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Report by - Geoffrey Saul – 2000 Churchill Fellow

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“Sustainable Agricultural Systems for Southern Australia – learning from European experience”

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1. Acknowledgments

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Staff at Agriculture Victoria, Hamilton, especially Paul Quigley, Trevor Pollard and Sandra Cattermole undertook additional work and responsibilities during my absence from Victoria. I am most grateful for their efforts, especially as it involved the busy period when projects were being costed. I would also like to thank Sandra for assistance in helping with the preparation and printing of this report.

On the study tour, I visited 19 research stations, 16 private farms and met with over 80 scientists in the UK, Ireland, Norway, Denmark and Germany. Full details of visits are provided later in this report. In addition, I attended 3 international conferences with associated visits to farms and agricultural industries. In all cases, I was made feel most welcome and people gave freely of their time and hospitality. Though it is difficult to single out individuals, I would like to especially thank Dr Paul Poulton from Rothamsted, Professor Martin Korchens at Halle and the scientists in Teagasc, Ireland whose assistance and time input was exceptional.

Special thanks must go to my wife Sue. She provided considerable encouragement to apply for the fellowship and supported me through the application and interview stages. Sue accompanied me for part of the European visit and without her navigational skills, I would probably still be looking for some of the UK sites, especially around Newcastle! She also provided great assistance with domestic arrangements in Europe, allowing me to concentrate on the visits and meetings.
2. Executive Summary; Sustainable Agricultural Systems for Southern Australia

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A Churchill Fellowship, provided by the Swire Group allowed a study tour to be undertaken to Europe. The aim of the fellowship was to determine ways to improve the sustainability of agricultural systems in southern Australia. During the study tour, I visited 19 research stations, 16 private farms and participated in 3 international grassland events including the 18th European Grassland Federation conference.

An opportunity to visit fertiliser experiments that have been running for over 100 years was a significant feature of the fellowship. These sites are now being used to quantify the impact of agricultural practices on environmental sustainability. Meeting with leading agriculturalists including Prof. David Leaver, Prof. Roger Wilkins, Prof. Jeff Maxwell, Dr Sinclair Mayne, Dr Padraig O’Kelly, and Dr Phil Haygarth and participation in three international conferences were also highlights of the study tour.

Significant findings include:
- There is the urgent need for temperate Australia to develop and implement sustainable agricultural systems that encompass the “triple bottom line” of economic, environmental and social sustainability.
- European research indicates that high input production systems (HIPS) are sustainable in the long-term, provided balanced nutrient inputs and management practices are adopted.
- P loss to waterways is a major environmental problem in HIPS. There is an urgent need to understand how P moves to waterways and develop management systems to reduce waterway pollution.
- Biodiversity in agricultural systems is a contentious issue in Europe and there is growing evidence of a negative relationship between productivity and floristic diversity in high rainfall systems. A mosaic of different vegetation types across farms, each managed for a specific outcome, provides a better result than trying to achieve all outcomes from the same land area.
- Many European countries have developed policies to keep people living and working in rural areas as the number of people employed on farms declines. While outside the scope of this fellowship, it is an important aspect of social sustainability in rural communities.
- There has been a rapid growth in agro-environmental schemes in Europe but many rely on high government support. However “Linking Environment And Farming” (LEAF) encourages farmers to adopt sound agriculture practices, has wide support and does not rely heavily on government support.
- Organic farming is increasing in Europe, partly using the high soil fertility built up over the last 50 years of high chemical fertiliser use. Under the current soil and production regimes in Australia, there appears to be limited potential for large-scale development of organic meat or wool systems.
- Research outcomes in southern Australia could be improved by greater emphasis on Strategic compared to Applied research. Also, funding arrangements that increase collaboration between research and extension providers and scientists undertaking production, environmental and social research could improve the development and adoption of sustainable agricultural systems.
- Long-term experiments (20-150 years old) are used extensively in Europe to understand the sustainability of agricultural systems. A national audit of Australian experiments could be used to encourage linkage into world networks, build local collaboration and ensure efficient use of the sites.
- There are many opportunities for collaboration between European and Australian scientists including silage production, internal parasite control and health benefits of meat from pasture.
- **Dissemination of information.** Knowledge from the study tour will be incorporated into future research submissions to both Victorian and Rural Industry Research Corporation funded projects. The rural media will be used to provide information directly to farmers. Seminars will provide details of sustainable agricultural systems and other potential collaborative research ideas to NRE staff.
3. Introduction

A recent Rothamsted paper (Powlsen and Poulton 1998) defines sustainable agriculture as "development that meets the needs of the present without compromising the ability of future generations to meet their needs". Maxwell (1998) stressed that sustainability must encompass economic, environmental and social aspects and highlighted the need to assess trade-offs to balance the conflicting demands of these issues. Agriculture in southern Australia must accept the need to maintain current productivity and ensure future prosperity of farmers and rural communities. Until recently, economic aspects of agriculture have dominated R&D and while environmental sustainability is now part of the research agenda, social impacts of agricultural systems are still rarely considered.

R,D&E in the high rainfall zone of southern Australia is recommending more intensive production systems to increase economic returns. In Europe, there has been a backlash against intensive systems. We need to learn to balance between productivity (economic survival) and pushing too hard and causing environmental damage, or alienating overseas customers through the perception that unsustainable grazing systems are used in Australia. However, because Australia relies on exports of agricultural products, productivity improvement is vital. There is also growing awareness of the social impact of new agricultural systems. Plantation forestry and cropping, which are taking over large areas of the high rainfall zone, are a major concern to many people.

I also have a particular interest in long-term agricultural research sites in Europe where different nutrient systems have been compared for over 100 years. Agriculture Victoria, Hamilton has the only long-term (22 year old), grazed fertiliser experiment in temperate Australia and we need to learn how to make best use of this unique resource. Information from sites at Rothamsted (UK) and in Germany is used to understand the consequences of different practises on long-term productivity and environmental issues. Learning from these sites and researchers will help plan the future of the Hamilton experiment.

The information presented in this report was obtained through participating in several key events. The British Grassland Society held a 3-day conference titled "Grazing Management" at which I presented a summary of recent Australian research. I also attended the 18th General Meeting of the European Grassland Federation titled “Grassland Farming- Balancing Environmental and Economic Demands” and presented a poster highlighting key aspects of sustainability in western Victoria. The British Grassland Society Summer meeting, “Industries in Crisis-Simple Survival Strategies” provided an opportunity to meet with leading farmers and scientists from across the UK. I also visited 19 research institutes and 16 private farms in the UK, Ireland, Norway, Denmark and Germany.

4. Development of agricultural systems in temperate Australia

The agricultural areas of southern Australia were settled in the 1800’s and until the early 1900’s, large pastoral runs dominated the sheep and cattle industries. After both world wars, large-scale soldier settlement schemes led to many of these properties being split into small lots for sheep and dairy production. Bishop (1964) discussed the changes in land use and productivity between 1900 and 1960. He showed that sheep numbers in western Victoria increased from around 4M to 10M while over 4M tons of fertiliser had been applied in western Victoria by 1960. The area sown to improved pasture species also increased dramatically during this period. A similar
pattern is evident in other areas of southern Australia although fertiliser use and pasture improvement in NSW and Tasmania was significantly lower than in western Victoria.

From the 1960’s to the end of the century, it is more difficult to determine trends in the grazing industries. Kemp and Dowling (2000) have argued that pastures are less productive now than in the “good old days” of the 1950-60’s. This could be expected given reduced fertiliser and pasture management inputs. However, there is little hard evidence to support this view. Data from the South West Victorian Monitor Farm Project (Beattie 1999) shows no significant change in the carrying capacity of farms in western Victoria over the last 30 years. The data of Kemp and Dowling (2000) does not show any real trend in stocking rate in NSW between 1975-95 apart from drought induced fluctuations. However, this is not to say that temperate pastures are in any way producing to the potential of the environment in which they are grown. Saul (1997) has suggested that most western Victorian pastures are only producing to half of their capacity.

There is a perception that these supposedly declining stocking rates and low pasture productivity values are a sign of failure of high input production systems (HIPS) that have promoted heavy use of fertilisers, herbicides, pesticides and high stocking rates. This failure is also blamed for many of the environmental problems that currently beset temperate agriculture in Australia. However, the question must be asked, have Australian temperate farmers really been using high input systems? If so, have they been used appropriately?

In southern Australia, pasture development only became significant after WWII and high fertiliser use only occurred in 1950-60’s. There is anecdotal evidence that fertiliser use decreased dramatically in the late 1960’s when the subsidy for superphosphate was removed. Computer models such as Superate also discouraged fertiliser applications in the 1970’s. Fertiliser use continued to decline until the Grassland’s Productivity Project (GPP) and Triple P extension programs (Court 1998) started promoting higher fertiliser use in the 1990’s. There has also been a poor understanding of the need for periodic maintenance of pastures with most farmers adopting a “sow and forget” attitude to pasture management.

Schröder (pers comm) has shown that farmers in western Victoria can be broadly divided into 2 groups based on their views on how best to manage grazing properties. “Intensive producers” focus on productivity and revenue whereas “Extensive producers” aim to reduce costs. While it is unclear the proportion of each group in the farming community, it is generally accepted that “Extensive producers” control by far the largest land area. The “Intensive producers” have probably always existed but have been encouraged by recent pasture extension programs such as the GPP and Triple P.

In summary, during the 20th century, the high rainfall temperate pasture zone of southern Australia has been dominated by extensive production systems. These systems have “mined” the soil, resulting in low nutrient and pH values, loss of sown perennial pasture species, weed invasion and either a decline in productivity or failure to increase productivity to known potential under optimum pasture management.

The Hamilton Long Term Phosphate Experiment (Saul et al. 1999) and the subsequent extension programs have resulted in rapid adoption of more intensive and managed pasture systems than previously practised in southern Australia. This rapid adoption phase has been underway for 10 years with about 600 farmers directly taking part in the structured extension programs, 10,000 farmers visiting trial sites or attending presentations on intensive systems and many other
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producers using private consultants for advice. Trompf et al. (1998) have shown that farmers who participated in GPP doubled their fertiliser use, increased stocking rates and the area of resown pasture on their farms compared to non-participants. Adoption of HIPS has been the largest change in attitudes to agriculture in southern Australia in the last 30 years.

We need to determine how far should these systems go in striving for higher production and economic returns. What is the limit to P applications and what problems will arise with higher soil P levels? Will HIPS adversely effect the local and wider environment and if so, what trade-offs are required to meet both economic and environmental goals? Will highly productive pastures collapse under adverse climatic conditions? What about effects on soil pH? Are soil organisms harmed by HIPS? What about N fertiliser for intensive systems in southern Australia? These are some of the questions that are being asked by farmers and extension agents. Given the longer history of intensive pastures in the UK, my aim was to learn from experience in these areas to try and avoid problems developing in southern Australia.

5. Development of intensive agricultural systems in England

Food shortages in the UK during the WWII, caused a major change in British government policies. Prior to 1940, the UK relied heavily on imported food from Commonwealth countries but during and after the war, the government encouraged intensive agricultural practices to rapidly increase food production (Frame 1995). This lead to a doubling of beef and lamb production and trebling dairy production, though the area under grassland was reduced due to the expansion of urban communities and increased arable farming (Hopkins and Hopkins 1994).

Roger Wilkins (pers comm) has charted the recent history of R&D in grassland research in the UK as shown below.

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Production research was about growing more grass, using more fertiliser, improved pasture species, pesticides, herbicides etc. An emphasis on higher quality saw issues such as the use of silage rather than meadow hay for housed livestock become a high priority for research. Good quality silage and efficient handling machinery also allowed rapid expansion of stock numbers. Efficient use of pastures came to the forefront in the 1980’s when the Sward Surface Height system of measurement was adopted across the UK. In the 1990’s, considerable R&D effort was directed to understanding the impact of agricultural practices such as P and N fertiliser use on the local and wider environment. The current emphasis is to study how agriculture can benefit the environment.

An important change in the UK in the 1990’s was a move away from R&D which focussed on economic benefits to farmers, to research that is focussed on the 3 pillars of sustainable agricultural systems; economic, environmental and social sustainability (Maxwell 1998). The importance of balancing these 3 issues is now well accepted in the UK. In the future, Wilkins and Vidrih (2000) suggest that agricultural research needs to consider biodiversity and landscape issues, food quality, ways to reduce unit costs of production and improved utilisation of grasslands.
6. **Agricultural and community concerns about intensification of grazing industries**

After visiting and talking with many scientists in Europe, it is my view that issues of biodiversity, nutrient loss to waterways and social impacts of changing agricultural practises are the key issues where we can learn from European experience. These issues are discussed in the following sections.

**Biodiversity and agricultural production - Pastures**

There is considerable debate in Europe as to the importance of biodiversity in rural landscapes (Wilkins and Harvey 1993, Johnson *et al.* 1996, Hamilton and Cresswell 1999). Many members of the urban community perceive that rural landscapes are monotonous and dominated by canola and intensive grasslands that are visually unattractive. Intensive agriculture may also lead to a loss of both insects (particularly butterflies) and other animal species from the countryside as many require specialised habitats for survival (Wilkins and Harvey 1993). This loss of wildlife has been exacerbated due to clearing hedgerows to improve the efficiency of agriculture. The interest in plant and insect biodiversity was apparent in the large number of posters at the conferences related to these topics.

There is also debate as to the importance of the biodiversity (or number) of plant species in pastures and any relationship with improved pasture and animal production or improved “resilience” of pastures to periodic environmental stresses such as drought (Johnson *et al.* 1996). The perception amongst some groups especially those with an organic or ecological leaning (“greens”) is that a pasture dominated by only 2-3 species (or cultivars) will be less productive than a more diverse pasture and could collapse under environmental stress such as drought, overgrazing, trampling etc. Also, a more diverse pasture should be able to better utilise the range of conditions found in most farm paddocks.

In Australia, there is also debate on the importance of biodiversity in rural landscapes, especially the value to resilience of pasture based systems (Lodge 1998). Landcare has also promoted the importance of providing areas to encourage wildlife especially birds and insects back into pastoral environments to act as natural control systems. Therefore, some discussion on ways to resolve the apparent conflict between agricultural production and biodiversity is warranted.

Wilkins and Harvey (1993) have highlighted the incompatibility between management to increase agricultural production and nature conservation. They suggest that the practises commonly used to increase agricultural practises will have a negative effect on the number of plants, insects and birds. Rotational rather than continuous grazing was the only agricultural practise to enhance biodiversity.

A negative relationship between biomass production (hay yield) and diversity of pasture species has been shown in the Park Grass experiment at Rothamsted (Tilman *et al.* 1994). Figure 1 shows that the most productive pastures are dominated by only a few species. Similarly, Hopkins and Pinto (1998) reviewed the compromises between the use of inorganic fertilisers and conservation and concluded, “no amount of inorganic fertiliser was compatible with maintenance of floristic diversity”. Wilkins (pers comm) has shown that as N fertiliser applied increased from 0-200 kg/ha, pasture output doubled but the number of plant species declined by 50%. An experiment in Wales (Fothergill pers comm) is studying the effect of reducing fertiliser and lime inputs in an attempt to increase species diversity. After 10 years, pasture production from the un-limed, un-fertilised plots declined by 50%, with little improvement in species diversity.
High plant species diversity has been suggested to improve the ability of a pasture system to cope with environmental stress such as drought, insect attack etc. These issues are more important in Australia than Europe and justify further study.

