The 1991 Farrer Memorial Oration
Sustainability and Agricultural Education

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Editor's Note: The Farrer Memorial Medal is awarded annually to perpetuate the memory of William James Farrer, Plant Breeder, and to provide encouragement and inspiration to those engaged in agricultural science. The Medallist is chosen by the Trustees of the Farrer Memorial Research Scholarship Fund from the ranks of those persons who have rendered distinguished service in agricultural science in Australia in the fields of research, education or administration. The recipient of the Medal is invited to deliver an Oration on a topical subject of his or her own choice.

The first Oration was delivered by the then Prime Minister of Australia, the Rt Hon J A Lyons, MP, on 3 April 1936, the anniversary of the date of Farrer's birth. Since then there have been 51 Farrer Medallists and Orations. Two of those have been agricultural economists - Professor John Dillon in 1987 and Professor John Longworth in 1991.

Professor Longworth, Professor of Agricultural Economics and Pro-Vice-Chancellor (Social Sciences) of The University of Queensland, is well known to members of the Australian agricultural economics profession. The Farrer Memorial Medal was awarded to Professor Longworth for his "outstanding contribution to agricultural economics and farm management and to agriculture in Australia and overseas".

The Farrer Memorial Oration has until recently been published by the Trust, however only an Abstract of the Orations are now being published by the Trust. It is fitting that this Oration **"Sustainability and Agricultural Education"** by Professor Longworth, a highly respected member of the agricultural economics profession, be published in full in one of the journals of the Australian Agricultural Economics Society, Inc.

My main thesis in this Oration is that we have recently rediscovered agricultural "sustainability" (that is, we have rediscovered the need for agricultural production systems which can maintain and even improve their productivity in perpetuity) and that the need to develop sustainable agricultural systems has major implications for agricultural education.

However, before I develop this thesis further, let me relate what I am interested in to the life and work of William Farrer.

1. Farrer: a Brief Re-evaluation

William James Farrer is remembered as Australia's first and most famous wheat breeder. Yet, after recently reading some of the available literature on Farrer, I am convinced that to remember him simply as a wheat breeder is to do the man an injustice.

There are three other aspects of Farrer's work which are closely related to the theme of my address and which do not seem to have attracted the attention they deserve. They are:

- Farrer's interest in the development of sustainable agricultural systems;
- Farrer's advocacy of agricultural education and the scientific approach to agricultural problems; and
- Farrer's recognition of the value of and need for international cooperation in the field of agricultural research.

Let me now briefly consider each of these three aspects in turn. I think I will be able to convince you that in each case, Farrer was a pioneer both on the Australian and on the international scenes and that his ideas and efforts have had a lasting and major impact.

(a) Farrer's interest in sustainable systems

William Farrer was possibly the first person in the world to cross-breed wheat with the specific aim of developing new disease resistant varieties. He was, therefore, one of the first to recognize the value of plant breeding in the quest for sustainable agricultural systems.

Farrer began cross-breeding for disease resistance

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in 1889. At that time, only a handful of people were scientifically experimenting with cross-breeding wheat in Europe, North America and Canada. Farrer who was a prolific letter writer corresponded regularly with virtually all of these individuals.

He also contributed to the annual so-called Rust in Wheat Conferences which were held in Australia in the first half of the 1890s. At this time, the fledgling Australian wheat growing industry was on its knees so to speak. Soil degradation and declining fertility were having an impact but rust and other plant diseases had become the major problem. Clearly, the wheat production systems employed in the 1880s were not sustainable. At the Rust in Wheat Conferences which were called to address rust and other problems facing the wheat industry, Farrer advocated plant breeding as the only long-term solution. Initially, his viewpoint was not taken seriously but gradually by the mid 1890s he had gained considerable support even though he did not release his first successful commercial cross-breed variety (Bobs) until 1900.

While Farrer recognized that varietal resistance was the key to more sustainable wheat production systems, this was only one facet of his interest in sustainable farming systems. Early in his career, he became highly critical of the wheat-fallow-wheat-fallow rotations widely practised in Australia. He advocated the use of green manure crops and legumes to improve soil tilth as well as fertility. His pioneering work on the importation and selection of legumes in an attempt to find a suitable legume for the Australian wheat belt, seems to have gone largely unnoticed.

