible. (Fieldes, 1969, 172)

Such a goal necessarily involved more effort in developing rapid soil-analysis techniques and a more detailed knowledge of chemical and biological processes occurring in the soil (Saunders, 1969, 22). Nonetheless, soil research was seen to be related to agricultural production even though not all the work was directed by the Department of Agriculture. That this work was not begun until the later part of the period when soil amending was widespread, would indicate that some inefficient utilization was bound to have occurred as a consequence of limited knowledge.

Research Restructuring

The study of mineral deficiencies, as in the case of molybdenum, to give but one example, provided results related to both animal health and pasture production. Such occurrences led, by 1964, to a restructuring of the Department of Agriculture's research organization in line with the changes advocated in the formulation of the NRAC. This was in accord with a proposal for concentrating research activity in discrete fields (Levy, 1961b, 130) while allowing closer co-ordination of research internally and with other organizations (Johns, 1966, 9). An Agricultural Research Division was formed to incorporate work being done by the Animal Research Division, the Farm Advisory Division, and the Horticultural Division. The aim was a reduction in the overlap of effort as:

> The new organisation recognises the unity of agricultural research as a complex of soil-plant-animal problems, each of which needs to be considered in relation to the others, and it is believed that it will be easier to achieve the necessary co-ordination between the activities of the various stations and units when these are all part of a single research division. (*ARDA,* 1964, 14).

This grouping concept was extended to the Ruakura and Invermay Stations which became Agricultural Research Stations comprising animal-breeding stations, hill-country stations, and soil-research stations (*ARDA,* 1964, 14; *ARDA,* 1967, 49).

The increasingly specialized nature of the soil-testing work led to the formation of a Field Research Section whose officers took over all general research duties taking place on farmers' properties from the farm advisory officers (Lynch, 1967, 12). The farm advisory officers could then concentrate on farm management using research results since their prime function was the promotion of production efficiency (Scott, 1967, 114).

There was concern that the service was 'outnumbered and out-manoeuvered' by other departments, independent bodies, stock and station firms, drug and chemical companies, fertilizer companies, and farmers' groups (McMeekan, 1963, 38). Farmers were receiving conflicting advice from people with greatly varying professional qualifications, a situation in which farmers' confidence in the practices being recommended to them was undermined. Nonetheless, the staff of the Field Research Section proceeded to conduct some

1,500 field trials annually, often in concert with other related organizations such as the Soil Bureau (Lynch, 1967, 14) to meet farmers' needs. The Farm Advisory Division's need to study fertilizer requirements of managed soils furthered the linkage as the complexity of the field experiments resulted in fewer being possible so that a determination of representative soil types was begun in 1963 with the assistance of the Soil Bureau (Lynch, 1972, 8-9). Results were conveyed to farmers by the advisory personnel, so linking them to the research organizations. Levy (1961b, 128) viewed this linkage as critical given his observation:

> It is evident today that in many ways science has forged ahead of practice and knowledge ahead of application ... It is still basically fundamental that research goes hand in hand with practice, and the more highly each is evolved the nearer we get to our maximum-production goal.

This message was reiterated throughout the following years (Hamilton, 1965, 10-11; Thomson, 1972, 5).

Grassland Research

With the increasingly ecological approach taken in studying pasture, the soils aspect was recognized as but one factor in plant nutrition. The biological components of the system were rightly seen as interacting elements. This viewpoint had been a major contribution of Levy's in focusing attention on the soil-plant-animal relationship (Thomas, 1966, 17). Researchers in the DSIR Grasslands Division recognized that improved pasture plants, pasture management, improved stock, and stock management were all important aspects in developing productivity (Corkill, 1971, 11).

Not all these aspects were tackled simultaneously, however. The need to establish clovers to supply nitrogen for grass growth had prompted the early concern with soil amendments. This need had also led to the breeding of improved plants suited to the New Zealand environment, improved clovers having higher yields and better nitrogen-fixing ability, and improved grasses having high and sustained levels of production (Corkill, 1966a, 67). The higher levels of animal production made possible by the use of these improved varieties brought about the extension of soil-amending techniques to build up the soil conditions most suited the plants' needs. It could be justifiably stated that the:

> history of grassland research in New Zealand is largely a story of selecting more productive strains of ryegrass and white clover and determining the best methods of establishing and maintaining pastures dominated by these two species.

as

> In early development, concentration on a few major lines is obviously wise. Probably no other policy would have produced the same rapid progress as that which resulted from concentration on ryegrass, white clover and superphosphate. (Filmer, 1955, 11)

There was criticism that this focus was too narrow in maintaining the need to improve soils to levels suited to ryegrass and clover rather than breeding species more suited to the conditions existing (Filmer, 1955, 12). This line was not followed strongly, for even by 1970 the concentration on breeding ryegrass and white clover varieties still merited comment (Corkill, 1971, 12, 14). It was still suggested that other grasses and clovers could provide the requisite levels of sustained, high-quality production but mainly in the less favourable, hill-country environments (Corkill, 1971, 14). Strain improvement was extended to cocksfoot, timothy, and red clovers, but resulting improvements did not alter the existing situation (Corkill, 1966b, 29, 31).

Except for subterranean clover, a species more suited to drier conditions, new plant species were not readily accepted by farmers, so the concern for strain improvement in known grasses and clovers was a logical procedure (Saxby, 1957, 11-12). The strain improvement achieved made white clover 'the legume basis of practically all seeds mixtures' (Corkill, 1966a, 67) on both cultivated land and hill country, with Grasslands Huia white clover being the most widely used variety, given its reputation as the 'greatest contributor to pasture improvement' (Corkill, 1966c, 20). Adding to this value was the finding that white clover's presence in the pasture sward was an important factor in the production of animal protein from pasture (Thomas, 1966, 18). The clovers were seen not just as an agent for grass growth but also a major contributor to feed quality.

Advances in biochemistry were providing methods of assessing the nutritive value of plants and the ability of animals to utilize these nutrients. Breeding of both plants and animals could lead to more efficient utilization of soil minerals, and allow the reduction of application rates of some soil amendments (Corkill, 1969a, 14-15). Advances in biology related to the need for molybdenum in nitrogen-fixation indicated the importance of the symbiotic relationship between host clover plants and Rhizobium bacteria. It was found that clover seed first inoculated with a bacteria culture would tend to ensure better production in areas where there had previously been little clover and so a low level of these soil bacteria. Work then developed on finding the bacteria most suited to the clovers available (Corkill, 1971, 15).

Management of stock and of pastures to achieve the best use of both became a central concern as it was realized that the adjustment of animal requirements and pasture growth was capable of 'at least doubling the average production of ... fat-lamb and dairy farms' (Filmer, 1955, 14). Feed availability could be improved by such management practices as utilizing autumn-saved or winter-saved pastures to ensure abundant, high-quality feed at periods when animal needs were high (Wallace, 1961, 76; Clifford, 1966, 29). The technique of seasonally saving pasture became more widely adopted in the mid-1950s as a bonus feature of rotational grazing whereby farms would be subdivided and stock moved from pasture to pasture rather than being free to wander about the entire property for the season (set-stocking) (Clifford, 1966, 29; Campbell, 1971, 146). Adjustments were made to the saving technique when it was realized that too much feed was wasted by rotting. Withholding the grazing of some fields later in the season (winter-saved pasture) was promoted (Clifford, 1966, 29). The evaluation of the superiority of set-stocking over rotational grazing was not properly investigated until the mid-1960s when the rotational idea was found markedly more productive (Campbell, 1971, 147-148).

What was demonstrated was the need to efficiently use the pasture-growth gains achieved by soil amending. It was not until 1950 that a clear statement of the largely direct relationship between the efficiency of per acre production on the efficiency of feed utilization was made. It was not until the middle of that decade that experimental data were obtained which showed that on dairy and fat-lamb farms production per acre could still increase at higher stocking rates even if per animal production fell (Campbell, 1971, 145-146). This finding was essential in the development of more intensive grassland production as it encouraged higher stocking rates, a requisite feature in building soil fertility and effectively using the fertilizers and lime spread. The techniques employed could also be seen as applicable to hill country (Wallace, 1961, 78). This closer integration of animals into grassland research was regarded as notably important by the end of the 1960s (Corkill, 1969b, 7).

With the increased mechanization of farm operations feed conservation using hay and silage became more important, though it took some time for improved methods to be employed. It was noted in 1955 that:

> In New Zealand we badly need to improve our methods of making hay and silage. Our present methods are not only wasteful but result in very indifferent products. (Filmer, 1955, 14)

The trend to increased usage continued into the 1960s and the 1970s (Table 6.13). Although methods had improved most of the conserved feed was harvested as hay, the least efficient conservation method in terms of feed quality and material loss prevention but that requiring the least capital and the least labour (Brougham, 1971, 7). The evaluation of animal feed requirements and the use of fertilziers to stimulate off-season plant growth began to encourage more feed consumption _in situ_, thereby reducing the need for hay and silage (Clifford, 1966, 30) just as the production of hay and silage had earlier reduced the need for supplementary fodder (Smith, 1966, 84).

The application of this aligning of feed requirements and pasture production in hill country suggested a reversal of the growth planning procedures which had been suggested. The amount of stock could be decided on first and development subsequently programmed to meet their requirements. Money invested in clearing, grassing, and fencing became productive immediately (Holden, 1966, 68). The initial development of grass production followed by the purchase of stock wasted the inputs applied as noted in the 1950s (Campbell, 1955a, 8). Production would be increased over a longer term while pasture utilization was improved over a short term.

ECONOMIC CHANGES

Although the research advances in grassland technology and their application by farmers were responsible for increased production seen in the greater number of stock carried (Table 6.16), and the doubling of wool, sheep meat and beef production since 1949-50 (Table 6.14) the trade in animal products became increasingly uncertain. The entry conditions into New Zealand's principal market in the United Kingdom began to alter following the renegotiation of the bulk-purchase agreements which had ensured a market and provided for increased sales (Ross, 1954, 317). The certainty of sales under those agreements had enabled farmers to plan production improvement with some confidence as seen in the failure of the wool price decreases following the end of the Korean action (Fig. 6.1) to halt the rise in the use of agricultural aviation (Table 6.2). Gross farm income still remained well above immediate postwar levels (Table 6.17). Funds earned in the boom period were spent on land improvement and the application of the new technology being developed. Export prices rose more rapidly than import prices nearly continuously until 1957, giving the country a new prosperity and higher living standards (Sutch, 1966, 410) as farmers enjoyed favourable terms of exchange (Table 6.18). Agriculture was the sector responsible for the improvement so it was not seen that any change in the existing economic structure was required. In a free-trade situation New Zealand's prospects for maintaining this prosperity seemed assured with the further application of technology to its grasslands. This view did:

> not mean that manufacturing did not expand its output during these years, but [the] country's thinking, including that of most economists, was directed to the necessary, but narrow, job of getting two blades of grass to grow where one grew before, rather than to getting the most out of all New Zealand's human and natural resources. (Sutch, 1966, 412)

Altenative markets particularly in the United States for some farm products were opening up but did not displace the traditional British market (Long, 1963, 31). The demand for capital goods could not be met by the small, local industry with the result that export earnings were used to buy these abroad as in the case of the Fletcher aircraft (Sutch, 1966, 421). The pressure on local resources was felt in labour shortages and increased wages (Sutch, 1966, 422) which encouraged

TABLE 6.17

GROSS FARM INCOME IN MILLIONS OF DOLLARS 1949-1969

Year	*Grain and Field Crops*	*Wool*	*Lamb and Mutton*	*Beef*	*Dairy*	*All Farm Produce*
1949-50	23.2	93.8	68.6	18.0	125.8	366.2
1950-51	25.0	227.2	131.4	24.2	136.4	582.6
1951-52	22.7	108.7	77.5	27.0	152.2	436.5
1952-53	23.8	128.1	93.5	44.6	179.9	522.2
1953-54	32.4	142.3	104.9	36.2	178.6	544.6
1954-55	31.9	151.7	112.1	44.7	169.1	562.1
1955-56	32.2	143.0	111.5	36.8	176.9	554.4
1956-57	29.7	183.0	124.1	41.7	179.2	614.0
1957-58	29.7	137.8	117.8	63.0	187.5	592.7
1958-59	31.8	130.4	106.0	67.4	172.9	564.2
1959-60	39.2	169.5	99.3	67.9	187.4	623.5
1960-61	42.3	158.3	109.1	55.0	184.5	613.9
1961-62	42.2	153.9	92.6	59.7	175.9	595.0
1962-63	43.3	180.5	107.8	68.8	180.5	654.0
1963-64	50.0	230.1	131.3	74.4	198.3	763.6
1964-65	48.7	172.9	166.9	87.1	229.4	792.1
1965-66	51.1	193.2	166.9	95.7	251.8	850.5
1966-67	58.6	162.7	140.4	103.9	261.4	824.6
1967-68	66.9	131.6	155.8	121.6	242.5	817.9
1968-69	74.1	155.8	168.5	141.8	237.5	885.6
1969-70	60.0	139.4	188.3	176.7	217.3	893.8

Sources: 1949-67 Hadfield (1971, Table XII).
1968-69 *NZOYB* (1973, 389).

TABLE 6.18

PRICES RECEIVED AND PRICES PAID 1949-1969
(1949-50=100)

Year	*Price Index of Farm Outputs*	*Price Index of Farm Inputs*	*Terms of Exchange*[a]
1949-50	100.0	100.0	100.0
1950-51	155.4	108.4	143.4
1951-52	116.4	127.0	91.7
1952-53	133.0	132.4	100.5
1953-54	138.7	133.9	103.6
1954-55	140.1	140.2	99.9
1955-56	135.1	143.7	94.0
1956-57	147.5	145.1	101.7
1957-58	132.9	152.0	87.4
1958-59	121.7	152.9	79.6
1959-60	132.8	154.8	85.8
1960-61	125.2	159.0	78.7
1961-62	119.2	161.5	73.8
1962-63	124.5	163.3	76.2
1963-64	140.5	164.2	85.6
1964-65	141.9	166.2	85.4
1965-66	144.0	172.8	83.3
1966-67	134.9	178.7	75.5
1967-68	130.0	182.6	71.2
1968-69	137.4	190.6	72.1
1969-70	..	..	..

Note: *a* Price index of farm outputs divided by price index of farm inputs.

Source: Hadfield (1971, Table III).

farmers to employ new technology as a substitute for labour (Blyth, 1961, 9)--a trend after the war deemed an indication of farming's increased efficiency (Ross, 1954, 330).

The period of prosperity showed signs of deteriorating in 1956 as export price levels began to fall, first in dairying and later in sheep products (Fielding, 1963, 160). The effect on income was the reverse as wool and sheep meat income fell more rapidly (Table 6.17). This accounts for the rapid decrease in demand for agricultural aviation operations after 1957 (Table 6.2). The domestic subsidy of agricultural production in Britain and the dumping of foreign subsidized butter surpluses in that market indicated the end of New Zealand's hope for a return to something approaching a free-market situation (Lewthwaite, 1971, 77, 83). An assured market to 1967 for meat had been negotiated as early as 1952 but dairy produce was not considered until 1957 (Long, 1963, 38-39). The drain on the Dairy Industry Stabilization Account, which was involved in the termination of the lime transport subsidy, exhausted its funds by 1958 and prompted a new entry agreement in 1959. Although entry into the market was retained, the volume of dairy produce was affected. A quota on butter was agreed to in 1962 because there was no other guarantee available (Lewthwaite, 1971, 84).

This crisis indicated the country's vulnerability to lower prices because of that sector's predominance in the economy. The creation of new industries supplying inputs to agriculture spread the adverse effects more widely as they were not geared to export markets as well. For example, when farmers reduced their demand for soil amending as their income decreased (Philpott and Stewart, 1958b, 37), the agricultural aviation industry was forced to decrease its operations (Table 6.2).

The return in 1957 of a Labour Government signalled the initiation of a program to develop a broader industrial base in the economy, to counter its vulnerability to economic changes in export markets. Processing local raw materials was to be increased along with the local processing of imported raw materials to reduce finished-product imports (Sutch, 1966, 427). Although opposed by a variety of interests, including farmers, the concepts developed in 1960 by the Industrial Development Conference (DIC, 1960, 78-148) had some effect. The prices for agricultural products were fluctuating, competition from synthetics was affecting the butter and wool markets, agricultural protectionism was increasing in New Zealand's North American and European markets, and the possibility of Britain's joining the European Economic Community (leading to the prospect of losing entry to the principal market) all added to the uncertainty faced by farmers (Sutch, 1966, 429). They were exhorted to diversity land use and contribute to the industrialization needed to process more of the wider range of agricultural produce. The degree of income fluctuation would be reduced in serving more markets with a greater range of produce (Westrate, 1959, 261). Nonetheless, the development of 'more intensive farming on the present pattern' was urged to promote economic development (Sutch, 1968e, 118), but falling income and deteriorating terms of exchange (Tables 6.17 and 6.18) made this task more difficult. Regardless of this problem, farmers did manage to increase output by the mid-1960s (Table 6.14) by almost steadily increasing their gross output per unit of aggregate input from 97.3 to 125.1 (1949-50 base = 100.0) between 1957-58 and 1960-61 (Hussey and Philpott, 1969, Table V). Thereafter, a decline began which continued to 1966-67 when output overtook input cost and created a short-lived improvement (Ellison, 1977, Table 1).

Some economists were concerned that overemphasis on the development of manufacturing could prove too costly because New Zealand's lack of raw materials would place the burden of earning the foreign exchange needed to acquire them on the agricultural sector (Long, 1963, 79) and consume investment capital required in the agricultural sector to achieve increased productivity (Blyth, 1961, 9). The buffering of the economy by the industrialization was questioned because of these features:

> whereas we once had a vulnerability problem in the form of fluctuating incomes resulting from fluctuating prices (which to some extent is amenable to control) New Zealand now has another and graver vulnerability problem in the form of the maintenance of a steady but increasing supply of imported raw materials to avoid industrial unemployment. In these terms the importance of agriculture as the main and almost sole earner of overseas funds has, if anything, increased rather than declined. (Philpott, 1963, 26)

With a change of government in 1960 came a re-evaluation of the industrialization policy. The push to promote manufacturing slowed as a consequence, along with the resource development required (Sutch, 1966, 430-431). Policy shifted to a promotion of fishing, tourism, and agriculture. Development conferences on the model of that for industry were held dealing with agriculture and exporting. At this juncture:

> The Agricultural Development Conference focussed attention on our dependence on expanded agricultural production to maintain, let alone increase, our standard of living (Johns, 1966, 9)

and set targets to be reached through the application of technology (Hamilton, 1965, 9). The Export Development Conference helped in the institutional reform needed to improve marketing and provide financial and administrative aids in exporting (Sutch, 1966, 431). Some evidence of a marketing policy was still considered necessary in 1968 to compensate for the maximum production policy in effect. The lack of co-ordination inhibited farm development through the lack of confidence in commodity prices (Jensen, 1968, 4). The production diversification aspect was left in abeyance as it was felt that:

> At that time, with the technical knowledge available, it could not be seen that there was any point in making major alterations in the New Zealand scheme of farm husbandry. It was established that the return per acre from pastoral farming was sound and attractive though it was agreed that a certain measure of arable farming and horticulture must always find a place in our farming economy. (Bevin, 1968, 43)

These changes began to be instituted in the early 1960s but were not fully in operation by 1968 (Long, 1963, 27-28; Rosenberg, 1968, 165-171). The view was expressed:

> we are beset with numerous marketing problems for our traditional exports of meat, butter, cheese and wool. Some of these problems are new but some have been with use for years. ... The outlook for our agricultural products is still good although on many markets we have problems of access and dumping, especially in the field of dairy products. Our dependence on traditional markets is being reduced and new markets are being developed. (Blomfield, 1968, 44, 47)

It was maintained that these changes were not dealing with the basic need to readjust the country's economic structure and failed to recognize the key role the expansion of manufacturing had had in increasing the country's standard of living (Sutch, 1968a, 183, 173). The economy's vulnerability continued as agricultural production and marketing had not significantly diversified to alter fluctuating price characteristics in the face of rising protectionism in industrial countries (Sutch, 1968a, 163-164). The Agricultural Development Conference and the recovery of farm earnings by the mid-1960s (Table 6.17) and an improvement in the terms of exchange (Table 6.18) served to create an optimistic production environment (Ward, 1973, 25) which delayed further action. The price drop in wool in 1966-67 (Fig. 6.1) indicated that Sutch's view had validity as it repeated features seen a decade earlier with the agricultural service industries entering a recession once again (Table 6.2).

The uncertainty of the export market when compared to the growing local market 'led farmers to place greater emphasis on import substitution crops and products', a trend which slowed the rate of increase in output for export while the output for local consumption rose rapidly (Ward, 1973, 19). Increased productivity tended to be absorbed by rising external costs over which farmers had little control (Ward, 1973, 26). The unrest which developed was thought to have markedly increased government involvement in the agricultural sector through subsidies and ad hoc schemes (Ward, 1973, 15, 26-27).

Despite the problems of dependence on the agricultural sector, economic planning remained based upon it. The National Development Conference of 1968 was initiated by the 'success of planning for increased pastoral production' resulting from the two Agricultural Development Conferences held in 1963 and 1966 and the ongoing work of the Agricultural Development Council (Lang, 1969, 8). Farm production was increased (Table 6.14) along with soil amending (Table 6.9). Other sectors sought to achieve the same performance, but Lang (1969, 10) noted:

> the whole concept of the National Development Conference is designed to ensure that agriculture will get the resources necessary to attain the targets.

based on the belief that all the increased volume of animal products would be sold. The manufacturing sector was to serve to absorb the increasing labour which agriculture could not employ, and become capable of exporting as well (Lang, 1969, 11). Food processing led manufacturing development in exporting through its utilization of domestic produce, a desirable trend for farming (Condliffe, 1969b, 85).

SUMMARY

The postwar period saw the intensification of the country's agricultural production based upon grassland farming. The area in grassland increased almost steadily throughout the period (Table 6.15). Crop land did show some increase after the mid-1950s and again after the mid-1960s (Table 6.15) as government policy and uncertain markets encouraged domestic grain production (Table 6.14), but yield increases tended to offset the need to boost acreage (Claridge, 1972, 5). The cutting of grass for hay and silage in a similar fashion offset the need to increase green fodder, root, and other crops to maintain the growing numbers of livestock. From 1955 the acreage in green fodder and root crops began to decline, albeit unsteadily (Table 6.15).

Though records indicate the rise in hay and silage acreage (Table 6.15), the contribution of saved pasture is not similarly noted. No doubt this technique aided the maintenance of more livestock through its emphasis on extending pasture production further into the winter season. Such a technique relied upon the knowledge of pasture-growth patterns and stock management by rotational-grazing methods employing substantially more fencing. Although suitable for more intensive forms of production, these concepts could be employed on less productive country, provided the essential soil amending had occurred. This was the role played by the mechanization of distribution in the form of aircraft and ground-spreading vehicles.

It was known that the nitrogen needed for grass production could be obtained through the establishment of suitable legumes in the sward. The soil conditions they favoured were known and were being established widely through topdressing in lowland areas prior to 1950. The increased livestock production (Table 6.14) pointed out further problems in the soil element cycles involved in pasture production. The recognition of sulphur, magnesium, and molybdenum deficiencies pointed out weaknesses in previous assumptions in soil-amending techniques and their evaluation. The role of superphosphate in overcoming sulphur deficiency was uncovered and served to promote its use in areas where other phosphatic fertilizers had been preferred. The reduction of phosphatic fertilizer imports (Table 6.11) and the emphasis on superphosphate production became permanent features of the expanded fertilizer industry.

The greater production levels being achieved created a potassium deficiency in many areas. The need for potassic fertilizers increased their import levels rapidly in the 1960s when this deficiency problem was recognized. The lack of such an input had been recognized earlier (Orchiston, 1957) but had not been acted upon in a major way.

The chemical and biological relationships involved in grasslands production were becoming more widely recognized not only by researchers but also by the farmers. The period marked the fruition of work done earlier. Analytical techniques had improved, educational institutions had developed to train both researchers and farmers, and research organizations had been developed to investigate production problems more fully. As one commentator, P.W. Smallfield (1970, 129) observed:

> Probably the greatest contribution to farming in the 1950s was the development of large and efficient research stations dealing with practically all problems of primary production; the Departments of Agriculture and Scientific and Industrial Research, Massey and Lincoln agricultural colleges and the dairy, meat and wool research institutes all made important contributions.

The co-ordination of institutional efforts was a critical feature of the period in promoting and developing soil-amending technology. Seeking means to solve soil erosion problems led the SCRCC to employ techniques utilized earlier by both the Departments of Public Works and Agriculture. Men involved in experimentation transferred knowledge so acquired not only to various public organizations but also to the private sector, an important development in the creation of the agricultural-aviation industry. Government involvement provided the substantial resources needed to establish the activity, and the publicity to promote its adoption.

The benefit accrued to entrepreneurs who soon made agricultural aviation available to farmers throughout New Zealand. The availability of the service was enhanced by a deployment of numerous small, if obsolete and somewhat inefficient, aircraft flown by wartime-trained pilots. Government operations did not eventuate as private firms demonstrated their capability to provide the service. Government only regulated the industry's development through licensing to ensure the growth of stable firms and the maintenance of the service over the country.

A similar concern was extended to the fertilizer and lime industries. Through price control and transport subsidies, the use of those materials was promoted as a means to boost agricultural production. In the case of the lime industry, once a general subsidy was withdrawn, consumption and production fell (Table 6.8) as alternative means of treatment had emerged. Recognition of the role of fertilizer prompted the opposite response--the direct subsidization from 1965 to offset rising costs. Its use was maintained and increased accordingly (Table 6.9). Public sector involvement in the research which established the technology and national concern with maintaining production explain this form of governmental intervention.

Farmers sought to maintain some influence on their production environment through the operation of such bodies as the Primary Producers' Boards. The Dairy and Meat Boards were involved in the lime transport subsidy program, and the Meat and Wool Boards actively encouraged the acquisition of better equipment by agricultural aviation firms, and the establishment of fertilizer plants. Farmers' co-operatives were also involved in the expansion of fertilizer production in both islands, and the farming industry as a whole appeared:

> quite prepared to carry on where the State is not, giving the requisite financial support and trained staff required for an efficient research and advisory service not entirely under the State's administrative control. (Levy, 1970, 349)

In seeking to improve its productivity the agricultural sector came to rely more heavily on other sectors to provide production inputs, innovations, and a suitable production environment. In so doing, the sector stimulated an expansion of agriculture-related industry and an increased economic reliance upon the sector's trade:

> The farming economic scene is fast changing, and there are now built up large and expensive supply services to the land to aid production, to buy, process, store, sell and distribute farm products. And so many more secondary industries and workers now depend on overseas exchange for raw products and for imports that govern our standard of living, that it is becoming more and more imperative that no bottle-neck in production of our national income lies in the soil itself. Somehow or other all land must be brought to a high state of production--lowland and hill-and this can be done by skillful manipulation of grazing animals and a build-up of soil fertility. (Levy, 1959, 9)

Inventive activity continued to be important, given the institutional structure present, but subsequent innovations had less influence in changing the existing technical structure. A highly productive agricultural system could be sustained by innovations which largely served to improve the productivity of production processes. Research concern centred mainly on finding techniques to best use existing resources. This was the case with the work on phosphate retention and with the substitution of more productive animals and plants for those in use through dairy herd testing and artificial insemination and through breeding new strains of grasses and clovers.