Results from Europe suggest that in high fertility pasture systems, there will be small numbers of well adapted pasture species and these will out compete other species, despite attempts to sow or intervene with other management techniques to maintain a wider range of species. Low soil fertility systems maintain a much wider range of pasture species but with a large (>50%) reduction in carrying capacity. I believe that for southern Australian pastures, provided one improved perennial grass is maintained together with an appropriate legume, there will be little value in trying to increase the number of species in any one pasture. However, this is not to say that a range of different pasture types should not be maintained across the farm, rather that it is a futile exercise trying to maintain a wide range of species in one paddock.

Most paddocks in Europe are small and relatively uniform compared to the large, variable paddocks in Australia. Some farmers argue that they like to sow a wide range of species or varieties to cover the range of soil, aspect, topography etc commonly found in paddocks. A better option is that areas with markedly different soils and conditions for pasture growth should be separated by land class fencing to ensure that appropriate species are sown on each area and managed accordingly. Using a “shotgun” approach to pasture species selection and management is inappropriate, costly and doomed to fail in most situations.

Maintenance of a varied landscape is required by the community (or will be in future years) and is also desirable to provide habitat for wildlife and insects. As was recommended by Wilkins and Harvey (1993), I believe that we need a mosaic of varying areas across farms and catchments. The majority of the farm should be managed for high pasture productivity with appropriate use of fertiliser, pasture species, grazing management etc. These pastures will therefore consist of perhaps 1-2 introduced grasses and 2-3 legume species. These desirable species should make up 50-90% of the biomass with other annual grasses and forbs making up the remaining amount, the
proportion varying with different seasonal and environmental conditions. Note that there may well be several different improved species on different soil or land types elsewhere on the farm.

Separate smaller areas need to be managed for biodiversity and habitat values. These biodiversity areas will still need to be managed (grazed, cut, sprayed, burnt?) to maintain the desired species but the primary focus is biodiversity and habitat, not pasture or animal productivity. It may be that these areas can be used by specific classes of stock at particular times of the year, ie wethers, bare shorn sheep.

One question to be considered is whether some payment (rate relief?) should be given to areas managed for biodiversity value. This is the most likely way to encourage farmers to move some land from production to biodiversity goals. Payments to encourage biodiversity are common in Europe where the general community appears to endorse this action. Whether the Australian community is prepared to pay for this type of environmental benefit is unclear.

Biodiversity and agricultural production- Soil microbiological flora
The impact of management systems on the microbiology of soils was considered early in the 20th century (Meiklejohn 1969) on the Rothamsted wheat experiment. Measurements of numbers and diversity of species were conducted at regular intervals and related to the soil conditions such as organic matter, soil fertility and soil pH.

Changes in the soil fauna caused by different agricultural practises on the long-term Palace Leas hay experiment at Newcastle University have been well documented (Robert Shiel (http://www.staff.ncl.ac.uk/r.s.shiel/index/html). The Newcastle site was established in 1896 with a range of treatments including farm-yard manure (FYM), and combinations of N, P and K fertiliser. Microbial activity and biomass are highest on treatments where FYM has been applied and soil organic matter is high. Intermediate microbial activity occurred on medium NPK plots. There was little or no activity on plots where ammonium sulphate had been applied and soil pH ($H_2O$) was 3.8. On these very acid treatments, the lack of microbial activity has led to a mat of un-decomposed grass in the top 5 cm of the profile.

Campbell et al. (1997) and Watson et al. (1996) have discussed ways to determine the level of microbial activity and diversity in contrasting pasture treatments. In July 1998, a new Soil Biodiversity Program (see web site www.mwnta.nmw.ac.uk/soilbio) costing over £3.4M per year was recently established in the UK. The remit of the program is “to determine whether there is a link between soil biological diversity and ecosystem function and understand biological diversity of soil biota and the functional roles played by soil organisms in ecological processes”.

It is apparent that as in Australia, researchers in the UK are still trying to understand importance and processes involved in microbial activity and biomass in agricultural systems. While it is very clear that gross changes to soils characteristics (low pH) will decimate soil biota and system productivity, whether less severe treatments cause a lasting impact is very unclear. Many scientists spoke of the ability of microbial populations to quickly respond once soil constraints were overcome. Cause and effect relationships were also very unclear. Poor microbial function seemed to only be a secondary issue when another soil parameter was grossly compromised. Therefore, it could be argued that provided that these more easily measured parameters (soil fertility, pH, soil organic matter) were monitored and maintained at acceptable levels, there would be little gained from expensive measurements of soil microbiology.
In Australia, a number of groups are promoting cheap spray and/or management techniques to improve soil microbial populations and hence pasture productivity. There was no evidence of this type of treatment being used in the UK. Given the difficulties in documenting changes in these microbial parameters in controlled field experiments, there would seem to be little chance of seeing any change in uncontrolled field conditions.

It is recommended that studies of the impact of contrasting agricultural systems on soil microorganisms be undertaken in conjunction with appropriate collaborators with skills in these disciplines. It is also be important for Australian researchers to maintain links with groups in Europe where considerable efforts are being made to unravel this relatively unknown science.

Phosphorus loss to waterways
Low soil P was a major limitation to grassland production in the UK and Ireland in the 1940’s. However, high use of phosphatic fertiliser after the war, has lead to many soils now having a higher P availability than is necessary for optimum pasture production (Tunney et al. 2000). Haygarth et al. (1997) summarised the P budgets for upland sheep and lowland dairy farms. They found that a combination of P fertiliser and P rich feeds imported onto the dairy farm resulted in an accumulation rate of 26 kg/ha P/year. In contrast, on the extensive sheep farm where little fertiliser or feed was imported, P accumulation was only 0.3 kg/ha/yr. Withers et al. (2000) calculated P accumulation for the last 60 years across the arable and grassland area of the UK at about 17 kg/ha/year. The rate of P accumulation has declined in recent years as farmers and advisers had become aware of the issue of over-fertilisation.

Critical soil P levels for optimum pasture production does not appear to be an important issue in Europe. Recent work in Ireland (Culleton et al. 1998, Culleton et al. 1999, Tunney et al. 1999) suggest optimum levels for silage and extensive grazing systems as Olsen P 12-24, and for dairy and meat production systems Olsen P 24-40. I was not able to obtain definitive recommendations for P levels for UK soils. However, to reduce P loss to water, the MAFF Code of Good Practise for the Protection of Water (MAFF 1998) recommends that no inorganic P fertiliser be applied where Olsen P exceeds 45 mg/l. Where Olsen P is 25-45 mg/l, it is recommended that P inputs should match off-takes. This suggests that Olsen P levels of 25 are seen as sufficient to maintain adequate pasture production. Most European soil samples are taken to 20 cm so the European soil recommendations are considerably higher than in Australia.

In contrast, in southern Australia, most soils are deficient in P (Olsen P 5-10) greatly restricting pasture and animal productivity (Saul et al. 1999). The Hamilton Long Term Phosphate Experiment and Triple P program have increased fertiliser use in western Victoria. P applications in western Victoria, increased from 6 kg/ha in 1986-92, to 10.2 kg P/ha in 1992-98 (Beattie pers comm). Data from the Hamilton long term Phosphate experiment suggests that an Olsen P of around 15 and annual applications of 15-20 kg P/ha/year provide the highest economic returns from sheep production.

In both Europe and Australia, a major concern in recent years has been the increasing occurrence of algal blooms due to eutrophication of lakes and waterways. The issue has generated high media and community interest especially when algal blooms have occurred in recreational waterways. In Europe, major problems have occurred on Loch Neagh, the largest lake in the UK and a major source of water for Northern Ireland. A web site www.afsni.ac.uk/research provides an excellent summary of current R&D on the Loch Neagh catchment.
In Loch Neagh, P pollution from industry and sewerage was initially thought responsible and targeted. Despite a significant reduction in the amount of P getting into the Loch from these sources, P levels continued to increase and it is now apparent that P movement from agriculture is the main source of pollution. A comprehensive study of the Loch Neagh catchment shows that there is a surplus (inputs – outputs) of about 13 kg/ha P every year. About 40% of paddocks in the catchment are classified as having “excess” P levels. Programs are underway to encourage farmers to soil test paddocks and only apply fertiliser if paddocks are deficient in P.

P movement to surface water is now receiving considerable attention with people at IGER North Wyke (Phil Haygarth, Steve Jarvis); Ireland, Johnstown Castle, (Hubert Tunney, Noel Culleton); MLURI, Scotland (Anthony Edwards); and Northern Ireland, Newforge Lane (Catherine Watson, Robert Foy) working on the problem. Work at North Wyke is focussed on understanding the ways P moves into waterways, but mainly funded to look at environmental aspects of P. In Ireland, the Johnstown Castle group is trying to balance environmental and production issues. An interesting technique used by Tunney et al. (1998) was to take samples of surface water from a long-term P fertiliser experiment. They found a strong relationship between soil P and P levels in water:

\[ y = 0.082 + 0.049x, \quad R^2=0.62, \quad p=0.95 \]

Tunney et al. (2000) proposed that soil P may be used to predict loss to water and that a “window” of soil P occurs whereby pasture yield is close to optimum and loss to water is minimised. Figure 2 is adapted from information provided by Tunney et al. (2000) and Culleton et al. (1998) and suggests that under Irish conditions, soils with Olsen P 16-24 will minimise losses to water and give close to optimum pasture production. (Note that Morgan P x 4 = Olsen P).

Figure 2. Relationships between Dissolved Reactive P loss, Relative Pasture Production and Soil P (mg/l Morgans test). From data of Tunney et al. (2000) and Culleton et al. (1998).

The threshold for good water quality in Europe is currently set at 0.035 mg P/l (Tunney et al. 2000). However, Haygarth (1997) has suggested that eutrophic limits are in the range 0.035-0.10
mg P/l. Information from Northern Ireland shows that 3 of 11 lochs in Northern Ireland were above these levels with Loch Earn (0.08 mg/l) and Loch Neagh (0.15 mg/l) greatly exceeding this threshold. These high P levels in waterways in Ireland occur against as background of excessive P use and a program to reduce P applications.

In Australia, the limit for healthy water is currently set as 0.05 mg P/l (Anon 1998). Having a higher P threshold for Australia waterways than for European conditions is contrary to expectations. River flow rates are much higher and water temperatures much lower in Europe than in Australia and it could be argued that a lower threshold is required especially under summer conditions. Of even greater concern are the background soil P levels in Australia. Algal blooms are occurring in Australia when many soils are well below that required for optimum pasture production. Extension programs such as Triple P are encouraging farmers to increase fertiliser application to overcome these deficiencies. Experience from Europe strongly suggests that the problem of eutrophication of lakes and waterways is strongly linked to soil P levels and will therefore increase as more soils in Australia approach optimum P levels. R&D on critical levels of P, the methods of movement of P from soil to water and ways to reduce movement to waterways is of very high priority.

Nitrogen leaching to ground-water
Excess nitrogen in the topsoil leading to movement of nitrates into the subsoil and surface and ground water can cause several problems (Jarvis 1999). There is a possible risk to human health from high nitrates in drinking water and high nitrate levels may also lead to eutrophication of coastal and marine waters. In addition, nitrates moving into subsoils may lead to acidification of the soil unless lime is applied.

Nitrogen fertilisers are applied to almost all improved pastures in Europe. Only on organic farms are legumes used to supply N for pasture production. This is in contrast to Australian systems whereby N fertiliser is only applied to boost pasture production in high value farming systems such as dairying and lamb production.

Jarvis and Aarts (2000), and Goulding (1999) have discussed the issues of N use in the UK on pasture and arable land respectively. For pastures, N applications range from 100 – 700 kg/ha and the surplus of N (N applied less N removed in product) was calculated as 63 – 650 kg/ha. This high excess of N has increased nitrate levels in water and lead to the formation of “nitrate vulnerable zones” (NVZ) where the use of N fertiliser is tightly policed. In these NVZ’s, there are restrictions on application rates for N fertiliser and the time and conditions when fertiliser may be applied. See the web site www.environment-agency.gov.uk for full details of the ground water quality issue in the UK.

In the past, many farmers applied well in excess of plant requirements and the low cost of N fertiliser provided little economic penalty. There is now a strong push to reduce N applications in both arable and pasture systems in the UK to bring economic returns and environmental outcomes more in line. However, it will take some time to see if farmers are prepared to risk any loss in potential yield from reduced N application.

In this debate on N pollution of water and soils, it has been widely assumed by many in the green movement, that N produced from legumes has less environmental impact than inorganic applied N. As shown by Hawkins and Scholfield (2000) and discussed by Younie and Hermansen (2000), it is now known that risk of nitrate leaching is due more to the total amount of N in the
system rather than the source of the N. Animal production per head is directly related to amount of legume in a pasture. Therefore, productive pasture systems need a high legume component that in light textured soils, can allow significant amounts of N to move into the subsoil.

The implication for southern Australian grazing systems is that depending on factors such as soil type, rainfall, perennial grass component and legume content, N movement may be a significant issue. When new pasture management practises are tested, the potential for N movement should be assessed. In vulnerable soils, management to reduce N movement by use of high-density perennial grasses and low legume content may need to be adopted. Also, the use of lime or sewerage by-products should promoted as part of the normal maintenance cycle for perennial pastures, not a remedial action to be used when soil acidity becomes severe.

**Enforcement or encouragement of Best Management Practises**

There are two ways to get adoption of management practises that cause minimal damage to the environment; imposition of regulations and penalties for breaches or voluntary codes of best practise and extension programs to get adoption. European countries often use the regulation:penalty system and it seems to be accepted by farmers. For example, it is not acceptable for a farmer to pollute a river with silage effluent and heavy fines may be imposed (MAFF 1998). If environmental works are not undertaken, subsidy payments are withheld in Ireland (Anon 1999). The underlying principle is that the farmer is a custodian of the land and so should be not be allowed to undertake practices likely to damage to the land or the environment.

In contrast, Australian governments are reluctant to fine or suggest penalties for breaching environmental guidelines. The approach is voluntary encouragement to adopt improved farming practises that minimise environmental damage. The view is that farmers own the land, so largely have the right to do whatever he or she likes. This view is encouraged by some state governments that appear to actively encourage, environmentally damaging practises such as tree-clearing, or use of marginal land for cropping or irrigation. (It is interesting to note that while Australian farmers/politicians are highly critical of the subsidies paid to European farmers, European scientists are just as critical of the unsustainable farming practises used in Australia!).

It could be argued that unsustainable farming practises eventually impact on the land productivity so forcing farmers to adopt agricultural systems that care for the environment. However, some undesirable practises (soil salinity) may take decades or even longer to impact on economic returns. Some practices such as N loss to waterways may never impact on individual farms. It therefore seems inevitable that as in Europe, some form of regulation will be required to ensure land is protected for future generations.

An observation is that the reverse attitude prevails to regulation or reward in the wider community. For example, Australians by law must wear helmets on bikes, cannot drink alcohol in most public places and accept heavy fines for speeding. In Europe, any attempt to bring in these regulations would be seen as an attack on individual rights. Yet it is acceptable to impose many restrictions on the way European farmers manage their farms!

