Thirty years of pasture research which changed Australia

Frank C. Crofts

Formerly University of Sydney Farms, Camden, N.S.W.
Now 10 Taree Avenue, Kelso, N.S.W. 2795.

Introduction

Thank you one and all for the great honour and privilege you have conferred upon me by inviting me to present this review. It carries with it an enormous obligation which I can only attempt to fulfil to the best of my ability. As I have been semi-retired from pasture research for about two years and my active work in pasture agronomy began in 1951 as an honours student under E. J. Breakable, I will be considering mainly the thirty year period 1951 to 1981.

During this period, the works and influence of Colin N. Donald on all pasture research workers in Australia, either directly or indirectly, was so great that it barely needs any special explicit recognition in a review of this kind. Suffice it to say that the first Australian textbook I ever read on pastures, and I consider the first Australian pastures textbook, was "Pastures and Pasture Research" by C. M. Donald, six lectures delivered at the University of Sydney in 1941 during the final months of a two-year tenure of the Pawlett Scholarship of the University of Sydney. I am proud to have a First Edition copy of this publication, given to me by my wife, who was at that time a demonstrator within the Faculty of Agriculture. The 1946 edition of "Pastures and Pasture Research" became the basic textbook for the teaching of Pasture Agronomy at Universities throughout Australia and New Zealand. It was the only textbook on Pastures freely available to students of the late 1940's and 1950's and has formed the framework of many Pasture Agronomy Courses including my own, which were delivered to students over the past thirty years.

Pastures and Pasture Research was a remarkable publication, not only because it was the first well-referenced textbook covering the six main pasture topics of the day and recording all the most significant pasture research done to that time in Australia and the whole English speaking world, but because it also indicated the increases in pasture and animal production that could be achieved if pasture research activities were expanded and their results applied to the whole Australian continent.

Colin Donald's life work in setting the framework for the study of pastures and in pursuing these studies and helping others in their endeavours, over a period of more than forty years, has clearly established him as the father of pasture research in Australia. I am more than proud this day to humbly present this review as one of many who have been greatly influenced by him and have, through his research work and teaching, been inspired to do more and better work in attempting to profitably improve the pasture productivity of the Australian continent.

Manning Clark when questioned on the validity of his history of Australia freely agreed that "All History is written from a personal perspective" and in presenting this review I must make the same confession. My review will be from the perspective of a farmer's son who in the 1930's saw something of what was then called "the magic of superphosphate and sub-clover" on a pasture in the N.S.W. Central Tablelands and then set out, by the best means he knew, to discover more about what was happening and apply this knowledge for the benefit of agriculture. I make no apologies for the fact that, as an agricultural scientist I was always more interested in agriculture than science. An improved, more productive, more profitable agriculture was my consistent aim and science was simply one important tool in achieving it. My interest, and therefore my review will consider research not primarily in terms of its scientific merit but in terms of its effects and possible effects on improving the productivity and profitability of our pasture lands.

Furthermore, because I am interested in research more for the impact that it can make than for its intrinsic scientific value I am also interested in the socio-economic-political climate into which it is projected because this, as much or more than the research itself, will determine what it will do for Australia. If we look back over the past thirty years, it is clear that some kinds of pasture research have had a huge

impact on pasture improvement and pasture improvement practices, while other research, although scientifically sound and useful as an aid to our thinking, has not as yet had much influence on either the area of land which has been pasture improved or the productivity of those areas.

I have selected the areas of pasture research which I believe have had the greatest impact on pasture improvement and pasture productivity. They are:-

- The discovery of the mineral nutrients and water requirements for sowing and maintaining improved pastures in a wide range of environments and particularly the needs for phosphorus, sulphur, calcium, the trace elements and water.
- The realization of the nitrogen requirements of improved pastures and the importance of effectively nodulated legumes and supplementary nitrogen fertilisers.
- The development of machines and methods for the large-scale establishment of pastures in a wide range of soil, climatic and topographical environments.
- The selection and/or breeding of new species or strains of pasture plants which are able to thrive where others fail or do poorly, and
- The development of pasture management strategies for different environments which will increase animal productivity while maintaining or increasing pasture production in the long term.

I would now like you to consider with me, how these five areas of pasture research have, over the past thirty years, changed the face of Australia, and also what their effect might be, along with the new technologies now available and now emerging, on pasture development and production over the next twenty years.

When I look back on the past thirty odd years of pasture research and pasture development in Australia, I am inclined to divide it chronologically into three main eras or phases. I look at the period from World War II to the early 1950's as that of "Setting the Stage", the period from 1951 to 1970 as "The Expansive Years", and the period 1970 to 1983 as "The Years of Trial and Tribulation". I hesitate to select a heading to cover the period from now to the end of this century, but a title that has no chance of being one hundred per cent wrong would be "The Years of Hope and Hopelessness".