Despite such technical progress, increasing uncertainty developing in traditional markets led to a review of the structure of the national economy. Industry was promoted but at a cost to farming through reduced investment and higher costs for protected locally produced inputs (Lane, 1973, 62). To 1970 this remained the direction of economic development. For agriculture, and hence, for New Zealand as a whole, changes in the 1960s initiated a 'search for stability' (Smallfield, 1970, 132) which continued into the following decade:

> The future of farming will not be resolved until the issue of the form and extent of industrial protection is resolved. This was not resolved in the last decade and there can be no guarantee that it will be resolved in the next. (Ward, 1973, 38)

CHAPTER 7

SOIL AMENDING, AGRICULTURAL GROWTH, AND STRUCTURAL STABILITY

In this chapter is reviewed the long-term role of soil-amending technology in the growth of agriculture in New Zealand. It is apparent from the preceding three chapters that the application of that technology has been an important factor in the historical development of grassland farming systems. Not only the direct production benefit created with the addition of soil nutrients and the control of soil acidity but also the indirect benefits acquired from the direction of scientific research effort to agricultural problems were an outcome of the concern with soil amending. This concern stemmed from farm enterprise changes brought about by transport technology innovation. Soil amending complemented these changes in meeting their increased soil fertility demand, and induced further change in the technology employed. In effect, agriculture's commercial orientation in serving local and foreign urban markets was secured by these developments.

The structure of farming accompanying the farm-enterprise changes was fixed into the production environment. As soil-amending technology suited the characteristics of that structure, its use was undertaken and extended. The result was the creation and long-run maintenance of a grassland farming system geared to produce for a market which offered generally stable demand over a long period. Thus, New Zealand's trading relationships have been an important factor determining the structure of the economy. The surety of the colonial period provided a basis for growth but, with the loosening of that bond, the unbalanced economic structure was apparent.

Pressure for structural change has been produced whenever agriculture's contribution to the economy has been reduced, yet change in the structure has been deterred by the possibilities of improving the performance of the existing structure, often through innovation and improvement connected with soil amending. The economic viability of agriculture has remained. Until the last decade of the period studied successive efforts to effect change did not produce important industrial development not also linked to agricultural output.

The government in New Zealand has participated increasingly in the processes noted above. From encouraging population growth, infrastructure extension, and industry establishment, government has moved to deeper involvement in stimulating economically desired enterprises. Closer land settlement marked a phase wherein government's contribution became more widespread, extending to produce quality control and founding research establishments to furnish information and technology to the intensive livestock enterprises. Economic reverses tended to deepen this involvement to the point where governmental decisions were part of the production environment of the agricultural sector.

Insofar as government has supported agriculture's economic primacy it has contributed to the stability of pattern which has characterized the economy. The pursuit of economic viability through specialized livestock production for almost a century has allowed such stability to develop, yet it has been technological change which has sustained that stability. The fixity of farming structure and the support of governmental policy have seemingly directed technology to suit the structure rather than allow it to create change in the structure.

SOIL-AMENDING TECHNOLOGY

It has been observed in the course of the previous chapters that the adoption of soil amending technology has been associated with the agricultural sector's development. The application of soil-amending technology through the topdressing of pastures with an increasingly broad range of chemical fertilizers has been a major technological change in New Zealand agriculture. The emphasis on grassland farming has developed through the capacity of soil amending to provide the nutrients and soil conditions required to sustain high levels of farm production.

With the low level of demand on grassland made by the ranching methods of extensive sheep grazing (Grigg, 1974, 253), the need for this technology was less apparent. Low rates of stocking on the land occupied (Table 7.1), the possibility of improving grassland output fourfold by sowing European grasses and clovers (Cockayne, 1918, 127), and the possibility of occupying unused land meant that the utility of employing a technology devised for more intensive farming systems in Europe was low. The mixed, semi-subsistence farms would have had a

TABLE 7.1

RATIO OF LIVESTOCK TO LAND (LIVESTOCK UNITS PER ACRE) 1851-55 - 1966-70

5-Year Period	*Sheep*			*Cattle*												*Horses*		
				Dairy Cows			*Other Dairy*			*Beef*			*Total*					
	AO	*IL*	*SG*	*AO*	*IL*	*SG*	*AO*	*IL*	*SG*	*AO*	*IL*	*SG*	*AO*	*IL*	*SG*	*AO*	*IL*	*SG*
1851-55	..	1.69	2.85	..	..	..				..			..	1.02	1.71	..	.10	.17
1856-60	..	2.02	2.86	..	..	..				..			..	1.09	1.55	..	.12	.17
1861-65	..	2.11	2.98	..	..	..				..			..	.73	1.03	..	.06	.09
1866-70	..	1.56	2.59	..	.11	.18				.23	0.4		..	.35	0.58	..	.07	.12
1871-75	.08	1.21	1.71	.01	.09	.13		.01		.22	.32		.02	.31	.45	--	.06	.09
1876-80	..	.63	.85	..	.05	.07		..		.11	.15		..	.17	.22	..	.04	.05
1881-85	.08	.39	.51	.01	.04	.05		.02		.08	.11		.03	.12	.16	.01	.03	.04
1886-90	.09	.35	.43	.01	.04	.05		.02		.08	.1		.03	.12	.14	.01	.02	.03
1891-95	.1	.33	.39	.01	.03	.03		.02		.06	.08		.03	.09	.11	.01	.02	.03
1896-1900	.1	.28	.32	.01	.03	.03		.02		.07	.08		.04	.10	.12	.01	.02	.02
1901-05	.09	.24	.28	.01	.03	.04		.03		.08	.09		.04	.11	.13	.01	.02	.02
1906-10	.1	.25	.28	.02	.04	.04		.03		.09	.1		.05	.12	.14	.01	.02	.03
1911-15	.10	.25	.28	.02	.04	.04		.03		.08	.1		.05	.12	.14	.01	.02	.03
1916-20	.1	.24	.27	.02	.04	.05		.05		.11	.13		.06	.16	.18	.01	.02	.02
1921-25	.09	.21	.24	.03	.06	.06		.05		.12	.14		.08	.18	.21	.01	.02	.02
1926-30	.1	.24	.27	.04	.07	.07		.05		.12	.13		.08	.18	.20	.01	.02	.02
1931-35	.11	.25	.28	.05	.09	.1		.06		.13	.14		.1	.22	.24	.01	.01	.02
1926-40	.12	.26	.3	.05	.09	.10		.06		.14	.15		.10	.23	.25	.01	.01	.02
1941-45	.13	.28	.31	.05	.09	.1		.06		.14	.16		.11	.23	.26	.01	.01	.01
1946-50	.13	.27	.30	.05	.08	.1	.02	.05	.05	.05	.1	.11	.11	.24	.26	--	.01	.01
1951-55	.14	.30	.34	.06	.1	.11	.02	.05	.06	.06	.12	.14	.13	.27	.30	--	.01	.01
1956-60	.17	.37	.41	.06	.1	.11	.02	.05	.06	.07	.14	.16	.14	.29	.33	--	.01	.01
1961-65	.19	.39	.44	.06	.09	.10	.03	.05	.06	.08	.16	.18	.15	.31	.34	--	--	--
1966-70	.23	.43	.49	.06	.1	.11	.03	.06	.07	.10	.2	.22	.19	.35	.40	--	--	--

Notes: *AO* = per acre of area occupied, *IL* = per acre of improved land, and *SG* = per acre of sown grassland.

Source: Calculated from data in Tables 7.4 and 7.5

greater interest in this technology as the fertility demands were greater and soil deficiencies made more apparent. The limited use of soil amending on the mission farms (Hargreaves, 1966, 47) raises this possibility as it indicates that arable farming and soil amending were closely linked at the time. As long as grass was not viewed as a crop, pasture benefited from soil amending only where it was sown in rotation with crops and those crops did not fully extract the nutrients provided. Through the nineteenth century the intensity of grassland use declined as seen in the falling ratio of stock to sown grassland (Table 7.1) and the decreased percentage of grassland cut for hay and silage (Table 7.2). The extension of sown grassland acreage was a more important process at this stage than intensifying its use.

Nonetheless, soil amending was being more widely practiced by the 1880s as shown by the rising levels of imports recorded (Table 7.3), and becoming more widespread as the greater quantities were not applied at a greater rate per acre of improved land (Table 7.2). This observation holds true until the 1891-95 period when the upsurge in imports (Table 7.3) began to catch up with the rate of sown grassland formation (Table 7.4). Grain cropping, which boomed prior to the 1890s (Table 7.4), provided an entry point for soil-amending technology and linked New Zealand and British practice in also showing the common concern with soil phosphorus deficiency.

The discovery of methods of producing chemical fertilizers and of suitable production materials facilitated the diffusion of soil-amending technology. The work of Lawes and Thomas on superphosphate and basic slag respectively formed an information pool which was tapped by New Zealand farmers. Their interest grew in the 1890s as the sudden rise in soil amendment imports shows (Table 7.3). The introduction of refrigeration and the opening of the British market for mutton, lamb, and dairy produce was accompanied by an extension of more intensive farming. The occupation and improvement of land continued (Table 7.4) and livestock numbers rose (Table 7.5) thereby tapping the existing fertility of newly cleared and newly ploughed land. The depletion of the fertility from that source was a stimulus to experiment with soil amending. Farmers could readily observe the positive or negative effects of soil amending and so, the characteristics of the innovation were to abet its adoption. The almost infinitely divisible nature of the practice allowed farmers to invest as much time, labour, and

TABLE 7.2

GRASSLAND TECHNOLOGY DATA 1851-55 - 1966-70

5-Year Period	Percentage of:									Application Rate[c]: (tons/acre improved)	
	Area Occupied Improved	Improved Land in:			Sown Grass:						
		Sown Grass	Green Fodder[a]	Grain Crops	Cut for Hay[b]	Proportion in:			Topdressed	Limestone	Chemical Fertilizer
						Hay	Silage	Lucerne			
1851-55	..	59.4[1]	3.9[2]	28.2[2]	..				..	..	..
1856-60[2]	..	70.6	4	20.1	..				..	..	..
1861-65[2]	..	70.6	1.9	21.4	..				..	..	..
1866-70	..	60.2[3]	1.7[3]	20.1[3]	5.5[2]				..	..	.001
1871-75	..	70.6	2.7	17.2	3.5				..	..	.001
1876-80	..	74.3	5.1	13.2	2.1				..	..	--
1881-85	..	77.2	6.8	11.7	1.4				..	..	.001
1886-90	25.9[1]	81.6	6	9.8	0.9				..	..	.001
1891-95	29.7[1]	85	5.8	7.3	0.7				..	..	.002
1896-1900	34.2[4]	86.5	6.3	6.4	0.8				..	--[1]	.002
1901-05	37.1	88.4	5.7	5.2	0.6				..	..	.003
1906-10	39.2	88.2	6.7	4.6	0.6				..	..	.004
1911-15	40.1[1]	88	6	4.4	0.4				..	..	.006
1916-20	40.7	89.6	4.1	4.8	0.7				..	.006[4]	.005
1921-25	42.2	89.6	4	4.4	1.1				..	.006	.007
1926-30	43.5	90.7	3.7	3.2	1.8	91.1[4]	9[4]		13.7[3]	.009	.015
1931-35	44.6	90.1	3.6	3.7	2.9	72.2	20.7	7.1	14.7	.012	.014
1936-40	45.6	89.3	3.2	3.0	3.1	79.6	13.4	7.1	20.8	.022	.024
1941-45	46.2	89.3	3.2	3.0	3.1	81.3	10.9	7.8	21.8	.038	.011
1946-50	46.8	89.9	3.2	2.3	3.3	82.8	9.4	7.8	25.9	.053	.023
1951-55	46.3	89.5	3.7	1.8	4.4	69.9	19.4	10.7	27.7	.068	.032
1956-60	41.4	89.6[4]	3.7[4]	1.6[4]	5.6[4]	68.1[4]	18.3[4]	13.6[4]	49.7	.054	.033
1961-65	49.5	89.8	3.3	2	5.6	70.6	15.2	14.2	55.7	.045	.042
1966-70	53.3	88.4	2.8	2.5	6.7	74.6	11.5	13.9	64.8	.044	.054

Notes: *a* Includes root crops used for fodder.
b Includes silage.
c An application rate of 1 cwt/acre = 0.05

Sources: Hay, silage, and lucerne percentages and topdressing data calculated from *Agricultural Statistics* (for years shown).

Other figures calculated from data in Tables 7.3 and 7.4.

TABLE 7.3

TONNAGE OF SOIL AMENDMENTS USED 1866-70 - 1966-70

5-Year Period	*Imports:*					*Domestic Production:*	
	Nitrogen	*Phosphorus*[a]	*Potassium*	*Total*[c]	*Sulphur*	*Phosphorus*	*Limestone*
1866-70	..	..	..	418[4]	41[4]	—	..
1871-75	..	..	..	916	185	—	..
1876-80	..	..	..	1,394	218	—	..
1881-85	..	..	..	6,497	294	—	..
1886-90	..	..	..	7,416	231	—	..
1891-95	..	..	..	16,803	161	—	..
1896-1900	..	..	..	26,346	137	—	1,000[1]
1901-05	..	..	..	37,763	459	4,023[3]	..
1906-10	..	..	..	65,925	1,207	7,020	..
1911-15	1,887[2]	36,231[2 b]	1,437[2]	104,438	1,522	9,540	..
1916-20	624	30,470[b]	152	93,600	2,958	5.398	100,232
1921-25	325	37,924	2,590	128,070	11,476	3,275[4]	117,774
1926-30	1,176	90,535	4,631	282,970	29,586	—	175,154
1931-35	1,273	82,908	2,827	259,801	34,644	—	223,056
1936-40	1,421	136,374	6,634	470,290	52,283	—	438,920
1941-45	901	74,351	1,537	210,015	44,568	12,376[3]	762,138
1946-50	895	165,536	4,044	455,863	60,878	5,624[2]	1,060,398
1951-55	2,728	219,920	16,842	648,353	100,262	—	1,370,828
1956-60	3,603	216,098	36,515	660,598	92,848	—	1,091,219
1961-65	4,678	281,189	75,216	930,047	156,322	—	980,632
1966-70	6,841	394,519	87,657	1,235,537	191,972	—	998,237

Notes: *a* Organic fertilizers not included.

b Guano and raw rock phosphate were combined from 1914 to 1918. The total is treated as raw rock phosphate.

c Imports are shown as the equivalent tonnage of the nutrient shown, but the total given is a summation of the absolute figures recorded.

TABLE 7.3 (Continued)

Sources: Calculated from:

i) Imports - nutrient type

1914-61 *Statistics of New Zealand*; *Trade and Shipping Statistics.*

1962-70 *Trade and Shipping Statistics* (1962a; 1962b); *Import Statistics.*

Imports - total

1867-1920 *Statistics of New Zealand.*

1921-70 *Trade and Shipping Statistics*; *Import Statistics.*

ii) Domestic Production - phosphorus

Table 5.6.

Domestic Production - limestone

1900 Orchiston (1957, 8).

1917-70 Tables 5.6 and 6.8.

TABLE 7.4

NUMBER OF HOLDINGS (THOUSANDS); AREA OCCUPIED, AND PRINCIPAL LAND USES (THOUSANDS OF ACRES) 1851-55 - 1966-70

5-Year Period	*Number of Holdings*	*Area Occupied*	*Average Area Occupied per Holding*	*Improved Land*	*Average Area Improved per Holding*	*Sown Grass and Clover*	*Hay and Silage*	*Green Fodder and Root Crops*	*Grain Crops*
1851-55	..	..	..	48.5[2]	..	28.8[1]	..	1.9[2]	13.7[2]
1856-60[2]	..	..	..	125.5	..	88.6	..	5	25.2
1861-65[2]	..	..	..	304.6	..	215.1	..	5.9	65.2
1866-70	12.7[2]	..	..	899.5	70.8	541.3[3]	29.7[2]	15.2[3]	180.6[3]
1871-75	14.5	23,530.2[2]	1,622.8	1,475.8	102	1,042.1	36.7	40.4	254.2
1876-80	20.1	..	..	3,466.2	172.1	2,574.1	54	177.3	458.5
1881-85	27.2	26,845.5[1]	987	5,646.4	207.3	4,362.2	62.8	385.8	660.5
1886-90	34.8	28,169.8[1]	810.6	7,296.9	210	5,952.1	52.5	440.1	711.7
1891-95	42.8	31,867.5[1]	744.4	9,452.1	220.8	8,032.2	54	546.2	691.2
1896-1900	61.1[4]	34,025.4[4]	556.7	11,630.5	190.3	10,058.3	83.6	730.5	745.7
1901-05	65.3	35,858.9	549	13,290	203.5	11,753.9	71.3	755.6	692.1
1906-10[4]	72.7	37,586.1	517	14,737.2	202.7	12,998.3	79.5	986.2	671.9
1911-15	73.9[1]	40,238.1	544.7	16,154.2	218.7	14,214.7	62.6	966.3	719.9
1916-20	79.8	42,807	536.5	17,410.6	218.2	15,601.5	112.5	706.9	831.7
1921-25	85.3	43,586.6	510.8	18,384.4	215.5	16,464.1	188.7	732.7	802.2
1926-30	85.6	43,508.2	508.5	18,929.8	221.2	17,163.8	311.4	705.9	608.1
1931-35	84	42,877.8	510.7	19,115.9	227.7	17,224.6	499.9	680.9	712.3
1936-40	85.6	43,094.4	503.5	19,666.4	229.8	17,556	550.5	637.6	592.4
1941-45	86.2	42,965.7	498.7	19,856.9	230.5	17,742.1	558.8	629.4	604.6
1946-50	87.4	42,969.5	491.6	20,106.1	230.0	18,080.6	590.7	653.3	467.3
1951-55	91.0	43,263.4	475.3	20,020.4	219.9	17,924.9	796.5	736.1	352.5
1956-60	82.5	42,874.8	519.6	20,217.0[4]	245	18,120.1[4]	1,021.6[4]	753.0[4]	323.8[4]
1961-65	72.1	43,644.4	605.5	21,592.0	298	19,386.2	1,095.8	716.7	424.0
1966-70	67.3	42,964.2	638.1	22,896.2	340.1	20,232.4	1,355	635.9	563.9

Sources: 1853-1920 *Statistics of New Zealand*; 1921-70 *Agricultural Statistics.*

TABLE 7.5

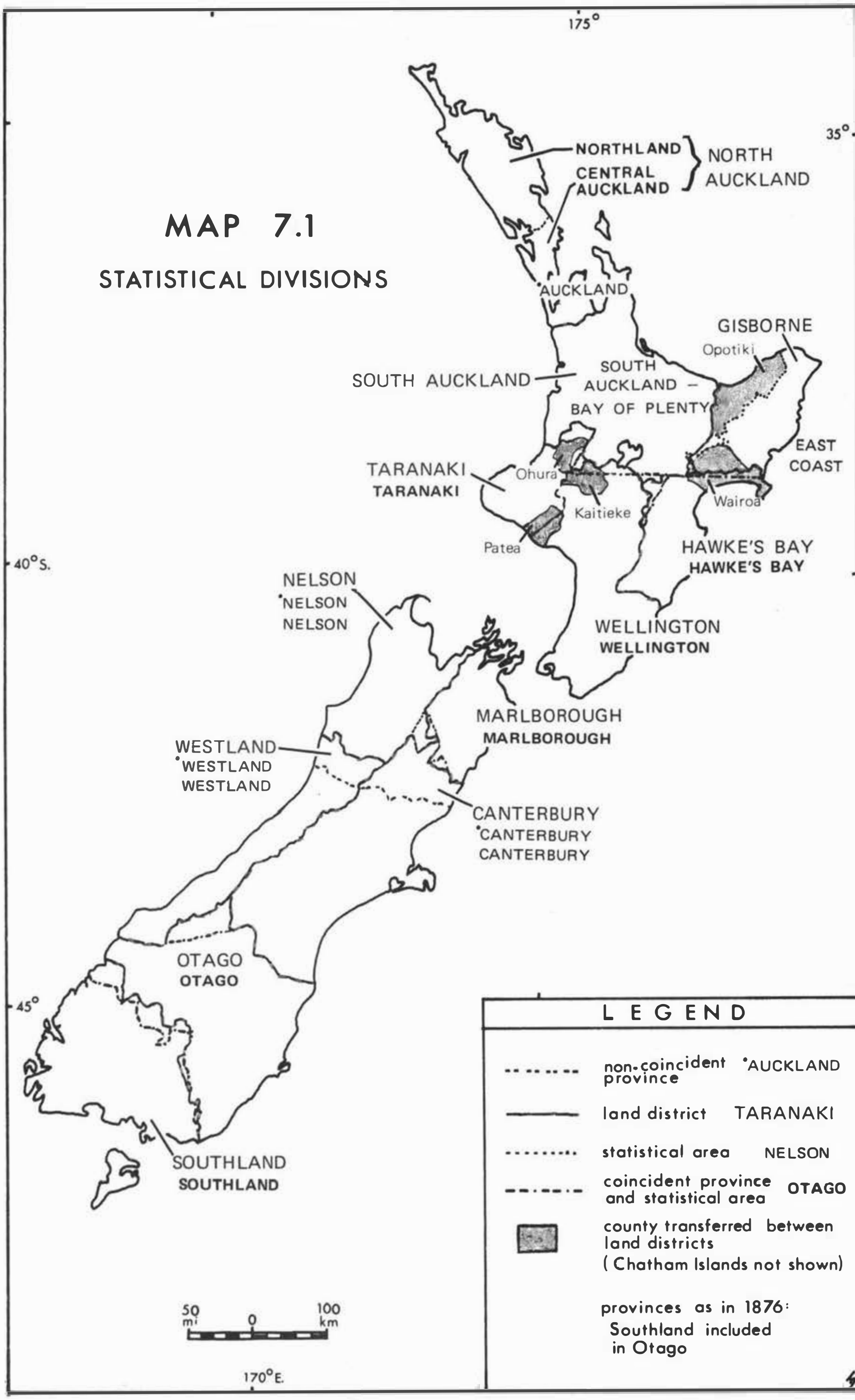
LIVESTOCK PRODUCTION IN THOUSANDS OF LIVESTOCK UNITS 1851-55 - 1966-70

5-Year Period	*Sheep*	*Cattle*				*Horses*	*Total*
		Dairy Cows	*Other Dairy*	*Beef*	*Total*		
1851-55[2]	82.0	..	..		49	5	136
1856-60[3]	253.8	..	..		137	15	405.8
1861-65	641.5	..	..		222	19	882.5
1866-70[1]	1,403.0	123.8	214		337.8	66	1,806.8
1871-75	1,783.9	168.8	331		449.8	90	2,373.7
1876-80	2,178.2	232.5[1]	392		624.5	138[1]	2,940.7
1881-85	2,214.4	283.8[1]	472		755.8	162[1]	3,132.2
1886-90	2,563.7	348.8[1]	574		922.8	187[1]	3,673.5
1891-95	3,158.7	321.3[1]	622		943.3	211[1]	4,313.0
1896-1900	3,240.2	397.5	846		1,243.5	252	4,735.7
1901-05	3,231.4	537.5	1,052		1,589.5	289	5,109.9
1906-10	3,709.7	668.8	1,278		1,946.8[4]	346[4]	6,002.5
1911-15	4,054.7	792.5	1,386		2,178.5[1]	404[1]	6,637.2
1916-20	4,211.5	985.0	1,992		2,977.0	367	7,555.5
1921-25	3,897.0	1,343.8	2,314		3,657.8	324	7,878.4
1926-30	4,586.0	1,571.3	2,183		3,754.3	304	8,644.3
1931-35	4,798.9	2,112.5	2,498		4,610.5	280	9,680.2
1936-40	5,225.4	2,218.8	2,674		4,892.8	276	10,394.2
1941-45	5,496.0	2,150.0	2,819		4,969.0	242	10,747.0
1946-50	5,494.5	2,157.5	948	2,065	5,170.5	204	10,869.0
1951-55	6,116.4	2,440.0	1,038	2,471	5,949.0	164	12,229.4
1956-60	7,422.5	2,432.5	1,028	2,941	6,401.5[4]	124	13,948.0
1961-65	8,422.7	2,483.8	1,149	3,510	7,142.8	87	15,652.5
1966-70	9,935.4	2,768.8	1,403	4,501	8,672.8	76	18,684.2

Note: The livestock units were calculated using the following conversion factor which is based on relative feed requirements given in Curry (1963):

1 livestock unit = 1 horse = 1 cattle beast = 6 sheep = 0.75 of a dairy cow in milk.

Source: Calculated from: 1851-80 Table 4.2; 1881-1920 *NZOYB* (1930, Statistical Summary); 1921-70 *Agricultural Statistics* (1970, Table 1).


MAP 7.1
STATISTICAL DIVISIONS
175°
35°
40° S.
45°
170° E.
NORTHLAND
CENTRAL AUCKLAND
NORTH AUCKLAND
AUCKLAND
SOUTH AUCKLAND
SOUTH AUCKLAND – BAY OF PLENTY
GISBORNE
Opotiki
EAST COAST
Ohura
Kaitieke
Wairoa
Patea
TARANAKI
TARANAKI
HAWKE'S BAY
HAWKE'S BAY
NELSON
NELSON
NELSON
WELLINGTON
WELLINGTON
MARLBOROUGH
MARLBOROUGH
WESTLAND
WESTLAND
WESTLAND
CANTERBURY
CANTERBURY
CANTERBURY
OTAGO
OTAGO
SOUTHLAND
SOUTHLAND
50 mi
0
100 km
LEGEND
non-coincident province AUCKLAND
land district TARANAKI
statistical area NELSON
coincident province and statistical area OTAGO
county transferred between land districts
(Chatham Islands not shown)
provinces as in 1876: Southland included in Otago

capital as they felt able to in trying this new procedure. Results would have been hindered had too little material been applied over too large an area because of the lessening of observable effects--greater crop or grass production--but after 1892 there was a government-organized group of advisers in the Department of Agriculture to assist in this aspect of the adoption process. The widespread use of the field trials held prior to the 1920s demonstrates the effect these few men were able to have and the interest level of farmers still in a pioneering phase in trying new practices. The simplicity of the practice encouraged its adoption before a scientific understanding of its processes emerged. Of greater concern was finding the most effective materials for the soils encountered within a given region or on a particular farm. For example, Waikato mixture, which included superphosphate, did not prove as effective in the conditions of Taranaki as basic slag; hence the adoption of domestically produced fertilizer was slowed because of this specificity problem. However, the overall use of soil amending was still extended and helped to overcome the difficulty of intensifying production on small farms with limited manpower.