**Social impacts of changes in agriculture**

A striking difference between Australia and Europe is the importance given to social impacts of agriculture. Many of the agricultural subsidy schemes are designed to keep people living in rural areas. The subsidy payments for UK farmers allow farmers to make a living from 500-800 ewes. Dairy farms running 200 cows would employ at least 1-2 workers in addition to the owner.
These practises have maintained the number of people living in small villages in rural England and reduced the migration to large cities and the need for expansion of infrastructure in already overcrowded urban areas. It is now recognised that these subsidies have resulted in more expensive agricultural products and moves are underway to reduce subsidies and the cost to the taxpayer. While this will reduce employment in rural areas, it seems that the number of people moving to dormitory towns within commuting distance from urban areas will counteract population drift to cities.

In Ireland, Pat Gleeson from Teagasc indicated that over the next 10 years, lower farm subsidies are expected to reduce the number of full time farmers by 20,000. The Irish Government recognise that many current full time farmers need to become efficient, part-time farmers or leave farming and allow neighbours to expand. However, they want to keep these displaced people living and working in rural areas to avoid exacerbating the shortage of housing and infrastructure in large cities. The government is therefore actively encouraging decentralisation of existing and new businesses. For example, the head offices of the Irish Department of Agriculture and the Environment Protection Agency have recently been moved to the Johnstown Castle Research Institute near Wexford, 250 km from Dublin. A new EU veterinary centre has been established at the Grange Centre. These 3 actions alone have moved over 700 jobs from Dublin to rural areas.

Part time farming is also being encouraged as Teagasc believe that a family income from a range of sources will avoid the “boom and bust” syndrome common in agriculturally dominated regions.

Norwegian farmers are paid extremely high subsidies so that a flock of 50-100 ewes is profitable. Obviously oil revenue allows this to continue. However, government policy is to encourage people to live and work in regional areas. As part of the EGF tour, we visited a machinery manufacturer and the largest fertiliser plant (Hydro Porsgrunn) in Europe. The fertiliser plant employed 3,400 people in a community of 80,000 people. Both factories were located in relatively small communities a long way from Oslo. It was also interesting to learn while visiting a hydro-electric plant that the power (actually the water used to generate the electricity) was owned by the local community and sold to larger cities resulting in a large income to the regional community. Despite a very hostile environment, Norway appeared to be very decentralised compared to Australia.

Computer simulations are commonly used in Europe to study likely changes to social values from new farming practises. The Macaulay Institute have a range of software packages such as LADSS (Land Allocation Decision Support System) and FEARLUS (Framework for Evaluation and Assessment of Regional Land Use Scenario’s). These models are used to run “what if” scenario’s of different land use policies and impacts on towns, rural and urban communities. Using this type of model in rural Australia may avoid some of the problems occurring through unregulated land use change.

7. Development of alternative agri-environmental schemes

Over the last 10 years, numerous schemes have been introduced in Europe to preserve and/or enhance the rural environment. These schemes are seen as a way of overcoming problems caused by intensive agriculture such as loss of biodiversity, nutrient pollution of waterways and landscape enhancement. Discussions were held with several farmers and government staff to
find out about how these schemes worked and implications for Australia. Only 3 systems are discussed in this report but there are many others, especially in mainland Europe.

**Environmentally Sensitive Areas (ESAs) - Britain**

ESAs are areas of the British countryside, highly valued by the community, that need careful management by farmers if they are to retain appearance of the countryside and continue to support a diverse range of wildlife for both current and future generations. The first ESAs were established in 1987. There are now 43 ESAs across the UK and they cover about 10% of agricultural land. (For people unfamiliar with the UK, most “national parks” are made up of farmland and are visited by 1000’s of walkers, day-trippers etc every year just as Australian’s might drive or walk in the Blue Mountains). Full details of the ESA schemes are provided in MAFF booklets provided for each area.

ESAs have clear boundaries and farmers inside the ESA area may elect to join the scheme, it is not compulsory. These volunteers must enter a contract to manage their land less intensively and less profitably but in ways to benefit the environment, subsidy payments are used to make up for lost income. There are incentives to farm traditionally, use traditional animal breeds, build traditional fences and buildings; it can be likened to creating an outdoor museum! Clearly, lower farm productivity is a key objective of the ESA scheme along with maintaining areas under threat from intensive agriculture. It should be noted however that there is lively debate as to just what constitutes traditional agricultural values. For example Dartmoor in Devon is an ESA and tree planting is discouraged to maintain a treeless landscape which has been created in the last 3-400 years. However, in Roman times it was thick woodland so what type of landscape should be maintained?

I visited the South Downs ESA, situated on a special chalk downland south of London. This ESA was established to reduce the pressure on farmers to plough up grassland and so destroy flower rich turf. The ESA prohibits the use of fertiliser on chalk downland, pays farmers to revert arable land back to grassland and allow public assess via paths and bridle-ways. The farmer we visited was quite up-front about the reduction in yield after he applied ESA management to his 70 acres of chalk. However, he was happy with the payments (undisclosed) and liked the wildflowers and butterflies which had reappeared on his land.

For the Shropshire Hills ESA, the aim of the scheme is to maintain the landscape and wildlife interest, in particular moorland and permanent grassland, increase traditional hedges and conserve and protect historical sites. Payments vary from £12/ha for arable land to £75/ha for moorland. To gain these payments, farmers must abide by strict regulations describing how the pastures are fertilised, grazed, cut for hay, sprayed etc. For example, for extensive grassland, the rules are to “only cut for hay and not silage. Do not cut or top the grass before 16th July or after 31st August. Do not cut or top enclosed rough grazing at any time”.

I believe that there is little potential or interest in ESA type scheme in Australia due to the high cost of subsidies and limited demand to retain historical farming systems.

**Rural Environment Protection Scheme (REPS) - Ireland**

The REPS scheme operates in the Irish Republic and started in 1994. By 1998, about 40,000 farmers were included in the scheme making up about 30% of agricultural land. Specifications of the scheme were revised in Jan 1999 (Anon 1999) and published in an 81-page booklet.
The current objectives are stated as:

- To establish farming practices and production methods that reflect the increasing concern for conservation, landscape protection and the wider environment.
- To protect wildlife habitats and endangered species of flora and fauna.
- To produce food in an extensive and environmentally friendly manner.

(To this list, a forth objective “To reduce agricultural production in Ireland” should be added. This is implied in objective 3 and was indicated as a “hidden agenda” by farmers and Teagasc staff.)

REPS is aimed primarily at small-scale Irish farmers, as a maximum of 40 hectares can be included on any one farm. If a farmer complies with the REPS measures discussed below, a base annual payment of $A250/ha is made (maximum $A10,000/yr) with additional payments for implementation of other measures.

To become involved in REPS, a farmer must develop a detailed agri-environmental plan in conjunction with an approved consultant; this plan provides full details of the land and all environmental features. There are then ten separate “measures” (plans) covering the following areas which are then developed to specify what management should be used to meet the REPS objectives.

Measure 1- Nutrient management plan, by far the most important plan which sets out details on nutrient use and management, target soil test and fertiliser applications allowed in relation to soil tests, animal housing, waste storage (manure) and management. Twelve pages of instructions outline maximum and minimum rates.
Measure 2- Grassland management plan.
Measure 3- Protection of watercourses and wells, guidelines on application of fertiliser and slurry.
Measure 4- Retention of wildlife habitats.
Measure 5- Maintenance of field boundaries, rebuilding stone fences, hedges to minimum standards.
Measure 6- Use of chemical sprays.
Measure 7- Protection of historical and archaeological sites.
Measure 8 – Maintenance and improvement of the visual appearance of the farm and farmyard.
Measure 9- Production of arable crops in an environmentally friendly manner.
Measure 10-Training in environmentally friendly farming practices.
Measure 11- Keeping adequate farm records.

In addition to these measures, farmers may choose to undertake additional measures and obtain extra funding for, rearing local breeds in danger of extinction, putting areas of land into long-term set-aside, allowing increased public access to farmland and converting to organic farming.

Government officers inspect farms annually and if farmers have not undertaken the scheduled work, REPS payments are deducted or withheld. Initially, non-compliance was quite high (25%) but it has dropped down to 7-8%. This policy of making farmers adhere to plans was initially poorly received (surprise!) but 5 years later is seen as one of the good points in that farmers now realise that the government is serious about its intentions!
I spent some time with a REPS farmer near Wexford. He was very committed to the scheme, had reduced fertiliser inputs and sheep numbers and undertaken to improve environmental issues, fencing off streams, wildlife margins around fields and rebuilding hedges and fences. REPS has kept many more small farmers on their properties and maintained rural infrastructure and population. However, even with REPS, it is anticipated that the number of Irish farmers will decline by about 33% in the next 10 years. It is thought that there will a large increase in the number of part-time farmers and more farmland available for rent as is common in other European countries. The annual payments from REPS also ensure that works undertaken are maintained and projects, which require more than 1-2 years of activities, can be included. The need to undertake work in 1-2 years is a major limitation of the Australian Landcare program.

The REPS system has some features that could be used in agro-environmental schemes in Australia, especially the close linkage of environmental and economic objectives. However, the high costs of subsidies, makes the system unattractive.

**Linking Environment and Farming (LEAF) - United Kingdom**

LEAF is very different to REPS and the ESA scheme. Its mission statement reads “LEAF is committed to a viable agriculture which is environmentally and socially acceptable and ensures the continuity of supply of wholesome affordable food while conserving and embracing the fabric and wildlife of the British countryside for future generations” (LEAF 1999).

LEAF does not receive any government support and pays no subsidies to farmers who adopt new management strategies on their farms. It relies on farmers wanting to improve the environment and social conditions in which they live and work, rather than paying for improvement works. LEAF promotes Integrated Crop Management (ICM), practises which are economically viable and environmentally responsible. For example, LEAF encourages farmers too:

- Minimise reliance on inputs such as fertilisers and chemicals by considering alternative measures.
- Use farm manures and crop residues to ensure that they do not threaten the health of soil, water, humans or animals.
- Manage of soil fertility.
- Reduce use of fossil fuel and improved on farm energy balance.
- Maintain and improve ecological diversity and wildlife habitats.
- Maintain and improve landscapes, farm buildings and amenity of the countryside.

In 1998-99, LEAF had 1,300 members, 125 corporate members and 36 demonstration farms with 7,400 visitors to LEAF farms during the year. Most LEAF members run arable or mixed farms with only a small number running significant numbers of livestock. The LEAF Advisory Board (29 members) has wide representation from many government agencies, universities, food retailers, farmer groups, countryside lobby groups and agri-input companies.

LEAF trains its members in ICM and more recently in Integrated Farm Management, which encourages farmers to critically evaluate all aspects of their farming systems. LEAF also has an audit system (voluntary) through which farmers can assess and receive feedback on their performance and a personalised action plan for the future. Conferences, regional meetings, newsletters and farm visits are also arranged to allow members to share information and ideas. LEAF also has a network of Demonstration farms, LEAF Audit Ambassadors and LEAF Supporters to help spread the word about the program.
It is difficult to judge the effectiveness of LEAF from visits to 2 farms. The LEAF farm in Lincolnshire was very large, farming over 2,600 acres of a range of arable crops. Phillip Ashton discussed how they had changed their operation from “clinical farming” (“in the 1980’s we were farming to within 1 inch of the life of the farm”) to now farming efficiently and environmentally. The main changes were to target sprays by questioning, does all the field need to be sprayed? is the weed, pest or disease likely to cause economic damage? Fertiliser use is carefully monitored using soil tests and nutrient audits. A major change was to restore wildlife habitats, hedges and woodlands. Field boundaries up to 24 m wide are sown with a special pasture mixture in some paddocks to encourage wildlife. In the past, paddocks were sown to the fenceline and many hedges removed to make larger paddocks.

On the farm in Yorkshire, it was less obvious what changes had been made. The adoption of the ICM philosophy was thought to be the main benefit. At both farms, there was considerable discussion on whether LEAF should use its name to promote, sell or endorse products. Farmers thought that LEAF would lead to premiums for their products and were disappointed with the amount of effort they had put in for no obvious $ return. The issue of LEAF endorsement is being considered by the board of management but is obviously a very sensitive area and one that will not be rushed into by the LEAF executive.

The LEAF annual report listed some of the main achievements as revision of the LEAF Practical Guide to IFM, development of IFM training videos, training for LEAF Demonstration Farmers, increased numbers of member meetings and increased press coverage in non-farming publications. The LEAF Audit returns were also used to show that on LEAF farms, despite the downturn in agricultural incomes, farmers were improving their business performance and environmental management. However the data was very limited and was not compared to a random sample from the wider farming population.

Despite these limitations, LEAF is probably the best agri-environmental model for southern Australia and already several LEAF members have visited Australia and spoken at conferences and seminars. It strikes a reasonable balance between environmental and economic values without costing government $$ though of course it encourages its members to apply for and take up government support schemes such as the UK Set-aside and Country Stewardship schemes where appropriate. The advantage of LEAF is that it integrates economic and environmental aspects of farming whereas Landcare focuses only on environmental benefits.

**Organic farming**

Organic farming (“ecological” or “biological” farming in mainland Europe) has grown rapidly in recent years due to a strong perception by many consumers that conventional agriculture is producing inferior foods from agricultural systems that degrade the environment (Younie and Hermansen 2000). Its current popularity has also been greatly assisted by recent health scares such as a “mad cow disease” and support provided by influential people such as Prince Charles! Organic farming has also been strongly supported by many European governments, especially Denmark as it will supposedly lead to reduced environmental damage, lower agricultural production and increase their popularity in urban areas! A recent conference paper by Younie and Hermansen (2000) provides a good overview of European organic farming and practical details are provided in an Irish leaflet (MacNaeidhe et al. 1998) and Danish organic regulations (Berbelsen pers comm).
So what constitutes Organic farming in Europe and what lessons does it have for sustainable agricultural systems in southern Australia? There is some variation between different countries but generally, organic farming means no use of artificial chemicals and fertilisers, but slowly dissolved material such as lime and rock phosphate may be applied. Livestock must graze pastures in the growing season, ruminants must be fed a diet of at least 60% green forage (maximum of 40% concentrates). Animal health policy must be based on preventative management rather that routine dosing. There are also prescribed times for conversion of a conventional farms to organic systems, often 2 years for grazed pastures. Of course, there are also large and in some countries, ongoing payments to farmers who convert to organic system.

All of these times, rates etc seem quite arbitrary. For example why is it 2 years not 2 months for conversion to organic grassland? Why is 60% set as the upper limit for concentrates? Why grazing on pasture for 150 days? There appears to be no scientific rationale for these figures; they are the rules set down by the EU and agreed by members.

Nutrient flows on organic farms require consideration as all farms “export” nutrients in milk, meat or wool and these must be replaced to avoid running down the capital of the farm. Considerable research is being undertaken in Europe to rediscover ways to use legumes to replace N fertiliser. However, replacement of P and K is more difficult, especially on dairy farms or intensive sheep and cattle properties. Stock are housed over winter and there are large amounts of slurry and farm yard manure available to spread on crops or hay paddocks. Also, many (most) farms converting to organic farming have excess levels of P and K in the soil so effectively can live off the legacy of 50 years of chemical fertiliser applications for some time! In fact, an organic adviser recommended that if farms to be converted to organic production were low in P, these deficiencies should be overcome with the additional chemical fertilisers prior to conversion to organic farming! Up to 40% of the ration can be concentrates and this may be bought into the farm, effectively bringing in large amounts of P. The import of straw for bedding in winter provides a significant source of K. Organic farmers can also purchase manure from neighbouring properties.