While his work on disease resistant wheat and legumes focussed on technological aspects of sustainability, Farrer also demonstrated his awareness of the economic and socio-cultural dimensions of sustainable agricultural production systems in at least three major ways.

First, he was prepared to sacrifice his initial primary goal of disease resistance to breed a new wheat variety capable of greatly enhancing the economic returns of wheat growers. His most famous variety, Federation, was not a variety which satisfactorily met Farrer's goal in regard to stem rust resistance. (In fact, none of his wheats ever did.) Nor, for that matter, did he regard it as being an especially good quality wheat. Nevertheless, he recognized that Federation had the potential to contribute to sustaining wheat grower incomes and indeed it did just that on a grand scale for almost 20 years.

Second, Farrer is also credited with being the first wheat breeder anywhere in the world to select for good bread-making qualities. In this regard, he recognized the need to integrate agricultural production technology with down-stream processing requirements aimed at a particular market demand. Even today, this critically important integration is often overlooked in the planning of agricultural research.

Third, Farrer was convinced that Durum wheats could provide a viable crop in much of the Australian wheat belt. However, to develop a sustainable Durum wheat growing industry required a domestic market for noodles - a culturally unacceptable food to a population overwhelmingly dominated by bread-eating migrants and their descendants from the United Kingdom. Farrer tried to persuade the authorities to promote the eating of noodles and to take other steps to establish a Durum wheat industry in Australia. He clearly recognized the need to overcome the cultural barriers to this new product before a sustainable production system could be developed.

(b) Farrer's advocacy of agricultural and scientific education

Farrer arrived in Australia in 1870. It is well known that he came to Australia for health reasons. Born in 1845, the first son of tenant farmers of modest means, Farrer lost his mother when he was eight years old. She died of tuberculosis. Soon after the death of his mother, young Farrer won a scholarship to the historic Christ's Hospital (Blue Coat) School in London. Entering the school at the age of eight in 1853, he graduated at nineteen with the highest honours in mathematics and as a "Grecian" - a kind of Head Prefect/Junior Master rolled into one.

Farrer went on to Cambridge University to study

Arts, again on a scholarship. He graduated from Cambridge with the highest distinctions in mathematics in 1868 when he was 23 years old.

Although originally aiming for a career in the Law, Farrer decided to return to Cambridge to study medicine. Towards the end of his first year in medical school, Farrer discovered, that like his mother before him, he had the beginnings of tuberculosis in his lungs.

An Australian friend at Cambridge, Frank Betts, apparently convinced Farrer that the climate in Australia would be good for him. So Farrer abandoned medicine and made his way to Australia. He was about 25 years old when he landed in Sydney in 1870.

I have outlined Farrer's educational background and, in particular, the depth of training he received in the mathematics discipline, in some detail for reasons which will become clearer in a little while.

Soon after arriving in the colony of New South Wales, Farrer was employed as a tutor by the Campbell family at Duntroon Station (where the Royal Military College is now located). Over the next three years, he took a great interest in the grazing and farming activities of the southern tablelands. By 1873, he felt so strongly about the need to apply science to finding solutions to the problems faced by the farmers and graziers with whom he was acquainted, that he published a pamphlet entitled "Grass and Sheep Farming, a Paper Speculative and Suggestive, by William Farrer, B.A., Pembrooke College, Cambridge".

Motivated in part by the heavy sheep losses from internal parasites in the early 1870s, Farrer's pamphlet was extremely critical of the complete lack of agricultural education and scientific investigation in the colonies. In his pamphlet, he pointed out that America had land grant colleges in almost every state "in which not only agricultural chemistry and scientific agriculture are taught, but at many of her colleges practical instruction is also given".

Farrer stressed the progress which had been achieved in American agriculture following the end of the American Civil War. He argued that this progress was due to the influence of the land grant colleges which had received generous government support. He called for a similar approach in the Australian colonies.

