

1. Future productivity on our farmlands

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Introduction

It is indeed a privilege for me to be invited to present this address, and I feel very humble for the great honour you have conferred on me. For I am aware of the outstanding skills of many other agronomists and the success they have achieved in both research and extension. I would also like to acknowledge the contributions made by many colleagues over the years in helping me to understand the scientific principles of agriculture, and I thank them for their kindness and friendship.

The Society of Agronomy is to be commended for having this award to honour the late Professor Colin M. Donald, for he made an outstanding contribution to Australian agriculture. His book "Pastures and Pasture Research" was the beginnings of numerous other publications that enriched both the science and the applied aspects of production on our farmlands.

My first association with Colin Donald was in the early 1950's when he was appointed a professor at the Waite Agricultural Research Institute. From that time onwards his lectures, talks and personal friendly discussions influenced me greatly. He had the capacity to listen and understand a point of view on a very comprehensive range of subjects; and then he would challenge you to find out how best this information could serve an agricultural system. In 1956, at our Minnipa Research Station; we walked through a very good mixture of standing oats and barrel medic pasture and debated the merits of this mixture compared with pure medic pasture. Maybe, it's a debate we should re-examine today, for the so called medic pastures are now dominated by poor quality grasses.

Later, it was due to his advice and guidance that my papers on fallowing were eventually published and in recent years he maintained a keen interest in the yield and soil measurements of the current continuous cropping experiment at Tarlee. These are but a few snippets of his very broad breadth of interest and understanding that appealed to all of us, and inspired us to aim for greater productivity in the countryside.

Agronomy is concerned with the applied aspects of soil and plant sciences; it seeks to establish a relation between agricultural production and factors that control it. In his book "Blades of Grass", Trumble (1) quotes the views of R.G. Stapledon the active leader of agronomic thought in the United Kingdom in 1939. "Research in agronomy is primarily research in the field and its main aim should be to study all the factors which are operative at once and together and in their natural interplay".

These concepts have been with me for most of my working life and no doubt influenced my multifactor approach to defining potential yield for the water supply. Within these concepts, I have also been aware that the farmer himself is a vital part of the equation, for conservation of soil and increased productivity cannot be achieved without him.

History of agricultural production

When one studies the history of our agricultural development and production, it becomes apparent that changes are influenced by a number of catalysts, these include:

- the social demands of the community and government
- the economics of market prices, costs of production and exchange rates.
- the impact of technology on biological efficiency
- the effect of climatic trends.

In his Farrer Memorial Oration, Donald (2) outlined the adaptive measures and purposeful changes imposed on the environment by landholders to meet the demands of the growing society in different eras

of the past. It is worthwhile recalling the effect of these measures, and while they apply throughout Australia, I would like to briefly summarise the development in South Australia.

Developments prior to 1945

From the early days of settlement, the basic tenet of the community was that the vast areas of land represented a source of untapped wealth. Clearing of vegetation was therefore strongly supported even though little was known about the climate and its variability, nor about the effect of cultivation methods on the soil.

Even though Surveyor General Goyder established a line in the countryside in 1865 beyond which he considered it was not safe to farm, community pressures forced farming to expand beyond this line. The farming proved successful for the next 15 years or so because, as we now know, the rainfall was about 50% above the long term average. This higher rainfall led to the catch-cry that "the rain follows the plough".

Subsequently, droughts forced a retreat from the margins of the farming lands from 1890, and a second retreat occurred in the mid-1930's when farmers could not achieve yields of 0.4 tonnes/hectare to cover costs of production. At that time, agriculture centred largely on the use of horses as a source of power, long fallowing, superphosphate and wheat varieties.

Nevertheless food and fibre were being produced to feed the State and supply export markets. Production was further boosted by the discovery of the need for the application of trace elements by research workers. However soil erosion was by now a major problem in the agricultural areas and overgrazing in the pastoral lands had destroyed a lot of the perennial bushes and reduced carrying capacity to about one third of the original number.

Development from 1945-65

Following the war, there was again renewed pressure from governments and society to clear more land, grow more food and increase the countries finances from the sale of exports.

Landholders were encouraged to clear land through taxation concessions and the bounty on superphosphate fertilizer was introduced to encourage higher yields. Governments participated in the development through War Service Settlement Schemes.

Tractors replaced horses as a source of power, thereby providing about 25% more land for agricultural production, wool prices soared giving a major encouragement to grow annual legume pastures, and myxomatosis controlled the rabbit plagues.