In order to gather some credence for the above divisions in what must, of course, in fact be one continuous time movement, I ask you to consider the following graphs and illustrations:-

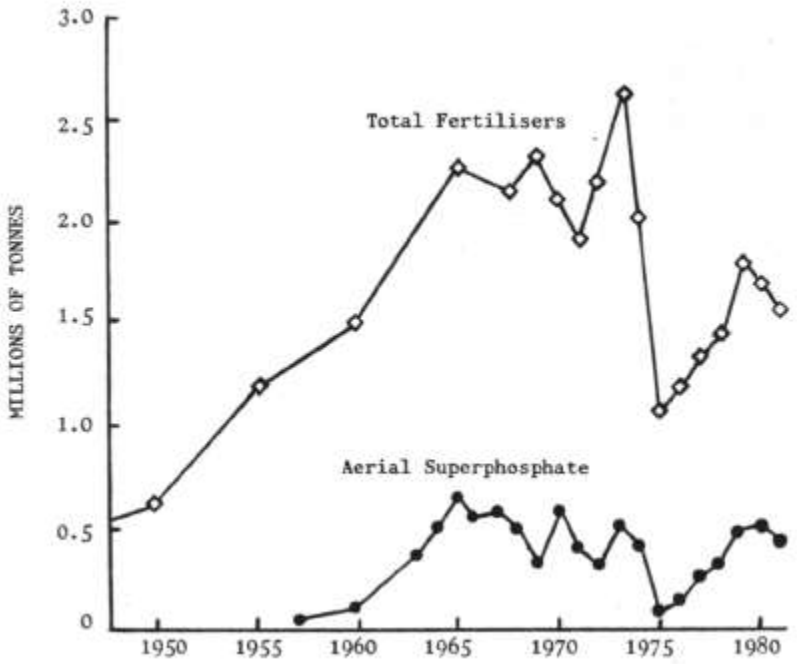

Fig. 1. fertiliser applied to pastures in Australia 1950-1982

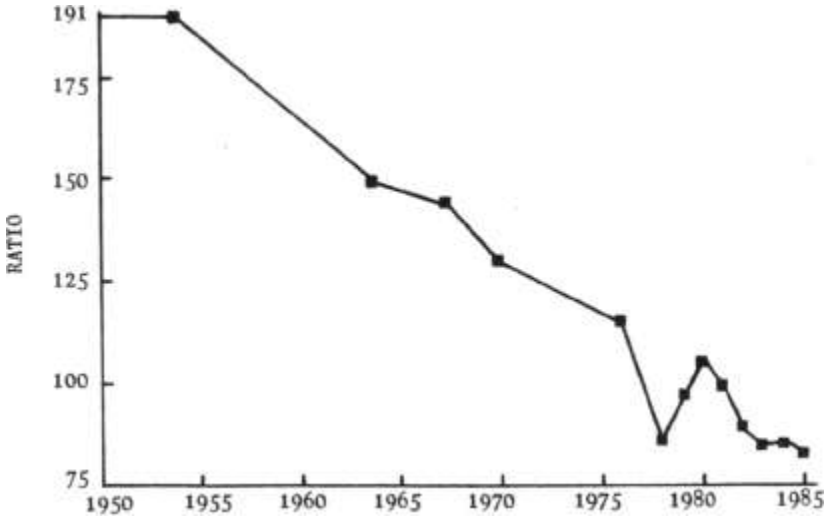

Fig. 2. farmers' terms of trade 1950-1985 ratio of prices received to prices paid [B.A.E. data with 1980-81 = 100]

Setting the stage - 1945 to 1951.

The experiences of World War II convinced most Australians that we must expand the population of Australia (then only seven million) if we were to hold this country and play a worthy role in post-war world reconstruction. The slogans "We must populate or perish" and "Let us help to feed a starving world" were expressed in the thoughts and actions of all politicians and most thinking Australians.

Because of the dominant role that primary industry played in Australia's exports (about 85% of total exports in 1950-53), increased animal and grain production through pasture improvement was seen as the principal means by which export income could be further boosted to provide funds for bringing in more migrants and developing secondary industries to employ them.

The political pressures behind pasture improvement were also enhanced by the perceived need to subdivide large natural pasture land holdings and set up Soldier Settlers on smaller improved pasture or mixed farming properties. These closer settlement schemes in all States established more than 2,000 new holdings and created strong demands for both knowledge and money for pasture improvement.

The literature records that although superphosphate became increasingly important as a fertiliser for crops in the early 1900's and subterranean clover was recognised as a valuable plant at Blakiston by A. W. Howard as early as 1889, the super-sub combination as a means of vastly increasing pasture productivity in many parts of Southern Australia, only became possible from 1923 onwards with the advent of mechanical threshing of sub-clover for seed. This resulted in the production in South Australia of 41 tonnes of seed in 1923/24 which increased to 259 tonnes in 1929/30. Despite this early progress, the depression of the thirties and the war and drought years of the early forties meant that large-scale pasture improvement was deferred until the late 1940's and early 1950's, when the abovementioned sociological and political pressures were combined with record boom prices for wool created by the panic buying of the D.S.A. in response to the expected nuclear future of the Korean War.

In the early 1950's there was a general expectation that pasture improvement could vastly increase the livestock production of Southern Australia. This expectation was justified by the socio-political-economic pressures indicated above plus the many crucial research discoveries that were made in the 1930's and 1940's.