The Australian continent was rich in resources potentially suitable for agricultural production but these natural resources would not be easily tamed. Farrer knew the value of education and science in equipping people to meet the challenges of Nature.

In the Australian context, Farrer was ahead of his time. He was apparently surprised and disappointed when his little pamphlet on "Grass and Sheep Farming" did not seem to have any impact. But perhaps it was more influential than he thought. Within twenty years of its publication, Roseworthy, Hawkesbury and Dookie Agricultural Colleges were all established, to be closely followed by Gatton College.

In particular, who is to say what part Farrer played in the chain of events which led to the establishment of Hawkesbury Agricultural College in 1891 and which, therefore, is celebrating its 100th Anniversary this year. Clearly, he strongly supported the idea of establishing such a college as early as 1873. It is hard to imagine that he did not play a modest role in persuading the New South Wales Department of Agriculture to establish Hawkesbury. Indeed, in 1889, he wrote to a leading American scientist and fellow wheat breeder named Blount who was working in Colorado, suggesting that Blount apply for a position that was about to be created at a new agricultural college (presumably he had Hawkesbury Agricultural College in mind since it opened in 1891). Blount had previously written to Farrer expressing a desire to come to Australia. It is also known that Farrer took a keen interest in the College once it opened. Whenever he travelled to Sydney in the early 1890s, he made a point of visiting the College. Indeed, it is recorded he bought a college bull (probably a Jersey) for the small herd of cows he ran on his little farm located near Queanbeyan. After he became Wheat Experimentalist with the New South Wales Department of Agriculture in 1898, Farrer would have had more formal ties with the College.

(c) Farrer's recognition of the value of international cooperation in agricultural research

While Farrer's parents were tenant farmers of modest means, he must have enjoyed wealthy family connections. It is not clear how he acquired the necessary funds, but his intention at the time he came to New South Wales in 1870 seems to have been to buy a pastoral property in the colony once he had acquired sufficient practical experience. Unfortunately, he lost his stake with some unwise investments in mining ventures. As a result, he decided to capitalize on his mathematical training and become a surveyor. After some preliminary experience with local surveyors, he studied for and easily passed the necessary examinations, becoming a registered surveyor in mid-1876.

As a surveyor with the Lands Department of New South Wales, he worked extensively in the Dubbo, Forbes and Cooma districts between 1876 and 1886. In 1882, he married a lady whom he had met first during his time with the Campbell family at Duntroon Station. The newly married couple acquired the small farm "Lambrigg" which was to be the site for all of Farrer's experiments until he became Wheat Experimentalist with the New South Wales Department of Agriculture in 1898.

It was also in 1882 that he published his first statements in *The Australasian* newspaper arguing that it should be possible to obtain wheat plants which could resist rust. The idea that cross- breeding and selection were the best solution to the rust problem was ridiculed at the time. Farrer later stated in his address to the Australasian Association for the Advancement of Science in 1898 that "the controversy (in 1882) ...convinced me that an opening existed here for useful work, and that work I determined to take in hand if ever the opportunity should be given me ..... Experimental work began in 1889, although a little had been done at great disadvantage, and very unsatisfactorily in 1885..... It was not until 1889 that the first attempts at cross-breeding were made...".

During the early 1880s while Farrer continued his work as a surveyor, he began to make contact with wheat breeders in many parts of the world. By correspondence with these people, he gradually acquired up-to-date knowledge and samples of wheat varieties from such diverse sources as Egypt, India, the United States and Europe. He was also busy establishing a network of like minded people in other Australian colonies, especially in South Australia and Queensland.

Even before he resigned his position as surveyor with the Lands Department in mid 1886, Farrer had become well acquainted with Professor Blount's work at Colorado. Indeed, Blount had sent Farrer samples of his latest crossbred varieties and it was probably from Blount that Farrer acquired detailed knowledge about cross-breeding techniques. Remember, Farrer had studied Arts and, in particular, mathematics at Cambridge. His detailed botanical knowledge of the wheat plant must have been acquired much later.