There was less cultivation due largely to the introduction of herbicides to control weeds, and soil conservation services were tackling the degradation due to erosion and salinity. Yields of crops and pastures increased, new varieties were released, plant nutrient studies provided a more efficient use of fertilizers, and livestock numbers increased. Higher production meant more exports for Australia and the scientists were meeting the expectations of the community.

Development from 1965 from 1980's.

This seems to have been an era where an increasing array of problems has arisen both in the farming lands and in the markets. There have been few gains in the yields of crops and pastures, livestock numbers are down and the economic viability of many farms is in question.

There are fewer farmers with bigger holdings, fertilizer costs have increased eg. the cost of a tonne of superphosphate rose from \$18 in 1970 to \$130 in 1986, there are higher costs from the farm gate to the consumer, and bank interest rates have soared.

Pastures have declined in quality and the inferior grasses have reduced yields in the following crops because of the carryover of root diseases and nematodes, there is an increasing need for defining nutrient inputs, there is a build up in soil acidity, and the use of bigger farm machinery is causing problems in soil compaction. While the adoption of soil conservation methods is more widespread than previously, there are increasing problems of erosion, structure decline and salinity.

Similar stories could no doubt be recounted of the development of agriculture in other states. In spite of the current difficulties, however, the nation has benefitted from its agriculture. There are a variety of different types of agricultural production in each state and the production represents about 40% of export earnings of Australia and up to about 60% of the export earnings of some of the states. A lot of this success is due to the skills and perseverance of scientists, many of whom have received world wide recognition of their efforts.

Their successes have been recorded in many publications, and recent reviews in the Jubilee Issue of the Journal of the Australian Institute of Agricultural Science and in the Jubilee Booklet - "Science for Agriculture - The Way Ahead" attest to their contributions.

Yield trends

In spite of increased funding for research from both government and industry councils over the last two decades or so, an examination of the trends in crop yields and in livestock numbers indicates that, overall, there has been little gain in productivity. Yields of cereals have tended to remain steady at a low level and stock numbers have not reached their estimates. The trends in Australian cereal yields can be seen in Table 1.

Table 1: Average yields of Wheat and Barley over three decades

Years	Wheat		Barley	
	Area	Yield	Area	Yield
	Sown (m. ha)	(t. ha ⁻¹)	Sown (m. ha)	(t. ha ⁻¹)
1956-65	5.9	1.19	0.9	1.14
1966-75	8.5	1.12	1.8	1.10
1976-85	11.1	1.31	2.8	1.26

These figures show only small increments per year; and the yields of wheat can be compared with gains of about 40 kg/ha/year in America and 80 kg/ha/ year in England. Our trends must be regarded as disappointing for in 1964, Donald (2) expected that our wheat yield would exceed 1.5 tonnes/ha by the 1970's.

The data indicate either that the increased spending on research has not increased the productivity of the land or that we have once again become obsessed with the colonial attitudes of using our vast area of land. Do we really need to sow 11-13 m. hectares each year to produce our current 18-20 m. tonnes of wheat? While many reasons can be offered for our low yields - overcropping, failure of pastures, soil degradation, extension of cropping to dry areas - very few areas give a yield that approaches the potential for the rainfall.

Donald (2) also predicted that, with improved pasture species and grazing management, sheep numbers should increase from 165m in 1964 to 265m in 1980. In fact, while sheep numbers reached a peak of 170m in 1970 they fell to 130m in 1978, and even now are still below 170m.

Again, many explanations can be offered, including low prices, lack of fertilizer, poorer pastures and increased area of cropping. But overall, for both wheat and sheep much of the lack of progress can be attributed to little or no overall increase in the productivity per unit of land.

Some gains in productivity have occurred, but we still have to ask the question, were these due to better farming or to variations in the climate?

We have examined rainfall trends for a number of sites in South Australia by plotting the cumulative sum of the deviations of the monthly rain from the long term monthly mean. The data show runs of years where the rainfall gave both higher and lower cumulative values. The results of the average rainfall for defined runs of years for 3 sites are shown in table 2.

The average annual rainfall varies by 70-80 mm between each group of years from the low rainfall site at Kimba and by up to 150 mm between groups of years at Georgetown. The Georgetown data was broken down into growing season (April-October) rainfall and related to the wheat yields of the surrounding Hundred. Calculations show that in spite of a general increase in yield per hectare the yield per unit of rainfall has shown little change over 50 years.