In the arable-grass rotation system adopted, pastures had to be ploughed and resown to maintain higher yielding grasses. In adjusting methods to meet the nutritional needs the breeding ewes and dairy cows, farmers put a greater emphasis on green fodder and root crops to meet seasonal needs when grass was in short supply. This adjustment enabled the climatic limitations of a given area to be partially offset (Curry, 1963, 101). This emphasis grew in importance as the availability of areas of unimproved land suitable for forage decreased. From the 1876-1880 period to that of 1911-1915 between 5 and 7 percent of improved land was devoted to such crops (Table 7.2). The English feeding practices noted earlier were introduced once the need for them became evident (Clark, 1949, 384). The sowing of turnips on newly burned forest to break up the soil while providing fodder promoted the use of fodder crops, but the later need for cultivation was a limitation because of the manpower demanded. For the same reason, haying and silage making were not readily accepted as an alternative source of supplementary fodder. Where ploughing was hampered by difficult terrain, reversion to scrub and fern, and soil erosion began. A need was perceived to create a long-term, productive grassland to reduce labour input and overcome the land deterioration problem. The continued cultural and intellectual link with Britain furnished the access to advanced agronomic practice which pointed to a solution using soil amending. The experimentation in the Waikato proved that applying this technique to grassland boosted production yet did not involve cultivation. The addition of soil nutrients increased the yield and the longevity of good pasture swards just as it had proven effective in increasing the yield of supplementary fodder crops.

The rising level of fertilizer imports (Table 7.3) and the increased quantity applied per acre of improved land from the 1886-1890 period to 1916-1920 (Table 7.2), point to an increasing adoption of soil-amending practice, interrupted only because limited shipping reduced supplies and postwar economic conditions reduced incomes, both as the area of improved land increased (Table 7.4). With a resumption of fertilizer shipments, the expansion of domestic fertilizer production, and higher farm income levels, the rate of application rose again to a new peak of .007 tons per acre of improved land in the 1921-25 period. This was still a low level in terms of effectively amending soil, however. What must be noted is the adjustment of soil amending from crops to grassland, though the absence of data on crop land fertilized is a distinct limitation. The collection only of data on grassland topdressed reflects the principal practice but an indication of the volume of soil amendments applied for crop production would be useful for comparison's sake. The mixture of grain cropping and pastoral enterprises (Curry, 1963, 106-107) suggests that nutrients not taken up by one enterprise are left for the other, but variations in soil-amending practice are left unclear.

The use of fertilizer to increase production was largely a feature of dairying. The subdivision of farms to make 'a more effective utilization of prolific grass growth on fully improved farms' began along with the extension of the topdressing technique 'to improve pastures on partially-developed land' (Belshaw, 1936a, 28). The techniques of pasture management in balancing stock requirements against pasture growth also began--creating the basis for their wider use through imitation. By the mid-1930s it was recognized that this concern with soil and pasture was paying off:

> in the process of improving land to effect a higher carrying capacity, conditions are created which automatically tend to increase production from all the animals carried. ... There is ..., sufficient evidence

> to prove that on land not fully developed, an improved carrying capacity is the first essential in raising production per acre, improved average yield per herd becoming to some extent automatic. (Fawcett, 1936, 462)

Thereafter, the ratio of dairy cows to sown grassland showed little further change (Table 7.1), an indication that the increase in the number of dairy cows (Table 7.5) approached that of the acreage in sown grassland (Table 7.4). The ability to alter enterprises in light of varying market prices by incorporating lamb rearing and dairying on the same lowland farms allowed the dairy-based grassland technology to be extended to farm enterprises centred on sheep. It was in the 1930s that the ratio of sheep to sown grassland began to increase (Table 7.1). Thus, meat and,dairy producers were the first to benefit from the better pasture brought about by soil amending.

The application of lime, also recommended practice in soil amending, rose with fertilizer application. Early records of its use are not available apart from an estimate that in 1900 some 1,000 tons were quarried for agricultural use (Orchiston, 1957, 8), but by the 1921-25 period the average annual quantity quarried exceeded 117,000 tons and the rate of application approximated that of chemical fertilizers (Table 7.2). From the 1946-50 period average output was about 1 million tons and the average application rate about 1 cwt per acre. Output and the rate of application had both increased, trends which continued into the 1951-55 periods. These trends point to the spread and application of the concept that soil acidity, a critical factor in clover growth, must be controlled to maintain the nitrogen input needed for the high-yielding, permanent pasture sought in grassland farming in New Zealand. Adding soil nutrients alone was insufficient to achieve the desired effect at the same cost. Nitrogenous fertilizer could be applied, and indeed, some experimentation was undertaken in the 1920s, but encouraging clover growth provided a similar result using more readily available resources. The limited importation of nitrogenous fertilizers (Table 7.3) demonstrates the success of the other technique.

Identifying the phosphorus deficiency had led to a predominant use of phosphatic fertilizers. Prior to 1951 the total weight of nutrients other than phosphorus remained under 10,000 tons while phosphorus imports exceeded 150,000 tons (Table 7.3). Domestic production of both rock phosphate and bone-based fertilizers was inadequate as the greater level of phosphate imports indicates. The rising demand accompanying the gradual spread of grassland topdressing (Table 7.2) increased the importation of the raw materials for superphosphate production, rock phosphate and sulphur. Fluctuations in the availability of these two materials were reflected in soil-amending practice. Limestone application and production rose sharply from 1940 to 1950 as phosphate imports fell (Table 7.2 and 7.3). Superphosphate was made available principally in mixtures with materials such as serpentine rock or lime to extend the supply available and allow as many farmers as possible to undertake some soil amending. The wartime restrictions nonetheless checked the rise of topdressing practice (Table 7.2). Subsequent sulphur shortages threatened to keep superphosphate production down but were not long-lasting (Table 7.3). Accordingly, phosphorus imports revived and application rates increased to prewar levels (Tables 7.3 and 7.2).

As the demand for chemical fertilizers grew with topdressing so did the level of imports and the facilities for domestic phosphate production. The decline of superphosphate imports and the rise of rock phosphate imports noted earlier (Table 5.6) shows that domestic production was coping with demand in the 1920s. Observing the location of chemical fertilizer plants serves to identify those areas where soil-amending practice created sufficient demand to attract production facilities. The price competition which followed encouraged adoption of topdressing practice over a wider area. By World War II the more intensive grassland-farming districts of the North Island, South Auckland, Taranaki, and Wellington each contained at least one chemical fertilizer plant. The core area of pasture topdressing, the Waikato, was served by three plants. The entire South Island was served by only three plants, one located in Canterbury and two in Otago, but they had ready linkages to Southland and Canterbury. Postwar extension of more intensive livestock farming can be traced in a similar fashion though competition between privately owned and co-operatively owned firms emerges as a source of explanation of the locational pattern.

What is significant is that each of those major plants has been producing superphosphate. Domestic supply has not been the only source of phosphate fertilizer as superphosphate has been but one of the phosphate fertilizers employed. Basic slag imports rose rapidly to prewar levels by 1924 once the European centres of production recovered from wartime disruption. Only following World War II did the importation of this fertilizer finally decline. Previously, the quantity rose sharply after each supply interruption. Farmers may have acquired knowledge of the advantages of employing superphosphate when basic slag was unavailable but they were not prepared to abandon its use completely. There was nevertheless a decrease in its importance relative to superphosphate as the domestic suppliers improved their production levels and decreased prices of the latter fertilizer. Starting in the 1930s, superphosphate became the predominant fertilizer employed in New Zealand. It has also been the principal type produced as the technology associated with its use has provided the basis of New Zealand's grassland farming systems.

Only with longer term intensive production did potassium deficiency become apparent and lead to the marked increase in potassic fertilizer importation after 1950 (Table 7.3). This was a new element in grassland farming but one readily accommodated as it fitted into the existing pattern. The availability of low-cost supplies meant that existing fertilizer plants were not converted to potassic fertilizer production nor were new plants begun. There was a refinement of technique apparent but not a change in the overall pattern of soil amending and its place in grassland farming.

The pattern was reinforced by the success of aerial topdressing beginning in 1949. Applying soil amendments from the air was an extension of grassland technology already developed. Oversowing seed of grasses and legumes which would thrive in the amended soil fertility and acidity conditions completed the process of providing areas previously constrained by relief with access to the productivity benefits of high-producing pasture. By the late 1950s, just under a decade after aerial topdressing's inception, the extent of sown grassland topdressing had almost doubled from the 1946-50 level (Table 7.2). There were particular management problems to be faced because of the nature of the terrain but they differed largely in degree from those faced earlier by lowland farmers. Subdividing land to control grazing and increasing stocking rates in order to fully use pasture growth and providing water were problems shared. Different strategies emerged but they shared a grassland technology devised to be potentially uniform throughout the country (Daly, 1973, 21). Providing ready access to this technology to extensive and semi-extensive farming systems was the contribution of agricultural aviation. The benefit produced is seen in the rapid rise in the ratio of sheep to sown grassland after 1950 (Table 7.1). The beef cattle ratio also increased while that of dairy cows remained stable. From this point of view agricultural aviation can be seen as a major innovation though in terms of the development of soil amending technology it was a minor innovation, simply a new distribution methods.

The effect of this distribution technique is seen in the doubling of the percentage of sown grassland in the 1951-1961 decade. The previous doubling had occurred over 30 years from 1921 to 1951 (Table 7.2). As aerial operations accounted for 41 to 55 percent of all sown grassland topdressed between 1957 and 1970 (Table 6.6) they must have contributed to this increase. The proportion of the tonnage of fertilizer applied aerially from 1961-65 to 1966-70 did decrease slightly from 46.4 to 45.8 percent (calculated from Table 6.6) as contractors using trucks increased their share of the market, but the place of agricultural aviation remained important. An increase in the share of lime spread, from 9.3 to 12.0 percent in the same period, points to the more effective role of more powerful aircraft in spreading soil amendments and to greater demand for this material on newly improved grasslands. Improved applications of mechanical power to soil amending broadened its scope using established techniques.

DEMAND FOR TECHNOLOGY

The use of soil amending was a manifestation of the high interest of the individual New Zealand farmer in employing technology to increase production. Farmers were on the path to a greater application of available science-based technology, a path requiring both research and educational establishments. Farmers evaluated and adopted both machinery and techniques. Learning was an integral part of farming in the period of pioneering soil amending. The existence of 'old' capital in the form of established farming practices was not a major source of inertia given the change of farm enterprises and the entry of many novices into farming following the introduction of refrigerated shipping. Repaying the comparatively high-cost of land was a further incentive to improve production using machinery and chemical inputs from the secondary sector. As natural growth and immigration did not overcome the small absolute size of New Zealand's population, labour remained scarce into the 1930s (Buchanan, 1935, 1) and became increasingly so as employment in other sectors of the economy expanded (Lane, 1976, 10). The observation of Buchanan (1935, 3) that the New Zealand farmer:

> in striving to keep his costs of production down to the limit set by world price has a constant incentive to reduce to a minimum the number of his employees by providing them with the maximum possible of mechanical equipment

has remained valid and confirms the assertion that innovation is directed to areas of production factor shortage. Similarly, with the full occupation of the land most readily utilizable for farming, the emphasis in farming moved to improving the quality of that resource to increase productivity. The need for innovation in production was strongly felt.

The important production innovations were still largely mechanical and within the range of the farmers' experience, and farmers responded most rapidly to these (Callaghan and Peren, 1936, 295). This pattern has persisted into the 1970s as Taylor (1977, 336) suggests from the 'obvious demand for invention and technical progress in farm mechanisation' identified from above average rates of inventiveness where farm enterprises requiring a greater investment in machinery were located. Although the bases of grassland production were chemical and biochemical, the important innovations in the introduction of this technology were mechanical distributors and tractors to increase the control of application rates and the speed of application. In an age when engineering was highly esteemed, this trend was not surprising. The biochemical aspects had not yet been fully explored but seemed simple enough and, accordingly, soil amending was deployed before its full implications were understood.

The scientific advances being made placed increasing importance on the farmers' being able to understand the principles being applied as innovations became increasingly biologically and biochemically based. Farmer education did not evidently keep pace in terms of formal training. There was concern that the emergence of a 'community dominated by small farmers' led to 'the deplorable indifference to higher education which has become a settled governmental and public attitude'--attributed to the 'indifference to educational values which is so often characteristic of small farmers with limited horizons'

(Condliffe, 1933a, 171).

The continuation of this situation is indicated by the high proportion of farmers with primary school education only in the limited information available (Tables 7.6 and 7.7) for 1966 and 1971 when data on education by occupation were first gathered and published in a census. This percentage increases with age, a probable indication of a later increase in the emphasis on schooling. The new entrants into farming in 1971 had received more schooling than those in 1966. Overall, the percentage of farmers with primary education only had fallen by half. Surprisingly, the percentage with university qualifications was lower, there being a decline in the number in this category.

The provision of advisory services by government and private firms has been a means of supplementing farmer education. It is evident in comparing the schooling of farmers and farm managers with that of farm advisers that the level of education of the latter is notably higher. The trend to forming farm management clubs indicates that farmers, being aware of their deficiencies, have hired experts to enable them to innovate with reduced risk in the face of more frequent and more complex inventions. Government has provided assistance with its Agricultural Instruction Service and farm advisory officers who have attempted to link the researcher and the farmer making the one aware of the achievements and problems of the other. Nonetheless, research to provide technology is performed principally off the farm with the farmer acting as an imitator applying technology developed by industrial concerns and government institutions (Taylor, 1977, 339).

PROVISION OF TECHNOLOGY

Developing agricultural technology by research was an aim of New Zealand science. Soil science played an integral role in promotion of soil amending in uncovering the deficiencies present in various soils so indicating the most appropriate amendment to use. A uniformity of approach to farming emerged even if variations to meet local conditions occurred. As scientific discoveries were made and/or applied in New Zealand, as in the uncovering of sulphur deficiencies and of phosphate retention, more precise use of chemical fertilizers could be made. Accordingly, the farmer could reduce costs in being able to more closely fix quantities needed for given requirements so reducing waste through either excess or inadequate application of materials. Scientific

TABLE 7.6

LEVEL OF EDUCATION IN THE AGRICULTURAL SECTOR BY OCCUPATION - 1966

Age	*Farmers and Farm Managers*				
	Level of Education:				
	Primary[a]	*Secondary*	*University*	*Total*	*%*
under 20-24	279	4,356	193	4,828	6.3
25-44	9,060	25,017	1,477	35,554	46.7
45-64	16,923	13,981	635	31,539	41.4
65 and over	2,786	1,398	72	4,756	5.6
Total	29,048	44,752	4,754	76,177	
%	38.1	58.7	6.2		100.0
Farm Workers					
under 20-24	2,190	20,739	444	23,373	46.8
25-44	6,194	10,490	504	17,188	34.4
45-64	5,608	2,648	127	8,383	16.8
65 and over	786	250	11	1,047	2.1
Total	14,788	34,127	1,086	49,991	
%	29.6	68.3	2.2		100.1
Biologists, Veterinarians, Agronomists, and Related Scientists					
under 20-24	2	106	126	234	16.6
25-44	12	122	687	821	58.4
45-64	15	74	236	325	23.1
65 and over	2	7	18	27	1.9
Total	31	309	1,067	1,407	
%	2.2	22	75.8		100.0

Notes: Percentage totals not equal to 100.0 are due to rounding error.
Includes 'other' types of education.

Source: Calculated from *Census of New Zealand* (1966, vol. 4).

TABLE 7.7

LEVEL OF EDUCATION IN THE AGRICULTURAL SECTOR BY OCCUPATION - 1971

Age	*Farmers and Farm Managers*				
	Level of Education:				
	Primary	*Secondary*	*University*	*Total*	*%*
under 20-24	53	3,604	255	3,912	5.5
25-40	2,817	28,996	1,867	33,680	47.3
45-64	9,451	19,219	864	29,534	41.5
65 and over	1,649	2,298	80	4,027	5.7
Total	13,970	54,117	3,066	71,153	
%	19.6	76.1	4.3		100.0
	Farm Workers				
under 20-24	500	19,738	660	20,898	42.1
25-40	2,401	15,431	495	18,327	36.9
45-64	3,897	5,319	140	9,356	18.8
65 and over	552	543	10	1,105	2.2
Total	7,350	41,031	1,305	49,686	
%	14.8	82.6	2.6		100.0
	Life Scientists and Related Technicians				
under 20-24	1	1,477	366	1,844	42.8
25-44	12	628	1,071	1,711	39.7
45-64	60	285	376	721	16.7
65 and over	7	7	18	32	0.7
Total	80	2,397	1,831	4,308	
%	1.8	55.6	42.5		99.9
	Workers in Agricultural Services				
under 20-24	128	3,286	86	3,500	35.7
25-44	631	3,975	108	4,714	48.1
45-64	638	843	26	1,507	15.4
65 and over	40	43	3	86	0.9
Total	1,437	8,147	223	9,807	
%	14.6	83.1	2.3		100.0

Note: Percentage totals not equal to 100.0 are due to rounding error.

Source: Calculated from data in *Census of New Zealand* (1971, vol. 6).

understanding was able to lead practical application and provide new information.

Soil amending was but one contribution of the agricultural technology development supported by research in New Zealand. Within thirty years of the Department of Agriculture's creation there had been 'a comparatively large development in both agricultural teaching and research', with 'The research activities devoted to other than farming problems ... few' (Williams, 1936, 40). Though at first, agricultural technology and all research were derived from foreign sources, the focusing power of the sector led to the situation where:

> Over the years New Zealand has developed strong and impressive research teams in agricultural research which have done an outstanding job of work of almost inestimable value to the national economy.' (Dick, 1960, 1)

Government identified the need for research, created the structure to support it, and engaged the personnel to perform it. Farmers were to receive assistance with production and marketing problems from this source. Condliffe (1933a,171) observed that the small farmers were interested in scientific and industrial research because of the 'material economic basis' behind it whereas 'The awakening life of the universities [had] yet to win public recognition'. The applicability of the teaching and research programs at the agricultural colleges must have improved this view. The concern with application was transmitted to researchers as basic research was neglected, so leading to an absence of the development of new technology (Mitchell, 1967).

Farmers, in their small firm situation, experienced difficulty in individually funding research and development. They relied on government which provided the money for more than three-quarters of the scientific research in New Zealand and directed most of that total to agricultural problems (McBride, 1967, 1118) as was the pattern in Australia (Ziman, 1976, 269). Advantage was to be taken of the grouping of researchers to deal with producers' problems though this principle was not fully kept with the continued separation of the Department of Agriculture and DSIR institutions beginning in the late 1920s. In the three years from 1964-65 to 1966-67, the Department of Agriculture alone received 24.7 percent of government's net expenditure on science (McBride, 1967, 1122). To this amount must be added the expenditure through the DSIR and the Cawthron Institute for work on crops, pastures, and soils, and the 50 percent contribution to running costs of agricultural industry research organizations[1] (McBride, 1967, 1121).

Agricultural production and processing have come, accordingly, to account for an average of 41.1 percent of the total estimated expenditure on research by industry group for 1964-65 - 1966-67 whereas secondary industry had only reached 15.4 percent in the same period (McBride, 1967, 1123). That percentage was double the amount spent in 1960 when it was observed at the Industrial Development Conference:

> If New Zealand is to look to manufacturing as one of the major means of maintaining full employment in the future, it we wish to see our manufactured products competitive in world markets, and if we wish to diversify our economy by the development of local manufacturing industry to ease our balance of payment troubles in the future, then one of the things I believe we will have to ensure is that the same scale of research investment is made for manufacturing as for agriculture. At present the amount of money spent by the State on research of more or less direct value to manufacturing industries is about £100,000 [$200,000] a year, about 7 percent of that spent in agricultural research. (Dick, 1960, 1)

Should the view prevail that the amount of research investment for an industry is conditioned by that industry's economic contribution, and by its own ability to undertake research and implement findings (McBride, 1967, 1125), the lead established by agriculture in production capacity and research infrastructure is likely to be sustained. Through the later 1960s the National Research Advisory Council recommended that an increased research effort be made in the primary industries with expansion being continued (McBride, 1967, 1125). The existing situation was to be maintained even though it could be contended that not 'every significant activity of society' was able to benefit from adequate research facilities--an indication of failure on the part of scientific policy makers (Ziman, 1976, 340). Indeed, it was felt that even within the agricultural industries more attention was paid to primary production than to processing, despite the belief that:

> Research of this type, if successful, could be of tremendous value both to the agricultural and the manufacturing interests of New Zealand. It could give us a more diversified economy and help us to become more self-sufficient. (Dick, 1960, 2)

Private firms, principally foreign ones, were also involved in developing the production equipment employed. Local private firms had begun farm implement manufacture in the mid-nineteenth century, survived strong competition from foreign imports, and, into the 1950s, supplied about 70 percent of the demand (Bryan, 1956, 169). Major New Zealand inventions in this field in the past were few however (Callaghan and Peren, 1936). Invention has occurred; for instance, the machinery used in agricultural aviation was created locally, but minor mechanical improvement has been more characteristic as it has been within the capacity of those working with the equipment and local engineering firms. Despite this progress, imported technology has remained important (Lane, 1976, 38). This pattern accords with the policy of the National Research Advisory Council of relying on outside sources of scientific invention and technical progress (McBride, 1967, 1124). New Zealand has benefited from adopting proven equipment and adapting it--a less expensive procedure.

Improvement in that process can then generate further-productivity increase and suggest further invention possibilities. Soil amending technology derived from British practice was enhanced in this way. The market tie with Britain, 'the natural alliance of the manufacturer and the producer of raw material' (Scholefield, 1909, 315), was reflected in this dependence on foreign mechanical invention while biologically and biochemically oriented invention became a principal area of research effort within New Zealand. It was only in 1963 that the New Zealand Agricultural Engineering Institute was established with funding from the Ministry of Agriculture and Fisheries 'to carry out testing and research, to promote developments in the field of agricultural engineering, and to communicate the results to the community' (MAF, 1974, 198). This grouping within one organization of those interested in machinery improvement and other engineering problems, such as drainage and soil erosion, imitated the pattern set earlier in grouping scientists concerned with grassland production in the DSIR.

FARM ENTERPRISE CHANGE

The development of soil-amending technology was linked with the emergence of farming systems wherein the quality of the soil resource was of importance. The early farm enterprises were based on extensive systems in which soil fertility was not heavily exploited. Early change in farm enterprises was more a reflection of both the failure of New Zealand's small and dispersed urban market to stimulate intensive farming and the difficulty of clearing and ploughing the land than of problems encountered with the soil. The environmentally adaptive wool enterprise based on grazing and introducing new grasses and clovers developed as a more economically favoured farming system than mixed, arable and dairy farming. The falling ratio of cattle to sheep (Table 7.5) demonstrates the rise in sheep production. This situation persisted until a decline in wool prices in the 1860s and again in the 1870s induced a change of farm enterprise to large-scale grain production. Although grain production had increased to meet Australian and then local demand during their respective gold rushes, it was only after 1872 with the introduction of mechanization (Simkin, 1951, 156) that production boomed. This change was not long-lived as other producing nations proved to have a comparative advantage in cropping and a better location relative to European markets. The change was important in terms of soil amending. Since cropping exploited soil fertility it began to indicate the deficiency problems present. It was in this period that soil amendment imports were first recorded and started to increase (Table 7.3) but the application to grassland had yet to appear. Improving grassland by sowing grasses had become a pattern of land development but the percentage of improved land was still about 20 percent of the area occupied in the 1881-85 period (Table 7.2). Native grassland was still an important production resource for wool producers.

The concern of the New Zealand and Australian Land Company with the profitability of its land sales activity led it to bring about the change in farm enterprises. Promoting closer settlement to improve land sales brought its New Zealand agents to consider meat sales and dairying. The success of a refrigerated shipment of mutton in 1882 and the ensuing organization of a processing industry based on freezing meat initiated the creation of a new industrial structure which emerged strongly after 1895 as prices rose (Condliffe, 1963, 228). Recognizing the expanding demand for livestock products from growing British industrial and urban markets and organizing production, processing, and transport to meet that demand were major agricultural achievements in the 1880s and 1890s. The market link forged with Britain through wool exports was expanded. The proportion of export value destined for Britain was sustained at over 70 percent of the total--a figure maintained or exceeded until the early 1950s (Table 7.8).

The outcome of the refrigeration innovation deeply marked the pattern of agricultural development in New Zealand beyond the change in export-product mix shown by the entry of sheep meat and animal by-products (Table 7.9). This market tended not to vary in the same way at the same time as that for wool and so allowed sheep producers to retain flock sizes where it was possible to sustain income by selling meat while retaining wool, or selling wool while sustaining the sheep. The efforts in the later nineteenth century to breed sheep with dual purpose meat and wool production shows the importance of both markets for producers (Simkin, 1951, 169-170). The importance of small holdings, characterized by 'one man' ownership, appears in the more rapid increase in the number of graziers than in the number of employees (Table 7.10). Owners working on their own account became increasingly frequent (Table 7.11). The number of farm owners in non-dairy, livestock farming grew from 1,800 in 1891 to 21,233 in 1916--an impressive rise indicating the extent of the shift to meat production from extensive sheep grazing for wool production. A higher return per unit of output meant that small landholdings would be economically viable. The need to more closely control stock increased the labour intensity required and made small farms suitable units of production. Greater numbers of stock in smaller areas also meant that the intensity of land use would be increased, a trend first appearing with dairy cows (Table 7.1), but this was not a concern at first. The pressure to create small holdings increased as successful production occurred. The value of mutton and lamb exports came to rival the value of wool exports within thirty years of the introduction of refrigerated marine transport, though the income so derived was greater only in periods of severely depressed wool prices (Table 7.9).