Farrer's basic knowledge and skills and much of his best genetic material came from overseas. He perceived his craft to be an international undertaking. He freely and unselfishly exchanged ideas and genetic material with other breeders both in Australia and overseas throughout his career. International cooperation made it possible for him to import first the knowledge and then the genes necessary to breed wheats better suited to Australian conditions. In turn, some of his varieties became widely used both commercially and for breeding in many countries including Kenya, Algeria, France, Canada and the United States.

2. Human Capital Formation for Sustainable Rural Development

Let me now return to "sustainability and agricultural education".

"Sustainability" is **not** new. While Farrer would never have used the word, I have demonstrated that he was concerned about sustainable agricultural systems. Most traditional farming systems are sustainable - albeit at a relatively low level of productivity.

What is new is a growing awareness that many modern agricultural production systems are not sustainable in perpetuity. In many countries, so-called "agricultural development" based on modern scientific advances has replaced the traditional sustainable farming systems. The new farming systems are imposing enormous burdens on the environment and in many instances they appear to be unsustainable in the longer term. A general example in the Australian context is the emerging widespread soil degradation problem. It is now clear that the farming practices which have been in use in many areas of Australia over the last three or four decades, are not sustainable in the long term because they gradually destroy the soil.

Agricultural education is an expensive process. It is an investment that creates human beings (human capital) capable of contributing to the improvement of the food and fibre sectors for 40 years or more.

The question that interests me is how best to train future research scientists and research administrators so that they are better equipped to address the difficult problems of sustainability in relation to agricultural production systems. I am interested in human capital formation for rural development not just in Australia but on a world-wide scale.

There has been a permanent shift in public attitudes. The media exposure of the concepts associated with sustainability has induced public opinion in most countries to incorporate ideas and attitudes which, less than a decade ago, were limited to dedicated but numerically small "greenie" groups in a few wealthy countries. The current widespread public concern about the sustainability of human activities is not a passing fad.

In particular, the public are demanding sustainable agricultural production systems. These demands have generated enormous challenges for agricultural scientists. At the same time, university programs and research administrators have been slow to respond.

On a world-wide basis, the number of university courses in agricultural science and related disciplines such as agricultural economics and farm management, increased dramatically in the 1950 to 1990 period. One of the most important factors influencing this growth in tertiary training opportunities was the perceived need to enlist the assistance of modern science to solve the world food problem. That is, for the last four decades, agricultural education at the tertiary level has been primarily orientated to increasing food production. Consequently, a large proportion of the human capital (researchers, extension workers, agricultural administrators and agri-businesspeople) created by these educational programs has been used to address production related problems. The result has been a massive increase in agricultural productivity. But these gains have not been achieved without putting great pressure on the natural environment.

Gradually, the negative impacts of the gains in agricultural productivity (soil degradation, salination, species extinctions, etc.) have become increasingly obvious and important. The recent growing public awareness of the need to develop sustainable agricultural production systems has given respectability to ideas which previously were dismissed by many production oriented educators, administrators and scientists as counterproductive.

3. The Challenge for Agricultural Educators

University programs have been slow to adjust to the new reality. While the intellectual challenges associated with "making two ears of corn grow where one grew before" inspired agricultural scientists in the mid 20th Century, the challenge for the 21st Century is how to ensure that the hard won gains of the last 40 years can be maintained and even developed further within sustainable farming systems.

Two fundamental changes need to be widely implemented if mainstream tertiary agricultural education and research is to answer the sustainability challenge.

First, undergraduate and postgraduate curricula in agricultural science must provide a greater awareness of the long-term costs and benefits of technological and social change. As Farrer recognized more than a century ago, sustainability refers not only to physical environments but to social and economic environments as well. Indeed, it is the conflict between these two aspects of sustainability which creates most of the fundamental problems facing Australian agriculture today.

Second, researchers need to be taught how to identify the real problems and to be rewarded for tackling these issues. A great deal of the agricultural research effort over the last 40 years has been misdirected. Most decisions about *precisely* what research will be undertaken are in the hands of the researchers themselves. Their concepts of "what counts" towards their own professional advancement greatly influences *exactly* what research is undertaken. We need to question whether the traditional personal reward structures for agricultural scientists are consistent with the social goal of working towards long-term sustainable agricultural systems.

