VG98105

Improving the long-term sustainability of intensive horticultural cropping systems

Dr Rowland Laurence
Tasmanian Institute of Agricultural Research

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Know-how for Horticulture™

VG98105

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Improving the long-term sustainability of intensive horticultural cropping systems
a feasibility study

Final Report for the
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by

Dr Rowland Laurence

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The purpose of this report is to document the progress and the outcomes of Project VG98105.

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Summary

It is certain that public awareness and concern for the environment has risen in recent years. Changes in the agricultural sector are occurring but are currently being driven by 'environmental market demand' rather than, perhaps, an understanding of the relative environmental benefits of different production systems.

Continuing profitability remains a key issue for producers and downstream industry and changing to more sustainable systems can often be seen to be inhibited by short-term costs whilst benefits appear to be longer-term, more difficult to quantify and may accrue to many who do not bear the immediate cost.

Many observers agree there is a need to quantify the environmental costs and benefits of different production systems over the longer-term and attempt to correctly attribute these costs and benefits in order that government policy can direct the required change.

This project builds on a previous regional study and seeks to determine the support of industry and government for developing a national strategy for establishing long-term investigations into the sustainability of intensive cropping systems. It reviews other long-term work throughout the UK, the USA and in Australia, to provide background information and guidelines upon which we may build. Particular consideration is given to what could perhaps be the prototype in long-term vegetable systems analysis in Australia – the Somersby project at Gosford, NSW. A wide range of potential stakeholders has been involved in developing the concept towards planning a national strategy.

The previous regional study was successful in involving local industry directly. In attempting to define support nationally for long-term investigations, this project targets a national network of champions, who will lead regional industry and government segments towards regional as well as national goals.

Industry involvement from the outset has shown that companies with a long-term association with production areas may be genuinely interested in participating. Clearly, any strategies developed must address a mix of short and long-term goals to maintain industry relevance. This has been a shortcoming of some previous attempts at long-term investigation where industry involvement has not been strong.

The communicative approach taken throughout the project has reached a broad range of potential stakeholders. Initial contacts with 24 individuals grew with distribution of a discussion paper to 51 individuals and organisations. This culminated in a workshop attended by 16 representatives from State and Federal departments and grower associations, all of whom subsequently received a report on the day's activities and outcomes.

While the high level of communication achieved throughout the project is an indication of support for a national framework, its ultimate success will depend upon a decision to

progress or not progress the development of regional proposals with industry, within a national framework, by a core group of regional champions.

With this in mind, the development of a national communication network is recommended, to aid the identification of those required to successfully champion regional activities as parts of a national network of long-term investigations into sustainable cropping systems. It is recommended that the Somersby work, with some minor modification, be further supported together with investigations in Tasmania, where the previous regional study identified the probable support of several local industries and State and Federal governments.

Introduction

It is clear that public awareness and concern for the environment has risen in recent years. Land degradation through erosion or compaction of soil, the health effects of using chemicals and residues of synthetic fertilisers are some of the concerns driving demand for 'safe' foods and more sustainable food-production methods.

Not only is there demand for clean, safe and healthy food, but increasingly also for the preservation of natural and sustainable rural environments. The success of both requires good industry standards as well as strong government support.

The idea of providing incentives for sustainable agricultural practices, rural stewardship and other conservation measures on farms, is currently being discussed in Australia[1]. A Parliamentary Inquiry into the impacts on farmers and landowners of various conservation measures is another recent development in the debate[2]. There is a real opportunity for agricultural research to provide sound advice to government, so farmers and regional Australia can take a proactive approach towards sustainable agriculture.

For growers, perhaps the single most important issue is maintaining both soil productivity and environmental sustainability in the face of declining farm profitability. To date, the real costs of environmentally unsustainable agriculture have not been fully quantified. There is a lack of understanding and objective measurement of the magnitude and rates of remedial change required to make our agricultural systems sustainable. The economic, environmental and social costs and benefits of such a change are also largely unknown and such externalities need to be measured to replace anecdotes with factual data.

While it is generally agreed that there are methods for measuring such changes, the studies required to produce much of the data need to be large-scale and carried out over

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[1] See AFFA discussion paper *Managing Natural Resources in Rural Australia for a Sustainable Future*, released for comment in December 1999

[2] The House of Representatives Standing Committee on Environment and Heritage called for submissions in April 2000 to an *Inquiry into Public Good Conservation: impact of environmental measures imposed on landholders*

long time-periods. In Australia there are very few such long-term field experiments, especially within the vegetable industry.

Experiments conducted at the Gosford Horticultural Research and Advisory Station, NSW, are an exception. Begun in 1992 on the Somersby section of the Station, the project aims to find ways of growing vegetables that have minimum impact on the environment while remaining economically viable for the long-term[3]. The systems approach employed attempts to provide an experimental environment more 'in-tune' with the problems of growers and to provide more relevant insights than would a reductionist factorial approach[4].

Given this attempt to provide relevance in the longer term, the current project considers the Somersby work within the proposed national network of long-term investigations.

The overarching aim of this project is, therefore, to determine the level of support, amongst key horticultural industry and government representatives, for establishing a national network of long-term field investigations to examine the costs and benefits of more sustainable horticultural cropping systems over time.

This concept builds on a previous regional study, which found several local industries with a long-term association in production areas to be genuinely interested in participating in longer-term research.

To build on the regional study, the current project seeks agreement on a *national* framework, for establishing long-term investigations, from government and industry representatives from each Australian State. Any agreed outcomes will thus have *regional* relevance.

The project will provide the impetus for the establishment of a much-needed, long-term approach to environmentally-sound food production. It will provide useful guidance for decision-makers at the local, regional and national level.

Methods

The first stage in the project involved updating the literature review (Appendix A) compiled for the previous regional study. As before, no attempt was made to define sustainability. Rather, the subjective nature of attempting a definition has been briefly discussed before considering some of the reasons behind the push for sustainable food production. The historical Rothamsted long-term experiments were reviewed as well as similar, more recent work in the USA, Europe and in Australia (including the Somersby project). The bulk of the review concentrated on the attributes of long-term agricultural

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[3] See Milestone Report for HRDC Project VG98046 *'Sustainable Vegetable Farming Systems'* by W Pitt and T Wells, February 2000.
[4] See Final Report for HRDC Project VG97020 *'Sustainable vegetable production systems'* by T Wells, June 1998.

experiments and considered the contribution they could make towards improving the sustainability of Australian agricultural systems.

In August 1999 introductory letters (Appendix B) were sent to 24 key staff in state grower associations, State and Federal governments and CSIRO, raising awareness of the project and asking for initial comments on the key related environmental issues in their regions. Using information gained from the responses (and from follow-up telephone conversations) a discussion paper (Appendix C) was sent in October 1999 to 51 individuals and organisations, including the leaders of the Somersby project at Gosford.

The level of interest in the issues in the discussion paper prompted the organisation of a workshop, which was held in Burnie in January 2000. Each State department (the NT and the ACT were not represented) was represented at the workshop[5], where 16 attendees reviewed a list of regional environmental issues (prepared from initial responses) and discussed possible steps towards establishing a national framework of LTAEs.

In a final round of discussion, a workshop report (Appendix D) was distributed in late January 2000 in response to attendees requesting further clarification on the issues from within their respective organisations.

Results

Following the introductory letter sent in August 1999, information was received from five State government departments and the remaining States were contacted by phone. Some respondents took the time to compile a package of information, some included statistics on food production, or maps of growing regions and some had detailed lists of specific environmental problems. More than 20 environmental issues (see workshop report) were identified from this information, with some common to all areas (e.g. water and soil quality). The principle vegetable growing regions for each State, in terms of value of production, were also identified at this stage (see workshop report).

The discussion paper mailed out in October 1999 not only reported back to previous respondents but also sought out other key potential stakeholders from government agencies as well as grower associations. A total of 19 responses were received from both the public and private sectors. The level of response ranged from detailed, well-researched information on current or similar work to individual indications of support by email. The majority of responses were positive, and the obvious effort undertaken by several respondents was encouraging.

One of the main outcomes of the workshop in Burnie was the development of an action plan to carry the project idea forward. It was deemed important to first develop wider communications within regions to gain broad consensus for the project.

[5] The Somersby project leaders were not represented at the workshop, although NSW Agriculture was. The Somersby work was later reviewed individually.

There was a mix of responses to the workshop report sent in January 2000. South Australia indicated they will be pursuing a State-based extension program, while individuals from Queensland, Victoria, Western Australia, CSIRO and AFFA are supportive of a national approach.

Discussion

This project has been driven by a growing need to quantify the economic costs and benefits of employing sustainability measures on farms. Such measures can only be reliably quantified over the longer term. Designing agricultural experiments and maintaining their relevance for periods of 20 years or more, is a relatively new concept in Australia, although several have persisted for such time-spans. For such experiments to be successful, they must be simple in design, flexible and relevant to all stakeholders.

These important characteristics were acknowledged throughout the discussion process as critical to establishing a national network of long-term investigations. They were described in one response, for example, as the *logical basis for a standardised approach* to the establishment of such sites nationally.

In addition, the recurring theme throughout has been the importance of regional planning and commitment. For example, there are some environmental issues, which are critical and measurable on a national scale (e.g. water availability/quality), and there are more specific issues that are only relevant to a particular region (e.g. disposal of spent plastic mulch). As such, the range of farming system characteristics to be investigated would be developed on a site-by-site basis, in consultation with regional stakeholders.

The concept, need for and value of long-term experiments for providing a realistic measure of some of the costs and benefits of sustainable cropping systems has thus been widely supported in this feasibility study.

Nonetheless, individual commitment at the regional level has been identified as perhaps the critical component of the proposed long-term research. From the outset, there has been a broad range in the quality of responses, which seems to reflect the commitment of the individuals concerned. The ultimate success of any effort to establish a network nationally will depend on the emergence and dedication of regional 'champions'. Acknowledging that such 'champions' must come forward of their own volition rather than being targeted, both time and opportunity should be provided.

With this in mind, there is merit in now establishing an on-going national communication network that will identify and support regional efforts in, and champions of, investigations of sustainable farming systems. In addition to those individuals contacted in the present study, the development and awareness of such a network will aid the identification of those required to successfully champion a network of long-term experimental sites.

Given the current spectrum of commitment from regional 'champions', the initiation of several regional long-term investigations on the ground at one time is unlikely. However, it is important that, for maximum effectiveness, such projects are compatible and harmonised in design, data acquisition and analysis. The successful design (with national input) and implementation of a prototype investigation is perhaps a progression towards this end.

The work at Somersby reflects many of the design characteristics necessary for long-term research to be successful. From the outset, a range of stakeholders has been involved in strategically defining the goals and objectives of each of the project's farming systems under investigation. As the original drivers for the project were essentially regional, there was little national input at the planning stage. However, linkages were developed over time.

The project team has benefited from some broader environmental science and management, as well as research and extension skills, although the latter has perhaps only recently gathered momentum with additional NHT funding. The complimentary development of on-farm demonstration needs to be continued and more closely integrated into project strategies to improve the overall work's effectiveness for change. In this regard, the relationships between demonstrated practices and quality assurance schemes, for both product and environment, should be identified.

The systems approach to the Somersby experiment is an asset in that it has designed flexibility into all individual treatments. While the treatment philosophy allows operational changes to treatment over time without impacting on analyses or interpretation, the measurement over time, of the effects of such changes to a treatment, compared to unchanged operations, requires subdivision of plot areas. Such subdivision is possible at Somersby, although perhaps somewhat restricted by site, resources and run-off monitoring requirements. The effects of operational changes to treatments are currently attributed by inference from analyses and records. The role of plot subdivision in future experimental strategies could be usefully reviewed (by all stakeholders).

Somersby's fully conventional 'District Practice' treatment, which targets maximum short-term profitability, would perhaps also benefit from such review. There is some risk of obsolescence if current operations are maintained as a 'control' over time, while real district practices may (or may have to) incorporate changes which reduce profitability. On the other hand, historical comparison will be lost if the treatment follows such change to real district practice and subdivision is not employed.

The knowledge gained by the Somersby team could be valuably used in developing basic analytical and data protocols to be followed in any national network of experiments eventually developed. Attempts should be made to incorporate the valuable data-set developed by the project into broader environmental economic models in order to allow the identification of any gaps in the data and to add strength to models themselves. Funds should be allocated to this task.

The Somersby investigation has, in some ways, served as a valuable learning prototype for Australian vegetable cropping system investigations and with strategic review by stakeholders (including national) will be an important contribution to any national network of LTAEs in intensive cropping in Australia.