Table 2: Annual rainfall variations in defined groups of years for three locations and the relation between rainfall and wheat yield for the Georgetown district.

Years	Annual Rainfall (mm)			Rainfall and Yield at Georgetown		
	Kimba	Lameroo	Georgetown	Apr-Oct Rain (mm)	Yield (t.ha ⁻¹)	kg.ha ⁻¹ mm ⁻¹
1903 - 26	380	429	510	392	1.26	3.2
1926 - 45	308	337	407	288	1.43	(4.9)
1946 - 56	403	426	536	400	1.74	4.4
1957 - 67	317	347	407	308	1.42	4.6
1968 - 81	387	404	559	428	1.99	4.6

It is possible that the water use from 1926-45 was significantly greater than the growing season rainfall due to widespread practice of long fallowing in that era - this would therefore tend to reduce the yield per millimetre. By contrast it is interesting to note that yield increases in the 1946-56 period are generally attributed to the improved soil fertility following the adoption of ley farming and annual legume pastures. Little cognisance is taken of the higher rainfall. Could it be that the claimed benefits of other crops, pastures and agricultural practices in increasing yields are due to a period of higher rainfall, and that the benefits disappear on return to normal rainfall. Similar trends also occur in our North East pastoral country and the number of sheep equivalents can be related to the groups of years with high and low cumulative rainfall deviations.

The need for relating yields to climate will have to be considered more seriously in the future because of the forecasted changes. Rainfall and temperature will vary because of the global warming of the earth's surface due to the increase in concentration of carbon dioxide, and the hole in the ozone layer will allow more ultra-violet light to reach the earth, affecting the yield of crops, particularly grain legumes.

Future concepts

There is no doubt that we need a strong and efficient agriculture if we are to survive as a nation. To achieve an efficient agriculture however we need to reassess our attitudes to land, our priorities for carrying out research on the land, and derive a better basis for assessing the success of field experiments.

In the past, the community supported the clearing and development of the land to create wealth. Today, a different attitude exists. Agriculture as a percentage of the economy has declined, there are strong pressures against clearing and farming, land rights have entered the political arena and the community is not concerned whether the orange juice comes from irrigated areas or Brazil.

Land is now seen as a resource for a number of different needs. There is the traditional agricultural role for the production of marketable products such as grain, wool, meat, fruit and timber; there is the urban need for housing, roads, airports and pleasure - sportsfields, entertainment centres and casinos; there are areas with specific land rights, and there is the community need for land with non marketable products - scenery, parks and reserves and water catchments.

We should therefore be more outspoken in ensuring that the land that can give high yields is retained for agriculture. However the assessment of the productive potential of land begins, not with a knowledge of the land or soils but with a knowledge of the climatic factors and the capacity of plants to produce within the climates. In essence, agriculture consists of harnessing the energy of the sun to produce food and fibre for man. Hence the steps in evaluating the productive potential of an area consist of:

- defining the climatic features - radiation, temperature, evaporation, rainfall
- selecting those plants that can harmonise their growth and development (phenology) within the climate
- selecting the crops and pastures that give best economic return
- selecting those soils that have good depth of root zone and available water capacity without any abnormal pH values
- devising a set of husbandry practices to promote optimum growth.

Setting of research priorities

One of the great difficulties we have right now is learning how to set the priorities in research, particularly as funding becomes less available. We have a mass of scientific publications and knowledge but have great difficulty in sorting out what is relevant to increasing the production on the farm. Reviews of the state of knowledge and discussions at conferences tend to finish up with the same recommendations - viz the need for research into the improvement of soil and water management, improvement in crops and pastures, improvement in livestock production and improved efficiency of

fertiliser use. Are scientists more interested in the complexity of a problem and in doing research confined only to a single factor in their own discipline? If so, how do their answers relate to field problems? These are the sorts of questions now being asked by the policy makers. Will we see a reduction in the number of research institutes as has happened in the United Kingdom.

Aims for agronomic research

If we are to maintain a strong capacity for agronomic research, then our aims should be to:

- produce quality products that can be sold on overseas markets.
- produce materials for special niche markets, locally and overseas
- increase the productivity of crops, pasture and livestock per hectare.
- devise new strategies to overcome gaps in the production during the year eg. the lack of feed at the end of summer for dairy cows.
- restore and maintain the fertility of the soils
- help farmers to develop new farming systems that increase their productivity and enable them to make a good living.

While all of these factors could be discussed in detail, I would like to enlarge only on the need for increased productivity per hectare on farms.