A series of publications in the late 1930's and especially "Natural Pastures - Their Response to Superphosphate" (1) and "The relation of Phosphate to the Development of Seeded Pasture on a Podsolised Sand" (2) left no doubt that, at least in some parts of South Australia, superphosphate and subterranean clover could increase pasture production more than tenfold and livestock production at least threefold. At the same time, and in other Southern States, field trials on the use of superphosphate and subterranean clover were being carried out, often at the instigation of fertiliser companies, by both farmers and Department of Agriculture officers. It is interesting to note that a high proportion of these early field trials were recorded as giving no responses to superphosphate, despite the fact that they were conducted in areas where subsequently large quantities of superphosphate were profitably applied. It probably indicated either that, on the trial areas, factors other than lack of superphosphate were limiting responses, or else that the experimental techniques of the times were inadequate for what seemed a very simple research problem. At all events, it was widely accepted by the late 1940's that superphosphate would at least be one of the critical factors in pasture improvement in Southern Australia, and that to use it efficiently and profitably, a great deal of additional research was required in a wide range of environments.

However, it was well appreciated before 1950 that the mineral elements present in superphosphate were not the only ones limiting pasture production in some areas. In 1938 Riceman, Donald and Piper (3) reported a field response to copper by oats, wheat, lucerne and black medic; in 1942 Anderson (4) reported responses by subterranean clover to molybdenum and in 1945 Riceman (5) reported responses in winter legume growth to zinc. By 1950 it was generally expected that these discoveries would make pasture improvement feasible over huge areas of higher rainfall land in southern and eastern Australia, previously thought to be of low potential productivity.

There was also, by 1950, some appreciation of the fact that legumes, in order to fix nitrogen, required root-nodule bacteria, but there was little knowledge of the species-strain compatibilities of the pasture legumes being used and the rhizobial strains being offered to effectively nodulate them. There was at that time certainly no guarantee that if one inoculated clover seed with a then held laboratory culture, effective nodulation in the field would result.

Similarly, before 1950 there were very few machines designed for specifically seeding pastures because most sowings were done on wheat farms and normal cereal seed combines were adequate. The "Sunprong", manufactured by H. V. MacKay in the 1920's was an attempt to provide a specific pasture seeding implement. It scratched the pasture surface with a series of off-set spikes and allowed seed and fertiliser to be dropped into these shallow crevices, thus improving establishment over simple surface broadcasting. However, it was suitable only for low-density pastures and medium to light soils and it was not widely used.

Although many new species and strains of pasture plants have been registered and added to seeding recommendations since 1950, nearly all the species used today on a wide scale were already defined by 1950. Aitken and Drake (6) had carefully classified all sub-clovers then available, Trumble and Donald (7) had demonstrated the relationship in South Australia between sub-clover strains, growing season and soil type, McMillan (8) had shown how to hybridise sub-clover and Millington (9) had already set up a breeding programme in Western Australia. Other winter annuals such as the medics had also received attention and strains suitable for shorter growing seasons had been selected. Furthermore, pasture species suitable for the higher rainfall areas such as white-clover, the ryegrasses, the cocksfoots and phalaris were available from either imported seed or naturalised ecotypes. A good start had already been made to providing satisfactory species for the whole temperate pasture zone but species knowledge with regard to the tropical and sub-tropical zones was in very short supply.

Before 1950 Pasture Management was not given a high research rating and few specific recommendations were based on Australian research. However, enough research had been done on grazing management to suggest that rotational grazing could not be accepted in many Australian situations as a reliable method for increasing animal production.

The social-economic-political situation after World War II plus the build-up of valuable research findings during and immediately after the war years, together with an appreciation of the huge potential for pasture improvement, set the stage for the "expansive years" ahead.

The expansive years - 1950 to 1970.

So many developments in pasture research and pasture establishment, which were to change the face of Australia, began in the early 1950's that it is difficult to put them into any clear chronological or geographical order. It was as though all the essential factors for development, already present in the pre-1950's picture, suddenly came together, interacted and spawned an era of pasture research and pasture development such that Australia had never seen before and may never see again.

In 1949, while I was a post-war student at Sydney University, Dr. J. Griffith Davies spoke to us about the huge potential for pasture improvement over about one-fifth or 400 million acres (160 million hectares) of the Australian continent and the huge economic benefits which could accrue to Australia by establishing improved pastures on this area as well as in existing wheat growing country. As the 1950's dawned, it appeared to me that all Jack C. Davies' hopes were coming to fruition because the following events happened in rapid succession:-

In the 1950-1953 period farmers received record prices for wool, wheat and butter and high prices were received for cattle. This prosperity can, in some measure, be related to the present 1984/85 picture by the S.A.E. Prices Received to Prices Paid ratios. This figure for the current 1984/85 year is estimated at 80 but for the three years to 1953/54 it was 191. It is clear that farmers and graziers in the early 1950's had a lot of surplus money available to invest in pasture improvement, if they so desired. It was fortunate that the S.A.E. began the collection of its regular Economic Survey data in 1951, so that some comparisons can be made with to-day's picture.

In the same year, 1950/51, the released or escaped myxoma virus had devastated the rabbit population of Southern Australia, thus removing one of the major physical limitations to increased livestock production and pasture improvement.