The opportunity exists to build on this work and to establish the forerunners of a national network of long-term investigations into the sustainability of intensive vegetable systems. As the previous regional study has now led to a significant commitment and expectation in both local regional industry and relevant government sections, long-term vegetable research in Tasmania is also worthy of support contribution from the HRDC.

The drivers of and debate surrounding sustainable agriculture in Australia are changing. The House of Representatives Standing Committee on Environment and Heritage has recently called for submissions on the impact of conservation controls imposed on landholders and farmers. This inquiry into 'public good conservation' will investigate a number of issues, particularly the costs incurred to carry out conservation measures and the benefits such measures may bring to landholders and communities. In recognising several measurable costs and benefits (e.g. costs of land clearance) the committee also acknowledges others that may be less quantifiable (e.g. benefits of pleasing landscapes).

In addition, the committee acknowledges the need to distinguish between the private and public benefits that result from landholders' conservation efforts and *to attribute the costs accordingly*. Importantly, it suggests that the equitable sharing of these costs may be more easily achieved with good data and methods to assess and model their impacts.

The release of the AFFA discussion paper *Managing Natural Resources in Rural Australia for a Sustainable Future* in December 1999 further illustrates the maturation of the debate at the national level. The paper acknowledges the need to develop new sustainable production systems and to adopt interdisciplinary approaches to research. It calls for the development of sustainability indicators as well as long-term research and monitoring at the regional scale.

Furthermore, the paper suggests the development of such research strategies nationally by December 2000 and that such work could be a higher priority for research and development organisations.

The links between the above ideas and those driving this project clearly place the future of Australian agriculture in the hands of committed individuals and organisations who are prepared to work with longer term objectives and outcomes. This is a real opportunity for farmers and regional Australia to take a proactive approach towards more sustainable horticultural cropping systems.

Recommendations

1. That an on-going national communication network be established to identify, promote and harmonise efforts in the investigation into sustainable agricultural systems, and to foster champions thereof.

2. That the Somersby experiment be further supported as part of a future network of long-term investigations into sustainable intensive vegetable production systems in Australia but strategically reviewed to complete its alignment with the critical success factors for such investigations.

3. That a long-term investigation in Tasmania be developed, with national input, which builds on previously identified regional industry and government support.

Appendices

Appendix A

Literature Review

1. Introduction

This literature review forms part of the background information being acquired in the implementation of HRDC Project VG98105, entitled *'Improving the long-term sustainability of intensive horticultural cropping systems – a feasibility study'*. The establishment of a program of long-term, practical field investigations, in order to measure and compare physical, chemical and biological changes in soil and environmental quality and their economic consequences, is likely to provide the following benefits:

- industry awareness of the rotations and levels of production inputs necessary to provide environmental as well as economic sustainability;
- industry awareness of the accumulated costs associated with soil structural decline and erosion controls and the costs and benefits of integrated management practices; and
- industry awareness of the rates, timing and associated costs of soil fertility programs required for environmental sustainability.

The research is also likely to improve:

- the holistic scientific approach to investigation of rotational practices on intensively cropped soils;
- the opportunities for students and industry personnel to learn the economic implications of current pressures for environmental sustainability; and
- the data input into models guiding policy and decision making in the area.

Environmental sustainability is a broad topic with a vast literature, which itself is expanding rapidly. There are over one thousand currently published journals and periodicals that carry relevant information. Within this subject, the sustainability of agricultural systems is also not a field easily traversed. There is still, in the author's opinion, a great need to distil the major issues to a point of action, rather than further discussion.

The following review therefore only briefly outlines some of the difficulties associated with defining sustainability and some of the reasons for striving towards it. The bulk of the review considers the attributes of long-term agricultural experiments (LTAEs) and the contribution they realistically could make to improve the sustainability of our local agricultural systems.

The review considers the historical points and current activities concerning LTAEs both overseas and within Australia and recent assessment of their effectiveness in Australia, before outlining the critical attributes which any future LTAEs should possess.

2. Sustainability – difficulties in defining the concept

> "I concluded some time ago that we didn't need to spend much more time and effort attempting to define sustainability. We have sufficient commonality among our different understandings of it to continue moving in the right direction, even if we are not yet all moving toward precisely the same destination by the same route. More recently, I have come to the conclusion that we may never have a generally accepted definition of sustainability, and perhaps, we don't need one." *John Ikerd, 1998*

Andrew Campbell (1994) suggests that like beauty, sustainability is in the eye of the beholder. Accordingly, attempts to define the concept of 'sustainable development' are common in the literature, although the definition advocated by the World Commission on Environment and Development (1987) is the most widely used and quoted. Sustainable development has therein been defined as *'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'*.

While it does contain a degree of subjectivity, and while different interest groups may well define sustainability to suit their own goals, the above definition embodies certain common concepts and assumptions. These are aimed at replacing protest and conflict with consensus by asserting that economic and environmental goals can be compatible (Beder, 1996).

In the agricultural context, a farmer's current and indeed future economic capacity is directly related to the quality of the farming environment. But what makes a farm sustainable depends on who is asking the question and whether it is asked within a context of economic or environmental, social or cultural terms. In reality, it is a combination of all these things. Perhaps we should heed the suggestion made by Pretty (1995) that we cannot define sustainable agriculture as a simple model or package to be imposed on a farmer, rather it is more a process for learning; a goal rather than a rigidly defined set of practices (Northwest Area Foundation, 1994).

A useful approach may be to determine sustainability based on effective land management, where the quality of a farm's resources, specifically the quality of air, soil, water and food resources, is maintained or improved. But this requires knowledge and use of a set of resource quality indicators, to firstly identify a problem and then to be able to monitor the effects of different management regimes. Many different groups will benefit from such a system (from farmers through to policymakers) but different users may want different indicators (Karlen *et al.*, 1999). For soil quality at least, such indicators have yet to be defined, although Doran and Parkin (1994) outline a range of possible criteria and review current thinking on those that could be used. Until such measures are established for *all* resources, it may not be possible to assess the 'weighting' of each criteria – how, for example, profitability issues are weighed against environmental concerns and vice versa (Larson and Pierce, 1994). More discussion on sustainability indicators is included further in this review.

In clear contrast to the lack of agreement on defining agricultural sustainability, a common theme in the literature is an acknowledgement of its 'multidimensionality' (Larson and Pierce, 1994) – the need to link economic, social, and ecological concepts and address them simultaneously when evaluating a farm's sustainability. Put simply, the components of a farm must be integrated for it to persist (Edwards *et al.*, 1993). Pretty (1995) gives a list of goals for achieving integration to thus attain more sustainable farming methods, and these range from practical management tools to ideological ways of achieving socially-just farming.

A useful example is integrated pest management (IPM), a term often associated with sustainable agriculture and which refers to a suite of farm practices that promote good plant and animal health and keep pest losses in check without the use (or with minimal use) of manufactured chemicals (Schillhorn van Veen *et al.*, 1998). Descriptions and reviews of IPM are available in much of the literature on agricultural sustainability (for example see Higley and Pedigo, 1993, Zalom, 1993 and Pretty, 1995).

Furthermore, successful farm integration must also incorporate farmers, local communities and governments, so as to achieve a more decentralised and participatory approach to sustainability (Serageldin and Johnson, 1998; see also Ashby *et al.*, 1998 and Narayan, 1998).

There are several misconceptions that equate sustainable farming with a step backwards to 'low technology' or 'antiquated agriculture', and that sustainable farming cannot work in hand with conventional farming, or even that low input farming techniques will only ever result in low outputs (Pretty, 1995). In a sense, such ideas may simply result from a fear of change among farmers who for generations have relied on traditional or conventional practices. These fears can be overcome and, ultimately, will depend on whether the change to more profitable, competitive and sustainable production systems is viewed as an *opportunity* and not a problem (Johnsrud, 1989).

3. Reasons for striving for sustainable agriculture

While the worst case scenarios of population explosion over the past 50 years have not been realised (Edwards and Wali, 1993) and gloom about such an explosion is probably misplaced (Pearce, 1999), the world population is currently growing by around 90 million people every year (WRI *et al.*, 1996). October 12 1999 was officially recognised by the UN as the birthday of the 6-billionth member of the human race, only 12 years after we hit the 5-billion mark (Pearce, 1999). There is concern that such rates of increase in human population cannot be sustainable without some alteration of current methods of food production and distribution (Edwards and Wali, 1993).

On a global scale, production of most food crops has achieved steady growth, and is generally expected to continue to grow, but there are some underlying issues to be considered. While globally there is the potential to grow enough food for all, food is often not available where it is most needed (World Commission on Environment and Development, 1987) and in certain countries, per-capita food production is slowing. Indeed, Africa's food production has risen steadily since 1961 but has not been fast enough to keep up with its population growth (WRI *et al.*, 1996). This scenario is true of other regions of the world, where for example, South Asia, Bangladesh and Nepal are also experiencing declines in their per-capita food production (Edwards and Wali, 1993). On the other hand, in India, where hunger and mass starvation threatened in the 1960s, a doubling of the population since then has not prevented the achievement of self-sufficiency in staple foods (Hazell and Lutz, 1998).

Much of the growth in global food production can be attributed to increases in technological innovations such as modern fertilisers, pesticides, antibiotics and machinery, as well as through the adoption of modern crop varieties and livestock breeds (Pretty, 1995; Hazell and Lutz, 1998). The book 'Silent Spring' (Carson, 1962) is commonly credited with first presenting the idea that these advances could harm the environment but it was more than a decade before such concerns were given significant investigation.

There is now widespread public concern over the environmental and economic impacts of current farming practices, and how they reflect actual threats to long-term sustainability (Ikerd, 1993). This general increase in public awareness and concern for the environment has increased demand for 'safe' food and more environmentally sensitive food production methods. As a consequence, less intensive, low-chemical and organic farming has increased in many countries, and in the European Union, conversion to organic farming attracts subsidies and is accepted as making a significant contribution to environmental protection. In Australia, the organic farming industry has the potential for very large growth in the future (Dumaresq and Greene, 1997) and with adequate planning and development, could well generate a billion dollars a year within 10-15 years (Colquhoun, 1998).

Clearly, under these market conditions, both producers and consumers will require better measurement of the positive and negative impacts of agricultural practices over time. LTAEs provide an ideal vehicle to increase understanding of these important issues.

4. Historical aspects

A global directory of LTAEs has resulted from an FAO study initiated at the start of the current decade (Steiner and Herdt, 1995) and the outcomes of a meeting held in 1993 to review the results of this study are well recorded (Barnett *et al.*, 1995a).

The field trials begun by Lawes and Gilbert in 1843 are usually taken as the baseline for the start of LTAEs in the modern scientific sense. Established on the Rothamsted Estate, near Harpenden in the UK, they still continue 156 years later, at what is now the Centre for Integrated Arable Crops Research at Rothamsted Experimental Station. The 150th anniversary of their inception was marked by a conference entitled *Insight from foresight: the role of long-term experiments and data-bases in agricultural and ecological sciences,* the proceedings of which were edited by Leigh and Johnston (1994). The history of these experiments, now known as the Classical Experiments, is discussed by Johnston (1994) in the context of the times.

Lawes took out a patent in 1843 for the manufacture of superphosphate by adding sulphuric acid to mineral phosphate and was able to fund his own private research program from the profits. He and Gilbert, an industrial chemist whom he hired, published prolifically over the next 50 years, by which time he had endowed trustees to ensure that the experiments would continue.

In essence, seven fields at Rothamsted were chosen (the most famous, Broadbalk, being 4.4 ha with 20 plots), on which to measure yields from six of the crops most commonly grown at the time, namely, turnips, winter wheat, beans, clover, spring barley, oats, and permanent pasture. The annual crops were grown in monoculture or in rotation. Both the crops and the pasture were given different treatments with fertilisers, including superphosphate and manures. A full discussion of the Classical Experiments is recorded by Johnston (1994), and Poulton (1995) provides a broad treatment of the importance of these experiments as examples of LTAEs in general.

The factors which contributed to the Rothamsted success are principally that the program was commercially driven initially, then sponsored through the Lawes Trust and that there was long term (57 years) commitment from the principal investigators, who produced 150 scientific papers and over 300 popular articles on the results. Perhaps the bitter competition with the German chemist Liebig may explain their endurance to some extent.

The above authors consider that the irreplaceable value of LTAEs, in understanding changes in soil fertility and the sustainability of production, can be highlighted by recognising that the investigative site, which has a long and well-documented history, can be used to help solve new and unforeseen problems as they arise. Given the reviews' conclusions, that the accumulated effects of changes in production systems are only evident after at least two or three rotational cycles, the observation that, "we'll never know where we're going if we look only at the long-term as a series of short-terms", summarises the sentiment well.