Increased biodiversity is claimed to be a major benefit of organic farming, though the value of species richness to ecosystem stability and resilience is not clear (Johnson, et al. 1996). Studies by Cobb et al. (1999) showed improvements in the environmental conditions on organic farms and increased species diversity, presumably due to more diverse vegetation in fields and field margins. Also, the overall environmental cost of an organic system was lower than for a traditional farming system.

Because of restrictions imposed by organic regulators, there are no direct comparisons being undertaken to compare the productivity of organic and conventional systems. Data available in the literature is questionable and varies from showing organic systems out-produced conventional farms (Phillips 2000) to a drop of 10-20% in productivity (Weller undated). There seemed to be agreement that a premium of at least 15-20% was needed for organic products in addition to government subsidies, to make the organic systems competitive with conventional agriculture. (In the supermarket, organic products were often 50-100% more expensive than normal products). The financial viability of organic farms is difficult to assess, as in Europe there is a complicated system of subsidies and premiums for organic food. Cobb et al. (1999) modelled the financial returns using current subsidies and premiums and a scenario where all support payments were removed. The results suggest that organic farming produced a 15-30% higher gross margin than the conventional farm.
Restrictions in the routine use of antibiotics and anthelmintics create difficulties in maintaining animal health. A range of strategies such as alternate grazing with sheep and cattle, boosting the natural immunity of stock and grazing worm free ley pastures and silage fields are used instead of drenching. Also, stock may be drenched provided the authorities are consulted and longer withholding periods are observed. If left untreated, farmers could be fined for poor attention to animal welfare.

Another issue is the perception by the public that organic foods are “superior” to normal foods. Some advertising for organic food has promoted conventional food as unhealthy or inadequate and this message has antagonised conventional farmers. (Ill feeling between organic and conventional dairy farmers was quite obvious at the BGS summer meeting!). However, there have been some reports of higher *E. coli* in meat from organic farms due to the high rates of slurry used (Prof Trewavas Edinburgh University pers comm) and higher cell counts in organic milk (less use of antibiotics).

Cobb *et al.* (1999) calculated the relative environmental burden of organic and conventional farming systems. These calculations considered costs of nitrous oxide and ammonia emissions, nitrate leaching, both direct and indirect carbon dioxide release and pesticide residues. Their results suggested that the conventional farm “cost” about £25-40/ha compared to £10-15/ha for organic farms. The major differences were in the “cost” of pesticides in the conventional systems with other values being very similar. It would be of great value to undertake similar calculations for some intensive farming systems in Australia.

The development of large-scale organic wool or meat production enterprises is unlikely in southern Australia. Low soil fertility is a major limitation in many areas and is difficult to maintain or increase under organic regulations. Also, control of animal health problems in sheep and cattle continuously at pasture without drugs would be very difficult. Finally, it is unclear whether the major countries which import Australian products, would be prepared to pay a premium for organic produce.

However, there are several lessons for the broad-scale grazing industries from the expansion of organic farming in Europe. The conflict between organic and traditional production systems should be avoided at all costs as this is likely to reduce consumer confidence in all agricultural products. The emotional advertising used by some sections of the organic industry in Europe has been very damaging. Control of internal parasites is a significant problem in temperate Australia. There is considerable work underway in the UK to study alternatives to the use of drugs including the use of rotational grazing with sheep, cattle and crops, using fodder conservation areas for safe grazing, anthelmintic plants, breeding for resistance, high N diets, and dietary selection behaviour of sheep. All of this work could have strong application in traditional animal production systems in southern Australia. There is also a large emphasis in Europe to find out more about the role of soil micro-organisms in recycling nutrients in organic systems. Again, this information is very relevant to our grazing industries.

8. Economic, environmental and social sustainability in Europe and Australia

In recent years, the terms “sustainability” and “sustainable production systems” have become the most used and abused terms in agriculture. People have quite varying views on what the terms mean, especially when used in different agricultural industries or countries. In Europe, sustainable development is taken in a wide sense to include all impacts of agricultural systems on
economic, environmental and social benefits (Lowe 1995, Maxwell 1998). These three areas are now taken as the 3 vital “pillars” of sustainable development (Costigan 2000). Different authors have used a range of figures to show the links between the three pillars of sustainability. Figure 1 is developed from Maxwell (1998) to show links between the different aspects of sustainability.

Figure 1. A framework for sustainable agricultural development

![Diagram](attachment:image.png)

Economic sustainability

Environmental sustainability

Social sustainability

All pillars are linked to each other to show that changes to one pillar will impact on the others and that trade-offs are necessary to achieve a balance between all objectives. For example, a heavy focus on environmental factors is likely to restrict the ability of farmers to manage farms efficiently and so reduce economic sustainability and perhaps reduce the number of jobs in local communities. A strong emphasis on keeping people working on farms is likely to reduce economic efficiency whereas total preoccupation with economic performance is likely to have severe impacts on the environment and the social fabric of rural communities.

The Macaulay Land Use Research Institute in Scotland is developing and evaluating tools to assess the impacts and trade-offs between different farming practices and rural sustainability (Maxwell 1998). They have been particularly active in developing models such as LADDS (Sibbald pers comm) which allow different land use patterns to be tried and the trade-offs between social, environmental and economic issues to be evaluated. Important points stressed in discussions at Macaulay were the strategic nature of the work; the need to accept that it is unlikely that there will often be “win-win” situations and that there will need to be trade-offs between for example environmental and economic outcomes. Sibbald (pers comm.) tested the paddock allocation for optimum landscape diversity or financial return for an estate in Scotland. The paddock allocation, pasture species, fence placement and stocking policy were very different for the two varying objectives.

At a regional or catchment level, the Macaulay Institute has also evaluated the socio-economic impact of different land use change scenarios and so helped shape agri-environmental policies in Scotland (Maxwell 2000). This work has lead to a greater understanding of the link between rural and urban areas and also provided an assessment of the non-agricultural benefits of environmental and heritage management. MLURI intend to place more emphasis on the sociological aspects of their work in the future as there is a strong view in Europe that the community is prepared to pay for environmental and social benefits.

It is interesting to consider the relative importance placed on these pillars of sustainability in different countries. Figures 2-5 indicates my impressions of the current emphasis placed on the different aspects of sustainability in England, Ireland, Norway and Australia. The figures use font size as an indication of the relative importance of the different issues in each country. Obviously, these are subjective and would vary between different agricultural industries, regions and management regimes. However, the figures indicate the interest in different aspects of
sustainability between countries and are aimed at promoting discussion on the relative rather than the absolute values. External intervention is also shown where this has an important modifying effect on the sustainability balance. Attitudes to agriculture are changing quickly and the emphasis on different pillars may well change in the next few years, especially due to financial pressure in Europe and environmental pressure in Australia.

Figure 2. Irish agricultural systems

![Diagram of Irish agricultural systems]

Ireland has a large agricultural export market and still undertakes a significant amount of production based R&D. However, the number of full time farmers will halve over the next 10 years as a range of measures to improve efficiency of the agricultural sector are implemented. However, the government has a very strong policy of job creation in rural areas to “soak up” these displaced farm workers. Jobs are being created in rural areas through decentralisation of government agencies, encouraging new business to set up in rural areas and development of support mechanisms for part time farmers. It is widely believed that part-time farming will lead to a more viable farming community, as part-time farmers do not suffer as greatly from the cyclical nature of commodity prices as full time farmers.

Figure 3. English agricultural systems

![Diagram of English agricultural systems]

In the UK, it is believed that environmental problems (biodiversity, nutrient movement) will largely be overcome through a reduction in agricultural productivity across the country, i.e. moving to low input-low output agriculture. The high value of the pound makes exports very difficult and most agricultural commodities are in surplus. This policy may mean that in some areas, agriculture will intensify but in many areas, economic sustainability and to a lesser extent social sustainability will be traded to improve environmental outcomes. Maxwell (2000) has suggested that large farms will get larger and become intensive agri-businesses whereas some medium scale farms will fail and release land for expansion of other farms. Small farms will operate part-time or be sold to hobby farmers. There will be fewer full time farmers in the future.
and part-time farming will become a normal practise. Government support (£) will be used to prop up the economic sustainability of the farms and maintain jobs to try and overcome some of the social issues of reduced employment opportunities in rural areas. Funding currently provided to maintain agricultural production will be moved to achieve environmental objectives.

**Figure 4. Norwegian agricultural systems**

![Diagram of Norwegian agricultural systems]

In Norway, social and environmental sustainability rate very highly. There is a complex set of laws that determine how land passes between generations. These laws encourage continuity of land ownership within a family and lead to a strong sense of identity with the land and maintenance of the environment. The farm must by law, be offered to the children of the current farmer and then his children etc. All heirs to the land must agree before it can be sold outside the family and even if sold, the heirs have a year to claim back the land. Farming enterprises are very small and inefficient, dairy farms 15 cows, sheep farms 50-100 ewes and high government subsidies are provided from the oil revenue. Direct economic support to farms and government decentralisation policies keep people living and working in rural areas and this appears to be supported by the general public.

**Figure 5. Australian agricultural systems**

![Diagram of Australian agricultural systems]

Australian agriculture is based on exports and so developing low cost, efficient production systems have been and still are a primary aim of R&D. Only in the last 20 years have the environmental impacts of agricultural systems have been considered with Landcare coming to the fore in the 1990’s. It could be argued that there is little difference between Landcare and the different European environmental schemes discussed in this report. The schemes have become necessary due to the previous (and current) preoccupation with economic outcomes at the expense of environmental values. Compared with Ireland and Norway, little effort has been made to provide alternative employment opportunities in rural areas as the farm workforce is reduced. However, recent changes in rural communities due to the rapid growth of the plantation blue gum industry has forced the issue of social sustainability back into prominence.
These comparisons raise the question, can even 2 goals of sustainability be achieved at the same time (“win-win”) as is proposed in the current Sustainable Grazing Systems key project (Mason and Andrew 1998). Clearly there will have to be trade-offs which will call for tough decisions to be made. For example, Kemp and Dowling (2000) have proposed that to improve environmental sustainability in Australia, a higher herbage biomass is required. Presumably, this means less livestock and lower short-term profitability for farmers. How will this change be implemented and what are the social consequences?

9. Economic, environmental and social objectives in Australian temperate agriculture

For agriculture in Australia to be sustainable in the long-term, there needs to be a change in thinking. The impact of new industries, the continuation of current practices and changes to the way current industries are managed, need to be considered against all three pillars of sustainability. In addition, sustainability needs to be considered at different levels, on the farm, in the region (catchment) and on a global basis. For example, adoption of higher fertility regimes may improve farm economic, environmental and social objectives but have a detrimental impact on regional water quality. Adoption of intensive cropping systems may improve on-farm and regional sustainability but release CO$_2$ and so impact on global sustainability. Tree plantations may improve on-farm and global sustainability but severely impact on regional social values. As previously indicated, there will have to be trade-offs between the different objectives but it is vital that the impact of changes to agricultural industries are considered so that people affected are made aware and take early action to reduce the damage.

Economic sustainability

Economic sustainability is vital for an exporting country like Australia. With a small population, there is little potential for subsidisation of agriculture as is the norm in Europe.

On-Farm –

Farm economic sustainability is the reason for most R, D & E in southern Australia. There are many indicators of economic sustainability used to compare farms and enterprises (Beattie 1999) and this subject will only be covered briefly. Several points emerge from discussions in the UK. The high cost of plant and buildings is often overlooked in simple economic analyses. High overheads, especially in complex and unnecessary feeding systems are a major cost on many UK farms. Also, gross margins need to be calculated on projected cost and price scenarios. The UK dairy industry budgeted on around 21p/l for milk in 2000 but current prices are around 14-16 p/l. Few farmers had plans on how they would cope with this low price scenario.

Useful indicators of farm economic sustainability are:

- Gross margins $/ha, net return $/ha.
- Return on capital or equity, Internal Rate of Return.
- Variability of gross margins between years.
- Future predictions for profitability.
- Farm returns compared to alternatives, housing, industry, mining, investment in shares.
- Investment in plant and machinery as proportion of net returns.

Catchment (region) –

Currently, most methods to study the impact of agricultural industries on regional economies are crude and rely on “guesstimates” by the various organisations with a vested interest in the competing industries. Inevitably, each interest group claims that any cutback will have a
devastating impact on the rural community. New industries claim that they will generate hundreds of new jobs. Work at the Macaulay Institute is developing models to allow realistic simulation of the impact of changes to agricultural industries on regional economies. This is vital to calculate the full flow on effect of changes to agriculture and rural communities.

In the absence of these tools, the best that can be done is to recognise that there will be a large impact of changes in agricultural industries to regional economies, not always for the better. These impacts need to be considered so that pre-emptive action can be taken to avoid conflict between different sectors and the collapse of secondary linked industries.

Some impacts to be considered include:
- Employment generated by adding value to products produced in the region.
- Change in employment on farms.
- Employment and growth of linked industries, farm chemicals, farm agencies, etc.
- Employment from associated industries, tourism.
- Export value of products.
- Local tax revenue from farms.
- Value of the sale of water or other products (wind?) from agricultural land.

Global –
For most European countries, export income is not an important reason for developing agricultural industries. However, Ireland and Denmark retain a significant export base. Australia relies heavily on exports of agricultural commodities to generate export income. Some obvious indicators include:
- Export value of alternative industries.
- Job creation elsewhere in Australia or overseas.

Environmental sustainability
For the past 100 years, Australian agriculture has “used” the environment to improve economic outcomes. Cheap agricultural products have been grown for example by running down soil organic matter, allowing soil pH and nutrient levels to decline, and over-clearing fragile ecosystems. It is now recognised that this cannot continue, in many situations, the environmental “bank” is completely empty! Developing useful indicators of environmental sustainability is a high priority in Europe and Australia and more detail is therefore provided.

Farm -
- Soil pH, absolute values, change in pH. In the UK, there are clear guidelines available on the optimum pH for arable and grassland areas (Goulding and Annis 1998). Unfortunately, there is limited information on the long-term changes and impact of soil pH change on grassland production in Australia. Poulton (pers comm) commented that in long-term trials, low soil pH had the greatest impact on pasture production and biodiversity. Low pH at depth is also difficult and slow to change. Australia has some advantages over Europe as we do not have a large input of acid from the atmosphere or use highly acidifying fertilisers. However, the increasing use of sulphur based fertilisers could have some impact especially in poorly buffered soils. Both absolute pH values and trends in pH over time need to be carefully monitored. Long-term changes and the impacts of soil pH on grassland production require further investigation in southern Australia.
Sustainable Agricultural Systems for Southern Australia

- **Proportion of farm with perennial based pastures, weed invasion into pastures, absolute values and change in proportion of perennial grasses.** The importance of perennial grasses to environmental sustainability in temperate Australia is well documented within the SGS program and is therefore not discussed in detail. Both the absolute amount of perennial pasture on a farm and the change over time are important indicators of sustainability.

- **Plant and animal species biodiversity.** There is considerable debate as to the importance of biodiversity for production, resilience and sustainability of ecosystems. This subject is explored fully in section 6 as it is a major issue in Europe. It is recommended that a mosaic of intensive pastures managed for agricultural production and adjacent areas managed for biodiversity be encouraged on farms. The proportion of each could be a useful benchmark.

- **Soil physical attributes, compaction, waterlogging, wind and water erosion.** Areas of the farm affected by wind or water erosion, areas affected by water logging or other structural damage.