The higher farm incomes and the low farm interest rates encouraged both existing farmers and graziers as well as financial institutions to invest in pasture improvement. The Australian Nutual Provident Society began its 400,000 acre (162,000 hectare) clearing and pasture seeding operation at Coonalpyn Downs in the Ninety Mile Desert of South Australia with superphosphate and the trace elements Copper, Zinc and Cobalt, and this move encouraged others to invest in pasture improvement throughout Southern Australia.

By 1951 the C.S.I.R.O., State Departments of Agriculture and Universities had developed extensive plans for pasture research. Breakwell had begun his N.S.W. North Coast programme, aimed at putting legumes into paspalum dominant pastures. The C.S.I.R.O. Tablelands programme was being extended to cover

wider areas of the State and the establishment of a Division of Tropical Pastures had been proposed.

Geddes had begun his "water harvesting" research at Badgery's Creek and pasture nutrition and pasture species research was being greatly expanded by all Departments of Agriculture. It was in this atmosphere of optimism and high expectancy the First Australian Agrostology Conference was conducted in the Institute of Anatomy at Canberra between 30th October and 6th November, 1951. It was called by C.S.I.R.O. to bring together the leaders in pasture research from all States to consider past results and formulate future plans. It was not a big event by to-day's standards. The total number of delegates was about 53, but they were people who were to have a large influence on the development of Australia's pasture research over the next thirty years. I will try to recall the names of the participants at this Conference, as shown in the photograph.

Delegates to the first Australian Agrostology Conference
Held in Canberra, October/November 1951

Back Row: Bob Williams, George McIntyre, Don Spencer, Lachie Myers, Chris

Christian, Dr. Phillis, Terry Paltridge, George Robertson, Ron Prunster, Alf Anderson, Ted Moore, Wilf Bryan.

Second.Row: Andrew Steinbergs, Newton Tiver, Bob Pennefather, Dave Paton, Keith Spencer, Harold Jenkins, Frank Crofts, John Begg, Fred Kleinschmidt, Erik Watson.

Third Row: Milton Moore, Eric Cuthbertson, Jim Jessup, Walter Andrew,

Cedric Vears, Stan Marriott, Norm Shaw, Bill Willoughby, Colin Donald, Reg Rossiter.

Fourth Row: Colin Andrew, Bill Disset, Frank Ryan, Ken McLachlan, Owen Williams, Colin Williams, Geith Barley, Dick Roe, Jack Milder, Abner Shavitsky.

Front Row: Jack Whittet, Carl Forster, Yvonne Aitken, William Summerville,

Tom Dunne, Jack Davies, Ev Fricke, Laurie Ellison, Miss Hemingway, Hugh Trumble, Jim Breakwell.

To me, then an honours student in Pasture Agronomy, it was a noteworthy Conference, the like of which was never to be repeated. It was combined with the inspection of hundreds of field plots on the Southern Tablelands, which demonstrated many of the research results reported. There were no specialist committees and everybody discussed everything. Many important resolutions emerged such as the need for greater knowledge concerning the effective modulation of pasture legumes, the establishment methods required for different pasture species, the appropriate means for testing newly introduced species and the means by which pasture research results could best be brought to extension officers and the farming community.

Important decisions that emanated from this Conference included those of C.S.I.R.O. to set up its Agricultural Liaison Section and commence publication of "Rural Research in C.S.I.R.O.", which aimed to provide summaries of recent research and stress its practical significance.

Such was the basis of the Expansive Years and those of us who began careers in Pasture Agronomy in the early 1950's were most fortunate.

Pasture research which changed Australia in the expansive years will be considered under the five headings already indicated.

1. Superphosphate, Trace Elements, Water Harvesting and Supplementary Irrigation 1950-1970.

As already indicated, the value of superphosphate and the trace elements as means of vastly increasing productivity on some soils and in some locations was already well known by the 1950's,and it was expected that the research in this area would have widespread implications throughout Australia. However, the extent of these possibilities and the economics of them under vastly different environmental and economic conditions were largely unknown. The 1950's was an era in which C.S.I.R.O. researchers combined with pasture orientated people in universities and State Departments of Agriculture, to spread the knowledge gained by individual researchers, and test the application of this knowledge, mainly through field-plot studies, to a wide range of environments throughout Australia.

It is significant that the first article in the first volume of Rural Research in C.S.I.R.O., dated June, 1952, was entitled "Increased Pasture Production - New Possibilities in Southern Tablelands". It summarised the recent work on the effects of superphosphate and its components together with molybdenum and lime, on the establishment and growth of subterranean clover, and strongly suggested that, by obtaining the correct nutritional recipe for each particular environment, the stocking rate of pastures throughout Southern Australia could be multiplied many times and soil fertility greatly improved. The significance of this article was not only that it conveyed the research results obtained by Anderson, McLachlan, Oertel, Spencer, Thomas and Noye, but that it interpreted these results in a form that could readily be applied by extension agronomists to the practical problems of pasture improvement. The ingredients for success on the Southern Tablelands of New South Wales were simply stated as clover, superphosphate, molybdenum, lime, grass and management. It was also a challenge for all research and extension agronomists to determine the factors limiting pasture production in their particular areas by setting up field plot trials. In Rural Research in C.S.I.R.O. Number 2, November, 1952, A. J. Anderson gave details of a relatively simple field-plot trial for testing pastures for mineral deficiencies, which could be used by extension officers or farmers anywhere. This packaged trial was made up by some Departments of Agriculture and commercial firms as the "Anderson Field Testing Kit"; it was widely used and brought in a great deal of knowledge on the range and nature of soil deficiencies for pastures. This trial, conducted on a large number of farms, became an important extension tool and did much to rapidly expand the areas of improved pastures in Southern Australia.