According to Greenland (1994), LTAEs have had mixed success in India. In 1905, the Imperial Agricultural Chemist sent to England reports on trials, which continuously cropped wheat and maize in Cawnpore, for comparison with similar ones at Rothamsted. However, a 1907 report states that "this experiment has now been in progress for some 24 years. Started on the plan of the famous Rothampstead (sic) experiments, it has passed through many changes of supervision and has never had the advantage of the continuous interest of two well-known experts. .... I think the experiment might now well be closed". This emphasises the need for the commitment of individuals to obtain successful outcomes. Greenland also notes that 22 years later, in 1929, advice to farmers on fertiliser use was still not forthcoming, in spite of many years of investigations on experiment stations.

5. American investigations

In the USA, the Hatch Act of 1887 authorised the establishment of state agricultural experiment stations at various universities. The oldest of these are the Morrow Plots, at the University of Illinois, started in 1876 on two hectares subdivided into 10 plots (modelled after Rothamsted). These plots were established to determine whether or not the prairie soils of the area could be depleted (Mitchell *et al.*, 1991). While providing insight into the effects of crop sequences on soil fertility, there was a lack of flexibility stamped on their management and they were soon criticised as being too academic (Aref and Wander, 1998), although the trial is now a Registered National Historic Landmark, which prevents its termination.

The Sanborn Field Experiment, established at the University of Missouri in 1888, is another, which continues to the present. Initial investigations addressed the concern of declining soil fertility on the prairies as crop production intensified. The treatments compared five cereal and grass crops grown in monoculture, with or without fertiliser, manure or with both fertiliser and manure (Brown, 1994). Recommended farming practices and established agronomic principles are a product of the many observations and discoveries made at Sanborn Field (Mitchell *et al.*, 1991).

In 1917, seven test plots for the purpose of measuring erosion were established on what are known as the Duley-Miller Erosion Plots at Sanborn Field. The work of Duley and Miller led to formation of the US Conservation Service and development of the Universal Soil Loss Equation, work that resulted in the Plots' registration as a National Historic Landmark. Even with the various changes made and considering the limitations of the site, the plots are considered useful. Not only do they serve as memorial to two scientists whose work played a role in the early days of the soil conservation movement, but they show that, even after fifty years, the eroded soil there has not recovered its full productive capacity.

In 1888 the Oregon State University organised the Oregon Agricultural Experiment Station, which now includes a central station at Corvallis and ten branch stations throughout Oregon. One of the branch stations is the Columbia Basin Agricultural Research Centre, in Pendelton, which is maintained in conjunction with the US Department of Agriculture.

A winter wheat/fallow experiment, the most comprehensive of several ongoing experiments, was started at Pendelton in 1931 to evaluate the long-term effects of fertiliser amendments and residue management on grain yield and soil quality, a trial that today remains relatively unchanged (Duff *et al.* 1995). Also begun in 1931, a long-term grass pasture is maintained at Pendelton to provide a grassland ecosystem for use as a reference for comparing the effects of cultivated agriculture on soil quality (Rasmussen *et al.*, 1998). Another started in 1931 is a continuous cereal experiment, which originally consisted of three adjacent sites cropped annually to winter wheat and to spring wheat. This experiment was altered in 1977 for site modification and the experiment now consists of three sections cropped to winter wheat, spring barley and spring wheat, each grown every year in the same location. It is used as a cereal monoculture baseline for comparing other crop rotations, all under conventional tillage (Rasmussen, 1997).

Other active long-term studies at Pendelton include a wheat tillage/fertility experiment begun in 1940 and a wheat/pea fertility study begun in 1963. The first experiment is a winter wheat/summer fallow rotation that has been modified four times, mostly to reflect increased nitrogen rates in contemporary agriculture. The second, which examines the effects of tillage on a wheat/green pea rotation, has been changed once since 1963 to replace fresh peas with dry peas (Dr Bill Payne, *pers. comm.*, 1999).

Proposed future changes to the Pendelton experiments highlight the need for continued flexibility in the management of LTAEs. For example, after realising that several of the experiments were encountering soil acidity (from repeated application of ammonium-based N fertiliser) there were changes proposed to apply lime, particularly in the tillage/fertility and continuous cereal experiments. In addition, different assessment methods were being considered to address concerns of soil erosion in some of the experiments. Another possible change at Pendelton will depend on whether the baseline grass pasture experiment is managed as a native grassland system or a managed pasture (Rasmussen, 1997).

The Old Rotation experiment at Auburn University, Alabama, began in 1896 and is the oldest continuous cotton experiment in the US. The experiment was one of the first to demonstrate the value of rotating cotton with legumes, providing evidence that Alabama soils could sustain cotton and that such rotations could improve yields. The Old Rotation consists of six cropping systems in 13 plots on one acre of the campus of Auburn University. Although it has been modified four times since it began, some treatments are the same as in 1896 (Mitchell *et al.*, 1991), providing a useful record on the fundamental problem of maintaining soil fertility and sustaining crop production (Traxler *et al.*, 1995).

A recent review of Old Rotation data shows that cover crops grown on croplands in that region maintain soil organic carbon and they improve the physical and chemical characteristics as well as reduce erosion of topsoil (Mitchell and Entry, 1998).

The longevity of these field experiments, when combined with ancillary data such as long-term climate records, production estimates and documented management practices, provides invaluable information for interpreting soil carbon changes (Paustian *et al.*, 1995). As studies relating to global climate change gain further momentum LTAEs become increasingly relevant for the study of soil carbon levels and the role agriculture plays in providing a source or sink for carbon.

Paul *et al.*, (1997) review a range of long-term sites across North America to assess the role of soil organic matter (SOM) in agricultural production and in the global climate system. The authors discuss the importance of SOM in agroecosystems, the relationship between SOM and global carbon, the role of land and crop management practices in the productivity of tilled ecosystems, the influences of management practices on SOM content, the type and quantity and usefulness of long-term data and whether there is enough data available to determine the rates and direction of changes in soil carbon and to develop sound SOM management practices. These are issues worth including in the range of studies available to future Australian LTAEs.

Another considerable record has been recently compiled from the results of more than 50 long-term field experiments across North America and is the outcome of a symposium entitled *'Estimating management and climate change effects on net CO^2 fluxes from agricultural soils: use of long-term experiment data'* (Paustian *et al.*, 1998). The editors conclude that such integration of information will facilitate a better understanding of carbon dynamics between different locations and management systems, information that will become increasingly important as we strive for healthy soils and to sequester carbon and thereby mitigate the buildup of CO^2 in the atmosphere.

The ability of agroecosystems to sequester carbon in soil is directly related to the management practices employed (for US cropland in general see Lal *et al*, 1999, for tallgrass prairie region see Huggins *et al.*, 1998, for Great Plains see Peterson *et al.*, 1998, for eastern Corn Belt region see Dick *et al.*, 1998, for southern Appalachian Piedmont of Georgia see Hendrix *et al.*, 1998). In their study of carbon and nitrogen changes in the semi-arid Pacific Northwest region of America, Rasmussen *et al.* (1998) found some long-term studies deficient in measuring carbon sequestering capability partly because soil loss by either erosion or biological oxidation could only be estimated and in many instances soil changes below 30cm could not be quantified because samples were not taken at those levels. On the other hand, Janzen *et al.* (1998) found that such estimates, when taken across a range of long-term sites, were still useful in yielding information otherwise not discernible from single experiments. Their work suggests the possibility for significant gains in soil carbon storage with the adoption of certain practices (elimination of summer fallow, increased use of forages, improved fertility management and reduced tillage intensity) and that the potential exists, at least in the short term, for Canadian prairie soils to provide a net sink for atmospheric CO^2 (Janzen *et al.*, 1998).

This work (Janzen *et al.*, 1998) examined more than 20 individual studies where three sites were greater than 50 years old, five between 25 and 50 years old and about sixteen between 10 and 15 years old. While using the older studies primarily for a long-term perspective, the authors suggest that such a blend of generations is complementary and the more recent studies provided both statistical verification and a chance to evaluate emerging practices. They also note some limitations of long-term sites in general – analytical imprecision, spatial variability, confounding effects of erosion, compromised statistical designs and human error – limitations that should be considered in the design of future long-term field sites.

Information from field sites established in the past is sometimes anecdotal, but such historical information does have a role in helping solve current agricultural production problems. In an effort to help address issues of sustainability, Jennings *et al.* (1990) stress the need to blend 'pertinent historical wisdom' with emerging technology. In their overview of dryland cropping in the Palouse region of the Pacific Northwest, based on more than a century of agricultural research and field experience, they report that farming techniques used over the last 100 years have not maintained the resource base. They found that technological advances and varietal improvements have masked a continual degradation of soil productivity in the region and suggest that integrating the historical record with current knowledge and future opportunities may improve the likelihood of sustaining the land resource and the agriculture it supports (Jennings *et al.*, 1990).

6. European investigations

LTAEs at Lautenbach in Germany and Nagele in the Netherlands began in 1978-9 and were followed by the Boxworth project in UK in 1981.

These and other LTAEs and demonstration/extension programs in Western Europe are reviewed by Holland *et al* (1994). These authors describe fourteen examples of such research, carried out at 36 sites in five countries, including "The Boxworth Project - see also Cooper (1990) and Cilgi *et al.*, (1993), SCARAB (Seeking Confirmation About Results at Boxworth – see also Frampton and van den Brink, 1997), TALISMAN (Towards A Low Input System Minimising Agrochemicals and Nitrogen – see also Cook *et al.*, (1996) and Young *et al.* (1996), RISC (Reduced Input Systems of Cropping), LIFE (Less Intensive Farming and Environmental Research – see also Jordan *et al.* (1997), Link Integrated Farming Systems, LEAF (Linking Environment and Farming), all in the UK, as well as INTEX (Integrated Extensification in Arable Production) in Germany, Third Way in Switzerland and Integrated Farming in France.

While LEAF is a commercial farm demonstration program sponsored by industry and Government, most investigative programs were large-scale experiments with little true replication of treatments on the ground (excepting TALISMAN, which had four replicates). Some utilised paired blocks, paired split-fields, compared contiguous fields and some utilised whole farm comparisons. Plot sizes ranged from 200m^2 up to 17 ha. Most used the basic approach of comparing a conventional or local current practice as a control, against which the effects of alternative regimes were compared. The main aim in all was to minimise agrochemical inputs and their off-site effects in the context of government-regulated standards or guidelines. The aims of TALISMAN also included the provision of information on the scale of compensation necessary to attract farmers to adopt such lower input systems.

Rotations were modified in different programs to include less root crops, more break crops or, in some cases, crops chosen for their biological, physical and chemical off-take characteristics. This suggests the additional value of LTAEs as a platform to demonstrate the incorporation of new crops into local production systems. Superimposed on rotations, in some programs, were permutations and combinations of tillage methods, pesticide regimes and other inputs, while some compared organic versus conventional and integrated systems. All the LTAEs measured profitability in some way, while most monitored ecological changes. Some also have measured energy balances of the compared systems.

Most of these programs have demonstrated that more integrated farming systems, particularly those based around cereal production, can show similar or improved profitability to conventional systems, although more than one rotational cycle (i.e. at least 10 to 12 years) may be required. Profitability of more extensified cropping systems is shown, as may be expected, to be very dependent on the frequency of the most profitable crops in rotations. Therefore, compromise must be reached in the planning phase, when choosing treatment sequences, which target the other anticipated positive biological/ecological effects of growing a crop. In this respect and from the point of view of the effectiveness of the extension of results, some programs may have suffered from inadequate input (Laurence, 1998).

The possibility was generally demonstrated in these experiments of reducing the use of pesticides, particularly insecticides and fungicides, by the incorporation of 'integrated controls', such as crop varietal resistance, pest monitoring and use of pest thresholds, crop hygiene and the addition of break crops. Overall, the need to test such prototype systems at the regional level and to flexibly extend these practices to commercial operations has been clearly shown. Both from the point of view of the validity of results and adoption, large-scale investigations were considered imperative. The programs must be planned for the long term in order that the use of time and true replication can be balanced at the outset. While these LTAEs have been very influential at both the farm practice and policy levels, *ex poste* analysis illustrates some limitations in design and implementation, which may be avoided in prospective work. These are considered further by the author elsewhere (Laurence, 1998). Holland *et al* (1994) also note the problems associated with reconciling scientific rigour with economic reality and the need to have a design sufficiently flexible to accommodate changes in commercial practice.