- **Soil chemical fertility, macro and micro-nutrients, absolute values, change in values.** Minimum soil availability levels for persistence and production of temperate grasslands are available. However, the upper limit to avoid P loss to waterways is unclear. This is of vital importance to Australian agriculture and is discussed fully section 6. Current research will provide some information on this subject within the next 2-3 years.

- **Soil health, microbial activity, biomass, diversity, soil organic matter levels.** The use of soil “health” indicators are discussed in section 6. There is presently little information available about the impact of different agricultural practises on soil organisms and this area requires investigation. As an interim measure, soil organic matter levels and changes over time can be monitored. A decline in soil organic matter is usually indicative of an unsustainable system.

**Catchment**

Environmental impacts in a catchment are the result of the balance between economic, environmental and social forces on farms. For example, high N applications may be good for economic and social outcomes on farms and have little environmental impact at a farm level. However, because of nitrate leaching to waterways, catchment authorities may limit the amount of N that can be applied on farms. Also, the amount of water for sale may be reduced by agricultural practises. Regional authorities such as Catchment Management Authorities are looking monitor the impact of agriculture on the regional environment. In Europe, these groups have the power to restrict agricultural activities such as fertiliser application in some areas.

Catchment environmental indicators that need to be considered in southern Australia include;

- **Water balance, change from natural system.** Is the region a recharge area for underground water? Will the change in agricultural practise impact on recharge? Alternatively, will agriculture increase recharge in a region with saline sub-soils?

- **Nutrient pollution, water quality.** See discussion in section 6.

- **Biodiversity of plant and animal species within the catchment.** The issues of biodiversity discussed in section 6 also apply to catchments. As for farms, it is desirable to maintain a mosaic of plant communities across the landscape to provide a range of habitats for insects, birds and animals. The issue at a catchment level is whether a payment or tax relief should be provided to encourage this type of landscape development. If driven by economics, it is likely that a monoculture of either arable farming, plantation forestry or intensive grassland will develop in high rainfall areas.
Pollution by farm chemicals. Allowing pollution of streams with agri-chemicals is unacceptable and leads to large fines in most European countries.

At a regional level, other issues of biodiversity warrant discussion. A region producing only 1-2 products is at risk if economic, disease or natural disasters strike. Regions need to consider the risk of having single enterprise farms and the negative impact that mono-cultures and homogeneous landscapes have on tourism and amenity value. The aesthetic value of the landscapes is important in the UK and farmers are paid to maintain picturesque landscapes.

Global –
To date, there has been little discussion in Australia as to the global impact of our agricultural systems. However, in Europe, this is an important issue with organic farming being proposed as a way to reduce the global impact of intensive agricultural systems (Cobb et al. 1999). In the future, there may well be pressure to account for the global environmental cost of different farming systems. For example, there is considerable anticipation on the likely value of carbon credits from tree planting in western Victoria. However, no one seems to have considered the possible negative impact of other farm practises such as release of CO\textsubscript{2} from arable farming or methane from animal systems. Efficient use of water for agricultural production is also becoming an important issue as there is increasing demand for urban water resources.

Indicators which should be considered include:

- **Environmental cost of the farming system.** The carbon balance from different farming systems, sequestration in the soil or products, pesticides, N and P loss to the environment and costs of cleaning polluted water, energy to produce fertiliser or other inputs, greenhouse gases production can be used to benchmark different farming practises.
- **Water use efficiency.** At both a regional and global level, it will become increasingly difficult to justify agricultural systems that use water inefficiently. For example, flood irrigation to provide herbage for meat or even milk production will probably be unprofitable due to competition from urban communities and will also be seen as an inappropriate use of a scarce resource.
- **Detrimental impacts of Australian commodities in importing countries.** Issues such as pesticide contamination of raw material will become increasingly important.

**Social sustainability**
There are many reasons why governments and societies try to maintain viable communities in rural areas. In some countries (Norway), keeping people living and working and in remote areas was/is justified to maintain control of disputed land areas. In Scotland, the main reason is to preserve the aesthetic quality of the landscape. In Ireland, keeping people in rural areas will decrease the pressure for housing and infrastructure in urban areas.

Another issue of social sustainability is the ability of people to cope with changes to agricultural systems. For example, agricultural practises that increase the stress on farmers (high stocking rates) are likely to be poorly adopted. Similarly, practises which impinge on family values (3 times day milking) will also be resisted despite economic benefits.

Some indicators of social sustainability include;
Farm

- Impact on lifestyle, working hours, time of work,
- Stress, pressure, complexity, availability and ability of labour to undertake the recommended procedures.
- Potential for health and safety impacts, acceptability of practise, ie use of chemicals.

Catchment

- Impact of agriculture on local communities, jobs, social networks, money circulation.
- What do local people think of agriculture? chicken production, forestry?
- Expectations that the rural environment will remain the same.
- Access to rural areas, tracks, paths etc, cows on roads?
- Acceptability of practises used, overall perception of agriculture?
- Impacts of agriculture on amenity values, tourism potential, (windmills), piggeries?

Global

- Animal welfare, genetic resources, GM products, organic agriculture, political issues
- What do importing countries think of our agricultural practises?

10. Improving research outcomes in southern Australia- lessons from Europe

There are different approaches in Europe to funding research, setting research priorities and management of research and extension than currently used in Australia. While research and extension management was not seen as a major issue before starting the Fellowship, I now believe that it has implications in our ability to develop and get farmer adoption of sustainable agricultural systems.

Balance between Strategic and Applied R&D

In 1989, I worked at the Macaulay Land Use Research Institute, based at Edinburgh and undertook studies of sheep and grazing systems. At that time, the research portfolio at MLURI and PV Hamilton was quite similar. Ten years later, there have been fundamental changes in the work at the 2 institutes; Hamilton has moved to undertake mainly Applied R&D, MLURI has moved to Strategic R&D. What are the implications for Australian agricultural research? Are we heading in the right direction? Why are we doing so much Applied work?

Applied research usually means working closely with client groups to solve a particular problem, there is not a lot of interest in why the new treatment works, if treatment “A” is better than treatment “B” recommend treatment “A” and that solves the problem. With Strategic research, there is a considerable emphasis on understanding why treatment “A” is better than “B”. Farmer input is usually lower as it is often quite distant or not seen as immediately relevant by farmers. Strategic research also has an element of “blue sky” work which looks for completely new or novel ways to solve fundamental problems.

Farmer participation in R&D in Australia over last 10 years has pushed the balance towards Applied work. While this has improved the adoption of research by industry, there is concern whether the full impact of the recommendations is known; we may be recommending practises that are subsequently found to be flawed or unsustainable. There is also less opportunity for experienced scientists to influence research priorities. It is appropriate for industry to have a major input into applied research issues. However, given that about half of the funding for research is provided from state and federal governments, it seems appropriate that there is
significant input from the scientific community, the people who have expertise in this field, into research priorities especially related to sustainability issues. It is interesting to consider papers by Wilkins (1995, 1999), Maxwell (1998, 2000) and Leaver (2000) directors of the largest grassland research institutes in the UK and consider how they see the future for R&D in Europe. There appears to be little or no opportunity for people with similar expertise in southern Australia to debate future research needs and the balance between applied and strategic research, or environmental, economic or social research.

However, if Strategic research is allowed to dominate the research agenda, it will alienate the farming community. At the British Grassland Society conference I attended, farmers and the rural media were highly critical of the lack of application of much of the research currently being undertaken in the UK. More Applied R&D and greater input from farmers to the research agenda is needed in the UK and greater emphasis on Strategic research, and input from scientists is needed in Australia. The balance between Strategic and Applied research needs changes in both countries.

To highlight the importance of this issue in Australia, some examples are presented below where a greater emphasis on strategic research may have assisted our knowledge of temperate agriculture and the development of sustainable agricultural systems.

**Land clearing in early 1900’s.** Forest and woodland was cleared in the last 100 years. The immediate response was increased carrying capacity of the land, the immediate problem was solved and farm incomes increased. However, no-one studied what the implication of tree removal was on other issues such as ground water or wildlife and consequently we now have many environmental problems caused by over clearing.

**Fertiliser cutting trials.** In the 1970’s, some short-term cutting trials were undertaken to determine pasture responses to P fertiliser. The results were used to develop the Superate program that was widely promoted by the Department of Agriculture and often told farmers not to apply fertiliser. Detailed research in the 1980’s found that Superate was flawed and industry is spending considerable resources to get farmers to apply sufficient fertiliser to pastures.

**Applied pasture research projects in 1990’s.** The temperate pasture sustainability key program studied pasture persistence at 26 farm-based sites across southern Australia. For each site, a local farmer group had a large input into grazing conditions and some treatments. Graham et al. (2000) reported a wide variation in response to grazing management treatments at the different sites and were unable to recommend a grazing strategy for perennial ryegrass that had wide application. Similarly, Avery et al. (2000) reported “Cocksfoot herbage mass under continuous grazing declined at 2 sites, remained stable at 2 sites and increased at 1 site. No single grazing strategy had a significant effect on cocksfoot herbage mass across sites and there were few treatments with a significant increase in cocksfoot herbage mass compared to continuously grazed control treatments”. Waller et al. (1999) conducted an applied grazing systems study with perennial ryegrass pastures. This approach comprised the experiment and made it difficult to control treatments and so no clear benefit of rotational grazing was determined.

While it is easy to be wise in hindsight, the important message is to improve future agricultural R&D. In these examples, future problems could have been reduced if a better mix of strategic and applied research was undertaken. It is vital that efforts are made to understand why
treatments or new technology works, rather than only measuring the immediate effect of the treatments on production.

**Long-term vs short-term outcomes**
Maxwell (2000) has discussed the problems or reduced funding for research and undertaking research in a society obsessed with short-term “wants” as opposed to long-term “aspirations”. The problem for agricultural sustainability is that it may often take many years before an environmental issue starts to have an impact on agricultural production and so effect farmers income and hence becomes a high priority topic for applied R&D. Some issues may never directly effect farmers (reduced water tables due to plantation forestry) so will be of low priority if only farmers set research agenda’s.

Pasture based systems may take at least 3-5 years to reach a new equilibrium following introduction of a new treatment, species or management system. Yet most applied R&D is only funded for 3-5 years. Consequently, recommendations are often made from experimental results where the full impact of the change is unclear. This has been a common fault in fertiliser and lime application experiments where short-term response trials have given very different results to long-term studies. Kemp and Dowling (2000) have also highlighted the problem of short-term funding of agricultural research in Australia compared to Europe. There is a clear need in Australia to maintain a series of studies that measure the long-term impact of common agricultural practises, ie fertiliser use, grazing management, lime application, annual vs perennial pastures etc. Further details on European long-term experiments and implications for Australia are provided in section 11.

**Integrated research and extension**
To develop sustainable agricultural systems, scientists, extension agents and farmers must work together to understand the trade-off’s between the 3 pillars of sustainability. This should avoid domination of one issue or group or a lack of understanding of the consequences of changes in agricultural practises. In southern Australia, there are some organisational impediments to the development of sustainable agricultural systems.

In the mid 1990’s, there was a change in the way R&D is funded in most states. Research projects are funded via industry programs (meat, wool, grains, dairy, etc). This has forced projects to address industry needs and improved links between research, extension and farmers. For issues where there is clear ownership by a specific industry, the new system works very well. However, for pasture and sustainability issues that go across industries, it creates some problems. The research may be split across several programs impeding collaboration by scientists or alternatively, no one industry may be prepared to undertake the research that has benefit all industries. “Cross-industry” funded projects are needed to provide an integrated and efficient way to address the needs of the grazing industries for R&D in pastures and environmental and social issues.

In many states, there is also separation of “production” and “environmental” R&D. This leads to the notion that research projects have either environmental or economic outcomes rather than addressing both issues. This attitude is most unfortunate and is at odds with overseas practise. In Ireland, Johnstown Castle undertakes R&D into environmental and sustainability issues for all the grazing industries along with production research on fertilisers and soils. North Wyke in England and Macaulay in Scotland have a similar remit to undertake research which looks at the impact of agricultural practises on economic and environmental outcomes. Integration of
environmental and production R&D needs to be encouraged at all times. The current Sustainable Grazing Systems Key Project funded by the meat industry and state and federal governments has forced integration of environmental and economic outcomes and is a model for other projects and industries.

In both Europe and Australia, research and extension are often conducted by different organisations, ie British Research Institutes and MAFF in the UK, Agriculture Victoria and Catchment and Agricultural Services in Victoria. This separation means that extension agents may have little ownership of research outcomes and research scientists have poor links to industry. There seems to be no rationale for this separation. Research scientists world-wide agree that it would improve the effectiveness of research-extension if both groups belonged to the same organisation.

Farm forestry creates special problems that are obvious in England and Australia. Forestry has traditionally been conducted on large areas of government owned land, usually by scientists in different organisations than for agricultural production. With farm forestry, there is a need for timber production to be combined with other outcomes including biodiversity, integration with other farming activities (livestock, cropping) water harvesting etc. Also, there is difficulty in getting traditional foresters to appreciate that small areas of high value timber may be very appropriate on farms compared to the common view of larger volumes of lower value timber. To date, in both countries, the potential value of farm forestry to help overcome some of the environmental problems facing temperate agriculture has not been realised and a more integrated approach to farm forestry is urgently needed.

11. Long-term experiments

Agriculture Victoria, Hamilton has the only long-term grazing experiment in southern Australia monitoring effects of fertiliser and grazing on soils, pastures and animals. The experiment was established in 1978 with 6 P rates (0-33 kg P/ha/yr) and a range of stocking rates (5-20 ewes/ha). Olsen P currently varies from 4-30 ppm. Over time, the experiment has shown that the application of 20 kgP/ha/yr has tripled pasture production and doubled gross margins from wool sheep with apparently little impact on environmental sustainability (Saul et al. 1999). Europe has a history of using long-term experiments and an important reason for the fellowship was to learn how to make better use of the Hamilton site. Visits and discussions were held with a number of scientists in Europe as detailed below.

Institute Arable Crop Research, Rothamsted
Lawes and Gilbert established experiments at Rothamsted in the 1840’s to study the impact of mineral and organic fertilisers on crop and pasture production. Some of these experiments were discontinued in the early 1900’s but several called the “Rothamsted Classical Experiments” (Anon 1991) have continued but with some modifications for over 150 years. Three of these experiments were visited and discussed with Dr Paul Poulton during 2 visits to the Institute.

Park Grass - This is the oldest grassland experiment in the UK being established in 1856 on a field that had been in pasture for at least 100 years when the experiment began. The experiment compares the effects of a wide range of mineral fertilisers and animal manures on botanical composition, herbage yield and soil properties. Plots are cut for hay once per year. The combination of acid input from the atmosphere, hay removal and use of ammonium sulphate has caused significant acidification of unlimed plots with many around pH (H₂O) 3.5 (Johnston et al. 32
In 1965, the original main plots were divided into 4 sections; one series of plots has remained unlimed while on other plots, lime has been applied to maintain pH at 5, 6 or 7. The treatments show a 3 fold effect on hay yield (2.6-7.4 t/ha/yr) with low soil pH causing the greatest reduction in yield (Jenkinson et al. 1994). On the acid soils, an organic mat has formed as there is little or no biological breakdown of plant material. Full details of effects of soil acidity at Park Grass are provided by Johnston et al. (1986), Blake et al. (1994) and Blake et al. (1999). On the very acid soils, scientists believe that the clay minerals have been irreversibly weathered with Al now occupying 70% of the exchange capacity. In the last 20 years, there has been a massive increase in the Al content of herbage such that it is now toxic to cattle.