4. The Knowledge Explosion: The Need for a New Strategy

The amount of scientific information relevant to agriculture has expanded greatly in the last 40 years. No longer is it possible to "cover everything" even in relatively highly specialized university programs. A new strategy for training agricultural scientists is required.

Some would advocate the holistic agricultural systems approach. While there is great merit in a systems approach to research (see, for example, Nagy and Sanders 1990), it is not the answer in regard to educating scientists to tackle the problems associated with the development of sustainable production systems. Students still need a rigorous disciplinary base on which to build. The question is which disciplines and what degree of depth in each is required?

Of course, some people would claim that, as in Farrer's case, it does not matter which discipline one studies. What is important is that the student experiences the thrill and confidence which comes only with the mastering of a particular field of study. Farrer studied and mastered mathematics. He learnt the benefits of attention to detail and the need for patience and perseverance in the search for facts if real progress is to be achieved. These lessons were to serve him well when he turned his attention to wheat breeding. But Farrer must have also studied other Arts subjects at Cambridge. Throughout his adult life, he was an avid reader and he was considered by his contemporaries to be a man of culture. It could be argued, therefore, that Farrer's education involved both a deep disciplinary study of mathematics and a general exposure to social and cultural issues.

Another aspect which needs to be considered in regard to the training of agricultural scientists in Australia is that very few students entering faculties of agricultural science are among the top students graduating from high school. Of course, there are exceptions, but in general, as was the case in Farrer's day, the best scientists will have been top students at high school. While many of today's best students like Farrer 130 years ago, aim to enter the professions such as Medicine or Law, a significant number gravitate to the pure science departments. If in the future we want some of the best scientists in the country to be working on agricultural problems, then we need to be seeking to attract postgraduates and postdoctoral students from the pure science departments into agricultural research.

The traditional Australian agricultural science course builds on the basic physical and biological science disciplines. Exposure to the social and behavioural sciences, while it has increased in recent years, is still inadequate. These traditional programs, for the most part, do not place sufficient emphasis on the social science concepts relevant to analyzing sustainable rural development issues.

Sustainability must be perceived as a community-wide phenomena. To be sustainable, an agricultural production system in a commercial economy like the Australian economy, must satisfy the economic and social requirements for the development of the rural community. That is, "sustainability" implies that much broader issues need to be addressed than are contained in the narrow biological and technological subjects which represent the core of traditional agricultural science training programs.

5. Sustainable Development: Some of the Broad Issues

Let us now explore some of the broader issues associated with sustainability in some detail.

In Australia, as in all countries, farmers and graziers are embedded in a local community which in turn is part of the agricultural sector. The agricultural sector is part of the whole economy. Changes which improve the incomes and well-being of farmers and graziers generate better business conditions in the local rural community. A prosperous rural sector contributes to improved economic conditions in the general economy.

Sustainable development - that is changes and improvements which are sustainable in the long term and which lead to a higher level of well-being for society - is a major goal both in Australia and elsewhere. But sustainable development, especially in regard to the rural sector, is a more complicated concept than many advocates of the idea acknowledge. In an excellent brief review of the issues associated with the concept of sustainable development, a Canadian agricultural economist, Terry Veeman (1989), suggests there are three interwoven aspects to be considered: a growth component, a distributional component and an environmental component. The following three sub-sections draw heavily upon Veeman's ideas.

(a) Growth component

Early theories about economic growth placed great emphasis on the accumulation of physical capital and the need for a high marginal rate of savings to finance capital accumulation. Gradually, the emphasis shifted to acknowledge the contribution of human capital formation to the growth process. The recent emphasis on sustainable development has added two more dimensions: the need to give greater weight to the stabilization of growth over time and to the intergenerational implications of economic growth; and the need to emphasize the role of natural resources in long-term economic growth.

There are two major difficulties with the traditional approach to analyzing economic growth which the recent renewed interest in sustainability has moved to centre stage.