While the strategies and implementation of these programs are of relevance to local prospective work, an additional goal in the European policy context was the reduction of farm production surpluses and consequential compensation payments to growers. Indeed, Holland *et al* (1994) note that "integrated farming in France is seen as an effective instrument for extensification and an alternative way to reduce over-production and declining farm incomes rather than a switch to a world-market system."

In their discussion of future husbandry practices, Holland *et al* (1994) note the effectiveness of 'strip cropping' in modifying the populations of monophagous (and therefore potentially commercially deleterious) insect species. Further work now in progress at some of these centres on 'beetle banks' and field margins planted to improve the survival of predators and aid biodiversity (Marshall, 1997 and Marshall, 1998) sit well with the potential fixed trafficking systems for intensive cropping. They also note that organic production is most suitable for mixed farms where reliable sources of animal manure are available. Given the equal prominence of dairy farms and intensive cropping farms in some areas of Australia, improving the incorporation of these enterprises should be considered in prospective work.

With rapidly advancing ecological problems in Dutch production, the Netherlands government accepted two policy plans to restructure and sanitize the national agriculture, one for pesticides and one for soil nutrients (Anon., 1990). Using 1985 as a base, a year 2000 target was set for a 50 per cent reduction in the total use of pesticides, for a 70 per cent reduction in the volatilization of ammonia and for similar reductions in nitrogen (N) and phosphorus (P) emissions into the North Sea. Water quality criteria were also set with regard to total N and P in surface water and nitrate N in ground water (Wijnands and Vereijken, 1992). As referred to above, the first Dutch LTAEs at Nagele, Vredepeel and Borgeswold were very successful in demonstrating that more integrated farming systems could achieve these environmental goals whilst maintaining profitability (Vereijken, 1992; Wijnands and Vereijken, 1992).

Collaboration of farming systems researchers in several European Union (EU) countries under the International Organisation for Biological Control of Noxious Animals and Plants (IOBC) has led to a systematic protocol for the development of the best suited farming systems prototypes for testing, modification and extension in different regions (Vereijken, 1997a). The principles of strategic planning, systems analysis and total quality management are used to design prototype systems, which are then tested and improved in an iterative way. Economic, environmental/ecological and social goals are prioritised for the regional system to be served by the prototype investigation (Vereijken, 1994, 1995, 1996 and 1997b). These are translated into a set of multi-objective parameters and methods under the following general headings: a multifunctional crop rotation, an integrated nutrient management strategy, techniques for minimum soil cultivation, guidelines for ecological infrastructure management, integrated crop protection and pesticides selection based on 'whole of the environment exposure' and, finally, a target for optimising labour and capital. The prototypes are described in three parts on standard 'Identity Cards'. The EU initiative had grown to 30 projects in 1997 comprising both integrated (minimal use of pesticides) and ecological (organic farming) prototypes, with more emphasis now being placed upon the latter in most EU countries. The EU 5-year funding milestone cycle also serves to refocus on two cascading extension phases where, in the first stage, about twelve committed commercial farmers try, and modify, the proven prototype and focus groups of further growers are drawn into testing in the second stage (Kloen and Vereijken, 1997). While perhaps over-elaborate in structure and employing little long-term statistical analysis or sample archiving, the prototyping system has strengths in the involvement of growers in prototype development, the reiterative nature of improving the prototype and the following extension phases. It provides a useful checklist in design (Laurence, 1998).

7. Australian investigations

LTAEs in Australia have been reviewed recently by Grace and Oades (1994). The earliest experiments initiated were those in 1913 at Rutherglen, in 1917 at Longeronong and in 1925 at the Waite Institute, Adelaide. Reporting on the Australian situation, Grace and Oades note that 23 of the 26 LTAEs of at least 25 years duration undertaken here in the last century have been associated with State Departments of Agriculture. Most have had as their basis, cereal/legume pasture/fallow rotational combinations and comparisons in the mediterranean and subtropical climates of the country. The positive effects of legume leys and of fallowing on water retention and subsequent crop yields have been variously described but the ecological effects poorly quantified. Grace and Oades comment that publication of data from LTAEs in Australia has been somewhat neglected, a shortcoming which could be rectified, in future, by ongoing improvements in networking between government departments, industries and universities, which could enhance a culture of peer reviewed publication.

The advantages and disadvantages of long term experiments were discussed at an Australian Institute of Agricultural Science Symposium in Adelaide in 1991, (Anon. 1991). However, no conclusions to the discussions or recommendations were recorded in the proceedings.

The value of data resulting from several Australian LTAEs was discussed at another workshop held in Canberra in 1994 (Martin *et al*, 1995). In this case, the objectives were to: identify and classify existing LTAEs with respect to their ability to measure changes in key sustainability indicators, document and address limitations associated with design and data management of existing LTAEs and establish a national working group to implement recommendations regarding (a) prioritisation for management and funding of existing LTAEs, (b) establishment and funding of new LTAEs and (c) publication and extension of findings.

A number of technical papers addressed the issue of the value of LTAEs, the effects of tillage and rotation on productivity and sustainability, data management, design and predictive modeling, soil physics and chemistry and production, biology and ecology (Martin *et al.*, 1995).

Regarding the value of LTAEs, Kirkegaard (1995) reviewed trends in wheat yield responses to conservation cropping in Australia, as measured in 33 medium to long term experiments, and observed that "20 to 30 years of field experiments have repeatedly demonstrated the benefits of direct drilling and stubble retention through reduced erosion, increased soil organic matter and improved soil structure (but) only 2% of the farmers in the Lachlan catchment of NSW direct drilled in 1994".

Penfold *et al.* (1995) reported on a South Australian LTAE started in 1989, comparing organic, bio-dynamic, integrated and conventional broad-acre farming systems, and which complements similar LTAEs in the USA (Janke *et al.*, 1991). In a later summary of the trial's results, Penfold *et al.* (1997) question whether any of the treatments, all suffering decline in soil carbon levels, are sustainable.

Grace *et al.* (1995) reported on the permanent rotation trial at the Waite Institute, which then provided a run of data over 70 years, enabling trends in soil organic carbon to be analysed and related to five other LTAEs in Australia. A significant role for the 'light/labile fraction' in both aggregate formation and nutrient supply was indicated.

Paustian *et al.* (1995) described a general methodology, which could be applied for Australian work, for combining long-term data with process-oriented simulation models and regional level, spatially resolved databases using information from a network of 39 experiments at 33 locations in North America.

The discussion, outcomes and recommendations from this workshop are summarised by Grace *et al.* (1995). The workshop recognised over 50 experiments in Australia, which have run in excess of ten years and which were considered to be relevant to current management strategies. Nevertheless, the workshop also recognised the need to debate their worth and discussion was focussed around questions posed regarding relevance, networking with other programs, design, the required measurements of indicators and externalities (non-marketed resources affected) and the contribution to adoption and policy. It was generally concluded that LTAEs were useful in providing data on soil physical and chemical processes, which only change slowly in response to management and climate, and represented the only way of measuring such changes, together with ecological and environmental effects. They generated knowledge databases from which simulation and prediction could follow. Shortcomings were found in poor design (several LTAEs are merely short–term designs which have not been terminated), dissemination of results and expense, but it was felt that LTAEs could not be wholly replaced by on-farm monitoring. Prospects for networking future experiments with geographic information systems, which might assist on-farm validation and feedback, were considered.

Contribution to adoption and government policy, two key facets for LTAEs (in the author's opinion) were scantily dealt with. It was recorded that the workshop discussion would stimulate participants to publish long-term data! Read in hindsight, the proceedings suggest that, the workshop and its outcomes were limited by an oversupply of academic input and a lack of industry contribution. Martin *et al.* (1995) record that "the group tended to blame poor extension and farmers' attitude to risk for the lack of adoption of results from long-term experiments. It was also assumed that adoption was affected by farmers' reluctance or incapacity to adopt systems requiring a higher level of management skill. Consultants and extension personnel were the key decision makers in the industry and that researchers needed to have more influence."

Gaining a balance of these and other sectorial interests is considered, by the present author, to be critical to the effectiveness of LTAEs in both agri-environmental policy development and in the adoption of results. Also important to their success is the overall broad management skills employed in their planning and implementation. All stakeholders must have initial and continuing input into the 'plan, do, check, act' reiterative cycle of project management.

It was noted in conclusion that a review of LTAEs in Australia, with specific terms of reference, had just been commissioned by the Grains Research and Development Corporation and the Land and Water Resources Research and Development Corporation. This review was carried out and reported by Martin and Grace (1998a and 1998b). The project report reflects the paucity of data available and, indeed, work carried out, on long term, intensive, temperate cropping systems. However, the primary issues identified are sufficiently general to apply to LTAEs in all contexts. The sponsoring R&D Corporations noted that they generally supported the report's conclusions but that establishing a network of LTAEs to facilitate coordination of projects and dissemination of results would require cooperation of all agencies. This was considered to be beyond the mandate of specific industries (in this case the GRDC, which further noted its intention to establish a small informal group for consultative purposes). The current project VG98105 recognises the fundamental importance of involving all stakeholders and agencies in the planning and implementation of future LTAEs and attempts to address this.

All LTAEs in Australia were reviewed and summaries included in the report. Case studies were made of two sites, including benefit-cost analysis (BCA). The definition of LTAEs embraced those experiments which targeted the development of sustainable cropping systems, operated for more than one rotational cycle or ten years, or those that ran long enough to measure change in indicators of the crop-resource base status. A survey was sent to about 50 custodians of LTAEs as part of the project, to seek opinions on relevance, design, networking and management plans. Twenty-two responses were received, which illustrated the predominance of broad-acre, cereal rotation studies outlined previously, with a contemporary policy decision being made to terminate Western Australian Government LTAEs due to a perceived lack of return on investment. This decision has resulted in a lack of LTAEs continuing in one of the three agro-ecological zones based on those derived by the Ecologically Sustainable Development Working Party of the Standing Committee on Agriculture and Resource Management (SCARM, 1993). There are few LTAEs in the most marginal cropping zones, where the conflicts between agricultural production and sustainable resource management are likely to be the greatest and, at the other extreme, no LTAEs appear to have been conducted in cool temperate zones of Southern Victoria and Tasmania.

The report sees the major advantages of LTAEs as allowing the monitoring of sustainability and environmental changes through biological and physical processes, which have long timeframes. It notes that the extrapolation of short-term experimental results can be (and have been!) wrong. LTAEs allow retrospective analysis, model development and a platform for other work.

Martin and Grace (1998a, 1998b) identify three main roles for LTAEs: monitoring sustainability, generating data for simulation models and generating information for policy decision-makers. While these are indeed major roles, their additional value in demonstrating more environmentally sensitive farming practices has been only minimally addressed.

Current work on the Somersby section of the Horticultural Research Station at Gosford, NSW, attempts to address these concerns. The development of such systems with better economic and environmental performance than current conventional approaches is indeed the primary goal of the project (Wells and Chan, 1997). Begun in 1992, the Somersby project has yet to reach 'standard' long-term status (typically 10 years or more), but the project approach and the focus on intensive vegetable production make it unique in Australia.

The innovative systems approach at Somersby compares five different vegetable production systems; each designed with specific goals and objectives (for full explanation of systems, goals and objectives, see Wells and Chan, 1997). These were transformed into a set of management practices typical for each treatment. This approach saw the investigators making management decisions more like a farmer would, in a deliberate attempt to make the research results 'more relevant to the real world' (Wells and Chan, 1997).

The research objectives at Somersby focus on comparing (1) profitability and productivity for each farming system, (2) their effects on soil, and (3) the pollutant loads they contribute to run-off and groundwater (Wells *et al.*, 1994). Consistent results throughout the project have shown that while relatively profitable and productive, conventional approaches to vegetable production are capable of having a large environmental impact (through very high losses of soil and nutrients). In contrast, a range of alternative practices (e.g. fertigation, drip irrigation, cover crops) were shown to reduce environmental impact, and in some cases to maintain superior profitability (Wells and Chan, 1997; Wells *et al.*, 2000).

The finding that 'some management practices are effective for achieving short-term economic aims but sacrifice environmental sustainability, while other practices work the opposite way' (Wells *et al.*, 1996) best describes the balancing act of farm system management. Overall, results from Somersby would, however, suggest that relatively small and simple adjustments to conventional management can result in substantial environmental benefits (Wells *et al.*, 2000).

How such benefits translate to adoption of improved farming systems, by local vegetable producers, may be a vital component of future investigation at Somersby. While analyses to date focus mainly on the above-mentioned objectives, the large data set could also be incorporated into broader environmental economic models, to include social as well as environmental and economic costs and benefits of different farming systems. Their inclusion in models may improve understanding of how to balance some of the presently non-priced costs of food production with the (also non-priced) benefits of improving farm sustainability in Australia.