The widespread use of field trials, pot experiments and soil analysis during the 1950's had confirmed the earlier contentions that improved pastures could be economically established over much of the high-rainfall fifth of Australia but, nevertheless, many individual failures did occur in this zone. One such area was the Central Coast of New South Wales around Sydney and particularly the erratic rainfall area of the Cumberland plain west of Sydney. While clover based pastures could be established here during favourable autumns they failed to persist. In the 1950's Hector Geddes (10) showed that the problem was not only one of major and trace element deficiencies but also of a shortage of available soil moisture due to the low moisture permeability of the soil and the high surface run-off. By harvesting the water in low cost earth dams and turkeys nests and using the stored water to sprinkle-irrigate pastures and fodder crops as required, feed costs in milk production were reduced by up to 75% (11). This development: "Water Harvesting Irrigation and Planned Pasture Production" (12), made it possible to use pastures profitably for whole-milk production in many parts of Eastern Australia in moderate rainfall areas which had no access to river or suitable underground water. The wide scatter of earth-walled private farm irrigation dams seen by air travellers as they approach Sydney Airport from the south or west, is testimony to the manner in which this research has changed the face of Australia.

There is no doubt that the widespread discovery of mineral and water deficiencies together with the economic means of correcting them, have greatly changed Australia in the 1950's and 1960's.

2. The Nitrogen Nutrition of Australian Pastures through effectively nodulated legumes and Fertiliser.

(a) Legume nodulation.

When one considers the excellent legume nodulation services that are available in Australia to-day for any person needing to establish a pasture or crop legume in a soil for the first time, it seems almost incredible that as late as 1950, no reliable strains of root-nodule bacteria were available and suitable for the effective nodulation of even the most common pasture legumes.

The problem was highlighted near Lismore in 1950 when it was recognised by J. M. Vincent (13) that subterranean clover sown there with seed inoculated with the standard Rhizobium trifolii culture then held, failed to produce effective nodules, became grossly nitrogen deficient and died. Fortunately, however, a very occasional sub-clover plant in one of the many sod-seeding trials being conducted did become effectively nodulated and grew, and still more fortunately, Vincent was able to check serologically that the rhizobial strain in the effective nodule was not the one applied to the seed. From these early observations the whole question of rhizobial strain specificity and cross compatibility was developed and strains became selected for compatibility, effectiveness in nitrogen fixation, invasability and durability in soils. It was also found in 1951 that nearly all the tropical legumes grown in the nursery at Pearce's Creek near Lismore were also ineffectively nodulated. This explained why tropical legumes had been grown on Wollongbar Research Station successfully in inter-row cultivation plots repeatedly over fifty years but had always failed when put out into pasture swards.

Once this problem had been clearly recognised both in temperate and tropical legumes (14), researchers in both Southern and Northern Australia developed techniques to answer Australia's legume establishment problems and made major contributions towards solving similar problems throughout the world (15). The availability of specific effective strains of rhizobia for all manner of tropical and temperate legumes is now almost taken for granted by agronomists, but this was not so in the 1950's. This knowledge, largely Australian developed, has greatly improved pasture establishment both in Australia and overseas

But Australian research has not only developed a superior strain of rhizobia for specific host plants: in addition, means of delivering these rhizobia safely from the rhizobial culture to the emerging root-hair of the germinating seed have been devised by Hely (16) even though the seed be delivered by a ground seeding machine or an aircraft (16).

(b) Nitrogen Fertiliser Nutrition.

In the early 1950's nitrogen fertilisers were being used extensively on pastures in Europe but not at all in Australia. While the reasons for this in general were economic and climatic, it was believed that there were particular situations here where they could be profitably used. One such situation, selected by Crofts (17) was for increasing the late autumn, winter and early spring growth of irrigated ryegrass and oats dairy pastures used for winter whole-milk production at Camden, New South Wales. Here in 1958 it was clearly shown in commercial-scale trials that the use of nitrogenous fertilisers as a means of replacing bought cereal grains and hay was a highly profitable business, despite relatively high nitrogen fertiliser costs. Subsequent trials throughout Australia have shown that nitrogen fertilisers can be profitably used in specific pasture situations where the growth of grass is restricted by available nitrogen supply and where the increased forage obtained replaces still higher cost bought feed.

3. The Development of Machines and Methods for the Establishment of Pastures on Non-arable Land.

(a) Sod-seeding and sod-seeders.