This same innovation also enabled dairying to emerge on a large scale. The successful sale of the dairy produce included in the first refrigerated shipment to Britain showed that that market was within the reach of New Zealand producers. Indeed, it has been claimed that both the meat and dairy enterprises were promoted by owners of meat-freezing plants and shipping lines anxious to boost their income by increasing turnover (Sutch, 1966, 140). Though dairy products had been exported in the late 1850s and during the 1860s, they had had little economic importance overall (Table 7.9). Gaining access to the far larger

TABLE 7.8

DESTINATION OF EXPORTS BY PERCENTAGE OF TOTAL VALUE 1841-45 - 1966-70

Year	*United Kingdom*	*British Dominions, Colonies, etc.*	*Other*
1841-45	29.5	59.2	11.3
1846-50	37.5	44.6	17.9
1851-55	18.4	79.2	2.4
1856-60	50.7	47.6	1.7
1861-65	35.8	63.4	0.8
1866-70	45.7	53	1.3
1871-75	65.3	30.3	4.4
1876-80	78.1	18.1	3.7
1881-85	72.9	17.9	9.2
1886-90	72.0	19.3	8.7
1891-95	79.8	12.8	7.4
1896-1900	79.3	15.3	5.3
1901-05	75.1	19.4	5.4
1906-10	81.6	13.5	4.9
1911-15	79.6	13.3	7.2
1916-20	77.3	9.1	13.6
1921-25	82.4	7.5	10.1
1926-30	76.0	11.2	12.8
1931-35	85.5	5.7	8.9
1936-40	81.8	6.5	11.6
1941-45	72.4	12.6	15.1
1946-50	72.0	7.6	20.4
1951-55	64.5	6.9	28.6
1956-60	57.7	8.2	34.0
1961-65[a]	49.3	9.4	41.2
1966-70	41.3	14.2	44.5

Note: *a* For June years from 1963.

Sources: Calculated from:
1841-95 Lloyd Prichard (1970).
1896-1970 *NZOYB* (1906-1972).

TABLE 7.9

AGRICULTURAL PRODUCE PERCENTAGE OF TOTAL VALUE OF EXPORTS[a] 1851-55 - 1966-70

5-Year Period	Wool	Veal and Beef	Lamb and Mutton	Other	Non-dairy Total	Butter	Cheese	Other Dairy	Dairy Total	Livestock Products	Vegetable and Fruit Products	Total
1851-55[3]	23.2	—		—	23.2	2.1	0.7	—	2.8	26.0	14.3	40.3
1856-60	60.4	—		..	60.4	0.9	0.7	—	1.6	62.0	6.0	68.0
1861-65	30	—		0.3	30.3	0.1		—	0.1	30.4	--	30.4
1866-70	33.5	—		0.8	34.3	0.1	0.1	—	0.2	34.5	2.6	37.1
1871-75	48.7	..		1.3	50.0	0.1	0.1	—	0.2	50.2	5.2	54.4
1876-80	55.8	..		1.9	57.7	0.2	0.1	--	0.3	58.0	8.6	65.0
1881-85	46.7	2.6		2.6	51.9	0.8	0.3	--	1.1	53	13.8	66.8
1886-90	44.7	8.8		2.5	56.0	1.3	0.9	--	2.2	58.2	10.4	68.6
1891-95	45.7	12.8		2	60.5	2.3	1.2	--	3.5	64.0	7.0	71.0
1896-1900	41.3	15.9		6.9	64.1	4.4	1.6	--	6.0	70.1	6.4	76.5
1901-05	29.4	19.0		7.9	56.3	8.6	1.4	--	10.0	66.3	6.2	72.5
1906-10	35.8	17.7		9.2	62.7	8.1	4.3	--	12.4	75.1	2.2	77.3
1911-15	34.2	21.1		8.7	64.0	8.9	8.2	--	17.1	81.1	2.4	83.5
1916-20	33.1	20.4		14.7	68.2	7.3	13.2	0.5	21.0	89.2	0.9	90.1
1921-25	25.3	2.2	17.9	10.8	56.2	21.9	13.5	1.6	37.0	93.2	1.3	94.5
1926-30	25.9	1.5	17.1	12.6	57.1	22.5	12.7	1	36.2	93.3	2	95.3
1931-35	18.6	2	20.9	11.1	52.6	27.6	11.3	1.0	39.9	92.5	2.6	95.1
1936-40	23.3	3.1	18.3	12.3	57.0	26.5	9.7	0.8	37.0	94.0	1.8	95.9
1941-45	18.3	1.8	16.9	15.5	52.5	22.3	12.5	1	35.8	88.3	3	91.3
1946-50	31.6	2.6	15.0	12.5	61.7	21.7	8.2	2	31.9	93.6	2.6	96.2
1951-55	38.8	2.8	13.1	12.1	66.8	19.9	6.6	2.5	29.0	95.8	2.0	97.8
1956-60	33.6	7.2	15.8	10.6	67.2	16.9	6.7	3	26.6	93.8	1,9	95.7
1961-65	33.2	8.2	15.7	11.6	72.4	15	5.8	3.7	24.5	93.2	1.9	95.1
1966-70	21.2	11.7	17.0	9.0	64.4	12.0	4.9	5.5	22.4	86.8	2.2	89.0

Note: a Specie excluded. *Sources:* 1853-84 Condliffe (1915, Tables G and J).
1885-1970 *NZOYB* (1934; 1972), *Export Statistics* (1962-70), *Trade and Shipping Statistics* (1962a; 1962b - 1970).

TABLE 7.10

EMPLOYMENT BY FARM ENTERPRISE 1874-1926

Year	*Farmer or Relative Assisting*	*Farm Manager, Overseer, Bailiff*	*Farm Servant, Agricultural Labourer*	*Grazier, Pastoralist, Stock-breeder, and Relative Assisting*	*Station Manager, Overseer, Bookkeeper*	*Stock-rider, Drove shearer, Shearer, Shepherd, Pastoral Labourer*	*Dairy-farmer, and Relative Assisting*	*Dairy Assistant, Milker*
1874	17,281[a]	104	7,426	1,189	308	3,431	..	..
1881	27,737[a]	225	12,544	995	371	4,063	..	..
1886	33,688[a]	265	13,996	936	387	4,577	..	..
1891	40,112	349	13,749	1,800	512	6,429	452	313
1896	47,677	373	20,236	1,918	477	6,742	430	425
1901	41,245	501	19,749	3,891	516	7,662	8,008	1,073
1906	41,988	616	21,615	5,748	536	8,742	9,958	1,447
1911	28,748	571	18,402	14,124	782	12,842	21,486	4,862
1916	17,584	330	9,972	21,233	1,605	14,585	38,250	5,594
		25,176			53,180		48,781	
1921		17,505			54,813		60,942	
1926		13,693			50,388		73,370	

Note: *a* Includes market gardeners (1891 total - 925).

Sources: 1874-1911 *Census of New Zealand* (for years shown).

1916-26 *Agricultural Statistics* (1924; 1925).

TABLE 7.11

FARM LABOUR BY TYPE OF OCCUPATION 1871-1971

Year	*Own Account*	*Employer*	*Relative*	*Wage Earner*[a] *(employed)*	*Other*	*Total*
1871	..	..	..	..	..	20,587
1874	..	..	..	..	..	34,390
1881	20,259		8,473	19,160		54,447
1886	..	..	..	..	..	65,178
1891	11,424	11,359	19,612	26,212	..	68,607
1896	18,087	15,051	17,516	29,891	..	80,585
1901	21,532	17,092	17,510	32,367	..	88,141
1906	22,581	20,976	17,027	34,988	..	95,842
1911	29,241	19,984	19,032	40,034	..	80,991
1916	34,176	21,870	17,222	40,871	2,308	116,447
1921	41,287	25,083	10,007	53,206	152	129,735
1926	38,258	22,881	9,379	48,003	431	118,952
1936	36,883	31,986	10,422	67,218[b]	400	146,910
1945	35,801	27,982	4,786	49,160	..	117,729
1951	42,950	30,252	2,062	52,572	287	128,123
1956	42,297	31,507	1,324	49,804	12	124,944
1961	34,220	29,267	984	56,505	41	121,015
1966	35,704	32,867	442	55,562	87	124,662
1971	35,743	29,218	357	52,095	2	117,415

Notes: *a* Unemployed workers not included.

b Includes part-time employees.

Sources: *Census of New Zealand* (for years shown).

markets of Europe was a basic factor in the expansion of this enterprise. The formation of small holdings suited to dairying as they were to sheep meat production, the establishment of dairy factories, and an increase in prices for dairy products beginning in 1895 (Condliffe, 1915, 899) attracted many producers into dairying (Table 7.10). As over 7,600 farmers started dairying while the number in other enterprises increased too, there was further pressure for land, and rising cost.

This flow was strongly promoted by government as it suited the 'one man, one farm' policy enacted at the time. By 1916, the number of dairy farmers exceeded 38,000 and by 1931 exceeded the combined number of farmers in other livestock and arable farming (Table 7.10). By the 1921-25 period the return from butter and cheese exports exceeded that of wool or meat taken separately, a situation which continued until the early 1950s (Table 7.9). Dairying's prosperity provided farmers with capital to invest in production improvement through the acquisition of new technology.

Dairying differed in its labour requirements. Despite the greater labour requirement, fewer people were employed by these farmers than by graziers, even though the number of dairy farmers rose more rapidly between 1896 and 1921 (Table 7.10). This expansion coincided with that in dairy export earnings. This trend to shift to dairying continued into the later 1920s. The increase in persons occupied in dairying exceeded the drop in the number employed in arable farming and non-dairy, livestock farming (Table 7.11). Dairying was attracting new entrants to the agricultural sector. A change in the tabulation of census data from 1936 on interrupts this series, but it has been noted that changes in prices for meat and dairy products influenced the enterprises undertaken in the succeeding decade. Farmers could enter both dairying and lamb rearing and so remain in the more intensive forms of pastoral enterprise as the prices for wool dropped sharply in the early 1930s. Dairy production remained important economically as, from the 1920s to the mid-1960s, butter and cheese export earnings exceeded those from meat (Table 7.9).

It was refrigeration which brought intensive livestock production to the fore in New Zealand agriculture. Although wool was not displaced as a major export product, this change was significant in allowing existing farm enterprises to develop fully and so influence the structure of farming and the use of the land. The export mix was altered by the increased outflow of meat and dairy products, yet a consistent pattern soon emerged once adjustment occurred. Subsequently, there were fluctuations in the relative importance of these livestock products but not in the overall direction taken by New Zealand farming. The increased importance of beef production after the later 1950s (Table 7.9) was a change, but one indicative of the continued emphasis on livestock production.

The emphasis was not just livestock but more intensive livestock production. Soil amending did not induce the change in farm enterprise but it did enable an increasing number of increasingly small farms (Table 7.4) to support greater numbers of stock per unit area. From the 1920s, as the application rate of fertilizer and lime increased (Table 7.2), the stocking rate on improved land began to rise most sharply (Table 7.1). Soil amending in combination with effectively managing the stock and pasture sustained by increased pasture yield, supported the growth of the more intensive livestock enterprises. Grass conservation methods proved able to supplant supplementary fodder crop cultivation. The latter remained at a stable percentage of the area improved as former increased as a percentage of sown grassland (Table 7.2). When in 1941-45 period fertilizers became scarce (Table 7.3), and the application rate fell, in the succeeding period, stocking rates also declined (Table 7.1), but recovered with a return to prewar fertilizer import levels.

Since that period, the use of soil amending has increased as has livestock production. Grassland topdressed became more frequent than that not topdressed by the 1960s. The quantity of fertilizer applied has increased while lime application has been reduced (Table 7.2). In this period of more intensified soil amending, stock ratios to land area have continued to increase except for that of dairy cattle (Table 7.1). The need to increase the dairy herd has been offset by animal productivity improvement through herd testing and artificial breeding and a change to breeds with greater output per animal (MAF, 1974, 91, 92, 81). The greater demand placed on soil fertility has been met with soil amending and the technological changes associated with the highly productive pasture it encourages.

COMMERCIAL ORIENTATION OF AGRICULTURE

In furnishing the productive grassland required by the more intensive livestock enterprises, soil amending has sustained the commercial orientation of New Zealand agriculture while broadening its basis. The successful export in volume of wool had established the economic viability of agriculture in New Zealand while directing it towards livestock production. The emphasis on sown grassland formation rather than crop land (Table 7.4) points to this early concern with livestock needs. The mixed, semi-subsistence farms provided some early exports of dairy products but their importance diminished relatively as the volume of wool output increased and accounted for a greater proportion of total export value (Table 7.9). What is illustrated is the commercial orientation of both wool producers, mixed farmers, and the stimulus provided by the capitalist institutions which backed them. The difference in importance of the two farming systems is a reflection of the more limited market opportunity of the latter. The small urban markets of New Zealand could not absorb large output increases and access to other markets was limited by transport technology. That wool was free of both these conditions assured its early production preference. In imitating the eastern New South Wales wool enterprise, New Zealand settlers also gained a share the British market already opened. Concern for achieving the consistent and high levels of production sought by the importer (Gould, 1972, 97) resulted in both the occupation and improvement of land into the 1880s (Table 7.4). Production could be improved by areal expansion and increased stocking alone. As long as wool prices were high enough sheep ranching proved rewarding. Wool remained the main export product through to the end of the nineteenth century. It accounted for over 40 percent of total export value until that period (Table 7.9). Indeed, seldom has wool not been the single most important source of export earnings, and those occasions mark periods of economic crisis (1931-35 and 1966-70) and a period of political crisis (1941-45) when wartime conditions reduced exports. The initial pastoral enterprise introduced into New Zealand remained important through later periods of land improvement and greater subdivision of holdings.

The commercial benefit of the grain enterprise to small land-holders was limited by the need for manpower to harvest the crops and the comparative advantage gained by large landholders through scale economies derived from mechanization. Once again the aim of production was commerical, though the local demand component became more important than in the case of wool.

Of more far-reaching importance was the opening of the British market to meat and dairy produce by the adoption of refrigeration. The boom in grain production was ended by competition from nations in a better location relative to the major urban markets of Europe. Wool had could have continued to support the country as it has prior to the introduction of refrigeration, however, the agricultural development contingent upon that innovation increased the sector's contribution to the economy (Table 7.9). The export of livestock products provided a basis for economic growth, especially since local consumption seldom exceeded 40 percent of production (Simkin, 1951, 33). Concern for improving the quantity and quality of agricultural produce was largely motivated by foreign market demand. Technology improving either aspect of production was tested. Soil amending, as a particularly important technology in this regard, came to be widely adopted by farmers interested in improving their returns. The overall effect was that during the period from 1871-75 to 1966-70 agriculture's contribution to total export value remained above 50 percent (Table 7.9). This comment would also be appropriate back to the 1856-60 period were it not for the gold rush of the 1860s when the value of gold exported reduced the proportionate contribution of agricultural exports, and the increase in domestic demand reduced their volume (Simkin, 1951, 25, Chart 2). This period was brief, lasting little over a decade. Subsequently, agricultural exports continued to rise in importance, barring three interruptions, until 1956. Even though there was a decline in the importance of these exports, the figure has varied only slightly about the 90 percent level since World War I (Table 7.9). The agricultural emphasis in the economy developed by the early colonists persisted into the 1970s. What changed was the type of produce. The absolute advantage found in livestock production was pursued vigorously the proportion of livestock product export value indicates (Table 7.9). Agriculture was the mainstay of the economy and it was a specialization though to have increased into the 1960s--a situation viewed as anomalous in an industrialized world (Sutch, 1969, 326, 330).

STRUCTURAL CHANGE

The farm enterprise changes provided an economic basis for land subdivision schemes based on the small, freehold or long-term leasehold, family farms. The large, leasehold farm structure which formed the basis of wool and grain production was challenged. A growing population increased demand for land because of the success of commercial agriculture and the absence of alternative employment opportunities in the other, little-developed sectors of the economy. The problem for the small landholder lay in the low return per unit area of wool and grain production. Acquiring sufficient acreage to enjoy scale economies was both difficult and costly where cleared land was already available, and a longer term proposition where bush land first had to be cleared. This economic environment difficulty was countered by the refrigeration following which, there occurred an expansion of more intensive farming based on smaller farms. From the 1891-96 period to the 1920s just under 50,000 new farms were established to achieve the level maintained relatively steadily until the mid-1950s when the maximum number was attained (Table 7.4).

The comparison of the increase in the number of holdings between 1891 and 1926 with that in the number of owners (Table 7.12) makes the extent of 'one man, one farm' ownership clear. Of the 47,660 new holdings, about 80 percent were created by their owners. Multiple holdings were relatively uncommon. The structure of the agricultural sector became one of a large number of firms competing in producing a limited variety of livestock outputs. The larger, more extensive farms concentrated on wool production almost entirely for export; while the smaller farms moved into dairying and fat-lamb rearing enterprises they found most lucrative and more stable in terms of price fluctuations (Simkin, 1951, 39), as they also had a higher domestic demand over time (Simkin, 1951, 33; *NZOYB*, 1970, 402). Livestock production expanded with the rising number of small holdings and the occupation of more land. The ratio of sheep to occupied land suggests some increase--10 percent of the 1881-86 ratio by 1915-16 (Table 7.5). This could mean that there was little change in the sheep farming system but the extensive wool enterprise masks the data for the more intensive lamb-rearing enterprise. More notable was the steady advance in the ratio of cattle to occupied land, and the prominent role of dairy cows in that trend as their numbers rose sharply (Table 7.5). The

TABLE 7.12

EVIDENCE OF INCREASED 'ONE MAN - ONE FARM' OWNERSHIP 1891-1921

Year		*Number of Holdings*	*Number of Owners:* *Own Account*	*Employers*
1921		85,743	38,258	22,881
1891		38,083	11,424	11,359
	total gain	+47,660	+26,834	+11,522
		- 38,356	+38,356	
	multiple holdings	+ 9,304		

Source: Calculated from *Census of New Zealand* (for years shown).

importance of dairying is underlined once more, but the disequilibrium situation created by refrigeration and the consequent opening of a new market was experienced by both sheep and dairy farmers.

In that situation, more productive farming systems on smaller landholdings were rewarded because increased output could be readily absorbed by foreign markets. However, the small landholders were constrained by the available labour supply. As a result they usually utilized their own family's labour. Whereas in 1891 the numbers of farmers working on their own account and farmers engaging labour were nearly equal, by 1926 only 37.4 percent of farmers were also employers, despite the fact that the number of relatives working on farms had declined (Table 7.11). The increase in the number of people on the land continued until the manpower demands of World War II led to a sharp reduction in the number of relatives working on farms and the pool of farm workers (Table 7.11). The number of owners also decreased, though not as strongly. The absence of a census in both 1931 and 1941 limits the amount of data available for a more detailed view of the adjustments during the major depression of the 1930s. Labour-intensive means of increasing production were unlikely to provide a useful solution. The grassland farming system based on soil-amending technology provided a comparatively low-labour-input solution to the problem. The continued rise of sown grassland and the decline of cultivated acreage (Table 7.4) show the importance of this farming system to the small farmers.

It has been seen that capital was relatively less scarce than labour. The introduction of labour-saving farm machinery occurred in part because of this production factor bias. The application of mechanical power was extended from horse-drawn implements in arable farming to the replacement of the horse by tractors. This increase in power enabled grass conservation methods to be pursued more vigorously as seen in the rise in sown grassland cut for hay and silage after 1950 (Table 7.2). So improving labour productivity became increasingly important as the land supply was restricted by continuing settlement. The general trend was a rise in land costs which seems likely to have directed capital to the improvement of the productivity of available production resources rather than to the acquisition of further acreage (Buchanan, 1935, 6).

With the stability of the land resource and the decline of the agricultural labour force, farmers were required to invest greater amounts of capital as a substitute to increase productivity (Table 7.13). From the data showing the relation between gross output and aggregate inputs (Table 7.13), it can be seen that from the late 1950s the investment paid off. The general trend was productivity growth as existing farm enterprises reached new production levels. One expects that the scale economies which could be achieved turned attention away from the diversification of farm enterprises and the economic structure of the country as a whole. Achieving scale economies provided the basis for countering unfavourable economic conditions in the later 1950s and 1960s. The creation of larger farms, evident in the decrease in the number of holdings while acreage per holding increased (Table 7.4), suggests the farmers' appreciation of a new set of economic imperatives operative in the production environment and their reaction some expanding improved land acreage while others left the sector (cf. number of farmers in 1966 and 1971 in Tables 7.6 and 7.7). A change of farm enterprises was not evident in the export product mix, but more intensive use of soil amending was, as the percentage of grassland topdressed and fertilizer application rates reached new peaks (Table 7.2). Soil-amending technology in sustaining a grassland farming system minimizing labour input, suited the small-farm structure created in the late nineteenth century and has served to promote agricultural productivity within that structure.

TRADE'S ROLE

The emphasis on production improvement in New Zealand agriculture and in the research serving it can be understood in view of the market's influence in the production environment. The value of agricultural produce sent to Britain consistently exceeded 70 percent of the total from the 1876-80 period to 1946-50 (Table 7.8). Only in the early period of settlement were the Australian colonies more important, and often, the produce sent there was re-exported to Britain (Lloyd Prichard, 1970, 80-81). The potential market may have been the world, but commercial and political ties with Britain led exports there. As Britain's needs could not be met fully by New Zealand's produce, that market was sufficient for New Zealand producers, and acted well into the twentieth century as the virtually unlimited market needed to boost

TABLE 7.13

OUTPUT PER UNIT OF AGGREGATE INPUT 1921-1969

Year	*Index of Gross Output*	*Index of Aggregate Inputs*	*Output per Unit of Aggregate Input*
1921-22	50.3	66.6	75.5
1922-23	51.3	67.1	76.4
1923-24	52.5	68.4	76.8
1924-25	54.1	69.0	78.4
1925-26	52.5	68.7	76.4
1926-27	55.5	70.8	78.4
1927-28	61.4	72.7	84.5
1928-29	63.7	73.9	86.2
1929-30	66.9	75.7	88.4
1930-31	67.7	76.9	88.0
1931-32	67.7	77.5	87.4
1932-33	77.4	78.6	98.5
1933-34	79.8	78.9	101.1
1934-35	77.4	79.7	97.1
1935-36	81.5	80.1	101.7
1936-37	83.9	80.5	104.2
1937-38	83.9	81.5	102.9
1938-39	80.6	81.2	99.3
1939-40	83.9	83.3	100.7
1940-41	92.7	83.4	111.2
1941-42	89.5	81.2	110.2
1942-43	86.3	82.7	104.4
1943-44	85.6	85.7	99.9
1944-45	92.7	90.5	102.4
1945-46	86.3	88.1	98.0
1946-47	89.5	84.2	106.3
1947-48	91.9	89.5	102.7
1948-49	95.1	89.0	106.9
1949-50	100.0	100.0	100.0
1950-51	102.4	121.2	84.5
1951-52	102.4	98.3	104.2
1952-53	107.2	114.0	94.0
1953-54	107.2	112.4	95.4
1954-55	109.6	114.0	96.1
1955-56	112.1	113.1	99.1
1956-57	113.7	116.9	97.3
1957-58	121.8	108.0	112.8
1958-59	126.6	108.3	116.9
1959-60	128.2	112.7	113.8
1960-61	133.9	106.9	125.3
1961-62	136.3	109.7	124.2
1962-63	143.5	116.1	123.6
1963-64	148.4	126.9	116.9
1964-65	152.4	130.8	116.5
1965-66	161.3	135.7	118.9
1966-67	166.9	129.9	128.5
1967-68	171.8	133.8	128.4
1968-69	175.8	141.2	124.5
1969-70	171.8	136.7	125.7

Sources: 1921-59 Hussey and Philpott (1969, Table V).

1960-69 Ellison (1977, Table 1).

export production. As a large and long-term market, Britain absorbed large quantities of livestock produce. In such a situation producers had the opportunity to plan enterprises on a longer term basis than would have been the case had market and market demand altered frequently. The chance to enjoy productivity increases through improvement to production techniques appeared because of continued participation in a market having comparatively stable demand over a long period. Learning by doing becomes a major explanatory factor in such improvement by New Zealand farmers. The market, by absorbing the additional output, provided motivation for production-increasing innovation. The effectiveness of this approach was demonstrated by the refinement of soil-amending technology. From a concern with phosphate application and soil-acidity control, soil amending moved to deal with trace element deficiencies as the pasture sward components' capacity to profit from the modified soil conditions was improved. The capacity of the final market to absorb output would have assisted the decision to undertake such improvements reducing per unit production costs.

The benefits from production research were widespread and economically important, so encouraging attention to be directed to them. Government's support of such research is not surprising in such a context. Within the human-resource constraint of its limited population and the financial constraint of its budget, New Zealand agricultural research was advantaged by this uniform market situation. The progress made in developing a grassland technology which offered the possibility of creating a uniformly productive grassland farming system with refinements made to suit local edaphic and climatic conditions was an outcome of this situation. It is less likely that producing for a variety of markets demanding produce from a variety of farm enterprises based on differing production requirements would have had as favourable an effect.

The strong market ties with Britain led to instability in the New Zealand economy as the British economy weakened following World War II. The ensuing loosening of ties with Britain reflected the inability of the increase in demand there to match the growth of New Zealand's agricultural production (Rosenberg, 1968, 33). The gradualness of this process reflected the inertia created by prewar marketing structures, despite warnings in the 1930s that market diversification was necessary (Dairy Industry Commission, 1934, 38), and the long-term postwar agreements for the sale of produce to Britain. Only after World War II did the shift to enter the markets of the United States, Western Europe and Japan develop (seen as the rising percentage of export value to other destinations in Table 7.8), indeed, the change has been noted as beginning only since 1958 (Long, 1963, ii). Although by the 1960s the destination of exports by value was increasingly diversified, this change masks the fact that for lamb, butter, and cheese, the British market still accounted for some 90 percent of the total (Rosenberg, 1968, 14) but was declining (Lewthwaite, 1971, 98). Hence, British moves to enter the European Common Market in the early 1960s intensified the need for New Zealand to identify both new exports and new markets as it was realized that the agricultural protection policy prevalent in the Western European countries would be extended to Britain so locking out the exports which had previously received preference (Condliffe, 1969b, 31). This theme had been taken up in the 1930s but had not served to stimulate change (Dairy Industry Commission, 1934, 11).

The benefits of market stability in permitting scale economies to be achieved in livestock production were reduced through the need to meet the differing demands for a greater variety of markets. The conflict of product uniformity and market uniformity appeared. The choices were product diversification to cater to wider demands in a single market, diversification to cater to the demands of diverse markets or continued uniform production with a stress on marketing to enter diverse markets. The advantages of long-run production of a few lines of produce in terms of improvement application were reduced in the first two choices. Major innovation would again become more important. It is not considered that such change is easily achieved because of the inflexibility of capital already invested.

The last option has been most actively pursued accordingly. In the face of the potential loss of the main market, the strategy adopted has centred on market diversification and on adjusting marketing structures as seen in the changes effected in the 1960s in wool, dairy product, and meat export organizations (Evans, 1969; MAF, 1974). Considering 'possible great changes in farming' did not eventuate (Sutch, 1969, 330). The success achieved with existing production methods and the long-term development of institutions supporting that success have retarded change. When agricultural price levels have fluctuated and declined, farmers have responded by employing technology to increase output. They were urged by government to farm their way out of price reduction crises in the later 1950s and 1960s using the fertilizer technology available in particular. That technology underpinned existing farming systems. Thus, the export of existing types of farm produce remained the basis of economic planning despite increasing pressures in world markets. The attempt by New Zealand to assure continued access to the British market while exploring new markets' demands such as that in the U.S.A. for beef and begin production to suit them (Table 7.9), is indicative of this approach. Developing the economy to reduce the reliance on agricultural production was even less forthcoming. The immobility problem raised by James (1971, 6) is emphasized by Rosenberg (1968, 175):

> the nature of an industrial economy is its ability to adapt itself rapidly to changing demand. It is the nature of primary exporting economies that they cannot so easily adapt themselves. Thus if demand for primary produce falls, the standard of living of the primary exporting country is severely threatened. All a primary producing country can usually do to meet falling demand is to reduce prices, and in some cases output. An industrial country can re-organize its production quickly to produce electronics instead of textiles, tankers instead of toys.