Integrating farm system improvements (in both product and environmental performance) into local vegetable farms, through participation in quality assurance schemes and through on-farm research and demonstration, will enhance the long-term relevance of the work. While maintaining relevance is one of the main attributes of the systems approach employed at Somersby, and while, overall, the work reflects many of the design characteristics necessary for successful long-term research, strategic review remains necessary to complete its alignment with such critical factors.

Involving the potential end users of experimental results in the design and conduct of LTAEs can assist in development and extension. The value of this approach is discussed by King *et al.* (1996), who describe a project to improve long-term productivity of rain-fed lands by improving water use efficiency, reducing soil erosion and maintaining soil organic matter in India. The project was based on 'action learning' principles as well as a partnership with farmers. Also of relevance is Harris and Bezdicek's (1994) description of a process of farmer interviews, focus group meetings, field stop interactions and follow-up interviews to provide an information base for a 'Soil Quality/Health Interpretive Framework'. In this context of ensuring the dissemination of results, it is worth remembering the Rothamsted case, where the importance was recognised of (at least) some stakeholders seeing financial reward, as was the important role of a champion in longevity of relevant work.

The report found that disadvantages of current LTAEs relate to poor design (many are extended short term experiments), lack of replication, soil movement across small plots, lack of adoption (stemming, in part, from inflexible designs), higher costs and the risks associated in achieving long-term results.

The report also found that many current LTAEs are poorly planned, restrictive in a systems sense in that rotational treatments are fixed and that there is a focus on profitability. These are often amenable to BCA but lose relevance in the long term. There should be greater focus on the interaction of farming systems and ecological/environmental issues. Many current LTAEs in Australia have a poor communication/publication record and this would improve through extending and networking results. The case studies show that a wide area of impact is necessary to deliver a positive BCA to the LTAE.

However, the limitations of BCA as a technique for valuing experiments, which study the ecological and environmental impacts of systems, are poorly explored in the report. Techniques for the BCA of externalities (non-marketed products) become more and more limited as the recognised number, range and importance of the latter increase with time and with the impacts of political decisions on their values. The point has been made, that such costings finally become as subjective as, and no more morally correct than, more intuitive decision making processes (Kelman, 1981).

As an example of the vagaries in such costings, the cost of soil degradation in Australia, which can be considered an externality of Australian agricultural production, vary widely. Reeves *et al* (1998) note that estimates range between $1 billion and $3 billion per year. Chisholm and Hone (1996) explore this cost at length and question the widely cited estimate of $600 million annually prepared by the Australian Soil Conservation Council in 1989. They compare this with a 1991 estimate of $609 million for Western Australia alone. Chisholm and Hone comment that conservation costs could be reduced by technology that improves the profitability of "non-extractive" farming systems and note that "there is surprisingly little R&D carried out in Australia aimed directly at these sorts of issues ... there is no evidence that any attempt has been made to use R&D projects to increase the marginal benefits, to farmers, of high soil quality." Well-planned LTAEs would rectify this omission.

Pimental *et al.* (1995) explored 17 aspects of wind and water erosion in the USA and concluded that these cause about $44 billion in damages every year requiring a total investment of $8.4 billion in control measures. One questions the variation in these figures that might be induced by other investigators exploring other aspects.

In addition to undertaking a BCA prior to commencement, Martin and Grace (1998b) list seven key issues, which should be addressed in the development of LTAEs and, given the nature of their origin, it is likely that these guidelines will need to be addressed in future proposals to R and D Corporations:

1: *A focus on farming systems issues.* Issues are discussed for each zone. However, while these issues may be the correct ones, the identification and prioritisation of these by a range of local and national stakeholders are likely to provide better design and adoption.

2: *Clarity of purpose and design.* Agreed purpose and definition of success by all stakeholders are vital. A distinction is drawn between 'comparative' (fixed treatments requiring replication) and 'monitoring' (more flexibility in design and replication) experiments. Few treatments with large plots are recommended. Given the demand for investigation of interactions between farming systems and the environment in the future, the latter type is likely have more useful outcomes.

3: *Contribution to a network.* Networking in implementation and results will facilitate the development of predictive models and be conducive to adoption of results and use of LTAEs in education generally. Martin and Grace recognise the importance of interactive skills in LTAE researchers, touching on the need for general management skills.

4: *Data sets and links with modeling.* While the need for overall essential (minimum) data sets is noted by the authors, protocols and processes must not compromise outcomes.

5: *Combining short and long term experimental goals.* LTAEs become a platform for short-term experiments. Low cost 'mothballing' of LTAEs is also possible until such platforms are recognised, as was reported from Rothamsted experimental management (Laurence, 1998).

6: *Communication, data collection and storage.* Networks should seek to increase dissemination of results as well as develop protocols for collection, storage and sharing of data. While acknowledging the importance of disseminating results, the authors give insufficient consideration to the formal linking of LTAEs with commercial extension and education programs. Rothamsted trials have shown that LTAEs, if located well, may become part of broad tourist attractions and may be 'showcased' as such.

7: *Archiving samples.* Martin and Grace recognise the importance of sample archiving and suggest a cross-site sampling program could be undertaken (see Paustian *et al.*, 1995). Other projects, however, have limited archiving due to cost. A reasonable compromise is to review archived samples over time as a part of overall management (Laurence, 1998).

The above key issues have much in common with a list of essential attributes of LTAEs proposed by Johnston and Powlson (1994):

1: sites with security of tenure
2: acceptable levels of funding
3: a multidisciplinary scientific approach
4: well-defined, but not rigid, objectives
5: designed for rigorous statistical analysis of the data, including time series analysis
6: large plots with the potential for subdivision to allow extra treatments
7: clearly defined experimental protocols but with flexibility to allow for essential changes
8: agreed sets of measurements and
9: continuous output of good data with well-documented interpretation.

These authors concur that, if these parameters are met, LTAEs can contribute to, and indeed are a vital component of, the measurement of the sustainability of agricultural systems as part of the overall measurement of changes in the environment, as required by policy decision-making processes.

8. Indicators of sustainability

A shift towards agricultural sustainability ultimately requires a supportive political climate as well as specific and tangible ways of measuring individual farm sustainability. Indeed, it has been said that the degree to which sustainability is achieved may well depend as much on public policy factors as on the ability of research to deliver new technology (Buttel, 1993). In this light, it is useful to first outline a number of policy considerations that could create an environment for change within current agricultural practices.

Pretty (1995) outlines 25 such policy ideas under the broad groupings of: policies that work, encouraging resource-conserving technologies, supporting local groups and community action and reforming external institutions and professional approaches (see also Pretty, 1998).

Some of the ideas listed are: developing a national strategy for sustainable agriculture and also specifically for IPM (see also Schillorn van Veen *et al.*, 1998), prioritising research into sustainable agriculture, offering subsidies and support for sustainable technologies, incorporating the 'polluter pays principle' (penalising polluters with taxes and levies), standardising regulations for pesticides, encouraging formation of local groups and rural partnerships, giving incentives for landscape conservation, and providing support for information to link research, extension and farmers (Pretty, 1995). Pretty concludes that while few such measures have been applied in an integrated way, and that while the full benefits have yet to be achieved, their adoption *can* result in agricultural systems that are economically, environmentally and socially viable.

On a similar note, in their six-year, multi-state survey of sustainable and conventional farmers, the Northwest Area Foundation (1994) identified three main reforms needed to level the playing field in American agricultural policy:

1. integrate economic and environmental goals under the federal farm commodity program (government subsidies should reflect environmental performance rather than high production);
2. invest in sustainable agriculture research and education; and
3. support beginning farmers (based on their finding that many American sustainable farmers started before age 30 which suggests that it may be easier to *start* farming sustainably than it is to convert after conventional practices are established).

Interestingly, both authors identify the development of a *national* rural policy/strategy as a necessary precursor to the development of sustainable agriculture. Comparative analyses and reporting from a national network of long-term field sites could well provide the foundation for such a strategy in Australia.

As this current project targets the feasibility of LTAEs for measuring the costs and benefits of soil and environmental improvement in intensive horticultural cropping systems, some consideration of measurable indicators is required. While immediate considerations usually focus on measures of enterprise and farm profitability, soil quality, product quality, the off-site impacts of polluting residues, monitoring energy use and carbon sequestration in soil also have relevance to overall environmental decision-making. Furthermore, there are roles for LTAE-based initiatives in enhancing bio-diversity (for biodiversity and agriculture in general see Srivastava *et al.*, 1998) and maintaining or improving the aesthetic attraction of the rural landscape, both through demonstration, education and attempting to define the associated costs and benefits to assist overall policy decisions.

While a review of all of these issues is beyond this project, it is worthwhile noting that a strategic planning process, required for the initiation of effective LTAEs, and the networking associated with their regular review, would provide improved input into policy decisions and a stimulus for more concerted action. In this regard the planning methodology of Vereijken (1997a) has merit, in that it starts from broad social and environmental, as well as agricultural concepts. The 'broad sustainability account' being derived by Goulding and Stockdale in their 'Organic Farming Study' (Laurence, 1998) is also a useful template. To some extent, the breadth of the issues involved induce 'paralysis by analysis' and the renegade would suggest any demonstrable action based on the intuition flowing from collective wisdom is better than inactivity. The above planning and networking would provide the platform for such action.

The Ecologically Sustainable Development Working Party (SCARM, 1993) proposed that a set of practical indicators be developed to be used unambiguously for decision making at regional and national scales, encompassing on-site financial indicators, on-site environmental indicators, on-site social indicators and off-site environmental indicators. This is not an easy task and is consuming resources in many countries.

A recent discussion document by MAFF (UK) (Anon., 1998a) notes that existing indicators in many countries focus on productivity and consumption of agricultural inputs and that these do not adequately reflect actual environmental damage. There are few useful response indicators in use in the UK, such as those measuring change in management practices, quality of the rural landscape or the social dimensions of agriculture. In this document, an initial list of 35 indicators has been prepared for discussion. These are grouped under the themes of nutrient losses to freshwater, nutrient management practices, ammonia and greenhouse gas emissions, pesticide use, water use, soil protection, the agricultural land resource, the conservation value of agricultural land, environmental management systems, the rural economy and energy.

In this context, Martin and Grace (1998a) consider that LTAEs are likely to be of most use in providing measures for the on-site environmental indicator but may also contribute to the off-site environmental and the on-site financial indicator. They note that the parameters used to measure sustainability would differ according to location, agricultural system and resource base and that LTAEs provide an opportunity for measuring some of these parameters and associated crop performance. They suggest also the collection of research data for the development of physically-based models of all of the components of the production system, their relationships with resource-base degradation, and integration of these into decision support or other user-friendly formats. Young (1994) reviews models potentially applicable to soils in all environments, and cites examples selected to indicate their relevance to modeling soil changes. Additionally, he notes that, for 1991 alone, the Commonwealth Agricultural Bureaux Soils Database contains 1314 papers indexed for 'models' and that there should be no research in modeling in isolation from field experimental work. Modeling in a broader perspective, Schans (1991) seeks to balance the productivity and environmental trade-offs in potato growing and Kelly *et al* (1996) discuss trade-offs among alternative crop rotations.

With reference to on-site and off-site environmental indicators, Reuter (1997) reviewed ways of understanding landscape processes in achieving environmentally healthy and productive catchments and highlighted the challenges, not only in developing indicators to audit catchment health, but also in ensuring that they are used. He described the evaluation of 135 indicators with respect to the practicality of their use, which resulted in 27 being recommended. He comments that a major challenge remains to develop national agreement on a core set of indicators that could be recommended for use to landholders. The same challenge would hold for researchers. Progress is most likely, perhaps, if the number of these core indicators is minimised and they are decided upon with landholders.

The increasing importance being placed upon soil quality as a contributor to the health of the earth's biosphere, "functioning ... in the maintenance of local, regional, and worldwide environmental quality" (Doran *et al.*, 1994), has led to the development of soil quality indices. Doran and Parkin (1994) have developed a performance-based soil quality index, conceptualized as: food/fibre production, plus erosivity, plus groundwater quality, plus surface water quality, plus air quality, plus food quality. These factors, in turn, were measured through: yield, erosion losses, chemical leaching, nutrient, chemical and sediment losses to adjacent surface water systems, greenhouse gas emissions, food nutritional composition and chemical residue levels. All have scope for measures which could yield data of both commercial and policy use, as each factor is given a pragmatic weighting, set in the context of economic and political constraints.