Park Grass has also clearly demonstrated the inverse relationship between pasture productivity and botanical diversity (Tilman et al. 1994). In general, the greater the productivity caused by fertiliser treatments, the lower the number of species in the pasture. Acid plots have even lower species number. This inverse relationship in the opposite of the view commonly expressed by many ecologists and is discussed in detail elsewhere in this report.

The main advantages of the Park Grass experiment are the long and detailed history available for the site, large amounts of archived soil, herbage and fertiliser available for reanalysis and the wide range in soil and pasture environments available on the same site. A major limitation is that the pasture species and management system (hay production) used are not representative of modern farms. Resolving the conflict between keeping the experiment relevant yet avoiding constant change is a problem all long term experiments face. Treatment are un-replicated so little direct statistical analysis of data can be carried out but this has not stopped an extensive publication record.

Broadbalk - The Broadbalk winter wheat experiment was established in 1844 to study the impact of different mineral and organic fertilisers on yield. In later years, a rotation including fallow and potatoes was introduced. Average wheat yields in the 1840’s were around 1.5 t/ha. Currently, a combination of increased soil fertility, new wheat varieties, control of pests, diseases and weeds allows yields of 6-7 t/ha. Dyke et al. (1983), and Anon (1991) provided comprehensive reports on the Broadbalk experiment.

An interesting addition to Broadbalk, are adjacent wilderness areas that were separated off in 1882. One half of the area was untouched and now is woodland of mature trees. Another section was maintained free of woody species and slashed periodically. The remaining area is grazed by sheep or cattle in summer and contains coarse pasture species.

The biggest difference between Broadbalk and Park Grass is the efforts made to keep the former experiment relevant to current farming practise through planned changes to experimental treatments and management. New varieties are regularly introduced and new cultural practises such as weedicides and pesticides adopted. Further changes were being discussed at the time of my visit to ensure that the timing and amount of N Fertiliser applied did not restrict wheat yields. As for the Park Grass experiment, the treatments are un-replicated though the similarity of some treatments and progressive fertiliser applications allow some statistical analysis.

Woburn Ley Arable Experiment - This experiment started in 1938 on a sandy loam soil. A 5-year rotation consisting of a 3-year treatment phase is used. Treatments include continuous arable cropping, all grass leys plus N fertiliser and a grass-clover ley (Poulton and Johnston 1996).
The different treatments have had a major impact on soil organic carbon (OC). Under continuous cropping, OC declined from 0.98%C in 1938 to 0.81%C in the 1980’s. Soils with 3-year leys have increased in OC to about 1.15%C. Wheat grown after grass or grass-clover ley yields 0.9 and 2.3 t/ha more than wheat under continuous cropping. Spring barley is sown after the winter wheat. Yields following leys were about 0.5 t/ha higher than for continuous cropping with no difference between grass and grass legume leys suggesting that increased organic matter provided benefits that could not be mimicked by additional fertiliser. In contrast to the other sites, this experiment is replicated allowing easier interpolation of data.

UFZ Centre for Environmental Research Leipzig-Halle
The experimental station at Bad Lauchstadt near Halle in Germany is situated in a low rainfall area (480 mm/yr) and contains several cereal experiments started in the early 1900’s. Professor Martin Korschens currently manages the site. The experiment shows the classic response to different combinations of mineral fertilisers and the higher yields obtained in the last 15 years compared to that in the early 1900’s (Korchens and Pfefferkorn 1998). Data from the longterm sites has been used by Korschens et al. (1998) to provide guidelines for soil organic matter (SOM) content of soils. (Due to the difficulty in accessing this reference, the table is reproduced in Appendix 1). Values for optimum SOM increase from 1-1.5% in sandy soils to 3.5-4.4% in clay soils. Korschens believes that the absolute level and change in SOM is essential benchmark of the sustainability of agricultural systems.

Long-term cereal sites were also visited at the Seehausen Experimental Station under the direction of Dr H. Matthies. The station has a large number of experiments comparing the yield and environmental impact of different crop rotations and fertiliser treatments.

Bronydd Mawr
An experiment was established in 1990 to study the impact of changes in fertiliser policy on the productivity and floral diversity of Welsh Hill pastures (Davies undated). The treatments being compared are lime, P, K & N; Lime, P& K; lime alone; or no nutrient applications. The density of perennial ryegrass declined as soon as nutrient applications ceased with a rapid increase in Poa ssp s and crested dogstail. Over 6 years, animal production declined by 50% but there was little increase in the number of species in the low fertility plots. The experiment will continue indefinitely to determine the new plateau in productivity when all inputs are withheld.

Johnstown Castle
A grazing experiment was established at Johnstown Castle Research Centre in 1968 to determine the long-term impact of different fertiliser treatments on the productivity of beef cattle (Culleton et al. 1999). P fertiliser was applied at 0, 15 and 30 kg/ha/year to pastures with a high initial soil fertility and perennial ryegrass content. N was applied to all plots at 220 kg/ha/year.

The experiment determined that P applied at 15 kg/ha was the optimum treatment over time and maintained Olsen P within the target range of 24-40 mg/kg. There was little benefit of the higher P application with an increased risk of P movement into waterways. Low P treatments were invaded by poor quality species such as Agrostis and ryegrass declined rapidly.

The experiment has been used to study movement of P down the soil profile and into waterways. Tunney (pers comm.) has used the site to sample surface water and study the relationship
between soil P and soluble P in surface water. This site is one of the oldest grazed fertiliser experiments in Europe but has had little recognition or publicity.

**Newcastle University**

The Palace Leas meadow hay experiment was established in 1896 to compare what was considered at the time, best practise for fertiliser. Robert Sheil currently manages the site and has established a comprehensive web site (http://www.staff.ncl.ac.uk/r.s.sheil/treatments.htm). Treatments include a range of farm yard manure applications with or without mineral fertiliser and all combinations of N (35 kg/ha as ammonium sulphate), P (20 Kg/ha as basic slag and recently triple super) and K (20 kg/ha).

Ammonium sulphate application caused pH to decline to 3.8 ($\text{H}_2\text{O}$). On this treatment, there is virtually no microbial activity as evidenced by the very slow breakdown of cattle dung on the plots and the organic mat in the top 6 cm of soil. Plots receiving all 3 nutrients are about pH 5.0 with manure treatments 0.1-0.5 pH units higher than mineral fertiliser treatments.

The site has several limitations common to other longterm experiments including outdated pasture species, inappropriate managerial treatments (hay and then grazing in common with cattle) and a relatively low range in soil fertility treatments. However, the information on microbial flora and organic matter dynamics is very valuable.

**Implications for the Hamilton Long Term Phosphate Experiment**

There is a strong belief in the value of long-term experiments in Europe. The interest and maintenance of long-term experiments is a reflection of the longer history of basic research and importance of environmental issues. Important issues for the Hamilton LTPE are:

*Managing change* - Unless changes are made to long-term experiments, they gradually lose relevance to current agricultural practises. For the Broadbalk experiment, new varieties, fungicides, weedicides and liming has been introduced so that maximum yield that is now much higher than in 1940-50’s. Poulton (1995) has discussed “enforced” or “planned” changes over time in long-term experiments. On Park Grass and Palace Leas, few changes have been made and it could be argued that the practises used are interesting historical management comparisons with little relevance to today’s farmers. The problem is to find the correct balance between keeping the experiments relevant but avoiding wholesale changes that are lose or compromise long-term effects. This is an important issue for the Hamilton experiment to over the next 2-3 years and we need to document which issues should remain constant and which issues can be allowed to change over time.

*Publication of results* - European long-term experiments have a strong history of scientific publication. Several such as Palace Leas and Rothamsted also have excellent web sites and Agriculture Victoria needs to develop a high profile site to allow access to information. In addition to traditional papers, Rothamsted also have published a detailed chronological history of the experiments every 20 years or so. The lack of replication does not appear to have adversely effected the publication rate. Detailed bibliographies are also available for most European experiments. Initial results from the LTPE have now been published but we need a publication that brings all results together and provides details of the first 20 years of the experiment. Rothamsted goes further than other sites and has a detailed daily log noting all activities undertaken on the classical experiments.
**Funding** - All experiments visited expressed concern about the difficulty in funding long-term experiments. Most sites were maintained by core funding provided to the Institute and then grants were sought to undertake specific studies. Some experiments have been put into “mothballs” for some time until funding became available. There appears to be no easy answer to funding these experiments especially in Victoria where core funding does not exist. The need to “sell” long term experiments every 3-5 years to funding agencies with short-term goals is likely to be an ongoing problem for LTPE.

**Archive samples** - Rothamsted have an amazing store of soil, fertiliser, grain and herbage samples going back to the 1850’s. These are often used to undertake new tests on old samples and are a very important resource. However, the cost of maintaining the samples in dry, warm conditions is high. At Hamilton, we urgently need to establish what samples are available to archive, the correct conditions for storage and the need for additional sample to be taken and stored.

**Sustainability issues** - An important use of European long-term experiments is to determine the changes in pH, organic matter, soil biota, floral diversity etc caused by different agricultural practises. There is potential to use the LTPE to determine the impact of the different treatments on soil biological and physical properties. This work should be done in conjunction with appropriate universities.

**Control areas** - Rothamsted have small, unfertilised areas set aside to use as “virgin” soil. There are some relatively untouched areas adjacent to the LTPE and management of these areas needs to be specified so soil samples with a known history are available in future years.

**Succession planning** - Long-term experiments undergo periodic upheaval when senior staff retire or are promoted away from the experiment. Again, Rothamsted seem to have overcome this issue with new scientists serving an apprenticeship under the previous manager. Also, there is a scientific panel that vet any changes to the classical experiments, to ensure continuity.

**Changes in productivity over time** - The Rothamsted classical experiments have been used to document the change in productivity of agricultural systems over time (Powlson and Poulton 1998). Despite the perception of some people, it is clear that the supply of balanced nutrients plus new cultural techniques and species has trebled crop yields over the last 150 years. There is less information available on long-term yields in pasture based systems and the LTPE could provide a significant contribution to the world literature.

12. **Farming systems studies**

In the past, applied farming systems studies were used extensively in the UK to determine the impact of different management options on farm productivity and economic returns. However, as indicated previously, these systems studies have fallen out of favour in the UK, no doubt due to the high cost of this type of research, the change to more basic research and the lower emphasis currently placed on economic outcomes.

In contrast, systems studies are still used widely in Ireland and Denmark. British farmers and journalists held Irish grazing experiments in high regard. At the Grassland Conference, the lack of applied systems experiments was held up as a key deficiency of the UK R&D portfolio. Irish workers were praised for the valuable systems work being undertaken.
I visited three key research centres in Ireland, Johnstown Castle, Moorpark and Grange. All three centres undertook systems studies but scientists were somewhat embarrassed at the praise being lavished on the work. While farmers eagerly sought results of the studies, there were many limitations in the work. Usually the different systems were not replicated, in an extreme example the livestock in the different systems grazed quite different land areas. Some systems studies were very complicated and it was hard to see their relevance to most farmers. The problem all workers were grappling with was how to harness the strength of the farmer interest in the applied work but at the same time undertake meaningful research at reasonable cost where the results would stand scientific scrutiny.

An interesting development of the systems approach was viewed in Northern Ireland. Andrew Carson at Hillsborough was conducting an experiment comparing the productivity of 2 ewe breeds at 3 different residual grazing heights. The full set of treatments was being compared at the Institute with detailed measurement of animal and pasture parameters. At the same time, he had established simple comparisons of components of the systems on a number of private farms. It seemed to me that he had achieved the best of both the applied and strategic systems. He indicated that the on-farm work was relatively low cost and he was not greatly relying on the results, the main understanding would come from the detailed experiment at Hillsborough.

Key messages for Australian systems studies seem to be:
- Systems studies on research institutes must be replicated and be able to stand scientific scrutiny otherwise why are they done on a government property?
- Strategic work is needed to understand why responses are occurring, ie with a new sheep breed, is the higher production due to greater feed intake or more efficient feed conversion
- Monitor farms may be a better option for some comparisons where the scale of the operation may impact on results.

13. Ideas with potential application in Victoria

While the main purpose of the study tour was to investigate aspects of sustainable agricultural systems, while visiting different research centres, a number of novel ideas were seen which may have application in Victoria. Only brief details are provided and the leads will be provided to relevant NRE staff for follow-up action.

**Whole crop silage (WCS)**

The use of cereal crops such as winter wheat and spring maize for silage has grown dramatically in Europe in the last 10 years. WCS provides high yields (10-16 t/ha) at one operation and for normal fermentation, is cut at soft dough stage so it is 35-45 % dry matter. Another alternative is to ensile the crop at 50-60% dry matter and preserve the crop with urea, which also improves the protein content of the silage. Ease of handling a finely chopped product and the dry nature of the silage were often quoted by farmers as their reasons for adoption compared with traditional grass silage. In Denmark and Ireland, the cereal is often sown with a legume such as peas, vetch or red clover to improve the quality of the silage. However, this may make decisions about cutting time and management more difficult.

Maize gives higher yields and quality but is only suitable for summer rainfall or irrigation areas. In some parts of Europe, maize is grown under plastic to boost early season growth and extend the areas where it can be grown. However, wheat or barley is more common in cooler areas of
Sustainable Agricultural Systems for Southern Australia

Scotland and mainland Europe. Details of the feeding value of urea treated WCS for dairy cows are summarised in a Milk Development Council report (MDC undated). There is also considerable debate on whether it is better to use early cut, high ME, WCS and natural fermentation or aim for higher yield lower ME, high dry matter silage treated with ammonia or urea for preservation.

O’Keily and Moloney (1995) reported the effects of early and late cut whole crop wheat silage with or without silage additives or urea, fed to 400 kg Charolais heifers (Table 1). The results show that animals performed well on the late cut silage, despite its relatively low apparent feeding value.

Table 1  The effect of cutting time and treatment on the quality and feeding value of wheat silage

<table>
<thead>
<tr>
<th></th>
<th>Early cut</th>
<th></th>
<th>Late cut</th>
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<tbody>
<tr>
<td></td>
<td>No treatment</td>
<td>Propionic acid</td>
<td>No treatment</td>
<td>Propionic acid</td>
</tr>
<tr>
<td>Dry matter (g/kg)</td>
<td>371</td>
<td>394</td>
<td>487</td>
<td>456</td>
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<tr>
<td>Crude protein (g/kg DM)</td>
<td>120</td>
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<tr>
<td>In vitro silage digestibility (g/kg DM)</td>
<td>675</td>
<td>677</td>
<td>557</td>
<td>532</td>
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<tr>
<td>Silage intake (kg/hd/d)</td>
<td>5.24</td>
<td>5.77</td>
<td>5.76</td>
<td>5.45</td>
</tr>
<tr>
<td>Liveweight gain when fed silage plus 3 kg/hd/d concentrates (g/hd/d)</td>
<td>889</td>
<td>944</td>
<td>921</td>
<td>894</td>
</tr>
</tbody>
</table>

For southern Australia, maize silage could be grown where summer rainfall is adequate or where irrigation is available. Whole Crop Cereal is the most useful option for cow calf systems, bull beef production and lamb-finishing where climatic conditions will usually limit maize silage.