INDUSTRIALIZATION AND ECONOMIC DEVELOPMENT

Successive efforts to broaden the economic base and provide a new source of economic viability have not overcome the agricultural primacy established and the unbalanced growth which had occurred.

> As a primary producer for Britain, the main labour requirements were for people to work in agriculture and associated industries, plus a tertiary sector to organize the production and exchange of its output for the imported manufactured goods. (Cant and Johnston, 1973, 15-16)

The large employment in the tertiary sector reflected the importance of this organizing function in an erstwhile colonial economy. It is a sector which continued to be important (Table 7.14) still employing 53 percent of the labour force in 1971. The secondary sector developed to meet two needs: the processing of primary produce for export and the production of basic requirements for local consumption using local resources (Franklin, 1969b,30). As wool did not require much processing, the first type of manufacturing did not become significant at first. Refrigeration brought a change for it was in the 1880s and 1890s that

TABLE 7.14

PERCENTAGE DISTRIBUTION OF THE LABOUR FORCE BY SECTOR

Economic Sector	*Year* 1874	1901	1906	1916	1926	1936	1945	1951	1956	1961	1966	1971
Primary[a]	44	32	31.0	30.4	24.0	27.2	21.3	19.5	17	15.2	14	12.0
Secondary[b]	20	29	25.9	22.8	22.6	24.4	28.1	32.5	33.6	35.8	38	36.7
Tertiary	36	39	43.0	46.7	53.4[c]	48.4[c]	50.6[d]	48.0	49.3	49.0	48	53.3

Notes: *a* Comprises agriculture, forestry, hunting, fishing, mining, and quarrying.

b Includes manufacturing and construction.

c Unemployed included.

d Armed forces included.

Sources: 1874, 1901, 1966 Cant and Johnston (1973, Table 1).

1956 Calculated from *Census of New Zealand* (1956).

remainder Lane (1976, Table 1.5).

meat-processing plants and dairy factories were founded (Condliffe, 1963, 247). Dairying has been labelled the 'dominant feature of economic development between 1898 and 1935' through its broad effects on different sectors (Condliffe, 1963, 239). The need to create processing facilities led dairy farmers themselves to form co-operatives to build and control the dairy factories (Duncan, 1933, 5). As the dairy factory was a much smaller unit than a meat plant, farmers could contribute the more limited capital required (Simkin, 1951, 171). The factory:

> usually became the economic focus of the district, providing opportunities for interchanging views, for spreading technical information, for enforcing decent standards, and for co-operative purchases of farm supplies. (Simkin, 1951, 171)

It was from this co-operative industrial structure that dairy farmers were able to establish marketing schemes in the 1920s and undertake to build fertilizer plants to meet their needs.

Depression of agricultural commodity prices in the late 1870s and 1880s had helped to promote the vision of creating a self-sufficient community through industrialization (Condliffe, 1933a, 169). The government took up this policy when in 1880 it offered bonuses as incentives for the establishment of a number of manufacturing industries to meet local demand. The sulphuric acid plant which became seminal in domestic chemical-fertilizer production was established through this scheme. Further government encouragement came with the implementation of a tariff in 1888 (Linge, 1958, 43) but the effects of refrigeration's introduction were reducing this concern for:

> if refrigeration had not placed New Zealand's meat and dairy produce on the world market and transformed the whole of the internal and external economy, New Zealand would have been forced to become an industrial country at a much earlier stage. (Sutch, 1966, 85).

The rise of more intensive livestock farming and small-farm settlement from the mid-1890s to the mid-1920s and an increase in relative real wages in New Zealand halted this growth of manufacturing employment (Table 7.14), particularly in types not related to agriculture (Blyth, 1974, 8).

The trade specialization in the period from the mid-nineteenth century to World War I during which unprocessed materials were sent to metropolitan countries in return for manufactures and services (Dairy

Industry Commission, 1934, 11) served to promote economic growth 'only in a limited sense' and 'might well be judged inimical rather than favourable to development ...' in that it offered 'little encouragement to the development of indigenous manufacturing' (Gould, 1972, 244). Here lay the source of New Zealand's 'industrial inertia' (Hewland, 1946, 208). With trade seen as detrimental to economic development, then:

> a reduction in their trade participation ratios might have helped promote the 'growth' [meaning structural change] of, say, New Zealand and Argentina just before and after World War I. ... exchange rates geared to the comparative productivity of the exporting industries, cheap freight 'backhauls', an orientation of credit, transport facilities and technology towards the sectors favoured by comparative advantage could and did stamp
>
> some economies with a particular structure which some would call 'underdeveloped'...; the tendency for this structure to change as soon as some adventitious event, such as world wars, offered a temporary 'protection' from trade is clear. (Gould, 1972, 287-288)

The outcome prior to World War II was a manufacturing sector which, apart from the main agricultural processing plants, emphasized small-scale, unspecialized, light industry and relied largely on imported raw materials or partly processed goods because of the absence of heavy industry (Sutch, 1966, 382; Hewland, 1946, 218).

This limited structure was all the Labour Government had achieved with its industrialization policy implemented in 1936. The severe effects of the depression of the 1930s showed once again New Zealand's vulnerability to external change in demand for its agricultural produce. Through import licensing, exchange control, and protective tariffs the aims of the Industrial Efficiency Act of 1936 were to be achieved (King, 1965, 15). Manufacturing was to become a second component of the economy. In being independent of fluctuations in world agricultural prices it would be able to support the economy whenever these prices were depressed. Wartime requirements brought greater industrial expansion (Leathem, 1947, 169-170) but the progress made was not sustained as capital was diverted to public investment in infrastructure (principally roads), to private investment in farms, and was absorbed in the recovery of private consumption (Sutch, 1969, 336-337). An influx of foreign investment starting in the mid-1950s helped to overcome this deficiency (Deane, 1970, 24), but there was only 'comparatively minor industrial development of the war and post-war years' as government policy changed after Labour's defeat (Sutch, 1966, 418). Manufacturing did continue to grow in terms of employment and value of production (Condliffe, 1959, 148), but the view was held that the economic structure did not need to be changed (Sears, 1962a, 65), and the country 'could live well by encouraging grass to grow' thereby remaining 'colonial' in its orientation and increasingly dependent on the condition of other economies (Sutch, 1966, 412, 415). There was concern that despite manufacturing's better productivity performance than farming in the decade to 1960, growth of the latter sector would be adversely affected by the passing on of increased costs and the reduction of available capital associated with industrialization (Blyth, 1961, 11-12).

An economic crisis in 1957-58 reasserted the vulnerability of New Zealand's economy to external events (Sutch, 1966, 420, 426). The secondary structure had changed but little by 1956 as factory production remained directly concerned with processing agricultural produce with a further section concerned with supplying production inputs, most importantly, fertilizer and machinery (Dalmer, 1956, 49). Small-scale production, with its high production costs and inefficient organization, persisted (King, 1965, 18). The contribution to gross national product of manufacturing's value added was considered to have remained at roughly the level it had been in the mid-1930s (Sutch, 1968c, 53).

The industrialization strategy was renewed with the establishment of such heavy industries as steelmaking in the 1960s following the adoption in the 1950s of a policy of import substitution using 'local for imported materials, components and capital goods' (Rose, 1969, 60-61). The election of a Labour Government brought this renewed determination to pursue this policy of establishing capital goods production and more local processing of both exports and imports (Sutch, 1969, 338). These proposals received a serious setback with Labour's electoral defeat in 1960 and that party's subsequent absence from office in the following decade. The long-term planning initiated with the Industrial Development Conference of 1960 was directed to other economic activities and to institutional reform. Apparently the desire to change the country's economy was lessened with the continued and increased world demand for agricultural produce (Sears, 1962a, 65) so that the next conference dealing with export development, though it repeated many of the aims of the previous Industrial Development Conference, concerned itself mainly with institutional reforms for exporting (Sutch, 1966, 431, 430). The agricultural sector was to continue as the base of the economy with manufacturing growing in importance in value of production terms but not yet displacing agriculture (Condliffe, 1969b, 127). The following planning conference, indeed, focused on agriculture.

The process of industrialization has begun despite this sporadic approach to its promotion. Condliffe (1969b, 126) noted that 'The statistics of manufacturing production in New Zealand show impressive growth', particularly since the introduction of export incentives following the Export Development Conference in 1963 and the 1967 devaluation. Marketing efforts assisted the above measures in broadening the industrial base to create new products and focus industrial development on export rather than just domestic production--the key to making such development successful (Condliffe, 1969b, 131). Another analyst has observed that in non-agriculture related manufacturing, 'the trend rate of growth of output over the entire period (1928-29 - 1969-70) has been steady and unchanged' (Blyth, 1974, footnote 13). In terms of employment such 'secondary manufacturing has growth for the last sixty years [since 1911] without major changes in trend, and apparently uninfluenced by changes in foreign trade' (Blyth, 1974, 13). Similarly, changes in government were less important an influence than population growth, whereas declining relative wages and labour costs were more important (Blyth, 1974, 18-19). However, tariffs and import licensing did provide means to influence the type of industrial development by promoting import substitution (Ichikawa, 1971, 5, 23).

No great certainty about the degree of industrialization achieved is evident. In the decade from 1963-64 to 1973-74 manufacturing's share of the gross national output rose from 16.5 percent to 17.4 and proportion of employment rose from 19.6 to 21.2 percent, only a little improvement (Blyth, 1977, 27). Economic development in the sense of broadening of activity had begun but was not complete. Progress was slow with the commitment to gradual change 'within the existing economic and social infrastructure' (McKay, 1975, 132). Employment data (Table 7.14) indicated that New Zealand had 'as high a level of economic development as most advanced nations', but the proviso was added 'we can recognise that numbers employed do not necessarily indicate the relative value of output of each sector' (Lane, 1976, 12). Agriculture's role is dominant not only within the primary sector but also extends into the secondary sector in the processing industries and into the tertiary sector in finance and transport activities (Lane, 1976, 14-15). Thus, in the agriculture-related industries, not surprisingly, farm output and export market conditions explained changes in development so that 'in this sense industrialisation has been consequent upon foreign trade' (Blyth, 1974, 13). It was anticipated in the 1960s that agricultural sector earnings would be threatened by price ceilings and a limitation on volume through greater protectionism in traditional markets. A need to create other exports in order to continue the importation of inputs required by the economy as a whole was clear. The response of urging greater agricultural production through an Agricultural Development Conference in 1963 and 1964 without a large measure of integration of plans with other economic sectors and open public discussion (Rosenberg, 1968, 206) is indicative of the inertia existing within the country's economic structure. The increase in manufacturing output and employment is considered to have been the first rise in the manufacturing's economic contribution since the end of World War II, yet could be 'insignificant' (Blyth, 1977, 27). Robinson's consideration that economic growth may not be sufficient to stimulate the change needed for development is thereby demonstrated. Concern with the consequence of the weak industrial structure resulting from a policy of import substitution to stimulate industrialization (Ichikawa, 1971, 23-24) reflects the view that:

> New Zealand will always remain dependent upon her agricultural exports since the country's resources in manufacturing raw materials are extremely limited. (King, 1965, 19)

This view of the handicap posed by a paucity of raw materials is questioned (Condliffe, 1969a, 11), but the fundamental role of the agricultural sector is not:

> Manufacture you must, if New Zealand is to escape from its precarious dependence on the traditional markets for pastoral products (and provide employment for a growing population unable to enter the primary sector) ... . But the grasslands will remain the foundation of New Zealand's economy. (Condliffe, 1969a, 10, 11)

The technology supporting grasslands thereby remained a central concern too. This continued dependence, regarded as inevitable in the 1960s (Fielding, 1963, 168; Cumberland, 1968, 10), constituted the 'inertia ... the principal feature of the country's economic life' which was countered by 'improvisation' comprising moves to industrialization and changes in marketing structures in order to 'avoid inertia becoming stagnation' (Franklin and McQueen, 1969, 506). This improvisation, however, incorporated 'a minimum of innovations' which constituted 'nothing radical' (Franklin and McQueen, 1969, 6), so leaving the structure of the economy little altered and future changes in doubt (Ward, 1973, 38). Balancing sectoral growth to avoid the stagnation envisaged by Lewis (1956, 277) suggests an unbalanced investment in the secondary sector could help to resolve the problem but the difficulty in implementing that procedure to achieve the desired outcome must daunt government, the only institution likely to undertake such a measure.

ROLE OF GOVERNMENT

At a number of points in the previous discussion government has appeared as a factor explaining some particular feature in agricultural sector development. Accordingly, it merits treatment as an agent bringing change through both direct and indirect involvement. This is notably the case in New Zealand since government, legislating the closer settlement policy, stamped out the pattern for subsequent development in the agricultural sector. The attention paid to intensive livestock enterprises, the basis of the small farms' livelihood, showed government's concern beyond making land available for settlement. Concern with assuring dairying's success, for example, was shown by the hiring of men in the public service to give instruction in dairying to processors and then to producers. Dairying involved a complex technology to control the biochemical processes in butter and cheese production. Maintaining quality in dairy product exports and improving production techniques were fundamental reasons for governmental involvement in the agricultural sector beginning in the 1890s (Rowe, 1973, 16-17). Meat inspection also appeared to protect that enterprise's place in the British market. In so bolstering these farming systems, government took part in establishing the production environment within which later grassland technology emerged. Creating a government department to give practical production assistance to farmers, promote agricultural research, and foster rural co-operative organization was an important additional step taken before the turn of the century (Condliffe, 1963, 210). The Department of Agriculture officers, who concerned themselves with preparing 'practical, simple, detailed forms of organisation', gave a lasting bias to New Zealand rural development (Condliffe, 1963, 242).

It has been noted earlier that the agricultural research undertaken was production-oriented. Since government did not evidently view itself then as a marketing agency, apart from guaranteeing produce quality, it was only later that concern with marketing research appeared. Wartime marketing control was seen as exceptional (Westrate, 1959, 58). The market being served and the approach to production appear again as explanatory factors. Fostering increased uniform output for an apparently insatiable market was a sufficient activity for government to engage in. The success of the soil amending and grassland technology developed in this context must have reinforced this feeling. It was meat producers and then dairy producers themselves, not government, who took steps in the early 1920s to form organizations to control marketing (Evans, 1969, 162). Indeed, government declined to introduce compulsory marketing of dairy produce (Westrate, 1959, 59-60). The producers remembered the advantages of high prices attained during the controlled marketing of World War I, particularly as prices fell sharply with the restoration of laissez-faire conditions (Westrate, 1959, 58-59). Only with the onset of economic depression in the 1930s and in following recommendations of the Royal Commission on the Dairy Industry in 1934 did government come to play a part in the New Zealand Dairy-Produce Control Board (reconstitution as the New Zealand Dairy Board). This part was augmented by the Labour Party's election in 1936 since that party's interventionist policy led to the creation of a Marketing Department which assumed control of that operation (Evans, 1969, 190-191). Similarly, the private trading in meat was suspended by bulk-purchase agreements with the United Kingdom Government during World War II and the postwar recovery period (Condliffe, 1959, 86). Wool was dealt with by joint disposal in co-operation with other Commonwealth nations (Evans, 1969, 96-97). The end of these arrangements brought price stabilization measures of varying types (Condliffe, 1959, 141) to retain the measure of income security farmers had enjoyed through the smoothing out of sharp price drops (Westrate, 1959, 156). The aim was evidently the provision of a comparatively stable production environment in which farm production and investment planning could proceed less hindered by sudden changes in income. Private enterprise was buffered by state intervention if not by state socialism, with a distinct trend 'towards the regulation rather than the nationalisation of capitalist enterprise' (Condliffe, 1959, 211). Controlling and directing the production of private enterprise in agriculture was a sufficiently effective way to deal with the economic problems encountered.

Government's perception of the problems and the condition of the production environment became increasingly important in such circumstances. Farm production decisions had to be made in light of those directives offered. Subsidies with regard to soil amending, such as that for lime freight by rail, are an illustration, for the long-term duration of that subsidy encouraged lime use, particularly by farmers located close to railways. Until the extension of this policy to road haulage in 1947, those farmers located away from railways were disadvantaged by greater haulage costs. The maintenance of lime output and application by the subsidy program appears in the downturn in lime production and application with the withdrawal of the subsidy scheme in 1962. The tonnage carried by rail did not fall alone. The use of molybdenized fertilizers could have provided a means to counter this change but soils had to be responsive to it. The effect was a change in farmer expectations and soil-amending practice because of a governmental decision.

In a like vein, restrictions on dollar currency transactions after World War II meant that the agricultural aviation industry was built up using comparatively inefficient but more readily available Tiger Moth aircraft. These restrictions did lead to the establishment in New Zealand of a plant for the manufacture of the Fletcher FU 24 agricultural aircraft, but this consequence was unlikely to have been foreseen in the adherence to a regulation which barred the importation of American aircraft already developed for agricultural aviation.

The agricultural aviation industry's development points to the powerful role of government in the agricultural sector. Trials of topdressing and oversowing were originally supported by government departments or government-sponsored organizations. After the early trials topdressing was envisaged as an activity of the RNZAF. Only the success of private operators' operations and their rapid proliferation headed off that plan. The private operators were, however, brought under regulation by government. The Air Services Licensing Authority Act was applied to ensure both the stability of the firms being formed and the widespread availability of the service in licensing operations in particular districts. These controls indicate the importance government had in disseminating soil-amending technology, given the importance of aerial topdressing observed in Chapter 6.

The decisions made by government on the country's economic structure have their effect too. Promoting industrialization to offset agriculture's primacy has upset stability in the attempt to create balance in an unbalanced economy. One would anticipate some upset in farmers' production planning as a consequence. The short-duration push to rapid industrialization staved off considerable change but the legacy of import licensing, currency control, and higher cost domestic manufactures remains in agriculture's production environment. The urge to improve productivity through the adoption of technology implicit in the fertilizer subsidization of the later 1960s points to the manipulative role of government within the economy and its effect on agriculture and the use of soil-amending technology in New Zealand.

CONCLUDING REMARKS

Technological change, more specifically, that involving soil amending, has been of fundamental importance to New Zealand agriculture. The above remark is scarcely surprising given New Zealand's contact with the areas where technology was evolving and the commercial orientation of agriculture whereby the advantages of improving productivity were perceived. Pioneering a new environment stimulated this adoption and adaptation of borrowed technology. Employing technology developed locally as well as that developed abroad proved both a cost-saving and an output-increasing method of expanding commercial production. In that mechanical invention was prominent and was more familiar to farmers, its adoption became widespread. Accordingly, the benefits derived from the greater application of power to farming became widespread. Farm enterprises wherein machinery plays an important role have continued to spawn mechanical invention.

Such enterprises are not notable in New Zealand farming for refrigeration induced substantial change in which mechanical invention was frequently less significant than biological and biochemical invention. Though the substitution of relatively less scarce capital for labour through mechanization has been an important process in the labour-shortage situation in New Zealand, it has been complemented by the creation of a farming system minimizing labour input and capital cost. The extension of grassland exploitation from sheep ranching to the lamb-rearing and dairying enterprises made viable by refrigerated shipping provided the basis for such a system. A reappraisal of land use and of the land's production potential took place. British farming experience re-emerged as a source of information but its application was hampered by the labour requirements of the arable-rotation pattern involved and was restricted by the limited availability of areas low, unbroken relief. Identifying and improving means to intensify grassland production to carry greater numbers of livestock became the aim of scientific research in New Zealand in the succeeding century.

In that success was achieved by plant and animal breeding, by improving pasture and stock management techniques, and by investigating the improvement of soil resources, science enabled the grassland emphasis to overcome the labour and land obstacles inherent in British farming practice. Findings of New Zealand agricultural scientists were transmitted back to Britain to effect improvement there. The disequilibrium created by refrigeration's introduction was worked out largely by technological change within New Zealand. The success of the effort and the social importance of assuring the viability of the small farms engaged in more intensive livestock farming served to direct science to applied research which would benefit those farms. The resultant technology suited the production environment of the existing small-farm structure. Technological disequilibria occasioned change in production technology rather than in the framework of production.

Soil amending's role was to sustain higher yielding pasture plants in the grassland farming system so that more stock could be carried and so provide the possibility of improving farm income. The extension, intensification, and refinement of soil amending was a process accompanied by rising output. The highly divisible nature of the application of that technology and of its demand for labour and capital facilitated its application by small landholders. They could adjust its use to suit their labour and capital supply. The readily observable result of experimentation was also an important factor which encouraged adoption. Adapting soil amending from use on crop land to use on grassland without cultivation was the breakthrough farmers achieved. Thereby, they extended the impact soil amending had on New Zealand farming.

Soil amending was not the only innovation to occur. In fact, it induced a stream of related technological innovation through its capacity to improve soil fertility and acidity, and so, grassland yield. As the basis for other production innovations it can be viewed as the key element in boosting agricultural productivity. The continued diffusion of pasture topdressing and the heavier fertilizer application at the end of the period studied point to this ongoing importance, though, research into the pasture ecosystem has pointed out that pasture and stock management techniques too have a prominent role to play in the effective utilization of the benefits of soil amending. Seeing soil amending as a key element in grassland farming is a more careful statement of its importance.

Also implicated in the grassland farming system's development is government. Governmental influence has been profound since its active encouragement of the formation of a small-farm structure in the agricultural sector. This settlement policy was backed up by a commitment to support small farmers with applied research, education facilities, and produce quality control. From there, in the face of challenges to the viability of the livestock product exports which were of fundamental importance to the economy, governmental intervention has extended to marketing to provide yet greater support. Assuring a stable production environment has led government to create subsidy programs to extend the adoption of production increasing technology. Change in this area has created uncertainty in the production environment but has not altered the basic pattern established.

Of greater importance has been government's review of the economic structure following the exposure of the economy's vulnerability to changes in demand. Augmenting national economic viability by broadening the economic base through industrialization has emerged as a policy from time to time yet agricultural primacy has continued. In the 1960s the decision to divert resources to non-agricultural industrial development was implemented but the economic development anticipated had yet to emerge by 1970.

What has been achieved through grassland farming has been economic growth encouraged by the long-term linkage to a market comparatively stable in product type demand and in capacity to absorb production increases until the 1960s. New Zealand farming has been able to exploit productivity increase by improvements to production technology because of this long-run uniformity of demand. Market stability encouraged stability within the production environment so creating an element of inertia within the agricultural sector and, from its continued primacy, in the structure of the economy. Attempts to achieve greater balance within that structure in seeking continued national economic viability have been parried by renewed demand for agricultural products or by productivity advances which have restored that sector's viability. Aggregate stability in agriculture and in the economy has been achieved through changing technology which, rather than altering the structure in which it has been applied, has been created to support that structure.

FOOTNOTE

1. These organizations given with their data of establishment, are: the Dairy Research Institute (1928), the New Zealand Fertiliser Manufacturers' Research Association (1947), the Meat Industry Research Institute (1955) and the Wool Research Institute (1961) (McBride, 1967, 1121). The earlier appearance of a Dairy Research Institute is indicative again of the technological leadership of that farm enterprise. The date of the establishment of the Fertiliser Manufacturers' Research Association suggests the later development of New Zealand-based production technology and the emergence of greater concern with the refinement of soil-amending technology.

CHAPTER 8

STABILITY AND CHANGE: A GEOGRAPHIC PROBLEM

The preceding chapter presented a summary of the role of soil amending in the development of grassland farming systems in New Zealand. The economic and institutional consequences of the adoption of that technology appeared in the stimulation of unbalanced economic growth, the focusing of research activity on the support of agriculture, and the encouragement and retention of a small-family-farm structure. The stability of the aggregate structure of production was shown to rest on continuing technological change--an apparent seeming paradox. In this chapter an interpretation of the problems created by the above paradox is presented, some directions which may be followed in studying those problems are outlined, the importance of such study is noted, and the contributions of geographers in this area are identified. Concluding remarks on the study of long-run structural change in New Zealand agriculture are offered as a basis for the development of further study.

PROBLEMS RAISED

For the geographer, the paradox poses particular problems in the relationship between spatial process[1] and its manifestation in spatial distribution. There could be a situation of stability where there was no change in either spatial process or spatial distribution. The opposing condition would be constant change in both, the situation of least stability showing the circularly causal relation of spatial process and the spatial structure of a distribution. The degree of change in either should have some effect on the other.

The appearance of a situation where spatial distribution apparently stabilized while spatial process continued to change prompted the review of the aggregate structure of New Zealand agriculture and of the contribution of soil amending thereto. The understanding gained in the process could then be applied in some spatial analysis of the structures active in New Zealand's agricultural development. Recognizing that the elements creating a spatial distribution could become a determinant of later spatial process permits a broader interpretation both of the aggregate pattern found and of the spatial variations which may exist within it. It then becomes possible to raise questions on the past interpretation of spatial distributions and suggest areas where study would be of benefit to the knowledge of New Zealand's agricultural geography and its regional variations, as well as to the development of strategies to cope with ongoing change of the whole and of its parts. Both the study of areas and of spatial structure (referred to as spatial organization) have a place in the attempt to understand the man-land relationship, as Taaffe (1974, 16) has observed.

Physical Environment

Robinson's four structures (Chapter 2, footnote 2) are a framework within which to assess the modifications and alterations of agriculture's production environment in New Zealand. It must be remembered, however, that the physical environment is a key feature therein. That is one of the agricultural sector's outstanding characteristics and one rendering it less directly manageable by man. The soil-amending technology being studied is but an example of man's attempt to control variation in the quality of a physical-environment production resource. Control of climate has been less successful to date and it is this fact which has prevented man from achieving efficient, factory-like production in agriculture (Georgescu-Roegen, 1969, 524). Climate becomes a given element of the environment in the location decision although its relative importance is reduced where methods to overcome other constraints through biological material selection and management are successful. When has this been the case in New Zealand agriculture? Approaching this question by the study of climatic variation can lead to an appreciation of farm-enterprise and farm-management variation insofar as climatic constraints influence the production of those enterprises. Curry (1956, 1962, 1963), Maunder (1966a, 1966b, 1968) and Fielding (1965b, 91) indicate the importance of climate in accounting for varied patterns in New Zealand grassland farming and underline man's ability to devise a range of agricultural systems attuned to given elements in the physical environment. Such attempts are nonetheless of limited success in that: 'every kind of agricultural production _inevitably_ imposes some idleness on _both_ capital and labour over the production period and complete idleness on every fund [production] factor during the rest of the year' (Georgescu-Roegen, 1969, 525). Maximizing production is but a way to reduce this idleness as far as possible.