An example of using soil quality indicators to determine environmental impact is given by Karlen *et al.* (1999). The Conservation Reserve Program (CRP) in the USA (initiated in 1985) aimed at converting highly erodible cropland to permanent cover. In an assessment of the (environmental) benefits of conversion under the CRP Karlen *et al.* (1999) used a range of physical, chemical and biological soil quality indicators – water stability and aggregate size distribution, bulk density, total organic and biomass carbon, nitrogen, pH, soil respiration, cation exchange capacity and others – and found that biological indicators were affected more quickly and to a greater extent than physical or chemical indicators. The soil quality indicators used in this work responded consistently across three broad geographic regions of the USA, demonstrating their benefit as general rather than location-specific measurement tools.

These individual factors can, however, be measured in a variety of ways. While the purists among us prefer quantitative measures, the simplest (and cheapest) are qualitative and these may deserve greater attention. Harris and Bezdicek (1994) evaluate the role of descriptive soil quality/health information in the development and application of technical and non- technical tools for assessing and monitoring soil quality for user groups of diverse backgrounds and interests. Their verbatim reports of farmers' comments point to factors, which may be reduced to numerical scores, e.g. "my soil is now like walking on a carpet instead of a highway" and "fuel costs are way down and wear and tear on our machinery is way down." They describe a 'correlative report card' as a possible format to record both descriptive/soft and analytical/hard data. This has been further developed by Garlynd *et al.* (1994). Smith *et al.* (1994) also developed an approach to integrating an unlimited number of soil quality measures into an overall soil quality index. This approach is also recommended as a research opportunity by Reeves *et al.* (1998) when commenting on the constraints to adoption of best practice land management, codes of practice and ISO 14002/eco-label marketing strategies.

There is a voluminous literature on the effects of farming systems on soil organic matter (Paul *et al.*, 1997), much recording the reductions incurred through intensive cropping. Aref and Wander (1998) analysed long term trends in soil organic matter in the Morrow Plots at the University of Illinois. They note: "in all but the longest (extensified) rotation, levels continue to fall. However, declining inherent productivity has not been noticed; even in the most depleted soils, ...technological innovations have continued to increase yield. Despite the fact that yield responses have been greater where organic matter is conserved, long crop rotations and manure are not widely used. When crop yield is the sole factor considered, use of these kinds of soil building practices may not be competitive. If the relationship between organic matter and soil quality, which includes the soil's ability to regulate water flow and/or its ability to act as an environmental filter, is considered, maintenance of organic matter and all it represents may become an imperative."

Collins *et al.* (1997) discuss methods of measuring soil organic matter, which permit functional descriptions of transformations relative to ecosystem functioning, biodegradation, soil fertility, and global change. They describe a suite of methods, which encompass both classical extraction and specific compound identification approaches, as well as those providing functional descriptions of organic matter pools and their dynamics. In the context of LTAEs, measurements need to have a practical bearing on the farming systems being investigated. Cotching (*pers. comm.*, 1998) for example, has reported a threefold difference in soil organic matter under pasture compared with kraznosem soils under intensive cropping, relating to a 30 per cent difference in water holding capacity. Given that irrigation costs can be readily measured, LTAEs can supply improved information on the true value of organic matter to farming systems.

Gupta *et al* (1994) measured thirteen different attributes of soil samples collected from LTAEs in southern Australia, designed to evaluate crop residue management systems for their ability to improve soil organic matter, carbon (C) and N availability. They discuss the implications of differences detected in the quantity and quality of microbial biomass, particulate organic matter, and mineralisable and labile fractions of C and N.

Duxbury and Nkambule (1994) evaluated methods for measuring biomass N and active organic N pools. They also assessed the usefulness of biomass N and active soil organic N measurements as predictors of N availability to crops. They concluded that there were unresolved inconsistencies in data addressing the relationship between microbial biomass N, potentially mineralisable N and active soil organic N. They also concluded that there was then "no published paper that convincingly supports the hypothesis that microbial biomass is a reservoir of nutrients for plant growth". Subsequent work, reviewed by Dalal (1997), indicated that, provided several methods are used, the size of the biomass can be realistically estimated. He considers the prospect that "hopefully in the not too distant future...we can make use of microbial biomass measurement as a routine tool for management of the land and the environment".

While well-designed LTAEs are able to provide a useful substrate, however, on which short term investigations of nutrient flux in soils may be carried out, the analyses conducted therein may add little direct value to LTAEs achieving the goals of prospective work in the current project. Indicators will need to be few and measure the economics of on-site production and off-site environmental pollution in a broad and robust way.

Bethlenfalvy and Barea (1994) have related the activity of vesicular arbuscular mycorrhizae (VAM), which have long been associated with soil health, to soil aggregation and thence water-holding capacity. Miller and Jackson (1998) surveyed VAM in the context of beneficial effects and other recent reviews are provided by Turco *et al.* (1994) and Roper and Gupta (1997). These, *inter alia,* consider the role of VAM in nutrient recycling and the links between VAM and plant disease reduction.

In the context of this review, improving our knowledge of such interactions will assist in the selection of farming systems which are balanced in terms of nutrient exchange and which employ integrated controls most effectively. Direct use of such methodology in monitoring economic and environmental change may not, however, be cost effective at this time.

Cheap unit costs of analyses will be important in successful monitoring and, in this regard, Janik *et al* (1997) measured twenty-three soil properties by near infra-red analysis and found excellent correlation with standard laboratory wet extractions and analyses. Gourlay and Sparks (1996) costed airborne radiometrics for measuring soil colour and texture, pH, electrical conductivity, bulk density and dispersibility at between 20cents and $2/ha. The system relies on the composition of radio-nuclides within 300mm of the soil surface, ground-truthed in soil samples for the particular parameter, and may have value in regional and national networking of LTAEs.

Combining a few robust quantitative measures with qualitative measures collected by farmers should result in the basic monitoring function associated with an LTAE being inexpensive. Such monitoring frameworks, as introduced by Williamson (1996), would also help overcome the poor technology transfer previously associated with current LTAEs. The importance of involving farmers in the monitoring process is also highlighted by Loby de Bruyn (1996).

Monitoring soil movement off-site and the calculation of erosion risk is an important feature of LTAEs. Karlen and Stott (1994) review this topic and comment that soil quality and productivity are frequently used synonymously when assessing the long–term impact of soil erosion on crop productivity. They describe a water erosion prediction project, which has helped improve erosion prediction methodology and provide a summary of a systems-engineering approach to developing an erosion indicator from standard scoring functions.

In addition to environmental impact indicators, economic performance indicators need to be agreed for the successful implementation of LTAEs. While the usual measures of gross margin, enterprise budget and internal rate of return etc are core indicators, a wide range of business performance indicators have been used to measure the sustainability of extensive grain production systems in the FAST (Farming and Sustainable Technology)

Project, (Hutchings *et al*, 1996). As an example, 'water use' is rated on the basis of farm income per 100mm of growing season rainfall per effective hectare.

A 'total water use efficiency factor' was used in a study of 16 different farming systems in Walgett, NSW, to compare outcomes of wheat, chickpea and sorghum crops grown in conventional and minimum-tillage systems in 1997 (Rummery and Coleman, 1999). This was achieved by dividing grain yield (in kg/ha) by total water (in mm) applied from the start of the fallow until crop maturity. Adapted to the context of the current project, a measure such as crop rotation income per unit of irrigation water or rainfall applied would give economically relevant results reflecting efficient water use.

Soil/water conditions and management factors are described by the authors, which affect sustainability, include indicators pertinent to both management and policy, at both the farm and the catchment level. The important point emerges, that a network of LTAEs, planned with broad involvement, could make a significant contribution to the debate on agricultural sustainability through providing the physical focus for discussions of results of the full range of indicators, whether site specific or global, whether driven by markets or public policy. Their educational value could help address the recent OECD observation that "Australia is facing the challenge of translating the principles of sustainable development into economic decisions and practices". OECD notes that "In many cases, economic objectives take priority over environmental concerns" and "In addition, process oriented approaches often dominate, at the expense of a focus on environmental results (Anon., 1998b). The complexity of the presentation of possible core environmental indicators for Australia (Anon., 1998c), in comparison to the MAFF document described above, is perhaps a reflection of this.

9. Economic analyses and their interpretation

Consideration of the broader scale indicators of sustainability inevitably leads into the discussion of how externalities (non-marketed products) are costed, how costs and benefits are attributed and analysed, and the illusive answer to that question of whether LTAEs represent value for money.

There is still considerable debate on appropriate ways to cost sustainability, stemming from the wide range of ideologies concerning the environment (Pretty, 1997), which themselves engender many definitions of 'sustainable development'. While it may be conceptually possible to solve the problem of costing externalities such as fertiliser and pesticide pollution, the monetary value of wildlife habitats and biodiversity and the aesthetic value of landscape are even more difficult to assess (Barnett *et al.*, 1994). Beckerman (1996) considers that the whole concept is "intellectually incoherent, based on flawed logic and a belief in disaster scenarios that fly in the face of all evidence." However, Pearce (1993) has a more constructive approach, tackling the problems of quantifying environmental factors, particularly in discounting externalities. The so-called 'tyranny of discounting', which under-estimates the present day value of long-term environmental damage, and also under-estimates the present day value of the long-term benefits of environmental programs are discussed by Turner, Pearce and Bateman (1994), together with the mitigating arguments. These reasons, and the difficulties of predicting the prices and politics associated with externalities in the long-term, lead many to object to the application of BCA to environmental issues. Turner (1993) contrasts techno-centric ideologies with their 'very weak sustainability' ethic and reliance on BCA with eco-centric ideologies with their 'very strong sustainability' ethic and abandonment of BCA.

Alternative analytical approaches are offered by economists to address perceived shortcomings, such as opportunity cost rates of discounting, additional factors to influence models' prediction of the effects of the precautionary principle or individuals' preferences (option values). However, there are arguments why such approaches also discriminate against the value of the environment (Markandya and Pearce, 1991). The idea of maintaining the capital value of the natural resource by compensating for projects, which deteriorate the environment, with those that ameliorate it, leads to a certain sustainable approach, from an economically rationalist viewpoint. However, this again may fail to put adequate value on the 'spiritual' value individuals may place upon recognition of the real historical identity rather than its exact replica. Courvisanos (1998) proposed a useful behavioural framework of analysis towards resolving the problem of economically driven investment in technological development leading to ecological 'market failure', based on the work of Kalecki (1986) and Lowe (1976).

The above arguments reflect the ease with which discussion moves from the tangible to somewhat nebulous concepts and Lynam and Herdt (1989) recognised the need to define the spatial levels at which the particular sustainability issue is operating and its interconnections.

Herdt and Steiner (1995), note the limitations of 'total factor productivity,' which measures an index of total output relative to all managed inputs, as an adequate measure of sustainability. They introduce the concept of 'total social factor productivity' to take account of externalities and recognise the need to include ecosystem health in the latter, as well as more direct externalities, such as secondary, waste and unused products.

While they recognise that a non-decreasing trend in yield and in total social factor productivity are necessary attributes of a sustainable system, as well as ecosystem health indicators remaining at acceptable values, they conclude that the evaluation is fraught with difficulty. Apart from assumptions that must be made about the impact of eco-system health on future productivity, and that past trends are reasonable indicators of future trends, what indeed constitute externalities and at what level their influence should be projected, come down to value judgements.

The conversion to low-input farming systems, and to organic farming in particular, do produce decreasing yield trends for several years and investigating the socio-economic implications and effects of food supply and prices have received considerable attention (Lampkin and Padel, 1994). The work continues to influence governments' policies in terms of the level of financial support for conversion. However, the dangers in modeling the economic effects of such impacts at a time when much macro-level data is still unavailable, have been expounded by Lockeretz (1989).

Cassman *et al.* (1995) use the TFP approach to analyse eight LTAEs. They conclude that "the lack of positive TFP trends since the 'quantum leap' of the green revolution is also a concern" and "where negative trends occur in TFP, there is no evidence that yield potential (of varieties) has decreased, so declining productivity must reflect degradation in soil quality".

The uses of the common arithmetic indexes in total factor productivity are reviewed by Rayner and Welham (1995). They, too, conclude that making the correct allowances for long-term trends in quality changes in inputs and outputs, and estimating the value of service flows is extremely difficult. Furthermore, there is scope and indeed a need, to incorporate other prospective values in any calculations. These are bio-diversity, tradable credits (or tax credits) for sequestering carbon in agricultural soils, being promoted for forestry generation but with wider beneficial application (Carter *et al.*, 1997), irrigation water rights and other issues raised in the Theme 5 of the National Land and Water Resources Audit (Anon., 1998d). A further, lateral approach might also consider intrinsic values of the rural landscape, for the maintenance of which UK farmers, for example, are paid. While it is recognised there is a strong 'anti-handout philosophy' in the Australian farmer's psyche, the concept is that the maintenance of the rural landscape is a public duty, in which they are in the best position to fulfil and for which they should expect to be paid. At the local level, strategies suggested by TBA Planners *et al.* (1998) to assist with the sustainable use of Tasmania's intensive cropping land, incorporate considerations of the whole community's investment in these lands as a public asset. Among other strategies, they suggest collaborative research and extension to, *inter alia*, develop and promote new techniques for sustainable land management. LTAEs could play a major role in such a strategy.