The first concerns the hypothesis that the role of natural resources in economic progress declines as economies become more industrialized. There are at least two compelling reasons why this hypothesis should be rejected. First, many of the natural resource products and services which are inputs to human well-being (e.g. clean air, personal space, 'green' surroundings) are not included in the conventional indicators of growth such as changes in GNP. Secondly, the income elasticities of demand for these (mostly non-market) products and services appear to be extremely high. Therefore, from both the supply side and the demand perspective, natural resources tend to become increasingly important determinants of aggregate human welfare as growth progresses.

The second major difficulty with conventional discussions about growth which the sustainability debate has highlighted is that national accounting measurement procedures do not allow for the depreciation/deterioration in natural resource assets. Improvements in national income (and hence economic growth) based on changes in such indices as GNP, therefore, may seriously overstate the true rate of improvement in the welfare of the society.

Technological change and economic progress based on increased productivity makes sustainable development possible. Yet, paradoxically, this growth aspect of sustainable development is frequently in conflict with the other two aspects of sustainable development (i.e. the distributional and the environmental aspects).

Agricultural students need to be educated to appreciate the complexity of this paradox. They must be given a conceptual framework and a set of analytical tools/skills with which to resolve this conflict on a case-by-case basis. Traditional agricultural science curricula have concentrated on scientific and technological approaches to increasing productivity and hence growth. They have not developed human capital which can recognize and contribute to the solution of the growth/sustainability paradox. Hence, the emergence of a plethora of environmental science courses. Agricultural scientists have become the "bad guys" trained to exploit the natural environment in the name of increased productivity and growth. Environmental scientists are the "good guys" trained to protect the environment for future generations.

Agricultural educational programs for the future must seek the middle ground. They must be designed to train people who can devise agricultural production methods which both contribute to increased productivity (growth) **and** satisfy the distributional and environmental aspects of sustainable development.

(b) Distributional component

Economic growth only improves the well-being of society in general when the benefits of growth are widely distributed.

A major debate has emerged in the last decade about whether agricultural research projects should be screened for distributional consequences. Research, for example, which promises to lead to significant growth (increased agricultural productivity) but which will benefit large-scale producers rather than the smaller family farmers, is seen as inappropriate research. This raises at least two questions.

First, can research administrators identify such "inappropriate" research ex *ante* with any certainty? Research originally conceived as inappropriate on "distributional" grounds may become most appropriate *ex post*. As in the case examined by Yee and Longworth (1985), this could occur because the advances achieved eventually prove not to be biased either towards larger producers or towards certain factors of production (e.g. capital) because conditions in the factor markets (and hence factor rewards) change during the gestation of the research.

Secondly and more fundamentally, should agricultural research be used to solve distributional problems in the rural sector? Research policy is an extremely blunt instrument with which to attack such problems. Other more direct policy measures such as tax reform and land tenure reform are more appropriate.

This is not the place to pursue this debate. However, it illustrates the critical need for agricultural educators who are training future agricultural researchers and administrators to acquaint their students with these broader issues of research policy. While the need to develop appropriate technology in a technological sense is relatively straightforward, the broadening of the definition of appropriate technology to encompass its distributional consequences raises a more complicated set of issues. Most agricultural science students are not being trained to understand or to address these distributional aspects.

(c) Environmental component

Economists have a long tradition of tackling environmental issues rather differently from biological scientists. The concepts of externalities, property rights, optimum rates of depletion, and option values are only four of the many ideas which economists have developed to help analyze environmental issues. Perhaps the biggest difference between the economists' paradigm and that of most biological scientists, is that economists do not perceive natural resources as a fixed quantum with a predetermined finite capacity to satisfy the needs of mankind.

Instead, economists stress the ingenuity of man. Our capacity to adjust over time and our creation of new institutions (e.g. property rights), technological change (e.g. development of fusion energy) and substitution opportunities (e.g. alternative food sources) can all greatly change the value to society of a particular set of natural resources. In general, economists are more optimistic and positive about the environmental component of sustainable development than most biological scientists (see Goeller and Weinberg 1976).

Natural resources are often grouped into renewable or flow resources (fisheries, forests, rangelands, natural populations, etc.) and non-renewable or stock resources (minerals, etc.). For certain analytical purposes, this is a most convenient division.