In 1950, E. J. (Jim) Breakwell began a programme of research on the Far North Coast of New South Wales aimed at regenerating the paspalum-carpet grass pastures of the hilly "Big Scrub" (Rainforest) region, and he visualised the direct seeding or sod-seeding of legumes into these pastures, as opposed to conventional cultivation and seeding,, as the only means of improving these pastures without causing

soil erosion. Harold V. Jenkins worked with him on this project and in 1951 they designed a seeding shoe which would penetrate the paspalum sod and positively place seed and fertiliser in a band in the soil without clogging and with adequate soil cover. These seeding shoes or types, attached to the ripping legs of a Ferguson Tiller with a Sunprong seed- box mounted on top and a ground-drive wheel behind, became the prototype of the first Australian sod-seeder. Both the principle of sod-seeding and the pattern of the shoe were patented by the University of Sydney under Australian Patent No. 157985 and the machine was described by Breakwell and Jenkins in 1953 (18).

The University patented sod-seeder was made near Sydney by Grasslands Pty. Ltd. and the first commercial implement was exhibited at the Sydney Sheep Show in June, 1954. Success of the implement was immediate and more than 500 units were sold in the first year of production and many units were exported to South America, South Africa, New Zealand, New Caledonia, the Philippines and even the Falkland Is. I.C.I. of England bought one such unit and used it at its Jeolot's Hill Research Station for the development of its new paraquat and diquat herbicides. By 1957 a number of different sod-seeders had been manufactured in Australia and these all contributed towards solving the problem of quickly and safely establishing improved pasture species, particularly clovers, in existing pastures, especially on erosion liable land.

After being associated with development of the sod-seeder at Lismore, N.S.W., up to 1954, I was moved to Sydney and there, at Badgery's Creek, the same machine was modified by the addition of a cereal seed-box and used in the Water Harvesting programme to seed oats, at high density and with nitrogen fertilisers, into paspalum-white clover irrigated pastures in the early autumn for the purpose of vastly increasing the winter feed from these pastures. It was the combination of Water Harvesting and Irrigation, Sod-seeding of high density oats and the efficient use of nitrogenous and other fertilisers that kept dairy farming profitable around Sydney from 1950 to 1980. Almost all remaining farms now use these practices which were incorporated into a dairy farming system and described in January, 1963 (12).

Despite its success, the Grasslands sod-seeder had some limitations in that it would not seed into stoloniferous grasses like Kikuyu and Couch, and, if the ground was very dry and heavy, it would not penetrate. A range of machines have now been developed to overcome these problems for particular situations and one of the earliest and best known such machine is the I.C.I. developed triple-disc seeder which is now made under a wide range of commercial names. The combination of type and disc sodseeders with cutting coulters and press wheels has made it possible, especially with the use of herbicides, to quickly establish pastures or fodder crops by ground on all but the very roughest and steepest land. Fortunately, most of the problems associated with establishing pastures on rough, steep country have been overcome by the use of aerial seeding.

(b) Aerial Seeding and Surface Seeding.

It was the early 1960's before Australian Agronomists paid serious attention to the possibility of successfully establishing pastures from surface or aerial seeding, although F. E. T. Suckling had reported some success in New Zealand as early as 1951 (19). However, with the availability in the 1960's of selective and short residual herbicides, it became a feasible proposition for a wide range of soil and climatic conditions.

The national importance of having the technology to successfully seed pastures from the air becomes apparent when one realises that about 251 of the high rainfall areas of Eastern Australia, eminently suitable climatically for pasture improvement, are inaccessible to ground-surface machinery.

In the course of investigations directed at controlling Nassella tussock on rugged hill country on the Central Tablelands of New South Wales in the early 1960's, Malcolm Campbell found it possible, under appropriate conditions of moisture and ground cover to establish a wide range of pasture species by surface seeding into chemically treated Nassella stubbles. Subsequent research summarised by Campbell (20) shows that aerial seeding can be a reasonably safe means of establishing pastures on large areas of Eastern Australia provided there is a good understanding of the climate, the seed-bed preparation and time of sowing is well designed, measures are taken to incorporate and deliver viable

root-nodule bacteria with leguminous seeds by means of coating the seed, the seed is protected by chemicals from ant attack and the appropriate post-seeding management treatments are applied.

Although the areas already sown to improved pasture species by these methods are so far not very extensive, I believe that this pioneering work of Campbell (21) with further refinements, will become the most widespread means of establishing improved pastures in the future.

4. New cultivars in Pasture Improvement 1950 - 1970.

The species and strains of pasture grasses and legumes which were used extensively in the expansive phase in Southern Australia were already largely defined by 1950, but noteworthy additions which became widely used were Barrel medic 173 and Kangaroo Valley Ryegrass.

However, the situation was totally different in regard to tropical and subtropical regions of Australia. Here very few cultivars, apart from Buffel Grass which was first introduced in 1930 and Townsville Style which was introduced from South America accidentally at some time before 1900, were freely available for use and seed of even these species was in very short supply. An intensive programme of plant introduction and exploration together with field experimentation and pasture plant breeding began in Queensland in the early 1950's, and by 1964 E. Mark Hutton of the C.S.I.R.O. Division of Tropical Pastures was able to describe and register fifteen new cultivars which he believed might form a basis for the improvement of tropical and sub-tropical pastures (22).