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Introductory letter

4 August 1999

Dear

Evaluating the long-term sustainability of intensive horticultural (vegetable) cropping systems – feasibility of long–term investigations

I am writing to inform you of an assessment which Professor Peter Cornish, University of Western Sydney, and I are currently carrying out on behalf of the Horticultural Research and Development Corporation. We are seeking the views of those representing the Australian vegetable industry regarding the prospective development of field investigations to measure the long-term costs and benefits involved in adopting more environmentally sustainable intensive vegetable cropping systems. Having completed a similar regional study, which showed broad support among a wide range of stakeholders in both industry and government for the production and progression of a proposal for a long-term field evaluation, the HRDC has seen merit in assessing the support for a national approach.

Pressure on production practices is now being felt through the increasing demand for food which is assured to be safe with respect to both the product itself and to the effect of its production on the environment. While some projects work presently towards this goal, there are few field sites coordinated nationally, which are planned to measure the costs and benefits of environmental improvements over the long-term, to aid policy and planning in government and business and demonstrate better systems.

Prior to providing a discussion paper to you and our collating responses to it, we wish to ask for your summary views on two points in order to improve the regional relevance of our paper:

1. The principal locations of vegetable production in your state with some ranking of their relative importance, and

2. Your consideration/subjective assessment of the key environmental issues in these areas relating to vegetable production.

We are collaborating in data acquisition, with those currently undertaking the Horticultural Environmental Audit for the HRDC, of which you may already be aware and you may have received survey correspondence from Brian Newman on behalf of that project management group. Therefore, we appreciate definitely the limitations on your time and ask only for a brief reply – a page, an email or a phone call to one of us below.

Thank you in anticipation of your interest.

Yours sincerely,

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HRDC

Appendix C

Discussion paper

The costs and benefits of more environmentally sustainable intensive vegetable production systems in Australia: is there a need for long-term investigation?

A discussion paper

The issues are broad

Public awareness and concern for the quality of the environment has risen in recent years and is most apparent, in the agricultural sector, through increased market and social demands for 'safe' food and more environmentally-sensitive food production methods.

The issue for growers, and the agricultural industry in general, in reaching more sustainable farming practices, lies in maintaining profitability. There is, however, a lack of understanding (and a lack of objective measurement) of the magnitude and rates of remedial change required, as well as of the economic and environmental/social costs (and benefits) of such changes in farming systems. These economic data and externalities (non-priced impacts/products) need to be measured in order to replace anecdotes with factual data, as well as to provide input into macro-economic models of interactions between agriculture and other industries (e.g. tourism) through their environmental effects. There is an associated need to demonstrate the outcomes of any such research in a practical manner.

It is generally agreed that measurable parameters (indicators) to evaluate the above-mentioned costs and benefits do exist, but the studies required to produce much of the data need to be large-scale, well planned and carried out over long time-periods. Yet, in Australia, there are few such long-term agricultural research experiments (LTAEs) investigating intensive vegetable production systems. While the need for work on a broad (catchment) scale is now influencing the planning of projects, the contribution of their outcomes to the understanding of how (practically) to improve the sustainability of vegetable systems is still severely undermined by short-term goals and funding.

Decisions on broad policy issues, such as the level of Government support for change and the mechanisms for its delivery, would therefore be greatly assisted by the acquisition of such information. For example, while the Australian producer's sentiment towards subsidy has traditionally been one of strong distaste, they are almost certainly in the best position to preserve and enhance the rural landscape for the general good. Indeed, in some countries, which compete in our markets, those farmers who adopt a role of rural 'stewardship' are financially rewarded for doing so. These support mechanisms could be included in economic models associated with such work. The data gathered would also improve the understanding of broader environmental issues such as greenhouse/carbon credits, biodiversity and rural landscape amenity values.

Related previous work

A recent regional study (Laurence, 1999) found support across a wide range of potential stakeholders within industry and Government, for the concept of establishing long-term, practical field investigations. This work is being developed further, at present, with a preliminary proposal for the establishment, in Tasmania, of one or more LTAEs. It has also highlighted the importance of regional input and the need for 'champions' to give specifically regional issues full hearing and fully raise local awareness. Such regional leadership issues should be borne in mind in the current, national context.

This work has also led to the current study, supported by the Horticultural Research and Development Corporation (HRDC), which is pursuing the views of key potential stakeholders across Australia, to determine the level of interest in the concept of a national network of long-term experiments.

Regional and national links

After first assessing the level of national support available, the current study aims to develop a framework to establish long-term, broadly based research and demonstration of the costs and benefits of more environmentally-sensitive intensive vegetable cropping systems. This will have the outcome of driving debate towards changes in such farming systems, as well as assisting the alignment of Government policy.

An important and timely link to this research is the Horticulture Environmental Audit (HEA), currently being carried out on behalf of the HRDC and the National Land and Water Resources Audit. The HEA aims to document the use of natural resources by Australian horticulture, assess the extent of current impacts on those resources (both positive and negative) and assess industry's current adoption of good management practices and its need to move to a more sustainable basis. The first stage of the HEA, one of information gathering, is currently concluding and will provide corroboration of the present study's findings.

Current work

Initial correspondence invited each State to outline the most important regions of vegetable production, and to summarise the associated key environmental issues for those areas.

The following table shows those regions most important in each State (in terms of production). Certainly, there are other important production areas but highlighting these serves the purpose of this discussion.

Table 1: Principle Vegetable Growing Regions for each State

NSW	NT	QLD	SA
- Southern Plains - Central Coast - Tablelands	- Darwin area	- Moreton - Northern - Darling Downs - Brisbane area	- Adelaide Plains - Adelaide Hills & Fleurieu Peninsula - Riverland
TAS	**VIC**	**WA**	*NB: The principle regions of vegetable production for each State are ranked in terms of their relative importance*
- NW Coast - North East & Northern Midlands	- Werribee/Keilor - Mildura/Swan Hill - Cranbourne - Gippsland/ Bairnsdale	- Manjimup - Wanneroo - Gingin - Wyndham (Ord River irrigation area)	

Responses show that there are some key issues common to most regions, and other issues more related to specific areas. Generally, concerns associated with water use, organic matter and the off-site effects of pesticides and fertilizers were the common issues highlighted in each response. The more localised issues included those related to soil erosion (by wind and water), salinity and land use/access.

What Makes A Successful LTAE?

Large commitments of personnel and budget are often considered typical of long-term investigations, but these are not necessities. A combination of simple design, prioritised analyses and an ability to meet short-term goals can help maintain cost effectiveness.

Yet not all past LTAEs have been successful. Those which have been criticised have lacked adequate planning for the long term. Some, indeed, were only planned for the short term and not terminated. Reviews of those that *have* been successful (e.g. Martin and Grace, 1998) have found some common critical attributes. Successful LTAEs tend to:

- have their objectives focused and agreed upon by the widest possible range of stakeholders;
- employ broad management skills and principles, and strategic planning;
- have committed individuals and include a balance of both long and short-term goals to satisfy all stakeholders;
- be planned from the outset for at least two or three rotational cycles, since change effects can take this long and the time scenario influences design and analysis. Designs must be simple and field areas need to be large-scale;

- have the flexibility to stay focused on the continual improvement of agricultural systems rather than the comparison of specific treatments/rotations. Comparison of fixed rotations may limit the flexibility of designs, unless options for treatment change are planned initially. Whether or not to use such 'treatments' should depend on the aims of the experiment;

- be commercially effective and, therefore, must be incorporated with programs to test their improved systems on commercial farms, and be linked to market-driven QA requirements, as well as to other rural industries and their education and training systems; and they

- ensure compatibility of data collection and handling methods across the entire network of experiments, to allow for accurate modelling and to maximise the value of outputs for stakeholders.

Progressing the concept

As a way of focusing further discussion, we propose that any plans for long-term field investigations be developed at a regional level, and by local and national prospective stakeholders. Based on a general protocol with prior national agreement, this would provide both regional solutions to problems, as well as nationally applicable findings. Such a protocol could include some of the following characteristics.

Their:

- design could facilitate the comparison of conventional and less intensive systems, with planned flexibility to allow for agreed periodic treatment change, and to guard against obsolescence;

- design would incorporate a balance of long and short term goals (and activities) to meet the needs of all stakeholders;

- designs could be un-replicated but fully-phased and of a large enough size to accommodate splits over time (allowing changes to rotations and treatments);

- experiments would be designed for at least three rotational cycles (or at least 15 years), with funding commitments and review every rotational cycle;

- investigations would be managed by a regional committee of stakeholders, with national linkages, and these committess could offer a range of educational and technology transfer opportunities; and their

- key topics of investigation would depend on the region, but most are likely to include the basic measures of productivity, profitability, soil erodibility (or erosion), carbon and other major nutrient budgets and measures of off-site water quality.

What do you think?

The success of a national framework of LTAEs will be highly dependent on regional input. We would greatly appreciate your comments and, indeed, your input will have a direct role in determining the final structure of this project.

We welcome any feedback, and look forward to receiving your comments.

Rowland Laurence
Principal Research Fellow

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Appendix D

Workshop report

Improving the long-term sustainability of horticultural cropping systems
– a feasibility study
HRDC Project VG98105

A Report on the Proceedings of a Workshop
held at the University of Tasmania, North West Centre
Tuesday 18th January 2000

Contents

Introduction

Australia's agricultural industry is facing increasing public demand for 'safe' food and more environmentally-sensitive production methods, yet there is a current lack of 'hard' data on the costs and benefits of such methods, particularly in horticulture.

This project aims to determine the level of national support for a network of long-term field investigations into the costs and benefits of more sustainable cropping systems. To date, there has been a high level of interest in this concept, with representatives from every state responding to a discussion paper sent in October 1999. This prompted the organisation of a national workshop to further discuss the issue of sustainable horticulture through long-term research and to develop a framework for its implementation across Australia.

Workshop Proceedings

Project background - Rowland Laurence

Reasons behind the work

- market drivers and concerns about environmental change
- the broad costs and benefits of alternative systems need investigation
- the means of measuring these changes are rare, particularly in horticulture
- some investigations have lost support
- still a need to obtain 'hard' data
- this is an attempt to gauge the level of interest in prospective long-term work

State of play

- previous regional study (Tasmania, Southern Victoria) supported by RIRDC had similar objectives to current study
- reinforced the do's and don'ts of long-term investigations
- showed that European work is increasing
- reinforced the limitations of BCA in long-term assessments and the need for inclusion of 'environmental market-failure' costs
- broad agreement across industry and government on a proposal
- preliminary proposal for regional work submitted to RIRDC in September 1999
- 4 positive, 2 negative responses from industry, 2 awaiting RIRDC outcome
- RIRDC indicated the project more suited to HRDC funding
- some logic in including this study in current project

Current study HRDC VG98105

- begun December 1998, rescheduled to finish January 2000
- seeking views nationally on developing long-term investigations
- literature review
- letter to key potential stakeholders August 1999 and ongoing awareness activity
- discussion paper sent in October 1999 to 52 interested recipients

- today's workshop – seeking consideration of the purpose, value and development of a national framework

Purpose and outcomes

The purpose of this workshop is to reaffirm the level of national support for long-term field investigations into sustainable cropping systems, through consideration of the purpose, value and development of a national framework.

Workshop outcomes:

- an agreed basic national framework for long-term investigations
- development of an action plan – what to do next?

Regional issues, commonalities and activities

The group discussed the principal regions of vegetable production, the key environmental issues within those regions, and the current activities in place to address these issues (see attached summary table).

Water availability (including quality and cost) and soil quality issues were common concerns across most regions.