Potential yield

The potential yield in an area is set by the range of climatic factors. Experiments throughout Australia have determined the potential yield for a number of crops; and in general, district yields are only about half the potential yield.

It is pleasing to see that an increasing number of scientists are carrying out research that will help farmers develop practical systems to reach the potential yield. Past research has tended to assess only the effect of a single factor but it is almost impossible to study a single factor in isolation, since the sum of the effects of all the other factors is of far greater magnitude (3).

Furthermore while the effects of a single factor may solve a problem, it may also create another problem. Thus the correction of an acidity problem by applications of lime did not increase yields because of the onset of the root disease "take-all".

Research programs should have a greater content of multi-factor experiments - such experiments have components similar to a symphony orchestra-and their success is well illustrated by the inter Institute research team of 10 scientists in the United Kingdom which produced wheat yields of over 11 tonnes/hectare (4). As well as multi-factor research, there should be closer links between laboratory and field staff. The appointment of a "facilitator" to link the two groups of scientists conducting research into soil acidity is a good step forward. In addition I believe that all field experiments should have a minimum set of measurements such as water use, nitrogen and phosphorus uptake and soil organic carbon contents so that yields can be expressed as a percentage of the potential yield and trends in soil fertility can be identified.

The potential yield concept should be an obligatory end point for all research whether it be with single factor or multi-factor inputs.

A further development in our understanding of the agronomic potential of our farming lands would be to generate a Productivity Index similar to that used to describe soils in Europe. This index expressed as points out of a 100, integrates the productivity of land for specific crops based on limitations imposed by climate and soil properties.

Experiments have defined the potential yield for wheat (Figure 1) (5). The relationship was defined by relating yield of wheat to the water used by the crop between sowing and harvest. The figure however, shows the relation between yield and derived April-October rainfall, which is the water in the soil on 1 April stored by long fallowing or heavy summer rains plus the April-October rainfall. It is an estimate of water use developed to help farmers make their own calculations on their own farms.

The figure also shows the gains in yield due to various agronomic practices in both field experiments (6) and farmer's fields (0). Yields were increased by the application of nitrogen (points linked by a B line), phosphorus (C line), copper (D line), control of eelworms (E line) and multi-factors (F line). Yields decreased due to delayed time of sowing (A line), weeds (G line) and waterlogging (H line). In general, after allowing for a loss of 110 mm rainfall by direct evaporation, wheat crops should produce 20 kg/ha/mm of water transpired. Potential yield graphs have also been developed for grain legumes, where the loss by evaporation is slightly higher and the production is 15 kg/ha/mm transpired.

These or similar formulae are now being used by various research groups in different states to evaluate their research programs, but it is also pleasing to see farmers use the potential yield as a target to aim at. Thus at Lameroo, a farmer has over the last 7 years increased his cereal yields from 50% to 70% of the potential; a farmer in the Lower North has increased cereal and grain legume yields from 29% to 64% of the potential, and another farmer has increased yields since 1970 from 27% to 55% of potential.

With pasture and livestock production, the potential yield concept is less well developed and requires more research. Results from past experiments in South Australia, ranging from a low rainfall site (Minnipa) to high rainfall sites (Waite Institute and Kybybolite) were used to produce our potential sheep carrying capacity model (Figure 2) (6)(7)(8)(9)(10). This shows that after 250 mm of annual rainfall, the

carrying capacity should increase by 1.3 sheep/hectare for each additional 25 mm rainfall. The evidence suggests that the existing carrying capacity is only half this potential.

Our knowledge of pasture management is somewhat inadequate particularly the relation between pasture species and animal production. We are unsure of many of the interactions e.g. the relation between seasonal growth and the grazing pressure, the capacity of pasture species to survive under different seasons, and the need for supplements to carry livestock over the non-pasture growth periods of the year.

Some experiments have measured the survival of pastures species under continuous grazing (eg. 11) and others show that higher grazing pressures can even produce more fodder. Thus at Kybybolite in South Australia, a 30% increase in pasture dry matter was obtained with 17.5 ewes/hectare compared with that produced from 7.5 ewes/hectare (8). At Kojonup in Western Australia, a stocking rate of 7.4 ewes/hectare on subterranean clover gave better results than with 3.7 ewes/hectare (12), while in north western Tasmania, an increase in the stocking rate of milking cows up to 3.4 cows/hectare increased the herbage available in spring and the milk production in summer (13).