A very significant step in the orderly handling and use of new pasture cultivars for the whole of Australia was made in 1965, when on the recommendation of the Standing Committee on Agriculture, the C.S.I.R.O. Division of Plant Industry was made responsible for preparing and maintaining a register of Australian herbage plant cultivars. The first edition of the Australian Herbage Plant Register was published in June, 1967, and this publication, updated from time to time and supplemented by the volume Herbage Plant Species, provides all Agronomists with a full botanical and agronomic description of all cultivars available in Australia. This publication has greatly facilitated the testing of new cultivars.

There is of necessity a large time lag between the initial selection of a cultivar and its subsequent widespread use, and we only hope that just as the cultivars used widely in the expansive phase were identified before 1950, so the wide range of species now being selected and registered will be widely used in the future.

5. Development of Pasture Management Strategies and 0ptimal Stocking Rates 1950-1970.

From the late 1950's onward observations in New Zealand and England, mostly with dairy cows, suggested that intensive subdivision and rotational grazing were possible means of greatly increasing the production from animals grazing improved pasture and trials were set up in most States to test the system.

In general, the responses to rotational grazing were small or negligible but such trials served to highlight the fact that the most powerful factor influencing both production per unit area and production per animal was the animal stocking rate.

Between 1948 and 1958 the area of superphosphate topdressed pasture in Australia had increased by about 148% to 9 million hectares but a study in 1961 by Kinsmen and McLennan (23) showed that the additional livestock in sheep units per improved hectare were only 2.6 for N.S.W., 1.5 for Victoria, 2.8 for South Australia and 4.1 for Western Australia. These figures strongly suggested, when compared with the stocking rates achieved in field-plot experiments, that most farmers who had gone in for pasture improvement were grossly understocked. The question then raised, loud and clear was "What is the optimal stocking rate for improved pastures throughout Australia?"

During the late 1950's and the 1960's large numbers of trials were set up by Agronomists, Extension 0fficers and Farmers alike in an effort to determine the optimal stocking rate for their particular situation. Most of these farmer and extension officer trials were terminated by the severe drought periods of 1965 and 1966 though many publicly funded studies were continued throughout the drought but terminated shortly after it. The results of all these grazing trials did little to define the optimal stocking rates for even specific situations, let alone provide general guidelines for regions.

People conducting such trials became to realise that there is no optimal stocking as such for a particular parcel of land but at best a rate which is suitable to the manager in terms of the past history of the land, its current inputs in terms of nutrients and water, the kind of livestock carried, the objectives of the manager in terms of quantity and quality of production and the amount of risk he is prepared to take both in terms of denudation of the land and economic loss. 0ne experienced researcher expressed the situation succinctly by saying that "it is inappropriate to attempt to define the optimal stocking rate for an area on the basis of field-plot experiments".

Another lesson learned from the summation of grazing trials and from a Review of Production and Management on Southern Tableland Woolgrowing Properties dated May, 1968 (24) was that it is most inappropriate to consider unimproved and improved pastures in two single categories. In fact there are pastures at all stages of development and denudation. It appears that when these ranges of productivity are taken into account, then farmer stocking rates are on average quite comparable to the most profitable stocking rates as assessed from field-plot studies.

The problem of selecting pasture management strategies and optimal stocking rates is therefore thrown back to individual graziers who finally have to make choices consistent with the needs and capabilities of themselves and their farms. However, if they can be taught to recognise the early symptoms of overstocking or understocking, both in pastures and livestock, then they are in a better position to take appropriate action.

The years of trial and tribulation - 1970 to 1983.

Although the golden years of high farm profits ended about 1958 with a downturn in world prices for agricultural products, farm incomes were reasonably well maintained through increased livestock numbers and increased output per farm and per person until the late 1960's, although the droughts of the mid sixties adversely affected a large number of producers in the Eastern States.

By 1970 wheat prices declined to unprofitable levels and they remained depressed until 1973-74. Worse still, in 1969/70 and 1970/71 the wool market collapsed and did not recover until 1972/73 (25). Although beef prices remained reasonable until 1974/75, these events, together with reduced income tax deductions for pasture improvement expenditure, spelled the end of the expansive years of pasture development and pasture improvement. Despite fluctuations since 1970 in both pasture improvement costs and prices for livestock products, there has not been a period of prosperity sufficiently sustained to bring about or even suggest another expansive phase. Rather, the continuing cost-price squeeze and the record or near record drought of 1980-82 has had the effect of not only virtually stopping further pasture improvement but also of reducing the maintenance by topdressing with superphosphate of existing improved pastures to a critically low level.