HRDC/NLWRA Horticulture Environmental Audit update – Leigh Sparrow

The Horticulture Environmental Audit (HEA):
- still working on the final version of Stage 1
- preliminary findings – a lack of information available on industry compliance with best practice, and a lack of a structure within the industry to gather that compliance data

Role of HRDC:
- natural resource management (NRM) issues are high on the agenda
- HRDC has a direct role in encouraging industry to invest more in NRM (e.g through their role in the HEA, mid-year presentation to the Board of a review on NRM operations)

Advice for future submissions to HRDC with regard to proposed long-term work:
- make the questions very clear
- gather regional industry support
- attempt to find the easiest, or most likely, way to answer these questions
- consider how these answers will lead to on-ground change

- consider how the work will benefit the industry and the community, regionally and nationally
- have regional 'champions' if possible
- collaborative projects lead to better science - 'true' collaboration may be supported

Regional values and goals of a national framework

Participants formed two groups to workshop the following points:

a. create a list of regional values for a national framework
b. create a list of what you think makes a successful framework
c. summarise into 2 sentences: what is the 'end picture' you have in mind for this framework? And why does this framework exist?
d. create a list of goals this national framework must achieve (prioritise these)

Group 1 (Leigh, Neil, Sandra, Richard, Paul, Craig, Bill A)

a. Regional values – taken from an individual/farmer viewpoint

- regionally relevant solutions
- economic benefits
- information on off-site impacts
- information on on-site impacts
- relationships between 'productivity' and 'degradation' defined
- efficient investment of research dollars
- recognition of social/eco(labeling) responsibility

b. A successful Framework would:

- have the capacity to relate understanding at different scales (farm and catchment)
- have mechanisms for communication
- have consistent protocols where appropriate
- involve industry 'champions'!
- have the capacity to investigate underlying causes

c. The end picture is:

- that the Framework will form the *rational* basis for knowledge and adoption of sustainable horticulture (emphasis on rational as opposed to ideological/philosophical)

The Framework exists to:

- facilitate communication (internal and external), collaboration and efficient use of resources.

d. The main goals (prioritised) of this Framework are:

- communication/collaboration
- resourcing
- holistic approach to farming systems (process based)
- to develop research priorities on a rational basis
- to improve the biophysical efficiency of horticultural industries

Group 2 (Bob, Andrew, Bill C, Brian, Louise, Shauna, Mike, Jason)

a. Principles and regional values – taken from an industry viewpoint

- local relevance
- benefiting from a greater pool of data and expertise
- flexibility to take into account change
- suit local institutional setups
- input and ownership from local regional industries
- the feeling of being part of a team and contributing to a greater good
- clear definitions of outcomes
- outcomes contribute to and enhance regional economies

b. A successful National Framework would:

- have a good mix of short and long term projects
- be relevant to most regions (to the widest range of stakeholders)
- have good communication
- use the same methodologies – uniformity
- have good planning
- be integrated with and complementary to other projects
- need to get the right people in the team
- focus on common issues only
- KISS

c. The end picture we have in mind for this framework is:

- satisfying market-driven requirements through a well-planned project addressing soil and water management issues, which have regionally relevant outcomes (soil and water were specifically mentioned as the group saw these as the major areas arising from the morning's session). (The group saw this as their Vision Statement).

This Framework exists to:

- ensure a coordinated approach to maximising research outcomes by being more efficient and effective. (And this as their Mission Statement)

d. The main goals of this Framework are:

- Goal A: to better use resources in production systems while ensuring the productivity and reducing the cost of production

- Goals B: to use systems to differentiate product (USP), ability to demonstrate responsible environmental practices as a feature of the product (these could be internationally accepted and audited standards, ahead of time), to have a positive market advantage and to have an internationally competitive industry using land and water in a sustainable way.

- Goal C: to have vibrant, profitable industries.

Action plan

As a group, participants listed the actions required to achieve the above goals:

- identify who to communicate with – who should be included in the network
- identify the stakeholders
- develop a communication plan
- gain regional input (broad consensus)
- develop a *small* project management group
- develop clear research questions, and clear outcomes

Participants agreed on the skills needed in a management group for the national framework:

- representative(s) from funding bodies should be included
- members should come from diverse backgrounds (outside horticulture) to encompass true farming systems (eg representatives from environmental groups, water providers)
- members should be zealous, full of energy and ready to act as regional 'champions' (succession planning was mentioned as an important consideration)
- members should be flexible and disciplined in good planning
- 'serendipity' is often the key
- 'finesse in management' is required
- a degree of luck!

Recap

It was agreed that a summary of the workshop findings should be distributed to all participants, so that they could discuss the issues further and gain regional input, before providing feedback to Rowland Laurence by the end of February. This information will then be included in the final report to HRDC of the Project VG98105.

This information and feedback will also help identify potential members of the management group and the regional champions, as well as identifying the resources and opportunities that are available.

It was suggested that having reached broad consensus on the ideas generated at the workshop, specifically the actions required to fulfill the goals, the next step would be to form a management/steering group, which could then agree on the priorities – the actions required to achieve those said goals.

It was suggested that industry should be involved in the management group and that resources necessary for long term investigation would need to come from both government and industry. While industry may be interested in these types of issues and the outcomes of such research, and may indeed already be financing some of it, it was mentioned that a more nationally coordinated approach was needed to improve their soil and water 'sustainable environmental management practices'.

To hold the commitment of both industry and government, a mix of short and longer-term goals are necessary and some current projects supported by industry are likely to readily fit into such a framework. However, the concept will still need some 'selling' to industry, including demonstration of the value of such work as an investment in future viability. The opportunity for industry to demonstrate pro-activity through such investment is part of this.

Environmental issues and remedial strategies for key vegetable growing regions of Australia			
Key Regions	**Key Issues**	**Remedial Strategies**	**Comments**
NSW - Southern Plains	Water availability (quality, quantity and cost)	- Waterwise Project	Driving other farmers into intensive vege production
	Salinity	- salinity mapping (Murray-Darling) - Salt Action Plan	Driving growers onto new ground
	Pests and diseases		An issue as growers move onto other ground
- Central Coast	Urban encroachment	- recycled waste projects - health/nutrition promotion - sustainability of water systems	Projects funded across State Dept's to promote healthy food
	Water/nutrient recycling	- Somersby project	
	Algal blooms	- Peter Cornish's work in Hawkesbury-Nepean	
- Tablelands	Water availability		Driving growers onto new ground
	Acidity	- acid soil program	
	Soil erosion		
NT - Darwin area	Low organic matter		
	Pesticide use/residue	- aquifer monitored	
QLD - Northern (Bowen)	Fertiliser overuse		Impacts on reef
	Pests and diseases	- IPM	
	Water availability	- audit of water efficiency	DNR/QFVG
	Spent plastic mulch (dumped)	- threat of prosecution under EPA	Stockpiling creates fire risk
			Other work on soil health research
- Bundaberg	Water availability		

	Salt intrusion		
Key Regions	**Key Issues**	**Remedial Strategies**	**Comments**
Bundaberg cont…	Overuse of aquifer		
	Elevated nitrates in groundwater		
	Cadmium buildup in leafy vegetables		
- Lockyer/Fassifern Valleys	Water availability		
	Exotic pests	- IPM	Pesticide residue may be a community perception
	Salinity		May relate more to water quality
- Granite Belt	Water availability		
	Acidity		Potential issue
	Pests		Potential issue
	Urbanisation		Increase in hobby farms
SA - Adelaide Plains	Poor soil structure	- soil management - crop rotation	Adoption programs developed for non-English speaking area
	Low organic C		
	Nutrient leaching		
	Fertiliser overuse		
	Salinity		
	Use of fumigants		
- Adelaide Hills and Fleurieu Peninsula	Poor soil structure	- soil management - crop rotation	Mostly adoption programs
	Acidity		Relates more to general agriculture than horticulture
	Land use conflict		
	Water competition		
	Native vegetation		
- Riverland	Salinity		A relatively new production area with water taken from Murray
	Soil erosion		
- South East area	Salinity		
	Nutrient leaching	- aquifer monitored	

Key Regions	Key Issues	Remedial Strategies	Comments
South East area cont…	Water competition		Licences purchased but not used immediately
	Waste water management		Mainly potato processing industries
	Change to perennial crops (carbon credit advantage)		May be potential threat to industry
TAS - North West Coast	Low organic matter, declining soil structure	- good range of rotations, crop diversity encouraged	
	Soil erosion by water	- cropping impacts on soil quality	Work by Bill Cotching and others
	Off-site impacts	- QA introduced	IPM in some areas
	Land use conflict	- PAL planning tool	Forestry and urban encroachment
	Water availability	- legislation proposed	Potential issue
- North East and Northern Midlands	Soil erosion by wind		
	Declining soil structure	- research into suitable legume for rotations	Rotations needed are in fairly new areas
	Salinity	- monitoring program	
	Water availability	- water partnerships program	
		- use of raised beds	
VIC - Werribee/West Melbourne	Water availability	- general extension programs are available	General note – some growers move onto new ground if degraded
	Land use conflict		
	Pests and diseases		
			Other compost work (K. Wilkinson)
- Cranbourne and Mornington Pen.	Water availability and other issues similar to Werribee		

Key Regions	**Key Issues**	**Remedial Strategies**	**Comments**
- SE Gippsland	Water quality	- local, seasonal extension programs	
	Soil erosion		
	Soil quality		May be potential issue
- Mildura/Swan Hill	Water quality/salinity	- irrigation benchmarking study (Swan Hill area)	Marginal issue now but potential in future
		- soil management programs - IPM	Relatively new areas under production – problems as yet unknown
- North Central (Goulburn Valley)	Declining soil structure	- soil management project proposed - drip irrigation - raised beds	Work by Bill Ashcroft
	Pests and diseases	- IPM	
	Use of remnant vegetation	- publicity and penalties	Landcare etc
	Weeds		Nightshade in tomatoes
WA - Manjimup	Soil erosion	- better land use management in hill-side country - Landcare	
	Water availability		
	Pesticide residues		Relates to past use
- Wanneroo	Nutrient leaching		
	Land use conflict	- PAL strategies	Major urban encroachment
	Water availability	- sunset clause in licences - irrigation management, fertiliser use	
	Declining seagrass beds		Unclear link to agriculture
			Other work on compost; EMS

Key Regions	Key Issues	Remedial Strategies	Comments
- Gingin	Water availability		e.g. olives and paulownia recently
	Nutrient leaching		
	Land use conflicts		
- Wyndham/Ord River area	Rising water table	- land use planning to develop appropriate use for different soils	
	Pesticide use		Endosulphan use in fishing
	Pests and diseases		

A National Framework for long term field investigations into the costs and benefits of more sustainable intensive horticultural cropping systems.

A Workshop – Tuesday 18th January 2000

Attendance List

Bill Ashcroft	ISIA, Tatura VIC
Bill Cotching	DPIWE, Devonport TAS
Shauna Dewhurst	QFVG, Rocklea QLD
Mike Hart	DPIWE, Launceston TAS
Craig Henderson	QDPI, Gatton QLD
Sandra McDougall	NSW Ag, Yanco NSW
Neil McKenzie	CSIRO Land and Water, Canberra ACT
Paul Moran	PIRSA, Adelaide SA
Brian Newman	AUSVEG, Strathbogie VIC
Jason Olsen	QDPI, Bundaberg QLD
Bob Paulin	AgWA, Perth WA
Leigh Sparrow	TIAR, Launceston TAS
Richard Stirzaker	CSIRO Land and Water, Canberra ACT
Louise Thomas	DPIWE/TFGA, Launceston TAS
Andrew Walker	AFFA, Canberra ACT
Rowland Laurence	TIAR, Burnie TAS
Nani Clark	DPIWE, Devonport TAS
Anna Renkin	TIAR, Burnie TAS

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Workshop Program

10:00 a.m.	**Assemble** (coffee)
10:15 a.m.	**Welcome** (RL) **Background and update of Project**
10:30 a.m.	**Workshop commences** (NC) **Introduction** **Define purpose and outcomes of the day**
10:45 a.m.	**Outline principal locations of vegetable production, key environmental problems and regional priorities of each state** **Identify common issues, across important vegetable production systems in each region, which have national relevance**
12:00 p.m.	**Lunch break**
12:45 p.m.	**Update on the HRDC/LWRRDC Audit** (LS)
1:00 p.m.	**Plenary Session** (NC) **Referring back to today's purpose - what makes a successful National Framework?** Everyone's perspective of 'what is the end product?' What are the key characteristics? Could refer here to those listed in the Discussion Paper? *(on separate handout)* Link back to the key areas of investigation, as outlined pre-lunch **Goal setting** (What must this Framework achieve?)
2:30 p.m.	**Tea break**
2:45 p.m.	**Actions Required** (NC) **How will the Framework achieve the above goals?** How will we manage this network? What structure? *(add onto w'board the appropriate actions for each goal)* Define the next steps, timelines, roles and responsibilities *(prioritise the actions listed)*
3:45 p.m.	**Recap** (RL)
4:00 p.m.	**Close**