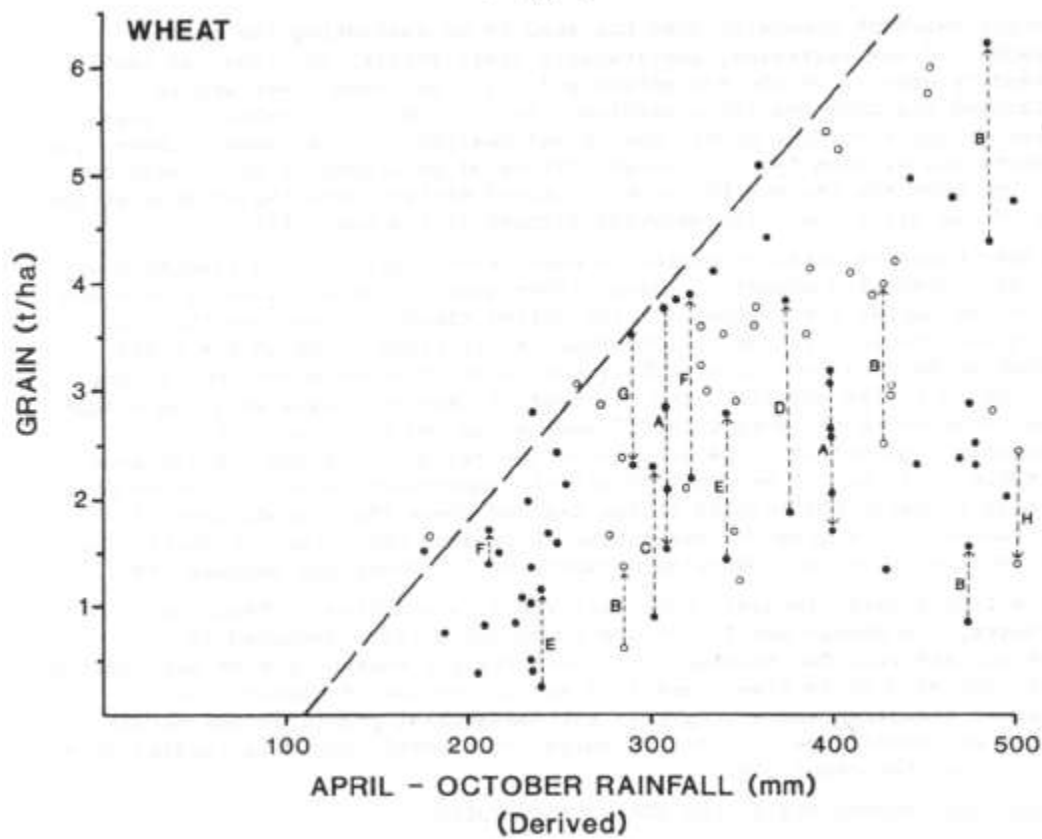


Figure 1. The relation between yield of wheat in experiments and farmers field and the derived April-October rainfall (an estimate of water use).