In the case of renewable resources, a number of conservation or management strategies have been suggested by biologically trained scientists such as maximum sustainable yield (MSY) and optimum stocking rate or carrying capacity. Unfortunately, in practice, it is usually extremely difficult to implement these strategies with any degree of precision. Furthermore, they are not usually optimal in an economic sense. Normally, for example, the economic optimum level of use for a renewable resource will be less intensive than that suggested by the MSY criteria. This is another instance where the paradigm of the economist is more constructive and positive with respect to the environmental component of sustainability than the approaches advocated by ecologists and other biological scientists.

There is a world-wide need for mankind to develop appropriate policies and management strategies for renewable resources such as soil, pastures, native forests, and native terrestrial and marine animal populations. In many parts of the world, over exploitation is causing irreversible changes. Renewable resources are becoming non-renewable. Appropriate policies and management strategies can not be developed nor successfully implemented from a purely biological perspective. For example, new institutions which create appropriate economic and social incentive structures are usually required. To be relevant in the future, agricultural research will need to address these non-biological constraints to the development of sustainable systems.

In the case of non-renewable resources, questions about how and when they should be utilized raise such issues as intergenerational equity, option values and resource stewardship. Indeed, even such fundamental philosophical questions as the rights of man versus the rights of other living creatures, may also be raised.

None of the ideas and broad issues discussed above are new. Yet, traditional agricultural science education, based as it is on the basic biological and physical sciences, does not equip students to address these complex matters. Future training programs will need to recognize and remedy these deficiencies.

6. The Challenge for Agricultural Research Administrators

Agricultural scientists have made great progress in the last 40 years in terms of raising agricultural output per unit of land and per unit of labour. A great deal of "the right" research must have been successfully undertaken. At the same time, enormous amounts of time and effort (money) have been devoted to "research" which has had no practical pay-off. A major part of the motivation for most research activity is the personal rewards it will bring to the researcher. Research administrators and policy-makers must be careful to structure the reward system so that "appropriate" research is rewarded the most.

Unfortunately, traditional reward structures for agricultural researchers, especially those employed in publicly funded research institutions and universities, do not encourage people to address directly the complex problems associated with sustainable development. The long term, multi-disciplinary, non-scientific features of the problems involved "frighten" young, ambitious and capable agricultural scientists.

The challenge for agricultural research administrators of the future is how to attract the best researchers to these complex areas of research. Two major barriers to progress are the conventional disciplinary divisions between research groups and conventional wisdom among agricultural scientists as to what constitutes "good research".

Researchers, like all human beings, prefer to work with and to receive the acceptance (accolades) of their peers. Consequently, research institutes and university departments tend to develop enclaves of scientists of like training (and hence values). Cross-fertilization of ideas is actively discouraged because the "best" journals in any field only accept research papers which maintain the traditional paradigm for that discipline. Future agricultural research administrators will need to break down these disciplinary barriers if worthwhile research on the development of sustainable systems is to be undertaken.

For most agricultural scientists, the personal need to be accepted as a scientist is in conflict with their social responsibility to tackle the major sustainability problems facing agricultural industries. Agricultural educators and research policymakers and administrators need to be fully aware of this conflict. Unless this problem is addressed, the raison d'etre for agricultural science education as distinct from a general scientific education, will disappear.

7. Conclusions

Sustainable agricultural development is like motherhood, no reasonable person is opposed to the idea in principle. Yet in practice, much of modern agricultural output arises from production systems which appear to be unsustainable in the longer term.

Gradually, the future sustainability of a large part of agricultural production has become an important issue in many countries. Agricultural educators, scientists and research administrators who have played a major role in the development of modern agriculture over the last 40 years, have been slow to recognize the new challenges ahead.

There are no easy solutions. However, the problems associated with sustainability are not amenable to purely scientific solutions. The economic and social dimensions are critical if meaningful progress is to be achieved. Sustainability issues will require agricultural educators, scientists and research administrators of the 21st Century to place greater emphasis than has been the case in the past, on social and economic aspects of agricultural production systems.

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