The view of climate and, indeed, of the physical environment as a fixed element is given by Chisholm (1962, 18):

> On the human time scale, ... changes in the physical environment are usually too slow to be noted by any one generation. For most practical purposes, it can be taken that natural conditions are unchanging: this eliminates the problem of variation in one set of factors, and so much simplifies the whole problem of location analysis.

Such a view suits the location pattern analysis performed in taking 'a situation at a moment in time, when it may be assumed that techniques are unchanging' (Chisholm, 1962, 19). The possibility of long-term climatic change cannot be so readily discounted in agriculture since plant and animal reactions can be highly sensitive to climate. Does the assessment made of climatic effects on production at one time apply to some other period? Long-term studies of climatic variation in New Zealand are needed to assure that taking existing climatic conditions as given in explaining climate-related agricultural patterns is factually correct. Maunder (1972) shows the type of study required.

Change Through Time

The soil resource, in being modifiable by man, is illustrative of the way in which technology is employed to smooth variation occurring in natural resource distribution and change man's appraisal of that resource's utility. Noting how its use has been approached also shows the importance of change through time in explaining spatial processes and spatial structures (Abler *et al.*, 1971, 61). The properties of virgin soil, in the context of the technical structure at the time of settlement, act on initial production and location decisions. In the absence of information about soil properties, are they ignored in fact and only recognized as important after experimentation? Following first exploitation of the soil, it is man's perception of the soil's utility and his effectiveness in amending it which influences subsequent spatial structure. In the present technical structure, soil can be readily modified, unlike climate. It is conceivable that man could achieve full control of soil properties. Realizing this possibility has been the outcome of farmers' experimentation and scientific investigation which produced a conceptual breakthrough in the work on soil chemistry in the 1830s and 1840s. Countering soil-mineral deficiencies through the addition of chemicals lifted a production constraint with a simply applied technology. Adding soil amendments to some level calculated from soil analysis provided a remedy. Not only could farm production be sustained by replacing nutrients lost but also the addition of more nutrients could lift production until some other deficiency made itself felt. This deficiency in turn could be remedied to sustain and improve the new production level. The limits to the approach were scientific ability to identify sources of constraint, the technological capability to produce and distribute amendments, the economic desirability of paying the additional costs and producing the additional output, and the farmers' ability to manage the use of the preceding sources of information in deciding how to utilize the land.

In dealing with the spatial distribution of farming systems and their characteristics, the geographer is observing the static evidence of decisions made in the dynamic process of information transmission and innovation. The effects of soil-amending technology's application have been helpful in this regard in being applied to reduce spatial variation in soil productivity. Were every soil deficiency to be remedied, the soil resource would, conveniently, be fully controlled as a factor in location analysis. The opening up of this prospect by soil science means that variation in soil amending can be seen as a management variable rather than a constraint in the technical structure, though further research may identify hitherto unknown soil deficiencies and pave the way for reappraisals of existing amending techniques and land uses. The time perspective employed is significant in determining whether the phenomena observed are acting as spatial processes or are seen as spatial distributions.

THE STRUCTURAL APPROACH

The physical environment factor is controlled in an unusual way during pioneering. The preference, institutional, economic, and technical structures were set at the time of European settlement of New Zealand. There was, at most, only limited knowledge of the environment in which settlement occurred, and so, its effect on resulting patterns was reduced. The more uniform the other structures the less variation would appear in the appraisal of the unknown capability of the land resource and the uses to which it was put. The uniformity of approach would diminish with increased experience of variation in the physical environment unless suitable and effective techniques were available. Knowledge of the settlers in light of the four structures becomes particularly important for it was people's motivations, expectations, and ability which began to set the course of agricultural development in New Zealand. The technology and techniques available to them help to explain their approach to environmental constraints. Varying approaches would be a consequence of different settler origins. Differences between settlement areas with settlers of similar origins in similar environments could point to either the influence of information from indigenous sources, missionaries or Maoris, or acts of insight. Consulting diaries and letters would provide the clues to the occurrence and initial importance of this process. Hill (1965) is an example of the utility of this approach.

The two agricultural systems established represented a conflict in the institutional structure. The success of the large runholders in selling wool for export eroded the influence on agriculture of the Wakefield settlement plan. Imitation of the successful operations set the pattern for the operation of the structures in the production environment and directed subsequent resource appraisal. Extensive sheep grazing was most readily established in areas of open grassland where labour and capital investment were minimized. Grassland furnished fodder which an investment in stocking could turn quickly into an export commodity. Vegetation was a more important constraint than slope in this instance. Soil was a factor in the location decision only insofar as it, in combination with climate, supported particular forms of vegetation either in natural or in man-modified conditions. Animal breeds were selected according to the economic desirability of their produce and their ability to cope with the physical environment. Indeed, enterprises were shifted to areas better suited to the breeds chosen. Raising Merinos for their fine wool, much sought after in the British market, developed principally in the drier South Island high country where animal health was a lesser problem than it had been in some areas first exploited in the North Island and the South Island (Hill, 1965, 41; Clark, 1949, 187). In the extensive enterprise sufficient manpower to deal with such animal-care problems as footrot was difficult to obtain.

In contrast, the slope constraint would have been more important in arable farming in imposing greater demands for power to work the land and in fostering land deterioration through erosion. Moisture requirements, too, were somewhat different as the more intensive care of stock would reduce the effect of problems such as footrot. Stock could be selected which were better adapted to the environmental conditions. The perceived resemblance of climate to that of Britain led to the importation of breeds better suited to moist conditions. Britain remained the principal source area of such livestock breeds brought to New Zealand.

The technical structure influenced location decisions in two principal ways. Firstly, the farming equipment available at the time was ill-adapted for use in the unbroken land of New Zealand. Ploughs devised for the long-cultivated fields of Britain were neither efficient nor effective in the newly cleared bush and fern land and tussock (Hargreaves, 1966, 148, 382; Cant, 1968, 164). The demand for sturdier American implements reflected this problem (Hargreaves, 1966, 382). Arable farming with the limited availability of machinery at the time necessitated seasonal labour which was largely unavailable where people could readily acquire their own holdings and work for themselves. The preference structure worked against the formation of a rural labouring class.

Secondly, transport technology linking New Zealand to the larger world markets could not yet deal with perishable produce and preservation techniques had not become sufficiently reliable to offset this disadvantage. Non-perishable produce such as wool became the basis of commercial agricultural production and New Zealand's success in the production of this commodity led to wool becoming the colony's principal export product. In being suited to the limited labour- and capital-supply situation in the economic structure and to the capitalist ownership pattern of the institutional structure, the wool enterprise could have developed stability. In terms of land use the grasslands would have been gradually modified by the introduction of exotic grasses and legumes to supplant and supplement the less productive native grasses. This would have been a largely environmentally adaptive undertaking where the extent of sown grassland was the principal index of land improvement. In this framework, with the limited demands placed on soil by low stocking rates, deficiency problems would have been less evident and so the adoption of soil amending postponed. The availability of land also meant that shifting to another area was an alternative should signs of diminishing production appear.

Demand change from the Australian and New Zealand gold rushes along with changes in the technical structure introduced disturbance. The demand for the produce of arable farming grew. Butter and cheese were exported to Australia, but local demand reduced the need to do so. Grain exports occurred, and the relatively imperishable nature of the produce made this a viable enterprise. The economies to be achieved by large-scale production and the use of labour-saving machinery meant that small landholders were not as favoured by this change. It was the runholders on areas of low relief with suitable climate conditions who entered grain production. The importation of machinery from North America, an area with a similar production environment, points to the importance of the operation of economic structures in the transmission of information and technology.

Land use, the proportion of crop land in grain, identifies the regions favoured by this new production environment. Linking the farm size in areas developing grain production would point to the extent to which this new enterprise wrought change in farming's institutional structure. Were small farms made more viable because of the possibility of entering grain production, or was a greater market for livestock production a more important consideration in explaining their viability?

The change of land use brought by arable cropping meant that an appreciation of soil properties increased. The demands placed on soil were increased and would have served to reveal deficiencies, so prompting interest in the soil-amending knowledge developed in Europe and Britain. Although soil amending was undertaken earlier than 1867, its importance began to increase after that date. Tracing the quantities of amendments imported and their point of landing, and then identifying the transportation routes available could be used in order to create an approximation of the distribution of soil-amending practice using chemical fertilizers. A measure of the association of soil amending with grain cropping would point to the importance of that arable enterprise in the development of more intensive agriculture. Should the areas of greatest association also be the regions developing most rapidly after the introduction of intensive livestock production, then the role of soil amending would assume greater importance; otherwise, tracing the role of other practices would be more worthwhile in explaining the pattern of change of farm enterprises.

The relationship of ploughed to unploughed sown grassland assumes importance as an index of the extent of mixed cropping and livestock production. Regional patterns of farming systems would become apparent as Hargreaves (1966) has shown. Did British farming practice then become a more important information source? It was influential in the period of initial settlement when mixed, semi-subsistence farming was important. Extensive grazing derived more information from Australian experience than from British experience given the similarity of grazing enterprise and the contact system developed. Changes in British technical structure during the nineteenth century became relevant to New Zealand and formed a basis of farming system development from the 1880s until local adaptation became an effective influence on new adopters.

The digression to the introduction of more intensive livestock production is an important reminder that the population increase following the gold rush and an active immigration policy brought change to the preference structure in that demand for land increased. In order to imitate the successful, large runholders and find employment opportunity where few others were developed in the sectorally unbalanced structure of the colonial economy, pressure was directed to the institutional structure to create small holdings. The political repercussions were to continue over the following two decades. The large landholders were well ensconced in the institutional structure in whose creation they had earlier participated and they were reluctant to modify their production environment by reducing their access to the cultivable land sought by new entrants to agriculture.

Until the key change in the technical structure, refrigeration of marine transport, occurred the viability of the small farms was doubtful (Duncan, 1962, 170). The investment in boiling-down and meat-preserving plants showed the interest in recuperating some of the investment in stock once wool prices dropped. Does the spatial pattern of those plants point to the intensity of concern with livestock disposal, and so, perhaps, become a measure of greater concentration of small farms? A positive association would identify the plants as the nucleus of small-farm formation in providing an outlet for produce. The change over time in small-farm location would be a measure of the importance of these agriculture-related industries to agricultural development. In that some of these establishments also produced organic fertilizers did they also exert some influence of the spatial distribution of soil amending and farming systems dependent upon the addition of nutrients? A comparison of the patterns of imported in domestically produced soil amendments would become possible and allow the geographer to gauge the extent of diffusion and concentration of soil amending.

Was it a largely physical environment related practice? If so, the environmental perceptions operating in the farming system could be deduced from an examination of the way soil amending was employed. These perceptions could become an explanatory factor in studying the spatial patterns which developed. Differing soil-amending practice in similar physical environments would point to the presence of culturally related perception differences in regional, institutional, economic, technical, and preference structures. Later changes in these structures could then have a regionally uneven effect through the varying resistance to change of existing structures in the production environment.

Refrigeration reintroduced a pioneering perspective in that the existing structures were all subject to modification. The physical environment had to be reassessed in view of the new enterprises made desirable. Farming systems had to be adjusted to cater for the nutritional needs of breeding ewes and dairy cows and so began an information search and experimentation. Existing environmental knowledge and that derived from British farming experience and science were examined. Stock management and pasture management increased in importance and directed attention to the appraisal and exploitation of the physical environment. The breeds of livestock were reappraised in light of the production possibilities so their environmental requirements had to be assessed (Buchanan, 1935, 49, 56-57). In view of the previous comments on pioneering, did a proliferation of enterprises over a wide range of environmental conditions occur until experience demonstrated the advantage of certain enterprises and lead to increased specialization? Such a situation would imply an absence of influence from other established structures. This is an unlikely circumstance as longer production experience was available as was not the case for the first settlers. Were its applicability perceived as limited, then, this production experience would have had little influence in guiding the new production location decisions. The apparent similarity of enterprise would probably limit this possibility's explanatory power. Verification would have to come from opinions expressed at the time. Regional perceptions based on past experience would be contained in farm enterprise location decisions. This finding would underline the importance of past spatial structure in the spatial distribution found at any particular moment.

Interacting with these location decisions, and later guiding them, were the decisions taken on processing-plant locations. Did the need to process meat and milk before export create an altered spatial distribution only approximated in the earlier established meat-preserving plants? Mapping the two patterns is indicated. Land transport was still an obstacle given the condition of roads, the vehicles available, the extent of the rail network, and the absence of refrigerated rail transport. Was refrigeration in coastal shipping to deliver produce to major exporting ports another important innovation and one worthy of study in explaining the regional pattern of farm enterprise adoption? The critical question raised is the importance of factory-location decisions in directing later farm-enterprise development. Was regional specialization more an outcome of physical environmental constraints or of economic structure? A largely overlapping distribution of meat-freezing plants and dairy factories would lead to the conclusion that environmental constraints played a greater part. Where this overlap was not evident, then tension between environmental and economic factors could occur as economic structure promoted one enterprise while the physical environment was found comapratively unfavourable. Did, for example, the early development of dairy factories in Southland retard the change away from dairying to lamb rearing?

An additional factor in small-firm location was government participation in land subdivision. Successive acts were aimed at providing land for settlement by small farmers. Did early success in acquiring land and subdividing it encourage further subdivision in that area or was the location of a processing plant of greater importance ? Duncan (1962) studied the former aspect between 1886 and 1906 but was not concerned with the latter. Evaluating the effectiveness of the land policy has been the subject of historical study to which the geographer could contribute. The approach of Gould (1976) in attempting to determine the degree of improvement of carrying capacity with the replacement of native grassland and forest by ploughed and unploughed sown grassland is of value. By controlling vegetation variation through the selection of counties or electoral districts showing a predominance of the vegetation type being investigated, Gould was able to analyze the productivity effect of replacing natural ecosystems in a range of physical environments.

In stimulating a small-farm structure in agriculture, government introduced an institutional structure with particular constraints, especially that of labour, in its economic structure. The capital substitution for labour which favoured the introduction of labour-saving production machinery proved especially important for the small farmers. The types of production undertaken could have been labour intensive but in the absence of sufficient rural manpower, such was not the case. The grassland basis of farming was successfully adapted to meet the needs of dairying and lamb rearing while keeping labour input low.

The development may be followed in observing the relationship between unimproved land and sown grassland as land subdivision brought the more intensive use of land shown by Gould (1976). The degree to which British farming practice became influential is apparent in the relationship between supplementary fodder crops and the area in sown grassland. The use of turnips, mangolds, and green fodder was extended until the research into grassland brought out a true perennial ryegrass which reduced the need for pasture renewal by ploughing and resowing. A second index, the ratio of ploughed to unploughed sown grassland, provides a check on the spread of this farming system change and any areal variation which occurred within the limits of the level of aggregation of the data recorded. Relating these observations to indices of soil amending would then show the degree to which the arable-grass rotation spread the practice prior to the pasture top-dressing innovation. Factors limiting or abetting the extension of arable farming could then be included in the explanation of soil amending's distribution.

It should be remembered here that farming practices were devised in a framework of the breeds of plants and animals available and their demands on the physical environment. A knowledge of these characteristics and their influence on the technical structure is essential to correct interpretations of past spatial distributions. Assuming that present breeds influence farming decisions in the same way as their predecessors could lead to misinterpretation of the relative effects of preference and technical structures. What appears as a cultural preference for a particular animal breed or plant species might well be a wise choice given the technical structure of the time. The changes in this technical structure resulting from plant and pasture research can be seen as significant contributions to New Zealand agriculture of New Zealand science.

Governmental policy had further profound effects in that it directed research and education to promote the small-firm enterprises. Were there spatial ramifications of this activity? Were areas not concentrating on lamb rearing and dairying increasingly disadvantaged as the research findings and their transmission provided means of productivity improvement for those farm enterprises? Environmental constraints on the application of the technology devised to implement the research discoveries would prove increasingly important explanatory factors in the spatial distribution of farming systems. Knowing the sites of research projects and the environments favoured by study become essential factors in the above explanation. A study of the distribution of field trials, experimental farms, instruction centres, and the diffusion of techniques would provide a background to subsequent study of small-farm development. Taylor (1977, 336) has observed the importance in the early 1970s of government-sponsored research establishments in not only producing inventions but also in stimulating private invention in circumjacent areas. Can this process also be traced back through time by the mapping suggested above and a similar study of patents? The importance of Department of Agriculture and DSIR research establishments particularly as regional influences would become more readily apparent.

The more intensive use of land in lamb rearing and dairying suggests that the importance of soil deficiencies and soil amending to overcome them became increasingly important as greater production tapped resources more fully. Was the effectiveness of soil analysis and of the amending practice recommended and carried out involved in the farm location pattern? For example, the inability the discover the cause of 'bush sickness' in livestock retarded the development of those areas of the central North Island where soils were deficient in cobalt. Farming patterns can be seen to be strongly related to the existing technical structure.

This view leads to an observation that the ability of farmers to employ soil amending is an outcome of the conjunction of the technical structure and the physical environment. Areas of low relief were not a constraint on the distribution methods used for soil amending. The greater the relief and the more broken it was, the more soil amending was restricted. This direct relationship meant that farming systems benefiting from its use were restricted to particular relief types until technology to overcome the slope constraint was devised. This is the root of the contribution of agricultural aircraft to New Zealand farming. The implication of the above consideration is that the more intensive livestock enterprises located on land of low relief were able to forge ahead in the use of productivity-boosting soil-amending technology and develop a relief-related spatial pattern as soil-related factors were overcome. As dairying favoured low relief areas and could outbid sheep enterprises through the higher return for their produce, it was dairying which benefited first from soil amending.

Research into soil amending provided a source of productivity improvement for that enterprise. Buchanan (1935, 35) identified the low relief factor in explaining the distribution of dairying but did not note at that time the effect of this feature on soil amending whereby it became linked strongly with dairying in its early diffusion. Does the fact that low relief and coastal location are also strongly associated mean that the farming enterprises favouring low relief were also to benefit from greater accessibility by rail, ship, and road for the shipment of their perishable produce and the importation of inputs? The bulky nature of soil amendments meant that accessibility was a basic factor to their use. Government recognized this fact in subsidizing lime carriage by rail in order to facilitate its use. Determining the areas which benefited most from this policy would demonstrate the effectiveness of such broadly applied policy. McCaskill (1966, 284) has pointed out that in one lowland area, north Westland, there were other factors which offset the lowland advantage: high transport costs, unfavourable climate, rapid reversion, and mediocre farming standards. A thorough examination of structural interaction is thereby indicated.

Buchanan (1935, 37-38) illustrated the importance of various land transport methods in explaining their contribution to sheep farming and dairying locations. Indeed, he held that butter and cheese production areas were differentiated by the ease of road transport. Cheese making required daily whole milk transport by farmers and was constrained by the need for good roads. Butter's principal ingredient, cream, was a less bulky product and could be collected less frequently. The demands made on road transport were less exacting and so suited areas where road construction was less advanced. Thus, Buchanan (1935, 38) attributed the regional pattern of dairying, butter production in Auckland and cheese production in Taranaki, to the difficulties in road construction in the former. He noted that with improvement in roads, the 'interaction of mutual cause and effect was gradually being broken' (Buchanan, 1935, 38). Measuring the extent to which butter production continued to predominate as roads were improved would show the extent of the inertia effect created by the existing economic structure.

The adjustment due to the introduction of milk tanker could follow similar lines. Was the use of milk tankers an outcome largely of improved roads or of the presence of cheese factories? If roading improvement was an outcome of tanker use then it could be associated with soil amending in that improved access for soil amendments would be likely to reduce its cost and increase its use. Where ground-spreading vehicles have demonstrated their importance such a study would indicate to what degree improved roads explain the use of these vehicles as opposed to agricultural aircraft or farmers' own equipment.

Indicated in the above consideration is the importance of farm enterprise type in the diffusion of technology. Dairying can be seen to be a more intensive farming system than sheep farming in terms of its land use. For example, the ratio of sheep to sown grassland declined from 1891-95 to 1901-05 and showed little change to 1921, but the ratio of dairy cows rose (Table 7.8). This evidence suggests that unimproved land remained important in sheep farming (the more intensive fat-lamb enterprise could not be identified separately), whereas dairying apparently took greater advantage of sown grassland.

A comparison of dairy cow numbers for each provincial district at five-yearly intervals from 1895-96 to 1920-21 indicated an increasing concentration of dairying where sown grassland formation was most prominent (Table 8.1). In 1895-96, four provincial districts each contained about 20 percent of the nation's dairy cows and they each contained more than 15 percent of the total sown grassland. By 1905, North Island dominance was appearing as Otago's share fell to 16 percent while all the North Island districts except Hawke's Bay held about the same share. The latter district's unsuitability for dairying had been identified but it did share in the North Island sown grassland emphasis evinced in the total sown grassland proportion's exceeding that of total improved land--a trend maintained to 1921 (Table 8.1). Auckland's share increased after 1906 at the expense of Taranaki and Wellington although its sown grassland percentage declined somewhat. The size of the Auckland provincial district masks an even greater concentration. With the later subdivision of that district into the North Auckland, South Auckland, and Gisborne Land Districts the importance of the latter appears.

The production effects of moisture balance and relief observed by Curry (1963) and Buchanan (1935) in influencing farming system location were playing their part in creating different spatial patterns for the livestock enterprises. Intensive livestock production displaced extensive sheep ranching, the latter system occupied largely unimproved grassland unsuited for the former according to the precepts of the time. The lowland areas of low relief (Buchanan, 1935, 30-31) with a climatic regime allowing 'the making of hay and silage on a considerable scale' (Curry, 1963, 106) became dairying areas. The more rigid and uniformly spread feed requirements experienced through the year in this farming system, and the greater returns it enjoyed, resulted in its displacing sheep production (Curry, 1963, 106). The farm enterprises were not evenly spatially distributed nor did they rely to the same extent on intensive use of grassland.

The diffusion of pasture topdressing shows that the flexibility of farming systems to incorporate new enterprises, a factor which may be largely environmentally related, encourages the diffusion of technology when new enterprises are adopted in the face of weakened or comparatively weak returns from a present enterprise. As sheep farmers were disadvantaged relative to dairy producers, those on environmentally suitable holdings entered dairying. The differences in pasture-management techniques and the utility of soil-amending technology incorporated in the technical structure of dairying were transmitted

TABLE 8.1

COMPARISON OF PROVINCIAL DISTRICT PERCENTAGE OF IMPROVED LAND, SOWN GRASSLAND, AND DAIRY COWS 1895-1920

Provincial District	*Improved Land*						*Change*
	Year						
	1895-96	*1900-01*	*1905-06*	*1910-11*	*1915-16*	*1920-21*	*1895-1920*
Auckland	14.1	15.9	18.4	21.7	18.6	20.9	+6.8
Hawke's Bay	11.8	13.8	12.5	11.3	17.2	17.2	+5.4
Taranaki	4.8	5.8	6.6	6.5	7.6	7.6	+2.8
Wellington	20.2	20.4	19.9	19.6	20.1	19.3	-0.9
Marlborough	2.3	2.7	2.8	3.6	2.7	2.1	-0.2
Nelson	2.5	4.2	3.7	3.8	2.1	2	-0.5
Westland	0.5	0.4	0.4	0.5	0.8	0.8	+0.3
Canterbury	22.4	19.0	18.7	16.9	15.8	15.2	-7.2
Otago	21.4	17.7	17.0	16.0	15.1	15.0	-6.4
	Sown Grassland						
Auckland	15.1	17.0	19.6	23.5	19.6	22.1	+7.0
Hawke's Bay	13.1	15.4	13.7	12.4	19.0	18.7	+5.6
Taranaki	5.4	6.4	7.2	7.1	8.1	7.8	+2.4
Wellington	22.4	22.4	21.6	21.5	22	20.8	-1.6
Marlborough	2.4	2.8	2.8	3.7	2.6	2.1	-0.3
Nelson	2.6	4.4	3.8	3.9	2.2	2	-0.6
Westland	0.5	0.4	0.5	0.6	0.9	0.8	+0.3
Canterbury	19.7	16.1	16.0	13.8	12.6	12.3	-7.4
Otago	18.8	15	14.8	13.5	13	13.3	-5.5
	Dairy Cows						
Auckland	21.6	20.2	22.4	28.5	31.7	38.1	+16.5
Hawke's Bay	3.7	3.7	4.4	5	5.7	5.4	+ 1.7
Taranaki	20.4	22.3	22.6	21.2	20.4	17.4	- 3.0
Wellington	16.4	20.1	21.4	18.1	18	15.2	- 1.2
Marlborough	1.4	1.1	1.0	1.2	1.3	1.3	- 0.1
Nelson	3.6	3.0	2.4	2.4	2.4	2.3	- 1.3
Westland	1.0	1.2	0.8	1.0	1.1	1.1	- 0.1
Canterbury	12	9.8	9.1	8.2	7.8	7.9	- 4.1
Otago	19.9	18.6	15.9	14.5	11.5	11.3	- 8.6

Source: Calculated from *Statistics of New Zealand* (for years shown).

as these new dairy farmers entered a learning phase. Later changes in economic conditions led to a return to an emphasis on sheep production but the advantages of soil amending and more intensive use of grassland would have remained. Case studies demonstrating this process would give support to the importance of the concept of enterprise-related information transmission from source areas of innovation and technology by imitation. They would also show the fluidity of enterprise-determined boundaries in outlining farming-system boundaries.

The classification of store-stock farmers in easier hill country would require adjustment as they found themselves able to employ more intensive grassland farming practices through their greater ability to employ soil amending and so fatten some stock previously sent to lowland farms. The distinction between farming systems is thus blurred in areas such as the Manawatu and the spatial structure modified. In the process, the store-stock farmers' appraisal of his land resource is changed through the potential unlocked by more intensive grassland technology contingent upon soil amending and the techniques acquired in the new stock-fattening enterprise. Disequilibrium is created which may effect further change in spatial processes and so the spatial distribution of farming systems.

The displacement of one farm enterprise by another viewed as more worthwhile by some criteria determined by the farmer can vary in its rate. The evidence from plotting adoption curves (Rogers and Shoemaker, 1971) suggests that a normal distribution during change is the pattern for farmers as well. Some innovate more readily than others. The early adopters act as sources of information for later imitators who form the majority. Thus, a management variable is built into diffusion. The curve of tractor numbers (Fig. 5.2) suggests such a pattern though the assumption must be made that each tractor is used on one farm. The single-owner pattern supports this idea by evidence of the number of farms using such terms of equipment would be welcome in order to gauge the extent of concentration present. Where environmental variation is controlled, the spread of technology can detect such regional differences as occur and point to reasons explaining leading or lagging tendencies in innovation. Studies over time of regional or national technological change, thus assist in defining those farmers and, perhaps, farming systems most susceptible to change. Regional concentration of such farming systems suggests that regional policies directed towards them would enjoy greater success than those where management was characterized by a greater tendency to lag. Introducing more sensitive farming systems would then become a means to compensate for regional inequality based largely on past development processes.