Despite the decline in pasture improvement since 1970, many new research results have emerged which will, if the economic situation improves, bring greater efficiency in pasture improvement in the future. Noteworthy among these findings are the recognition of the factors associated with successfully seeding new pastures from the air on rugged hill country and the importance of controlling ant predators, and the seed-bed conditions through grazing and herbicides (20), the breeding of improved cultivars of both grasses and clovers which will establish more easily and cause less animal toxicity problems, the development of pasture management techniques which will maintain or increase animal production while reducing fertiliser inputs, and the development of more efficient means of both determining the fertiliser requirements of pastures and then supplying the nutrients at the most appropriate time and in the most appropriate places. However, unlike in the 1950's and 1960's, the impact of pasture research conducted

in the 1970's and 1980's will be small unless pastoralists have money available to utilise these new research findings. The challenge to pasture researchers is therefore greater now than ever before. They must develop techniques and programmes for both pasture improvement and pasture maintenance which can be applied at low cost and give a high net return to the pastoralist. This, I believe, although a difficult task, is not an impossible one. It is one, however, which requires a lot of thinking both on a broad and specific basis. For example, it might be as important to discover how to deliver specific essential nutrients efficiently and cheaply to the farm gate as it is to further increase our knowledge of how to effectively apply them and utilise the products which they produce.

The years of hope and hopelessness - 1984 to 2000.

Some might say that pastures, and the livestock products which emanate from them will, in the world of 2,000, be luxuries which an overpopulated world will be unable to afford. If this is so, I am glad to be at retiring age right now, because I would gain little pleasure from either living without the company of pastures and livestock grazing them or without the products that they provide.

Nevertheless, I believe that pasture agronomists must accept the fact that ungrazed crops of all kinds will continue to replace pastures, especially on land equally suited to both. I guess this belief explains why my wife and I currently run a 800 ha. hilly "Horse and Aeroplane" farm with about 6,000 D.S.E. of sheep and cattle with the knowledge that, at least in our life time, it will never be used for cropping.

Pastures will, for a long time ahead, remain even on gently undulating country, if not permanently, at least as a part of the cropping programmes. 0n hilly country, unsuitable for ground operated machines but suitable for horse mustering and aeroplane delivery of seed and fertilisers, they have a very long-term or permanent place because no machines are as efficient as grazing livestock at gathering and processing for human consumption the plants that grow on this kind of land. But a high proportion of the high rainfall land in Eastern Australia and especially Tasmania, has topography too steep for the use of ground operated machines and a very small proportion of this land is already pasture improved. It does, I believe, offer considerable scope for the expansion of improved pastures when the economic conditions are right. The development of techniques for improving and managing this non-arable land will become of increasing importance as less steep land is used more extensively for conservation-tillage cropping.

0ne of the major factors restricting the establishment and maintenance of improved pastures in the 1970's was the high cost on farm of fertilisers, especially superphosphate, in relation to the price of animal products derived from the pasture, yet it is a fact that on long developed and top- dressed pastures there are heaps of plant nutrients lying around unutilised. After all, in most grazing operations, less than 5% of the total plant nutrients ingested by the animal in the process of grazing are taken out of the system in animal products. The other 95% are returned to the pasture, although most unevenly by the animal in the form of dung and urine, so in every old pasture we have a strong gradient of plant nutrients from the farthest away day-grazing areas to the night--camping areas where the concentration of essential plant nutrients is often so high that no useful species can grow.

It should be possible, by using temporary low-cost electric fences, to progressively exclude animals from high fertility camp areas, grow luxuriant crops or pastures on them and, by on-off grazing, push the plant nutrients back onto the fertility-drained areas.

Furthermore, it should, from satellite maps which show up high-fertility areas and livestock camps, be possible to program the delivery of additional fertiliser from aircraft to ensure that it is applied where most needed and not on high fertility areas.

I believe that these two measures could do much to maintain or increase the productivity of our pastures while reducing the requirement for expensive new fertiliser applications.

The research requirements of the 80's and 90's, although quite different from those of the 50's and 60's, will be equally demanding and no less rewarding. My plea to young researchers is simply "Look at to-day's pasture problems from the grass roots to the finished animal product and

select research problems which, if solved, will further change the face of Australia and thus preserve and embellish our land resources for all future generations."

Summary and conclusion.

Of all the pasture research conducted in Australia since 1950, which areas have done most to change the face of Australia?

On reflection of events over the past thirty years, I would have to give first prize to the plant nutritionists and fertiliser technologists, and all those who participated in the overall problem of determining the nutrient requirements of pastures and working out how to best supply them with the needed fertilisers. Alfred J. Anderson's words of 1969 are equally true to-day. I quotes "By correcting deficiencies, high levels of production are possible almost wherever the rainfall is adequate but there are many questions concerning nutrition that remain to be answered." Nutrition research and its application has changed the pasture face of Southern Australia and it is, I believe, slowly but surely, about to do the same for the north.

Along with nutrition, rhizobiology would also justify a high prize. The selection and supply of appropriate nitrogen _fixing bacteria for legumes has greatly extended the areas in which pastures can be grown successfully.

Farm water management, in all its ramifications, also needs a special mention because water is the final limiting factor to all our endeavours, and increases in water use efficiency are finally the only means we will have of producing more food.

We cannot, however, forget the importance of pasture establishment methods and seeding techniques. I firmly believe that sod-seeding and aerial seeding methods, not available at all in 1950, will, from now to the turn of the century, be the main techniques used in the establishment of improved pastures and there is room for much research in this area.

Species and management research will continue to make useful contributions to our knowledge but to me they appear unlikely to produce sweeping changes over large areas.

Even with further replacement of pasture land with crops, it is my belief that in 20 and 100 years from now pastures and pasture research will still be vital to the well-being of most Australians.

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