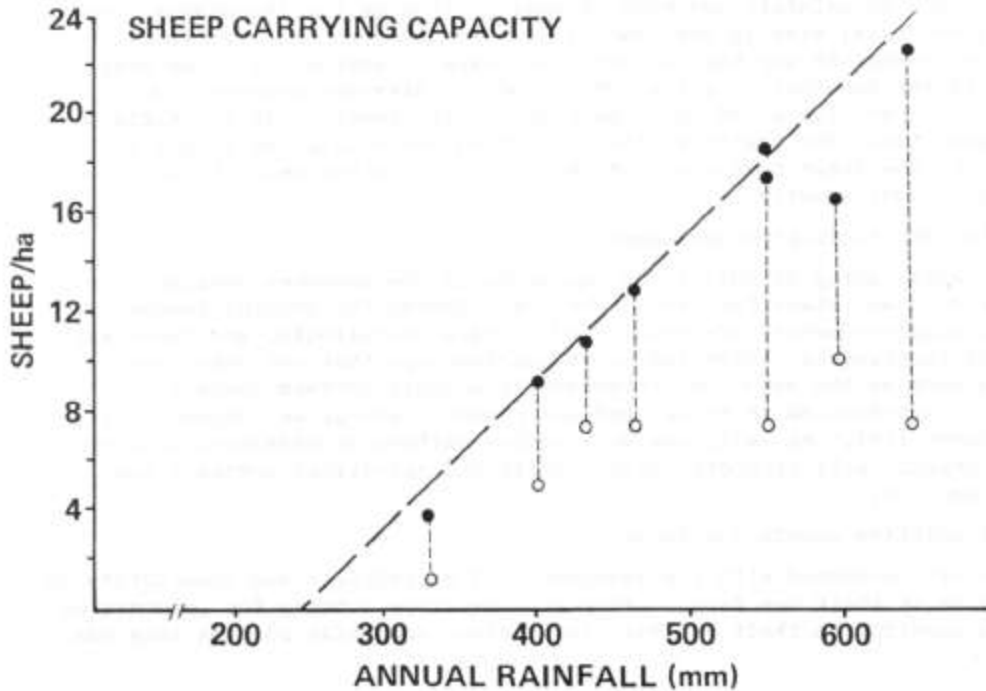


Figure 2. The relation between sheep carrying capacity and annual rainfall derived from field experiments in South

Pasture research generally does not seem to be evaluating the grazing capacity of new varieties, particularly their ability to withstand high intensity grazing in the springtime and still set seed. Nor are we selecting the most adaptable species. Thus in South Australia, 50 years after sowing a mixture of Mt. Barker and Dwalganup subterranean clover, the pasture has evolved into a complex mixture of genotypes of which only 30% are the sown species and the rest contained earlier maturing strains at the top of the hills and later maturing strains at the base (14).

Further research needs to define to what extent pastures and livestock can be integrated with cropping, using either cereals, or mixtures of oats and vetch, or barley and lupins. In the United Kingdom, about one-third of the grain produced is fed to livestock and in other parts of the world, higher production from livestock is now being obtained where feed is cut and carted to the animals. And, in pasture research, have we given enough consideration to the activities of earthworms and the like. It is generally regarded that the species in Australian soils are not the most suitable (15), but if we could obtain the appropriate species then we might be able to match the results in New Zealand where the introduction of earthworms into a grass-clover pasture increased dry matter production by 29% (= 2700 kg/ha) and carrying capacity by 2.5 sheep per hectare (16).

While I have only discussed potential yield in relation to crops and pastures, one should not forget the successes already achieved in horticulture with for example the Tatura trellis whereby yields per hectare have increased up to five times (17) and in irrigation whereby soil physical standards and appropriate soil management practices now permit double and continuous cropping on soils which previously deteriorated after only one or two crops (18).

Other developments for better agronomic studies

Duration of field trials

One of the major drawbacks affecting the quest for higher productivity is the short duration of field trials funded by government and industry councils. The results from a 3 year project may be more affected by

factors such as rainfall and time of sowing, than by the treatments, and often a new trial site is used each year. Furthermore the effects of rotation treatments may take a number of years to evolve. A three year period is far too short to allow for changes in nitrogen storage and mobilisation and the build up of soil microbial biomass. In the Tarlee continuous trial for instance, the production per millimetre tended to decline in the first four years of the trial, but since then it has increased significantly.

Non destructible measurements in situ

An increasing array of scientific equipment is now becoming available to measure soil and plant factors in the field during the growing season. Neutron moisture meters are being used by farm consultants, and there are now many instruments, using infra-red spectroscopy that can determine factors such as the need for irrigation, the grain protein content, nutrient deficiencies in crops, and the protein, energy and digestibility of pastures (19). As well, non destructive methods of measuring changes in water content, soil strength, bulk density and air-filled porosity are being used (20).

Predictive models for farmers

Farmers are concerned with the management of variability and uncertainty as it applies to their own farms. They are therefore looking for information that is specific to their weather, their crops and soils so that they can decide what action they should take. Developments in this area which could help farmers are farm weather boxes, "farmer friendly" plant growth models using their weather data to generate estimates of yield during the growing season and simple economic models to assess the viability of options.

A key feature in the progress of agriculture is the rate at which farmers incorporate new ideas into their farming systems. There is an increasing need for government and private advisers to select the features that are relevant to each individual farmer's properties. Even so, because many of a farmer's existing practices are time bound, it may take him up to 3 years to implement a new practice. An innovative move would be to hold conferences in which farmers and scientists outline the programs they employed to reach the potential yield.

Our agriculture is vital to our future. We should accept the challenge to make our farmlands more productive per unit (per hectare, per millimetre etc) and grow the products that are relevant to markets.

Our future agronomic programs should aim for the potential yield of these crops, pastures and livestock on farmers properties. And to do this means a return to the theme listed in the introduction - "Research in agronomy is primarily research in the field, and its main aim should be to study all the factors which are operative at once and together and in their natural interplay".

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