Physical environmental constraints upon the desired farming systems could then be tackled by research with a well-defined problem. Such research has tended to be the pattern in New Zealand. In soil science, relating soil amending to soils has had a largely pedological focus as a consequence (for example, During, 1972). A geographic appreciation of soil-amending practice has been absent. Tracing the areas and soils studied would give an excellent idea, through time of the progress made in soil science in New Zealand and of the concerns of the government departments involved. Mapping soils and their deficiencies has been accomplished but the mapping of soil-amending practice has not. Such mapping would provide information on the efficiency of fertilizer use in outlining regional- and enterprise-related trends and suggest the degree to which soil amending was either underutilized or overutilized. From there, identifying reasons for those patterns would furnish the basis for modifying policies to encourage more efficient soil amending.

Has soil amending appeared to be evenly or unevenly distributed? This distribution can be shown using topdressing data available for land districts after 1930-31 (Table 8.2). The land districts have been standardized as far as possible to include the same areas. Land-district boundary changes outlined in Map 7.1 have been compensated for whenever possible by controlling the topdressing figures for the relevant counties as shown in Table 8.3. The absence of county level data on topdressing prior to 1935-36 mean that shifts seen in the North Island land districts except North Auckland resulted in part from the transfer of counties.

A comparison over time of the percentage of the national total of sown grassland against the percentage of the national total of grassland topdressed (Table 8.2) indicates that topdressing was not evenly distributed over New Zealand. The importance of South Auckland as a source area of grassland topdressing is clear from its high proportion, nearly 37 percent, of all topdressing 1930-31. North Auckland and Taranaki were the only other land districts where the

TABLE 8.2

COMPARISON OF LAND DISTRICT PERCENTAGE OF TOTAL SOWN GRASSLAND TOPDRESSED AND TOTAL SOWN GRASSLAND 1930-1969

Land District	*Percentage of New Zealand Sown Grassland Topdressed:*				
	1930-31	*1940-41*	*1950-51*	*1960-61*	*1969-70*
North Auckland	16.1	15.6	14.3	13.4	11.8
South Auckland	36.6	30.7	28.9	27.7	24.1
Gisborne	1.6	1.8	1.9	2.3	3.9
Hawke's Bay	4.6	8.9	9.9	10.9	11
Taranaki	12.6	9.4	8.1	6.0	4.6
Wellington	12.1	15.1	13.4	13.7	13
Marlborough	0.8	0.6	1.0	1.4	1.8
Nelson	1.2	1.1	1.0	1.3	1.5
Westland	0.4	0.4	0.4	0.5	0.6
Canterbury	4.7	4.6	8.1	9.6	11.2
Otago	3	3.4	4.1	5.1	7.5
Southland	6.4	8.3	8.8	8	9
	Percentage of New Zealand Sown Grassland				
North Auckland	9.7	10.0	10.1	10.5	10.6
South Auckland	13.0	13.8	14.8	18.2	19.1
Gisborne	11.3	8.9	8.5	7.8	6.9
Hawke's Bay	8.2	10.7	10.3	10.5	10.1
Taranaki	6.9	5.4	5.1	4.2	4.1
Wellington	20.4	20.6	20	17.9	16.6
Marlborough	2.0	2.1	1.8	1.8	2.1
Nelson	1.8	1.7	1.5	1.5	1.5
Westland	0.9	0.8	0.8	0.8	0.8
Canterbury	11.8	11.4	12.6	12	11.4
Otago	7.2	7.5	7.5	7.6	9.1
Southland	6.7	7.0	6.8	7.2	7.7
	Difference of Above Percentages				
North Auckland	+ 6.4	+ 5.6	+ 4.2	+ 2.9	+ 1.2
South Auckland	+23.6	+16.9	+14.1	+ 9.5	+ 5.0
Gisborne	- 9.7	- 7.1	- 6.6	- 5.5	- 3.0
Hawke's Bay	- 3.6	- 1.8	- 0.4	+ 0.4	+ 0.9
Taranaki	+ 5.7	+ 4.0	- 3.0	+ 1.8	+ 0.5
Wellington	- 8.3	- 5.5	- 6.6	- 4.2	- 3.6
Marlborough	- 1.2	- 1.5	- 0.8	- 0.4	- 0.3
Nelson	- 0.6	- 0.6	- 0.5	- 0.2	—
Westland	- 0.5	- 0.4	- 0.4	- 0.3	- 0.2
Canterbury	- 7.1	- 6.8	- 4.5	- 2.4	- 0.2
Otago	- 4.2	- 4.1	- 3.4	- 2.5	- 1.6
Southland	- 0.3	+ 0.7	+ 2.0	+ 0.8	+ 1.3

Source: Calculated from *Agricultural Statistics* (for years shown).

TABLE 8.3

METHOD OF STANDARDIZING LAND DISTRICTS[a]

Land District	*Period of Adjustment*			
	1926-27 -1934-35	*1935-36 -1956-57*	*1957-58 -1959-60*	*1960-61 -1969-70*
North Auckland	-	-	-	=Northland S.A.+ Central Auckland S.A.
South Auckland	+Ohura+ Katieke[b]	+Ohura+ Katieke	-	=South Auckland - Bay of Plenty S.A. - Opotiki
Gisborne	-Wairoa	-	-	=East Coast S.A. +Opotiki
Hawke's Bay	+Wairoa	-	-	-
Taranaki	-Ohura- Patea	-Ohura	-	-Patea
Wellington	-Katieke+ Patea	-Katieke	-	+Chatham Islands +Patea
Nelson	-	-	-	-
Marlborough	-	-	-	-
Westland	-	-	-	-
Canterbury	-	-	-	-Chatham Islands
Otago	-	-	-	-
Southland	-	-	-	-

Notes: *a* Land districts are considered to equal statistical areas (S.A.) unless other change is noted

b Areas changed are all counties

topdressed percentage exceeded the sown grassland percentage in 1930. The livestock pattern in each of these land districts (Table 8.4) shows that all except Southland contained a higher percentage of dairy cow livestock units than sheep livestock units. This also applies to Westland, but the addition of the criterion that dairy cattle must represent more than 60 percent of total cattle removes it, while introducing Southland and Marlborough. An association between dairying and topdressing becomes a possibility from this evidence alone. The confirmation provided by observers at the time becomes important in the argument that dairying and pasture topdressing were closely associated. The consideration that Southland's earlier development had been more strongly based on dairying prior to the 1930s offers additional proof of soil amending's greater relevance to dairying and its link with that farm enterprise.

In the successive periods the diffusion of pasture topdressing appears. The difference between sown grassland and area topdressed percentage decreases (Table 8.2). The predominance of the source areas remains but the degree of difference decreased for each land district, almost without exception at each time interval, as an increasing proportion of grassland was topdressed (Table 8.5). The topdressing of grassland had not developed equally in all land districts by 1970. Although more than half of the sown grassland in all but one land district was topdressed, this figure rose to 75 percent or more in only four land districts.

What is particularly noteworthy is the rate of increase in the above percentage and the period in which change occurred. In South Auckland, the grassland-topdressing source area, the proportion of sown grassland topdressed increased by approximately 10 percent each decade. The rate was more variable elsewhere, especially between 1950-51 and 1960-61. In Gisborne, Marlborough, Nelson, Westland, Canterbury, and Otago this percentage was almost, or more than, doubled. The importance of soil amending was being appreciated rapidly and its use disseminated. The role of agricultural aviation should be apparent here, if that innovation was indeed major.

The percentage of sown grassland topdressed in Canterbury and Marlborough had been similarly doubled between 1940-41 and 1950-51 when aircraft use was available and an explanatory factor only in the last two years of the decade. Concern for, and methods of, topdressing

TABLE 8.4

PERCENTAGE DISTRIBUTION OF LAND DISTRICT LIVESTOCK UNITS 1930-1969

Land District		*Percentage of Livestock Units* *Year* 1930-31	1940-41	1950-51	1960-61	1969-70
North Auckland	*D*	50	58	60	46	38
	ND	23	19	18	24	33
	S	27	22	22	29	29
South Auckland	*D*	55	53	49	39	36
	ND	20	18	18	24	26
	S	24	29	33	38	38
Gisborne	*D*	7	9	9	7	5
	ND	31	35	38	43	45
	S	61	56	53	50	50
Hawke's Bay	*D*	10	7	7	4	4
	ND	20	25	25	31	33
	S	70	67	68	65	63
Taranaki	*D*	55	61	58	60	61
	ND	15	12	12	11	14
	S	30	27	30	29	25
Wellington	*D*	18	17	16	12	12
	ND	22	23	23	26	29
	S	60	60	60	62	59
Marlborough	*D*	27	31	32	26	22
	ND	17	15	17	18	27
	S	56	54	51	56	51
Nelson	*D*	10	8	9	6	6
	ND	9	8	13	15	24
	S	82	84	78	79	70
Westland	*D*	32	32	34	26	23
	ND	39	41	45	40	45
	S	28	27	21	34	32
Canterbury	*D*	9	9	8	5	3
	ND	6	6	8	9	14
	S	84	85	84	86	83
Otago	*D*	9	8	6	3	2
	ND	7	6	8	8	15
	S	84	86	86	88	83
Southland	*D*	16	13	10	4	2
	ND	10	8	10	8	13
	S	73	79	80	88	85
New Zealand	*D*	24	25	25	20	18
	ND	18	18	18	21	25
	S	58	57	56	59	57

Note: *D* = dairy cows in milk, *ND* = other cattle, *S* = sheep.

Source: Calculated from *Agricultural Statistics* (for years shown). using conversion factors given in Table 7.5 .

TABLE 8.5

PERCENTAGE OF SOWN GRASSLAND TOPDRESSED
BY LAND DISTRICT 1930-1969

Land District	*Year*				
	1930-31	*1940-41*	*1950-51*	*1960-61*	*1969-70*
North Auckland	27.6	40.7	49.1	66	76.5
South Auckland	46.8	58.2	67.9	78.3	86.4
Gisborne	2.3	5.3	7.9	15.4	38.5
Hawke's Bay	9.3	21.8	33.2	53.6	74.2
Taranaki	30.1	46.1	55.4	73.6	77
Wellington	9.9	19.2	23.4	39.5	53.6
Marlborough	6.3	7.7	19.8	39.7	58.5
Nelson	10.9	16.6	22.8	46	67.1
Westland	6.9	13.2	18.9	36.1	54.3
Canterbury	6.6	10.5	22.4	41.4	66.9
Otago	6.9	11.7	18.6	34.7	56.8
Southland	15.9	31.1	43.8	57.2	79.5
New Zealand	16.6	26.2	34.7	51.6	68.4

	Net Change	
	1930-50	*1950-70*
North Auckland	+21.5	+27.4
South Auckland	+21.1	+18.5
Gisborne	+ 5.6	+30.6
Hawke's Bay	+23.9	+41.0
Taranaki	+25.3	+21.6
Wellington	+13.5	+30.2
Marlborough	+13.5	+38.7
Nelson	+11.9	+44.3
Westland	+12.0	+35.4
Canterbury	+15.8	+44.5
Otago	+11.7	+38.2
Southland	+27.9	+35.7
New Zealand	+18.1	+33.7

Source: Calculated from *Agricultural Statistics* (for years shown).

were evident prior to agricultural aviation's arrival. Information on the extent of aerial-topdressing coverage prior to 1960-61 is not available from official sources, but the pattern set out by that year is one of North Island predominance (Table 8.6). This accords with the spatial pattern found by Brockie (1958, 14). In the following decade, this pattern was but little changed (Table 8.6). An additional 5 percent of the national total of sown grassland aerially topdressed was located in the South Island, but the greater usage in the North Island persisted as Moran (1974, Fig. 28c) noted.

Within that distribution, land districts varied in the importance of aerial topdressing (Table 8.7). The heavy reliance in Gisborne particularly, the most and also in Hawke's Bay, is exceptional. Another group where aerial work accounts for about 55 to 60 percent of the total topdressed acreage includes the South Auckland, Wellington, Marlborough, and Otago Land Districts. The remainder still cover a wide range, from 8 to 40 percent, but aerial topdressing is clearly less important there. Some stabilization of use is evident in the slowed rate of increase or slight decrease observed in North Auckland, South Auckland, Hawke's Bay, Canterbury, and Otago. In the other land districts the rate of increase between 1960-61 and 1969-70 varied between 5 and 10 percent of the 1960-61 figure in Gisborne, Wellington, and Southland; and exceeded that rate elsewhere, Marlborough showing a rapid increase.

The evidence above suggests that the need for further disaggregation. The land districts are neither homogeneous in landform (Wallace, 1955) nor, consequently, in the farm enterprises located therein, as the distribution of livestock proportions in the land districts had indicated (Table 8.4). The availability of data by counties provides some solution but Warr (1970) showed the problems of variability in both factors even at that level. Case studies or the selective approach used by Gould (1976) could both help in finding more exactly the extent to which aerial topdressing is a farm-enterprise or landform-related activity. The presence of other variables could be discerned were the above two factors not found to account for significant levels of variation.

The importance of such findings lies in the demonstration that governmental policy applications can have distinctly different results on different farming systems. Measures changing aerial

TABLE 8.6

LAND DISTRICT PERCENTAGE OF TOTAL SOWN GRASSLAND AERIALLY TOPDRESSED

Land District	*Year* 1960-61	1965-66	1969-70	1965-70
North Auckland	10.7	10.7	9.4	- 1.3
South Auckland	31.1	27.6	25.8	- 5.3
Gisborne	4	6	6.9	+ 2.9
Hawke's Bay	16.8	15.7	16.6	- 0.2
Taranaki	3.9	3.4	3.3	- 0.6
Wellington	15.9	15.6	15.7	- 0.2
Marlborough	1.3	1.7	2.1	+ 0.8
Nelson	0.9	1	1.1	+ 0.2
Westland	0.1	--	0.1	—
Canterbury	5.4	5.8	6	+ 0.6
Otago	5.7	8	8.3	+ 2.6
Southland	4.1	4.4	4.8	+ 0.7

Source: Calculated from *Agricultural Statistics* (for years shown).

TABLE 8.7

PERCENTAGE OF SOWN GRASSLAND TOPDRESSED DONE AERIALLY

Land District	*Year* 1960-61	1965-66	1969-70
North Auckland	39.2	48.1	40.4
South Auckland	55	60.7	54.5
Gisborne	85.4	91.1	90.6
Hawke's Bay	75.6	78.1	77
Taranaki	31.4	37.2	36.4
Wellington	57.1	63.6	61.6
Marlborough	47.8	56.6	60
Nelson	33.4	38.7	38.3
Westland	6.3	9.1	7.6
Canterbury	26.2	29.2	27.1
Otago	55	62.1	56.4
Southland	25.6	30.0	27.6
New Zealand	39	54.7	50.6

Source: Calculated from *Agricultural Statistics* (for years shown).

topdressing intensity could have an effect on certain farm enterprises, and, to the extent that such enterprises were unevenly spatially distributed on certain regions. Framing such measures on the basis of national level information could prove to be ineffective. An analysis of variance[2] of the sown grassland acreage topdressed using one of three soil amending methods: chemical fertilizer applied alone, lime applied alone, or the two applied in combination, over the period from 1935-36 to 1969-1970 in each land district showed that the differences in the methods used did vary significantly over time but not between land districts (Table 8.8). The different soil-amending treatments were not used equally. The use of fertilizer on its own became a more common method, This change was not restricted to particular land districts, however. The evolving soil-amending technology was used widely and variation in treatment type also occurred in many areas, perhaps a reflection of the wide variation of soil types within land districts. None of the interactions between topdressing method, location, and year was found to be significant, an indication of independence between these three variables.

Variations in topdressing method were not significantly different from chance over space and over time. The interaction of the spatial and temporal variables did not show a statistically significant trend. The pattern of change in topdressing method among the different land districts in any particular year did not differ from any other year. A measure of random change was evident. As a guideline for soil-amending policy such findings ignore possible differences between farming systems. The assumption that land districts represent an adequate level for discriminating between farming systems would prove dangerous on this basis.

The coincidence of the rapid increase in stocking rate, which occurred especially between 1950-51 and 1969-70 (Table 8.9) and the great increase in soil amending is evident. The land districts with the highest rate of pasture topdressing, South Auckland and Southland, (Table 8.5) also had the highest increases in stocking rate. The rapid increases between 1950 and 1969 in grassland topdressing were matched by greater increases in stocking rates. Cant and Johnston (1973, Fig. 1) observed the latter aspect but not the former factor involved.
The extension of topdressing capacity brought by agricultural aviation is surely involved in this process but the refinement and further

TABLE 8.8

ANALYSIS OF VARIANCE RESULTS

Source of Variation	*Sums of Squares*[a]	*Degrees of Freedom*	*F* F^2
Soil-Amending Treatment	893.045.446	2	$10.00 > F^{2}_{726}(.95) = 3.00$
Land District	18,273.353	11	$0.04 < F^{11}_{726}(.95) = 1.79$
Year	4,601,592.674	33	$3.14 > F^{33}_{726}(.95) = 1.41$
Treatment/Land District	48,222.794	22	$0.05 < F^{22}_{726}(.95) = 1.54$
Treatment/Year	463,149.777	66	$0.16 < F^{66}_{726}(.95) = 1.31$
Land District/ Year	10,894,819.883	363	$0.68 < F^{363}_{726}(.95) = 1.00$
Treatment/Land District/Year[b]	32,229,529.134	726	
Total	49,148,633,060.380	1,223	

Notes: *a* all times 10^3

b used as error factor

TABLE 8.9

LAND DISTRICT STOCKING RATE PER AREA OF SOWN GRASSLAND[a]

Land District	*Year Ending 31 January*				
	1930-31	*1940-41*	*1950-51*	*1960-61*	*1969-70*
North Auckland	2.7	2.9	3.2	3.9	4.9
South Auckland	3.0	3.7	4.1	4.9	6.1
Gisborne	2.6	2.7	2.7	3.1	3.9
Hawke's Bay	3	3.3	3.6	4.6	5.4
Taranaki	2.7	3.2	3.6	4.6	5.8
Wellington	2.9	3.1	3.2	4.1	4.9
Marlborough	2.4	2.3	2.5	3.0	3.4
Nelson	4.6	4.7	4.6	5.8	6.4
Westland	2.1	2.3	2.4	3.2	4.1
Canterbury	3.1	3	3	4.2	5
Otago	3.9	3.4	3.4	4.6	4.8
Southland	3.1	3.1	3.6	4.9	6
New Zealand	3	3.2	3.4	4.3	5.3

	Change	
	1930-50	*1950-69*
North Auckland	+ 0.5	+ 1.7
South Auckland	+ 1.1	+ 2.0
Gisborne	+ 0.1	+ 1.2
Hawke's Bay	+ 0.6	+ 1.8
Taranaki	+ 0.9	+ 2.2
Wellington	+ 0.3	+ 1.7
Marlborough	+ 0.1	+ 0.9
Nelson	—	+ 1.8
Westland	+ 0.3	+ 1.7
Canterbury	- 0.1	+ 1.2
Otago	- 0.5	+ 1.4
Southland	+ 0.5	+ 2.4
New Zealand	+ 0.4	+ 1.8

Note: *a* Measured in livestock units per acre.

Source: Calculated from data in Tables 8.2 and 8.4.

intensification of soil amending is evident in the increases stocking recorded in Taranaki and South Auckland even though the increase in topdressed acreage was lower there. Several concurrent trends were operative, hence discriminating between the factors having an effect is critical in deciding on government policy matters seen as integral in the productive environment. The 'arbitrary slice of reality' taken may not correspond to an actual boundary defining the process under consideration (Georgescu-Roegen, 1969, 505-506). In helping to define that boundary, geography contributes to understanding process, and relates it to distributions in space.

GEOGRAPHERS' VIEWS OF GRASSLAND TECHNOLOGY IN NEW ZEALAND AGRICULTURE[3]

The question raised the extent to which geographers, in studying agriculture in New Zealand, have observed the processes operating in agricultural development. Have omissions occurred which make the outlines given in the preceding pages of use in identifying further areas of study? This dissertation's emphasis on establishing a basis for discussing agricultural geography in terms of the technology employed means that its contribution depends upon geographers' willingness to re-examine identified spatial pattern and organization using a technological criterion. Furthermore, the appearance of continuity of pattern has indicated the need to assure that adequate studies of long-run development are carried out and so provide a sound basis for comprehending current spatial distributions. The effect of the structures in the production environment can be gauged and the operation and significance of change understood.

Farming Systems

This is not to say that the technological factor has been ignored in the operation of grassland farming in New Zealand. The nature of the farming system has elicited comment on the way man controlled and developed it using mechanical and biological means. The replacement of crops by pasture has been regarded for some time by geographers[4] as one of the most noteworthy characteristics. The prevalence of this pattern has meant its acceptance as part of the production environment in later, more detailed analyses of variations in the use of grassland.[5] Also included has been reference to the concentration on livestock production of just a few types.[6] The aggregate pattern created over time is obvious. What is not always so obvious is the process by which that pattern emerged. Commenting on the structural changes implicated is a necessary explanatory feature. The role of soil-amending technology would then have been isolated earlier and its study pursued beyond the observation that it was present in the grassland farming system. Seeing the themes geographers have isolated in New Zealand's agricultural development provides some insight into that development and the structures seen as operative.

Learning and Innovation

Learning has been one process followed. Pioneering a new physical environment is a situation where this process is particularly powerful. Clark (1945; 1949) pointed to the blending of British and Australian experience in the early agricultural systems in New Zealand. The part of preference and economic structures in the creation of commercial farming is demonstrated for both extensive wool production[7] and the mixed, semi-subsistence farming.[8] These studies have pointed to the link to urban markets but the importance of that relationship as a change agent in New Zealand agriculture (Taylor, 1977) is less apparent. The concern of the studies lay with the identification of two institutional structures in pioneer farming sharing common characteristics of private control and commercial orientation.

Learning in a new production environment, a situation frequently created by change in technology, has been followed too. Writers observed that experimentation emerged early in both farming systems in the quest for viable commercial output. The farm enterprises which predominated following substantial change in the production environment wrought by refrigeration and had been tried prior to that change (Clark, 1945, 229). The changing cultural environment of Britain may well have contributed to the facility with which new practices were adopted (Watters, 1965, 190) but British agricultural practice was quickly tempered by New Zealand experience as physical and production environment differences were recognized. This perception brought about a substantial reappraisal of the land resource and the techniques suited to production in New Zealand.

Geographers have been aware of this human factor in the formulation of agricultural systems. Cumberland (1961) signalled the extent to which human control was responsible for the soil fertility cycle--

the basis of grassland farming. However, the recognition of grass as a crop by farmers, a principal breakthrough in the evolution of New Zealand farming, has been noted but once when Cumberland (1948, 46) observed that 'expert and original skills in pasture management' had been developed. The importance of management practices has been noted in geographic literature[9] but only in the studies of Harré (1969), Keys (1969), and Watson and Cant (1973) have the implications of management as a parameter in the choice of farming systems been fully recognized. Evaluating national patterns of land use with this factor has yet to occur. Mapping farm productivity patterns (Wolpert, 1964, is an example) remains as a challenge to agricultural geographers. The results would be of great value in establishing areas where production could be improved for the least cost should market demand require it. Maintaining output levels while diversifying land use is the alternative which would benefit from the results of such an appraisal of the current views of farmers on the resource potential of their holdings. A study of resource appraisal and changes which have occurred in the economic environment becomes a desirable contribution to an understanding of agriculture's spatial distribution and the possibility of modifying it.

The ability to more readily trace certain innovations in the production environment has led interest there. In general terms, Watters (1965, 189) has pointed to the 'rapidity and thoroughness which the processes of change have worked in New Zealand'. Here was an indication of the conjunction of a faith in science and technology brought by European immigrants and the economic motivations of the capitalist system (Watters, 1965, 190). Innovation in transport rather than innovation on the farm has been the principal focus in that it brought the intensive livestock enterprises to the fore. The significance of refrigerated marine transport innovation has been commented on frequently.[10] Milk collection by tanker trucks has been accorded a similar, though lesser, importance in its effects on dairying.[11] Location in relation to markets and the variation in infrastructure development have attracted geographers to this aspect of technology in particular. Certainly it is relevant to the production environment of farming as structural and enterprise have been induced by the adjustment changes of relative location through technological change in transport.

This relevance has been observed by agricultural geographers in the changes of farm enterprises,[12] the structure of farming[13] and the related processing industries.[14] The interrelation through spatial structure has been so traced. A bias towards dairying is evident in that change in the processing of sheep products has not been as marked. This situation, noted by Buchanan (1935, 37) over forty years ago, persists. The complex technological environment of dairying has appeared as a key factor in encouraging technological change in New Zealand agriculture. Nonetheless, other changes have not been accorded a similar importance despite their important effects on production. Fertilizer use and its method of application is but one example. Isolating other technological components and evaluating their effect on the distribution of farming systems remains as an open area for geographic investigation.

The Importance of Labour-saving Technology

The structural manifestations of changes in transport technology have been rightly associated with the particular type of technological change prevalent in New Zealand agriculture. In encouraging the output of high-value, low-weight livestock products, the new transport methods enabled the smaller, family-owned farms to become fully viable. The extensive grazing and extensive cereal operations ceded to that, originally less important, structure (Lewthwaite, 1964,61).

More intensive land utilization in the small-farm structure was constrained by a limited labour supply. Family labour was pressed to cope with the needs of intensive livestock production when hand-feeding and cropping were necessary (Hargreaves, 1965, 124). In dairying the need was particularly acute and innovation there was most pronounced (Lewthwaite, 1964). The small population meant labour costs tended to be high and the move to the land following the introduction of refrigerated shipping and the encouragement of closer settlement accentuated this difficulty. Although capital too was dear, its relative cost was less than that of labour (Buchanan, 1935, 3), so labour-saving technology entered farming rapidly. This concern was first evident in shepherding, which changed because of labour shortages (Grigg, 1974, 254). The capital substitution for labour has been a continuing trend as alternative employment in other economic sectors developed.[15] The high per capita productivity of New Zealand's agriculture rests on this substitution, geographers have often commented.[16]

A Pattern of Technological Change

The pattern created by this substitution has been less well followed, as only in Grigg (1974, 284) is the path of technological advance outlined by Parker (1972) related to changes in agriculture. The case of New Zealand is shown in this dissertation to represent a variation, in that a specialization in biological and biochemical processes related to agricultural production emerged early, was pursued scientifically as part of the rapid agricultural development, and was enhanced by the emergence of intensive livestock production. The full use of the advances made was somewhat checked without matching progress in mechanical invention and in the application of power to farming. The different phases have been described in the cited geographical studies but they have not been traced as a pattern demonstrating the full extent of the reciprocal effects between farming systems and technology. The possibility of overcapitalization by this process has only rarely been mentioned (Sears, 1962a,70) just as the problems of undercapitalization (Brockie, 1958, 17; Cumberland, 1968, 12) and the squeeze induced by the increased application of technology to boost production in the face of falling prices (Cumberland, 1968, 8; Nason, 1975, 25) have only occasionally entered as areas of concern to geographers identifying sources of change in agricultural systems. Fielding (1963) for example, viewed the change from dairying to sheep as a means of keeping labour input down. Watson and Cant (1973) provide a study of management-related considerations amongst Waikato dairy farmers and their relation to change but further empirical examination is required to furnish a broader view of the responses farmers are making to changing economic conditions and the ensuing adjustment in agricultural systems.