There are several advantages of WCS. If the silage is not required, the cereal crop may be headed in the normal way rather than being used for silage. WCS would be harvested in November-December when weather conditions in southern Victoria are much more amenable to making silage. The cereal could be combined with a legume to boost quality and reduce the need for applied N. Also, many cereals used for WCS are undersown and the early removal of the cereal allows the pasture to develop without competition. Disadvantages include the need for contractors using specialised cutting equipment to harvest and fine chop the WCS, problems with rapid changes to dry matter content in summer in Australia and the low quality of some WCS.

Internet sites
When making arrangements for this study tour, the high quality of many overseas agricultural web sites became very apparent. Many scientists also provided details of their sites during visits. The following are some examples of different sites available. Agriculture Victoria urgently need to develop innovative sites to market and disseminate research results.

[www.staff.ncl.ac.uk/r.s.shiel/treatments.htm](http://www.staff.ncl.ac.uk/r.s.shiel/treatments.htm) This site gives very good details of the long term experiment at Palace Leas Newcastle. It is a good example of what could be done for LTPE.

[www.res.bbsrc.ac.uk/era/parkgrass](http://www.res.bbsrc.ac.uk/era/parkgrass) Rothamsted maintains a very detailed site on the classic experiments. Scientists may apply for a password that allows access to archived data.
www.afsni.ac.uk/research/p_sources  This site based at Queens University Belfast provides an excellent summary of the research on P movement into waterways. The site contains a presentation that can be downloaded and used by students and farmers.

www.teagasc.ie/contacts/agriresearch.htm  Teagasc in Ireland maintain very good web sites for the different centres which allows easy access to information about projects and staff.

www.wye.ac.uk  Wye College maintain a comprehensive site explaining the role of the college. A useful feature is maps that can be downloaded to help find the college, accommodation etc. Comprehensive timetables and details of transport are also provided.

Internal parasites in sheep
The growing importance of organic farming systems has lead to a resurgence in research on alternatives to anthelmintics to control internal parasitism in sheep. Younie and Hermansen (2000) provide a good overview of the issue. Under European conditions, sheep are often housed for 3-4 months so clean pastures can make a significant contribution. Also, mixed farming allows farmers to use stubble from crops, hay and silage aftermath, fodder crops and newly sown pastures to reduce chemical use. These opportunities are not as readily available to Australian farmers but integration of sheep and other enterprises needs to be encouraged.

At Edinburgh University, scientists are investigating trade-offs between nutrient intake and faecal avoidance by sheep (Hutchings et al. 1999), effects of protein intake on faecal egg counts (Houdijk et al. 1999) and effects of condensed tannins on parasitised sheep (Athanasiadou et al. 1999). It would valuable for Victorian scientists with expertise in sheep parasitism to maintain contact with this group and look for collaborative projects. There is local evidence (Saul 1996) that ewes grazing pastures with a high clover content had reduced faecal egg counts compared to those on low clover pastures.

NIR technology
Two new applications of NIR technology were observed while visiting European centres. At the Agricultural Research Institute, Hillsborough, Northern Ireland, the laboratory processes over 10,000 silage samples per year @ £13/sample. In recent years, the centre has provided information on DDM, ME and potential intake (Agnew et al. 2000) of grass and silage samples. Predicted intake is based on calibrations from field trials where intake of pasture or silage was determined on representative samples scanned by NIR equipment. Information on potential intake is particularly important for high producing dairy cows where feed intake is a major limitation to increased productivity. At Hillsborough, fresh silage was scanned without any preparation or drying. The silage was wrapped in a “Gladwrap” style film into a 3 cm X 10 cm sausage which was then scanned. This system greatly reduced time and cost of the analysis.

Several groups indicated that they expect to have direct reading NIR equipment attached to plot harvesters within 1-2 years. Halstrup, the major manufacturer of plot machinery has NIR systems under trial on their harvesters and expect to be in commercial release quite soon. This innovation will greatly reduce the need to take sub-samples of herbage for later analysis and reduce the cost of pasture cultivar comparisons.

Computerisation of records
While visiting several institutes, I was impressed by the way different groups had developed simple systems using small hand held computers, to input plot data directly in the field. Direct
input has major advantages in avoidance of transcription errors, reduced time, capacity to immediately analyse data and the ability to run programs to check data for incorrect entries and outliers.

Brian Waters at the Plant Testing Station, Belfast uses a small computer and a program developed by the local biometrician, to enter all DUS data collected from the thousands of trials conducted by the centre. In addition to the standard measurements of height, width, flowering date etc, the group uses computer-derived values (width x height etc) to separate different cultivars. Brian demonstrated the ease by which field data was down-loaded to a desk computer and then could be immediately analysed.

It is recommended that AV-H investigate ways to use small hand held computers to enter field data, reduce errors and streamline collation and subsequent analysis of the results.

**Meat and milk quality from grass**

Wilkins and Vidrih (2000) discussed the opportunities to manipulate meat and milk quality through diet. They reported results from other workers that indicated beef from cattle raised on grass had more favourable ratios of omega-6 to omega-3 polyunsaturated fatty acids than that from cattle on concentrate diets. These ratios are important to reduce the risk of coronary heart disease. Other studies have shown that pasture may significantly increase the conjugated linoleic acid (CLA) content of milk. CLA is known to be a strong anti-carcinogen.

It is suggested that local nutritionists review the literature on these issues to determine the applicability of the work to Australia. Additional references are available from the author.

**End of project reports**

Teagasc, the Irish Agricultural Research and Advisory organisation has established a process of printing “End of Project Reports” (EOPR). Pat Gleeson, Director of the Production Research Directorate seems to have been a key person behind this initiative. His concern was that in many projects, there is a delay between the completion of the work and scientific papers being published. Also, many advisory staff did not take information from research journals. The EOPR’s aim to quickly publish the important implications of the work for other scientists, extension agents and any farmers who want detailed information though EOPR are not seen as a major method to get new information directly to farmers. Pat indicated that until the EOPR format was adopted, final project reports were produced and filed and never used. He felt that the format adopted was much more useful and provided the funding agency with a summary of the project and other interested people with details on the application of the results.

The EOPR are A5, 12-16 page books and make good use of photos, tables and graphs. It was stressed to me the importance of leaving all details of preparation, editing, printing and circulation with the local research organisation so they owned the idea and did not see it as another imposition from above. At all institutes I visited, EOPR were readily available and provided and seemed to be well accepted. Adoption of this type of upgraded EOPR could be well worth consideration in Australia.

**14. Opportunities for Post-doctoral positions and staff exchanges**

Australian scientists working in temperate agriculture are isolated from other scientists. New Zealand has significant research expertise in temperate agriculture occupies but both Australia
and NZ have a similar view on many aspects of agricultural production. Exchanges and visits to NZ therefore only go part of the way to expanding knowledge of other practices and world views of agriculture. Opportunities for staff exchanges or post-doctoral positions for Agriculture Victoria staff were therefore actively sought while visiting Europe and are listed below.

**Phosphorus movement from pastures to waterways**
P movement is being studied at several centres in the UK and Ireland. As in Australia, there is concern about the growing problem of eutrophication of lakes and rivers. There is considerable potential for students from Victoria to work at centres such as North Wyke or Johnstown Castle to gain a more basic understanding of how P moves into waterways and control methods.

**Systems modelling**
There appears to have been little attempt made in Europe to use computer models to simulate grazing systems or predict pasture growth from weather data as is commonly done in Australia with programs such as Grasgro. In contrast, groups at MLURI have developed very sophisticated models to help make better decisions on land use and compromises between financial, social and environmental consequences in land use change.

There could be value in staff with modelling skills spending time at MLURI to learn different ways to use simulation models, especially in environmental and land use issues.

Staff at Grange in Ireland expressed interest in using programs like Grassgro to predict pasture production and run simulations of different management strategies. Current pasture models used in Europe appear to be very rudimentary, compared to the Australian models.

**Pasture ecology and grazing management**
Centres such as Macaulay Land Use Research Institute and Institute for Grassland and Environmental Research have considerable expertise in the ecology of pasture species, especially perennial ryegrass and white clover. Scientists from Australia could gain considerable knowledge by working at these centres alongside leading pasture specialists.

**Silage production, conservation and feeding**
As discussed earlier in this report, there are major opportunities to improve the use of silage for beef cattle and meat sheep. It appears that high rainfall farmers in Australia are behind in the use of new silage technology. A major limitation in southern Australia is the lack of expertise in the fodder conservation with only the group at Wagga undertaking significant R&D in this field.

The Grange Research Centre runs a major program on silage production and beef cattle management systems. There is strong interest by the director Dr Eddie O’Reardon and senior staff in arranging collaborative R&D with Australian scientists. An exchange program over 2-3 years would benefit scientists at both centres and quickly bring new silage technology to Australian farmers.

**Closer relations between Victoria and Ireland**
During my fellowship, I visited Johnstown Castle, Grange and Moorepark research centres in the Irish Republic and the Agricultural Institute of Northern Ireland at Hillsbrough and Belfast. There are many similarities between Irish and southern Australian agriculture such as strong export focus, interest in productivity improvement, reliance on grazing animals and a need to strike a realistic balance between economic, social and environmental issues. I believe that AV
Sustainable Agricultural Systems for Southern Australia

should encourage exchange of people and ideas between the two countries. There is very strong support for this concept from senior Teagasc staff such as Dr Pat Gleeson, Head of Production Research. Recent visits by Dr Chris Granger and John Roche at Moorpark and Dr Padraig O’Keily from Grange have paved the way for the process to develop. There are a wide range of fellowships and trusts to fund visits to Commonwealth countries but these exclude Ireland. Alternative funding arrangements to encourage scientific exchanges between Ireland and Victoria should be explored and made known to AV staff.

15. Recommendations

The major recommendation from this study tour is the urgent need for temperate Australian agriculture to develop and implement sustainable agricultural systems that encompass the “triple bottom line” of economic, environmental and social sustainability. We also need to determine the trade-off’s between these different issues as it is unlikely that “win-win” situations will commonly occur. For too long, we have allowed economic outcomes to override social and environmental values. This has lead to the current situation where the environment has been “mined” to prop up the economic returns from agriculture. For example, soil fertility and soil pH has been allowed to decline, the potential impact of agriculture on the soil water balance has been ignored and pastures allowed to run-down, in order to maintain the short-term profitability of the grazing industries. In addition, the impacts of changes in new agricultural practises such as tree plantations on social issues have not been well considered.

Other significant findings include;

- Overseas research supports the view that high input production systems (HIPS) are sustainable in the long–term provided a balanced approach to soil nutrient inputs and pasture management is used. There is no evidence that well managed HIPS collapse or rundown over time due to poor microbial activity or nutrient or soil problems. The problem in Australia is that many sown perennial pastures are poorly managed and so rapidly decline leading to major economic and environmental problems. There is an urgent need for increased knowledge of the ecology of perennial grasses and extension of management systems specific to the diverse range of climatic and soil conditions in southern Australia. The Sustainable Grazing Systems Key Project is the first major cross discipline and cross state border project addressing these issues and need to be encouraged.

- P loss to waterways is potentially a major problem in HIPS. In Europe, eutrophication of waterways is occurring against a background of high soil P, relatively cool conditions and high river flow rates. In Australia, we have currently low soil P levels and high summer temperatures. As we encourage farmers to move to higher soil fertility systems, it is likely that we will increase the potential risk of P movement to waterways. There is an urgent need to understand how P moves to waterways so that management options that balance economic and environmental outcomes can be developed.

- Biodiversity in agricultural systems is a contentious issue. In Europe, many farmers are paid to adopt grazing systems that encourage wildflowers and other traditional plants to re-colonise pastures as is now well accepted that there is a negative relationship between productivity and floristic diversity in high rainfall, fertile grazing systems. In southern Australia, it is suggested that encouraging a mosaic of different vegetation types across farms and landscapes, each managed for a specific production or environmental outcome, will provide a better result than trying to achieve both outcomes from the same paddock or land area.
• European countries particularly Ireland have developed policies to keep people living and working in rural areas as the number of people employed on farms declines. Industry is actively encouraged to establish in rural areas and part-time farming is encouraged. This issue is outside the scope of this report but is an important aspect of social sustainability in rural communities.

• There has been rapid growth in agro-environmental schemes in Europe in recent years. Some of these such as “Environmentally Sensitive Areas” in the UK are a way of maintaining “living museums” for urban people to visit. In contrast, the LEAF scheme encourages farmers to adopt viable agriculture that is environmentally and socially acceptable. This linking of environmental and economic outcomes should be encouraged at all levels of agricultural research, extension and adoption.

• Organic farming is being encouraged by in many European countries. This is possible in Europe due to high soil fertility brought about by 50 years of chemical fertiliser application and purchased stock feeds and bedding from off-farm used to import nutrients. Also, farmers can use drugs for animal health treatment if serious health problems occur, provided longer withholding periods are adopted. There appears to be less potential for the development of organic production systems for meat or wool production in high rainfall southern Australia where these conditions do not occur.

• Research outcomes in southern Australia could be improved by a greater emphasis on strategic compared to applied research. Also, organisational arrangements are needed which encourage integration of production and environmental research and of research and extension activities.

• Long-term experiments are used extensively in Europe to understand the impacts of agricultural systems. There are few long-term experiments in southern Australia and these need to be funded and used to explore sustainability issues. A audit of the current value and future potential use of Australian long-term experiments could be used to build collaboration with European workers could greatly assist in efficient use of these experiments.

• There are many opportunities for collaboration between European and Australian research workers. In particular, R&D in Ireland has many similarities to Victoria and it is recommended that strong links be established between the respective agricultural organisations, Teagasc and Agriculture Victoria.