Mechanical invention other than in transportation has been widely appreciated as the means of boosting productivity over the range of farm enterprises in New Zealand[17] though the term mechanization has tended to mask the increased application of power through the replacement of draught animals. A geographic examination of the adoption of tractors is lacking for example despite their importance to the expansion of feed conservation by saving labour input. Only Johnston (1965, 159) and Lewthwaite (1964, 80) have mentioned their importance, and the effect of crawler tractors in particular in overcoming the restriction of slopes on cultivation is noted in the former study alone. Brockie (1956a, 1956b, 1958) and Murray (1967) record the extended use of mechanical power in agricultural aviation though the equally important part played by ground-spreading vehicles has yet to be studied. Their relative importance in providing the basis on which current agricultural systems operate cannot be fully evaluated, so making policy decisions concerning either or both less reliable.

The great impact of biological invention has received even less recognition. Animal breeding has earned frequent mention;[18] but plant breeding has remained more in the background despite New Zealand's achievements in this scientific field. Cumberland (1948, 50) was one of the first geographers to point to the importance of this development in agriculture but later reference to it is scanty (for example, Johnston, 1965; Rutherford, *et al.*, 1966; Moran, 1974). Though reminded of this by grassland scientists (Sears, 1962a, 1962b; Levy, 1955, 1970) only Sears (1945) has attempted to trace the use of improved grass and clover strains and the various refinements of the perennial ryegrass and white clover pasture. Sears' (1944) study of cocksfoot grass has remained unique in New Zealand geographic literature. Following the diffusion of certified plant strains has not been attempted as Griliches (1957) did in the case of hybrid corn in the United States. Uncovering the spatial distribution would reveal much about the distribution mechanisms of innovations in the agricultural sector and the relative importance of governmental agencies and tertiary sector firms such as stock and station agents. The spatial pattern of farm management practices in relation to climate and stocking are not known, although it is recognized that balancing stock requirements and pasture growth is the basis of farm productivity.[19] The varying approaches to the problem have been used as a regional differentiation factor,[20] yet a full geographic survey of grassland farming methods remains to be done. Given the range of possible management approaches available, finding regional patterns could well be difficult. Daly (1973) and Sears (1962a) more as grassland scientists than as geographers have commented on the uniformity of the grassland farming system. The thrust of this grassland technology is the reduction of limiting physical factors: insufficiently endowed soils by the addition of nutrients and acidity regulation, relief by bulldozing and aerial application, incorrect vegetation by sowing productive grasses and clovers, and climate by the compensatory use of plants, stocking, and irrigation (Rickard and Fitzgerald, 1971).

Have these trends countered or followed the concept of O.E. Baker (1921, 23) of increasingly recognizing and responding to subtle variations in the physical environment to gain economic advantages? Franklin (1967, 9), Moran (1974, 147), and Nason (1975, 25), have suggested that this is the case but it has yet to be fully tested. Identifying resource deficiencies has definitely been a trend in New Zealand agricultural science but the extent to which the inevitable geographic variations are exploited is not clear. Cumberland (1948, 46) held that farming was not finely adjusted to the natural environment. Moran (1974, 124) states that adjustment has occurred over time as anticipated from the continued specialization in a limited number of farm enterprises and the possibility of making improvements through production experience which Johnston (1965, 160) observed. The effect of changes in resource appraisal on the distribution of farming systems is, accordingly, not well developed. A measure of the present state of environmental adjustment and the factors involved would provide important insights into the occurrence of change in current agricultural systems and methods of directing it, and the spatial dimensions of such change.

The central position of soil amending within the technological environment of New Zealand farming has seldom been noted in the geographic literature. The mapping of aerial topdressing activity in 1956 by Brockie (1958) has not been repeated, although Moran (1974, Fig. 28c) presented the percentage of area topdressed aerially as percentage of the total area topdressed for 1969-70. The first map of fertilizer application rates only appeared in 1974 (Moran, 1974, Fig. 28D) and was later presented in Anderson (1977, 79). Technological changes have been examined though usually without relating them to the operation of the pasture ecosystem and its dependence upon amending soil to stimulate clover and grass growth. Buchanan (1935, 39, 32) recorded that topdressing accentuated the dominance of grassland and related its development to the rise of dairying. Cumberland (1948, 50, 53-54) repeated these observations. The problem of relief as a limitation to the extension of the practice has also been made (Cumberland, 1948, 56; Hamilton, 1947, 162). The farm-enterprise specialization based on relief which Buchanan (1935, 32) presented was enhanced by this discussion. The need for high actual or easily induced soil fertility for dairying (Buchanan, 1935, 32) was overcome by the application of amendments using equipment suited to the low relief situation also favoured by dairying.

The extension of the area topdressed depended upon overcoming relief and it was the aircraft which proved to be that means as Brockie (1958) demonstrated in relating the extent of topdressing and landform. As aerial application was also a labour-saving practice, aircraft use was extended to easier country too (Brockie, 1956b, 108; 1958, 13), though advances in ground-spreading equipment reduced the advantage gained (Lewthwaite, 1964, 81). Dairying did not relinquish its predominant involvement with soil amending but proceeded to make more intensive use of it.[21]

The effects in increased output, while not solely a consequence of soil amending as Brockie noted (1958, 18), were induced through the associated innovations involved in better managing the higher yielding pastures soil amending made possible.[22] Agricultural aviation itself was diversified from its initial topdressing role[23] to meet these other management demands.

Spatial variation in aerial activity and soil amending have not been studied by geographers apart from Murray and Brockie. Agricultural geographers have regarded them as part of the production environment but not a deciding factor in explaining the distribution of various agricultural systems despite their influence in changing pasture production resources (for example, Cumberland and Fox, 1962; Symons, 1972; Grigg, 1974; Moran, 1974). This may argue for the uniformity of the availability of these techniques but could also simply represent an absence of investigation.

The Importance of Institutional Structure

The absence of a link between the use of soil-amending technology and the structure of farming is significant. The features of the small-family-farm structure and the difficulties created by it have been outlined: the absence of economies of scale,[24] the difficulties imposed by a limited labour supply,[25] the tendency to become inflexible in management habit,[26] and limited attractiveness to capital investment.[27] The benefits of this structure have also been observed: the viability of the structure not necessitating radical social or economic change to develop;[28] technological innovation;[29] institutional innovation in the form of co-operatives, factory production and marketing agencies,[30] and increased intensity of operations.[31] Concern with management of pasture and stock developed to an extent not apparent in the extensive grazing and grain-cropping enterprises. The intensification of production brought about by this structure also promoted the recognition of the need to remedy production-limiting soil deficiencies. Pressure on the soil resource initiated the search for remedies, which British-based soil-amending practices furnished. The growth of the livestock market there brought the conjunction of the economically desired and scientifically possible circumstances which stimulated technological development and change in livestock farming in New Zealand. The resultant grassland technology reinforced the emerging farming structure and enabled it to survive through periods of further economic and technological change. Smit (1973; 1975a; 1975b) is the sole geographic source found referring to the stresses experienced in recent times by this structure although Johnston (1962, 221) indicated the need for more land shown in the fragmentation of holdings in Canterbury. Both studies involved limited areas and so a national survey is required to explore the variation present and the explanatory function of farm enterprise type. Shifts in enterprise type to preserve the structure could then be planned or countermeasures taken should the policy decision to permit a change of structure be made.

The Research Factor

Research in New Zealand provided the means of expanding knowledge of the operation of the grassland ecosystem and harnessing it to the needs of small farmers unable to undertake their own experimentation. The essential contribution of research is little reflected in geographic writing, Taylor (1977) being an example of what can be achieved. Of the literature noted, only four articles have referred to the importance of research institutions.[32] Their part in developing and transmitting inventions clearly merits greater recognition since it helps to define the way resources have come to be used in farming. As innovativeness is an explanatory factor in optimum farm development (Fielding, 1965a, 119; Watson and Cant, 1973), then the extent to which it has been encouraged by research and development organizations is important in outlining the adoption of new technology. Innovation diffusion from these centres has remained unexamined though Taylor (1977) has pointed to its likely occurrence. Keys (1969) and Harré (1969) both point to the need to determine the network whereby new technology is spread as a feature in understanding change in agricultural systems. The part played by public and private agencies thus remains largely speculative in geographic literature. Taylor (1977) has recently provided some insight into spatial patterns of invention in New Zealand. Reference to the role of stock and station firms is notably absent despite their close contact with farmers and capacity to sponsor innovation through management advice and capital supply.

Governmental Influence

The research establishment erected was the outcome of small farm social policy implemented by government. Supporting that policy remained a function of state activity expressed in land development, returned-servicemen settlement, agricultural education, and advisory services (Cumberland, 1968, 8). Directly and indirectly the participation of government has affected the character of agriculture (Fielding, 1965b, 87-88; Taylor, 1977, 339). As its role in economic management expanded, the extent of its impact grew (Cumberland, 1944, 217; Cumberland, 1968, 9, 13). From quality control, research and instruction, and marketing, government activity has come to include the directing of economic development with implementing a policy of industrialization from the late 1930s. The pervasiveness of this influence suggests that the study of agricultural systems must include reference to government policy as recommended by Fielding (1965a, 119). Changes in it would be part of the farmers' production environment providing both incentives and obstacles in channelling resources through the economic sectors (Sears, 1963).

The commercial orientation of New Zealand farming makes concern with economic policy and trade critical. Market security has been an objective of trade policy but maintaining access to the traditional British market (Rutherford, *et al.*, 1966, 130) has become more difficult at its stability and capacity to absorb more livestock products waned (Cumberland, 1968, 10). Indeed, market saturation appeared in the 1960s (Fielding, 1963, 160), so making access for a limited range of produce increasingly difficult (Symons, 1972, 76). The gradually proceeding attempt to diversify markets met with some success (Franklin, 1967, 10) but the British linkage remained prevalent. The approach of Britain to the Common Market traced by Lewthwaite (1971) shows how this uncertainty continued to build. It appears as a critical factor in the governmental push to industrialization of the late 1950s (Franklin, 1967, 10) yet farmers' reactions to this uncertainty in changing enterprises or output have not been traced by geographers examining production adjustments. For example, Moran (1974) notes such changes but not underlying reasons for them. The success of government negotiation for market access must also be seen as another factor in production decisions reflected in the spatial distribution of agricultural activities.

Agricultural Sector Primacy

The concern with trade is a measure of agriculture's continued commercial orientation and of its primacy in the New Zealand economy. The importance of agriculture in the early phases of economic development has been accepted but its continued importance in a country viewed as developed is seen as noteworthy (Rutherford *et al.*, 1966, 16). Resolving the problem of resource allocation between the existing agricultural sector and the emerging industrial sector has earned comment from agricultural geographers. The limited moves to industrialization in the late 1930s were viewed as impinging on the availability of labour and capital in agriculture (Cumberland, 1948, 53). This single observation was amplified with the emergence of a broader industrialization policy by 1960. Writers with an agricultural orientation tended to view the process unfavourably although it has been recognized that it is urban interest which has penetrated agriculture in the drive to improve production and efficiency in the primary sector (Taylor, 1977, 339). Indeed, there is a view that urban-based industry must be directed to contribute inputs to agriculture (Georgescu-Roegen, 1969, 525-526). The industrial development of the early 1960s diverted investment away from agriculture and hindered progress in that sector (King, 1965, 19). With the expansion of industry in cities, social and urban investment also increased (Sears, 1962a,65) as did the investment in services (Watters, 1965, 199), to the apparent detriment of agriculture. It was not anticipated that industries erected for import substitution would be able to develop the same export potential agricultural produce had (Fielding, 1963, 168). The higher cost of domestically produced manufactures was criticized as a contributing factor to the cost-price squeeze experienced by farmers (Fielding, 1963, 168). Manufacturing, in being dependent upon agricultural export earnings to finance its production inputs (Johnston, 1965, 160-161), represented a serious misallocation of national resources by the later 1960s (Franklin, 1967, 10; Cumberland, 1968, 8, 13) because agriculture became increasingly subject to the forces of industrialization and urbanization (Watters, 1965, 193). The use of science and technology to maintain agricultural productivity kept that sector competitive economically, while linking it with the manufacture of the chemicals and machinery which were of increasing importance in production.

Identifying these linkages and the structures which can best exploit them are a contribution agricultural and economic geographers can make as they investigate the spatial structure of the agricultural sector and the decision-making processes and institutional structure involved therein. LeHeron and Warr (1976) have pointed to the importance of exploring these connections in relation to horticultural production in New Zealand, and the extension of the approach to other enterprises would furnish important economic planning insights at a time when new directions are being sought.

The need to maintain agriculture's productivity arose from the paradoxical problem that the investment in domestic manufacturing heightened the need for imports of plant, equipment, raw materials, and fuel (Heenan and Trlin, 1974, 113). As its output was not readily exported to earn the returns required to sustain these imports, agricultural exports were of increasing importance, so leaving New Zealand as a high per capita income country dependent on agriculture (King, 1965, 18; Franklin, 1967, 9), one increasingly, not decreasingly, reliant upon external markets and so more subject to instability in their demands and prices (Heenan and Trlin, 1974, 113). The attempt to generate unbalanced growth has proven less successful as the linkage effects noted by Myint (1960) have not been effectively exploited (Franklin, 1967, 8) because of the relative isolation of agriculture from the development process. The view of Sears (1962a), King (1965), Johnston (1965) and Cumberland (1968) that New Zealand's future depended upon promoting agriculture, and its allied processing and servicing industries is borne out.

Diplomatic efforts to retain and open access to markets for traditional agricultural exports can be seen as a necessary thrust which must be bolstered by turning to alternative farm enterprises such as horticulture (Cumberland, 1968, 13; Moran, 1974, 147), which also provide high-value, low-volume produce. In view of the reliance of current farming practice on imported phosphates which are rising in price as Pacific Ocean sources are depleted, finding alternative enterprises becomes even more important. Acquiring the necessary production and processing expertise along with the industrial structure to exploit favourable markets should become the basis for economic resource-allocation decisions. Developing markets for the equipment developed to keep agricultural production costs low would provide an outlet for the manufacturing potential created. Research into processing could similarly provide techniques which are just as saleable in earning royalty payments. The benefits of agricultural specialization could be transmitted to linked industries to reduce competition for resources and employ labour no longer required in agriculture (Franklin, 1967, 2). Manufacturing need not be divorced from agriculture given the increased need for secondary sector inputs in the latter sector to replace labour and the possibility of establishing industries using local agricultural inputs to supply world markets. Reviewing economic policies inhibiting investment in either development becomes a priority. Controlling transport cost, a major component in export costs, must be closely examined, along with marketing arrangements by which sources of investment capital and expertise may be tapped.

Adjustment must be made in the existing, specialized program devoted to production research; yet such adjustment is dependent upon having sufficient forward planning to allot scarce research resources, notably of personnel, to new fields of endeavour. If the move to more horticultural production continues as suggested (Cumberland, 1968; Moran, 1974), new expertise has to be developed rapidly using the existing base to meet the new challenges offered. Knowledge of the effectiveness of the systems of innovation diffusion would indicate means to disseminate information, techniques, and equipment. The technology needed must be advanced to offset the continuing shortage of agricultural manpower particularly the seasonal type (Lloyd, 1974, 83) associated with horticultural production. The cost of acquiring the necessary machinery must be offset by considerable export potential to make the shift worthwhile. Developing processing potential appears as a solution which incorporates agricultural production advantages with the need to employ urban labour and develop indigenous manufacturing to meet world demand (Cumberland, 1968, 14). Identifying and stimulating demand is the crucial role of marketing. A research aspect largely neglected during the period of British market predominance, it must now assume more importance relative to production research. The transmission of market-demand information to producers is a process in which geographers can make a contribution. Outlining contact systems and their relationship to the spatial distribution of farming systems is a necessary component of planning change and understanding the rate at which change can be effected.

The study of technological change can pinpoint the set of circumstances wherein progress was made. By understanding the characteristics of the technical and institutional structures, it becomes possible to identify opportunities to introduce technological advances through the most appropriate farm enterprises. A powerful tool for effecting economic development becomes possible in stimulating growth in the agricultural sector. Building linkages with processing industries and production-equipment manufacturers imparts this dynamism to other sectors and establishes the possibility of initiating economic development. New Zealand has experienced agricultural growth through the processing linkage with meat and dairy exports but has yet to branch to a greater extent into enterprises requiring a more substantial manufacturing input. Turning to types of manufacturing unrelated to domestic raw materials and output before that step is taken can be seen as a misallocation of resources. Examining other countries' experience gives New Zealand decision-makers the opportunity to evaluate the possible outcome of investment decisions and governmental resource-allocation policy just as New Zealand's experience is of value elsewhere. Though its economy has been considered colonial in being dependent upon a single market for primary produce, New Zealand is an independent state which enjoys a high per capita income and is viewed as developed on the world scale (Rutherford *et al.*, 1966, 11).

Accordingly, its economic development provides some information to less-developed former colonies. Though the historical circumstances may not be repeated, identifying components of the development process does provide insight into the planning required to improve the income position of similarly dependent economies which share New Zealand's scale limitation difficulties. Insofar as geographers relate spatial analysis to structures within the economy and to the technological environment they can contribute to such national economic planning.

CONCLUDING REMARKS

This concluding chapter has concentrated on a review of change effects seen in New Zealand's agricultural development and the problems and possibilities offered by change to the geography of man-land relationships in the context of areal studies and spatial organization. The operation of the structures in the production environment have an important influence on the constraints offered in the physical environment where agriculture is concerned. Man's appraisal of the environmental resources is conditioned by the interaction of preference economic, institutional, and technical structures. Learning, through the application of those structural influences in production, can produce new appraisals and generate demands for adjustment in the production environment structures. A view over time of the sequence of spatial patterns present must incorporate the notion that there are changes going on in the structures producing the patterns observed. As Chamberlain (1968, 6) noted, the present is indeed a combination of past experience and future expectations. The change can be derived both from within the area concerned, as learning occurs within that restricted environment, as well as from without. The model of farming devised by Olmstead (1970) serves as a useful guide to the possibilities present in determining the sources of change and the role of the production environment structures.

It has been observed in this dissertation that science and technology have been important in contributing to the technical structure and so enabling producers to enjoy the lifting of particular constraints by the application of new techniques and equipment. Identifying the constraints removed, those still operative, and their relative importance is a means to predict future trends in and possible spatial outcomes for the types of production most influenced. The introduction of refrigeration brought change to these structures. The reappraisal of the production environment brought intensive livestock production based upon grassland to the fore. Within that environment dairying displaced sheep production, and lamb and mutton production displaced extensive wool and grain production. Here was a spatial component to economic structure change. It was accompanied by spatial change in both institutional and preference structure and the technical structure which was directed to support it. Evidently, a measure of an innovation's importance is the number of structures disturbed by the change accompanying it. The extent of change within those structures remains a subjective measure but the occurrence itself of change is evidence of some impact which can be employed as a measure of innovation importance.

The pattern of change in New Zealand agriculture appeared as one of following a pioneering pattern. The wide dispersal of a number of farm enterprises followed change. With learning came a greater concentration as production environment advantages were identified and acted upon in accord with the concept of O.E. Baker (1921). In agriculture's case this environment also included the constraints of the physical environment. Subsequent innovations produced a similar effect insofar as they reduced constraints and created an altered production environment harbouring unknown advantages and disadvantages. However, a gradually decreasing innovation impact appeared as structures other than the technical structure stabilized with export market stability. The technical structure was seen to have focused on improving the performance of the production systems within the other existing structures. Pasture topdressing and other forms of soil amending produced change within the framework of those structures and created change spatially as various constraints with their own spatial distributions were lifted; yet, on aggregate, the outcome was general stability. With the aerial topdressing innovation fewer farming systems were involved and the outcome was a transfer of aspects of more intensive livestock farming systems to less extensive systems--a blurring of difference rather than a major change to either system.

In such a situation technology is transferred between farming systems, through successful adoption and adaption. This opens up the prospect of further change to both the recipient and donor systems as similarities developed allow reciprocal transfer to become possible.

The transfer of pasture topdressing in the 1930s to sheep farming through the economic structure which suggested the adoption of dairying to offset decreased returns from wool and meat is an illustration of such a process. The difference between dairy cow and breeding ewe demands led to concern with grassland farming techniques, including pasture topdressing, in which lamb-rearing farming systems had previously shown less interest. Subsequent economic structure changes led to increased specialization which again separated the two enterprises but the technical structures had been modified through contact and imitation.

Effecting such transfer could be a policy decision by government. Understanding the contact systems present and the structures operative in the farming system become important considerations in which geographic knowledge of spatial organization must play a significant role. Area studies can provide detailed accounts of the operation of structures within a specific production environment while studies of spatial organization outline the processes whereby the operation of the structures is transmitted to producers and translated into location decisions. In so identifying spatial patterns, the real significance of the boundaries, often implicitly defined in proposed governmental measures, becomes apparent and the possible results of those measures predicted. Where government involvement in the economy is as important as in New Zealand there must surely be an interest in ensuring that planning measures do take account of the spatial realities which are the geographer's central concern.

FOOTNOTES

1. Spatial process comprises 'mechanisms which produce the spatial structures of distributions'. Spatial structure is the 'internal relative location', that is, 'the location of each element in a spatial distribution to each of the others, and the location of each element relative to all the others taken together'. (Abler, *et al.*, 1971, 60).

2. The calculation was performed using the IBM System/360 scientific subroutine package, version III, analysis of variance program (IBM, 1970, 422-425). The assumption made was that the use of fertilizer was a decision made independently of past use. This is possible since farmers are not required to carry stocks of soil amendments from year to year, and so are not bound to employ them. Autocorrelation is so removed as a consideration. The error factor is derived by using the interaction of the soil-amending method, year, and land district variables and assuming that they acted independently (a supposition borne out by the absence of significant interaction between any two of them).

3. The literature reviewed here comprises not only that used in the dissertation itself but also articles in geographical publications and books on New Zealand's agricultural geography, that were not of direct relevance. Dissertations have been cited only where they deal with a topic not mentioned elsewhere. Where a substantial number of references are cited on a particular point they are included in the footnotes to avoid cluttering the text; otherwise the references accompany the point made.

4. Duckham, 1932, 107-109; Buchanan, 1935, 41; Hamilton, 1947, 149; Cumberland, 1948, 46; Curry, 1962, 174; Sears, 1962a, 67; Fielding, 1963, 163; Lewthwaite, 1964, 68-69; Fielding, 1965b, 89; Johnston, 1965, 156; Rutherford, *et al.*, 1966, 137; Cumberland, 1968, 8; Symons, 1972, 123; Laut, 1973, 395; Grigg, 1974, 189, 201; Moran, 1974, 125; Anderson, 1977, 78.

5. Cumberland, 1944; Cumberland and Fox, 1962; McArthur and Sanderson, 1968; Critchfield, 1969; Nason, 1975.

6. The references in Footnote 2 mention this pattern.

7. Condliffe, 1933a; Cumberland and Hargreaves, 1955; Hill, 1962; Watters, 1965.

8. Hargreaves, 1960, 1963, 1965; Johnston, 1961; Lewthwaite, 1964, 61.

9. Buchanan, 1935, 54; Hamilton, 1947, 149; Cumberland and Fox, 1962; McCaskill, 1966, 284; McArthur and Sanderson, 1968, 49; Harré, 1969; Keys, 1969; Dobson, 1972, 3-4; Watson and Cant, 1973; Lewthwaite, 1964, 68-70; Moran, 1974, 146.

10. Buchanan, 1935, 37; Cumberland, 1948, 50; Lewthwaite, 1964, 63; Hargreaves, 1965, 127; Johnston, 1965, 156; Rutherford *et al.*, 1966, 139, 142; Cumberland, 1968, 8; Symons, 1972, 72-73; Hearn and Hargreaves, 1974, 80; Moran, 1972, 124.

11. McArthur and Sanderson, 1968, 49; Bewley, 1970, 41; Rowlands, 1971, 163; Dobson, 1972, 3; Laut, 1973, 353; Grigg, 1974, 195; Nason, 1975, 65.

12. Buchanan, 1935, 37; Cumberland, 1948, 50, 53; Hargreaves, 1965, 128; Rutherford *et al.*, 1966, 139, 142; McArthur and Sanderson, 1968, 49; Rowlands, 1971, 160-161; Symons, 1972, 124; Grigg, 1974, 199.

13. Buchanan, 1935, 5; Cumberland, 1948, 50; Johnston, 1962; Rutherford, *et al.*, 1966, 139; Rowlands, 1971, 162; Symons, 1972, 128; Smit, 1973; Smit, 1975a, 1975b.

14. Buchanan, 1935, 62-63; Bewley, 1970; Rowlands, 1971, 158; Laut, 1973, 353.

15. Sears, 1962a,70; Cumberland, 1968, 8, 13; Symons, 1972, 85; Grigg, 1974, 284.

16. Cumberland and Fox, 1962, 47; Johnston, 1965, 159; Symons, 1972, 85; Laut, 1973, 359; Grigg, 1974, 189; Moran, 1974, 124-125.

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24. Sears, 1962a, 70; McArthur and Sanderson, 1968, 55; Laut, 1973, 358.

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28. Fielding, 1965b, 88; Watters, 1965, 204; Franklin, 1969b, 53.

29. Buchanan, 1935, 47-48; Symons, 1972, 125, 137; Nason, 1975, 20.

30. Buchanan, 1935, 62; Hamilton, 1947, 149; Lewthwaite, 1964, 61; Laut, 1973, 352.

31. Symons, 1972, 104-105; Laut, 1973, 358.

32. Cumberland, 1944, 218-219; Sears, 1962a, 70; Cumberland, 1968, 8; Critchfield, 1969, 66.

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The following abbreviations have been used in these bibliographic entries:

CSD Census and Statistics Department
CSO Census and Statistics Office
DS Department of Statistics
GS Government Statistician
R-GO Registrar-General's Office

Agricultural Statistics 1921, 1924-1926, 1929, 1930, 1934: *Statistical report on the agricultural and pastoral production of the Dominion of New Zealand for the season [given].* CSO, Wellington.

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