Guidelines ranges for the SOM content of sandy and loamy soils without ground-water influence (% SOM in ploughing layer) depending on fine silt and clay (<6.3 µm).
(from Korchens et al. 1998)

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<tr>
<th>Clay &amp; fine Silt (%)</th>
<th>Sandy soils UpperValue</th>
<th>Sandy soils LowerValue</th>
<th>Loamy soils UpperValue</th>
<th>Loamy soils LowerValue</th>
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## 17. Program of Visits

*Churchill Fellowship Itinerary, February – June 2000*

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Places Visited, Activities</th>
<th>People</th>
<th>Main Issues Discussed</th>
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<tbody>
<tr>
<td>19th – 20th February</td>
<td>Devon</td>
<td>Travel from Hamilton to London</td>
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<tr>
<td>21st February</td>
<td>Devon</td>
<td>Travel to Exeter</td>
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<td>Tuesday 22nd February</td>
<td>Devon</td>
<td>Institute Grassland &amp; Environmental Research, North Wyke “Town Barton Farm”, Sanford</td>
<td>Mark Rutter, Robert Orr, Dave Munday</td>
<td>Grass clover pastures and animal preference.</td>
</tr>
<tr>
<td></td>
<td>Devon</td>
<td>North Wyke – IGER, “Home Farm Newton”, St Cyres, Devon</td>
<td>Phil Haygarth, Prof Roger Wilkins, Head, North Wyke, Steve Jarvis, Mary Quicke, Allan Hopkins</td>
<td>Beef cattle systems demonstration. Past, current and future issues for grazing systems in the UK and Europe. Overview of nutrient issues, potential for collaboration and post doc. positions. Keen advocate of improved pasture utilisation, extended grazing, critical of R&amp;D undertaken at IGER through lack of applicability to farmers.</td>
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<tr>
<td>Date</td>
<td>Location</td>
<td>Event Description</td>
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<tr>
<td>Friday 25th February</td>
<td>Cornwall</td>
<td>“Hendra”, Camelford, Cornwall</td>
<td>David Cray,</td>
<td>Established beef cattle unit run under along typical UK guidelines, supportive of IGER.</td>
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<tr>
<td>26th – 27th February</td>
<td>Cornwall</td>
<td>Travel to Harrogate and rest days</td>
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<td>Monday 28th February</td>
<td>Yorkshire</td>
<td>“Scarah Bank Farm” Ripley, Yorkshire, LEAF Demonstration Farm, “Manor farm”, Eddlethorpe, Malton.</td>
<td>Andrew Walmsley, Chris Rigley</td>
<td>Large and expanding dairy farm, using traditional grazing methods with tight management. What is “Linking Agriculture and Farming” all about, positives and negatives, structure, LEAF audit, using the LEAF name to sell products.</td>
</tr>
<tr>
<td>Tuesday 29th February – Thursday 2nd March</td>
<td>Yorkshire</td>
<td>British Grassland Society “Grazing Management Conference”</td>
<td></td>
<td>Conflict between advocates for production and environmental values. Future research needs for grazing systems. Irish farming systems compared to British systems.</td>
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<tr>
<td>Friday 3rd March</td>
<td>Hereford-shire</td>
<td>Rothamsted – Institute Arable Crop Research</td>
<td>Paul Poulton</td>
<td>Inspection of classic Long Term Experiments (LTE’s) Park Grass, Broadbalk. Discussion on funding, management, succession planning, archive samples and publication of LTE results. Using LTE to answer sustainability questions.</td>
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<tr>
<td>Saturday 4th – Sunday 5th March</td>
<td>London</td>
<td>Visit to Churchill sites</td>
<td>War Cabinet Rooms, Battle of Britain display</td>
<td>Balancing profit, environmental and social issues, future of farming in UK. N loss in arable and grazed pastures, IACR projects, “overexposed and over-emphasised”. Subsidies and changes to payments for milk in the UK, implications for social sustainability.</td>
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<tr>
<td>Monday 6th March</td>
<td>Kent</td>
<td>Wye College,</td>
<td>David Leaver, Liz Braggs, Stephen Bates</td>
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<tr>
<td>Date</td>
<td>Location</td>
<td>Activity</td>
<td>Details</td>
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<tr>
<td>6th - 8th March</td>
<td></td>
<td>London to Hamilton</td>
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<tr>
<td>15-16th April</td>
<td></td>
<td>Fly to London</td>
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<tr>
<td>Monday 17th April</td>
<td>England</td>
<td>Pick up hire car in London and drive to Bronydd Mawr</td>
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<tr>
<td>Tuesday 18th April</td>
<td>Wales</td>
<td>Institute Grassland &amp; Environmental Research, Bronydd Mawr Field Station</td>
<td>• Arthur Davies, Mick Fothergill, Brian Evans</td>
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<td></td>
<td></td>
<td></td>
<td>• Sustainability of Welsh Hill farms.</td>
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<td>• Pasture ecology under different fertiliser regimes, evaluation of</td>
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<td>clover cultivars under grazing.</td>
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<td>• Adoption of productive pasture systems.</td>
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<tr>
<td>Wednesday 19th April</td>
<td>Wales</td>
<td>IGER – Transgoed Farm</td>
<td>• Richard Weller</td>
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<td></td>
<td></td>
<td></td>
<td>• Organic dairy production systems.</td>
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<tr>
<td>Thursday 20th April</td>
<td>Wales</td>
<td>IGER – Plas Gogerddan</td>
<td>• Mervyn Humphries, Terry Michaelson-Yeates, Ann Cresswell, Evan Jones</td>
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<td></td>
<td></td>
<td></td>
<td>&amp; Phil Evans</td>
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<td>• Perennial grass breeding, future directions.</td>
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<td>• White clover breeding, future directions.</td>
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<td>• Sustainability issues in grazing systems.</td>
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<td>• Beef cattle production systems and evaluating pasture species under</td>
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<td>grazing.</td>
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<tr>
<td>Friday 21st April</td>
<td></td>
<td>Travel to Ireland by ferry from Fishguard, Wales</td>
<td>(Good Friday)</td>
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<tr>
<td>22 – 24th April</td>
<td>Ireland</td>
<td>Rest days in Ireland</td>
<td>Easter weekend</td>
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<tr>
<td>Tuesday 25th April</td>
<td>Ireland</td>
<td>Farm visits in Ireland, county Wexford</td>
<td>• Michael Brennan, John, Ann &amp; Dennis Asple</td>
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<td></td>
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<td>• Rural Environment Protection Scheme.</td>
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<td>• Highly productive, dairy production systems in Ireland.</td>
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<tr>
<td>Wednesday 26th April</td>
<td>Ireland</td>
<td>Teagasc, Johnstown Research Institute, Wexford,</td>
<td>• Noel Culleton, Owen Carton, Michael Ryan, Hubert Tunney, Brian</td>
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<td>Coulter</td>
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<td>• Optimising P fertiliser recommendations.</td>
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<td>• Balancing production and the environment.</td>
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<td>• Environmental issues with N fertiliser.</td>
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<td>• Environmental issues with P fertiliser.</td>
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<td></td>
<td>• Irish soil testing service.</td>
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<td>Date</td>
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<td>Event Details</td>
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</table>
| Thursday 27\(^{th}\) April | Ireland      | Teagasc, Moorpark Research Institute, Cork (Visit to Moorpark joined with Hayden Jones and Kevin Bellamy of the Milk Development Council, UK)  
• Pat Gleeson, Director  
• Dermot McCarthy  
• Michael O’Donovan  
• Imelda Casey  
• Seamus Fitzgerald  
• Pat Dillon & John Kennedy  
• Overview of Teagasc RD&E.  
• Teagasc advisory services.  
• Grazing management of dairy cows.  
• R&D to increase intake of dairy cows.  
• Systems studies with dairy cows.  
• Implications of high genetic merit livestock on productivity of pasture based systems. |
| Friday 28\(^{th}\) April | Ireland      | Teagasc, Grange Research Centre, Meath  
• Michael Drennan  
• Jerry Keane  
• Padraig O’Kiely  
• Dave McGilloway & Padraig French  
• Bernie Early  
• Eddie O’Riordan, OIC  
• Beef cattle production systems.  
• Beef cattle, sustainability, production, payments.  
• Whole crop silage.  
• Beef cattle systems studies, limitations, benefits.  
• Cattle health and welfare.  
• Systems studies, opportunities for staff exchanges. |
| 29\(^{th}\) April – 1\(^{st}\) May | Ireland      | Rest days in Ireland and travel to Northern Ireland  
• Overview of R&D in grazing in NI.  
• Sheep systems studies.  
• Arable systems and environmental implications.  
• NIR, direct measurements and intake prediction.  
• Dairy cows systems comparisons. |
| Tuesday 2\(^{nd}\) May | Northern Ireland | Agricultural Research Institute, Hillsborough  
• Prof Fred Gordon  
• Alister Carsen  
• Lindsay Easson  
• Mike Porter  
• Scott Ferris  
• Ryegrass and white clover variety testing.  
• DUS testing of new cultivars.  
• Grazing management and modelling to improve intake of livestock.  
• Agroforestry systems, biodiversity, sustainability.  
• P pollution of Irish lochs, literature search. |
| Wednesday 3\(^{rd}\) May | Northern Ireland | Department of Agriculture – Plant Testing Station and New Forge Lane  
Ferry to Stranraer, Scotland in evening  
• Trevor Gilliland  
• Brian Waters  
• Peter Barrett & Scott Laidlaw  
• Jim McAdam  
• Catherine Watson |
<table>
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<tr>
<th>Date</th>
<th>Location</th>
<th>Event Description</th>
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</thead>
<tbody>
<tr>
<td>Thursday 4(^{th}) May</td>
<td>Scotland</td>
<td>Macaulay Land Use Research Institute, Sourhope Research Farm</td>
</tr>
</tbody>
</table>
|                     |           | - Angus Russel
|                     |           | - Harry Sangster
|                     |           | - Alternative animal production systems, goats, sheep. 2 pasture production systems. |
| Friday 5\(^{th}\) May | Scotland  | Scottish Agricultural College, Penicuick Private farm in Edinburgh               |
|                     |           | - Jos Houdijk
|                     |           | - Mike Hutchins
|                     |           | - John Vipond
|                     |           | - Willie Crawford
|                     |           | - Management to control internal parasites in sheep. Selectivity of sheep for parasite infected pastures. Improved efficiency of sheep grazing systems. Sharlea sheep in Scotland. |
| 6\(^{th}\)-7\(^{th}\) May |           | Travel from Peebles to Brinsbury, College, Sussex                                 |
| Monday 8\(^{th}\) – Wednesday 10\(^{th}\) May | Sussex    | British Grassland Summer meeting, West Sussex College of Agriculture, “Industries in Crisis” including visits to 5 farms |
|                     |           | Different views by farmers in their approach to current economic pressures and how they worked within existing environmental rules. |
| Wednesday 10\(^{th}\) May pm | Berkshire | Centre for Dairy Research, Reading                                                |
|                     |           | John Sutton & Richard Phipps
|                     |           | - Whole crop silage. |
| Thursday 11\(^{th}\) May | Lincoln-shire | Visit to LEAF farm near Lincoln                                                  |
|                     |           | Philip Ashton
|                     |           | Integrating production and environmental objectives onto large intensive arable farms. |
| Friday 12\(^{th}\) May | Northumberland | Newcastle University, Redesdale ADAS farm                                       |
|                     |           | Robert Sheil
|                     |           | Ray Keating
<p>|                     |           | Long term fertiliser experiment. Organic sheep production systems. |
| Saturday 13(^{th}) – Sunday 14(^{th}) May |            | Ferry Newcastle UK to Stavanger Norway                                           |
| 15(^{th}) – 17(^{th}) May | Norway    | Recreation Leave touring in southern Norway                                       |</p>
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<tr>
<th>Date</th>
<th>Location</th>
<th>Event Details</th>
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<tbody>
<tr>
<td>Thursday 18th – Sunday 21st May</td>
<td>Norway</td>
<td>European Grassland Federation Conference 2000, pre-conference tour from Stavanger, Norway. Norweigan farming systems dependence on government subsidies but very strong protection of social and environmental values.</td>
</tr>
<tr>
<td>Friday 26th – Sunday 28th May</td>
<td>Germany</td>
<td>Travel to Germany and sightseeing</td>
</tr>
<tr>
<td>Monday 29th May</td>
<td>Germany (former GDR)</td>
<td>Martin Luther University, Halle-Wittenburg                                    Stephan Scheacke Management of pastures in the River Elbe flood Plains</td>
</tr>
<tr>
<td>Tuesday 30th May</td>
<td>Germany (former GDR)</td>
<td>Lysimeter Station, Brandis Centre for Environmental Research, Leipzig-Halle Hydrologin Ulrike Hafeukorn H. Matties Martin Koerchens Basic research to understand movement of pollutants into ground-water. Long-term ley and arable experiments. Value of long-term experiments to understand sustainability of agricultural systems, importance of soil carbon in agricultural systems.</td>
</tr>
<tr>
<td>31st May</td>
<td></td>
<td>Travel to London</td>
</tr>
<tr>
<td>Thursday 1st June</td>
<td>Herefordshire</td>
<td>Rothamsted Institute Arable Crop Research                                      Paul Poulton Revisited 2 longterm experiments. Park Grass and Broadbalk to view differences in mid spring.</td>
</tr>
<tr>
<td>Friday 2nd June</td>
<td>Herefordshire</td>
<td>Rothamsted IACR                                                                Paul Poulton Keith Golding Visit to Woburn longterm arable-ley experiment. Indicators of sustainability in agricultural systems. Management, collaboration &amp; funding of LTE’s.</td>
</tr>
<tr>
<td>Date</td>
<td>Location</td>
<td>Event Description</td>
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<tr>
<td>Saturday 3(^{rd}) June</td>
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<td>Travel to Aberdeen,</td>
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<tr>
<td>Sunday 4(^{th}) June</td>
<td>Scotland</td>
<td>Rest day, report writing</td>
</tr>
<tr>
<td>Monday 5(^{th}) – Wednesday 7(^{th}) June</td>
<td>Scotland</td>
<td>Macaulay Land Use Research Institute, Aberdeen Glensaugh Research Station</td>
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<tr>
<td></td>
<td></td>
<td>• Prof Jeff Maxwell</td>
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<td>• Jim Mcleod</td>
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<td></td>
<td></td>
<td>• Allan Sibbald</td>
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<tr>
<td></td>
<td></td>
<td>• Overview of sustainability issues in Scottish Agriculture.</td>
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<td></td>
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<td>• HillDeer DSS for vegetation changes under grazing.</td>
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<tr>
<td></td>
<td></td>
<td>• Farm forestry systems, productivity, biodiversity</td>
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<tr>
<td>Thursday 8(^{th}) June</td>
<td>Scotland</td>
<td>Scottish Agricultural College, Craigstone</td>
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<tr>
<td></td>
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<td>• John Weddell</td>
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<td>• Pat Wrightman</td>
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<td>• David Younie</td>
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<td>• Whole crop silage, grass cultivar testing.</td>
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<td>• Basic research on the ecology of Nardis sps.</td>
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<td>• Organic farming systems, animal health issues, sustainability of organic systems, P &amp; K fertilisers.</td>
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<td>Friday 9(^{th}) June</td>
<td>Scotland</td>
<td>MLURI, Aberdeen</td>
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<tr>
<td></td>
<td></td>
<td>• Margaret Merchant</td>
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<td>• Iain Gordon</td>
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<td></td>
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<td>• Ed Paterson</td>
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<td></td>
<td></td>
<td>• Fine wool production systems.</td>
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<tr>
<td></td>
<td></td>
<td>• Animal behaviour and internal parasites.</td>
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<td></td>
<td></td>
<td>• Soil health, indicators, problems, methodology.</td>
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<tr>
<td>10(^{th}) - 11(^{th}) June</td>
<td>Scotland</td>
<td>Rest Days, report writing</td>
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<tr>
<td></td>
<td></td>
<td>• Social evening with senior MLURI staff.</td>
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<tr>
<td>Monday 12(^{th}) – Tuesday 13(^{th}) June</td>
<td>Scotland</td>
<td>MLURI, Aberdeen</td>
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<tr>
<td></td>
<td></td>
<td>• Robin Pakeman</td>
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<td>• Iain Wright</td>
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<td>• Tony Edwards</td>
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<td>• Jeff Maxwell</td>
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<td></td>
<td></td>
<td>• Pasture ecology.</td>
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<td></td>
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<td>• Animal production systems, future collaboration.</td>
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<td></td>
<td></td>
<td>• P movement to waterways.</td>
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<td></td>
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<td>• Overview of work.</td>
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<tr>
<td>14(^{th}) - 16(^{th}) June</td>
<td>In transit to Aberdeen-Hamilton, Australia</td>
<td>Travel to Aberdeen,</td>
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<td></td>
<td></td>
<td>Rest days, report writing</td>
</tr>
</tbody>
</table>

**Table:** Daily events and locations for a sustainable agricultural systems tour in Scotland.
18. References


MDC (undated). Making the most of whole crop cereals. Published by Milk Development Council, Stroud Rd, Cirencester, UK.


Teagasc (undated). The Organic Option for Irish Farmers. Published by Teagasc, Dublin.


