Australian grasslands research at the crossroads

Alan Robson

School of Earth and Environment, The University of Western Australia
Contact email: alan.robson@uwa.edu.au

Abstract. Grasslands research in Australia is at a crossroad. There are several difficulties. First, the decline of sheep production and dairying within Australia and increased cropping has focussed attention on crop research rather than pasture research. Second, enrolments in agricultural and related education have declined, and graduate numbers are insufficient to meet demand for expertise. Third, there has been a move towards specialisation in research and there are relatively few generalist agricultural scientists able to integrate research results into agricultural ecosystems. There remain very many challenges. Adapting grassland production to minimize the emission of carbon dioxide and methane is a major challenge. Another major challenge is to develop production systems that will be productive in the changed environments resulting from climate change. A third challenge is to secure funding for grassland research with research and development corporations focussed mainly on off-farm and cropping research. .

Keywords: Grassland research, grassland production, climate change, funding.

Introduction

In this paper I will examine the state of grassland research within Australia. I will use grassland and pasture research interchangeably. There have been several reviews covering historical aspects of pasture research and Australian grasslands (McIvor 2005, Clements and Henzell 2010, Nichols *et. al* 2012). After considering the prospects for animal products and the changed context of agricultural production in Australia, I will consider the availability of grassland scientists, the sources of funding for grassland research and finally the major challenges facing grassland research.

The changing face of Australian agriculture

In the last fifty years the proportion of agricultural land cropped has markedly increased, sheep numbers have fallen dramatically while cattle numbers peaked in 1975 (28m), fell between 1975 and 1983 and then increased since 1988 to 26m in 2011 (Australian Bureau of Statistics 2013). In the last decade agricultural production has also changed markedly (Table 1). The area sown to cereals, oilseeds and grain legumes has increased by more than 20% from 17.7 to 21.5m ha, while sheep numbers have fallen from 111 to 73m, dairy cattle numbers have decreased from 3.2 to 2.6 m, while beef cattle numbers have remained fairly constant (Australian Bureau of Statistics 2013).

Table 1. Changes in area cropped and livestock numbers from 2001 to 2011 (Australian Bureau of Statistics 2013).

	2001	2006	2011
Sheep (m)	111	91	73
Meat cattle (m)	24	26	26
Dairy cattle (m)	3.2	2.8	2.6
Wheat area (m ha)	12.1	12.4	13.5
Total crop (m ha)	19.5	20.3	21.5

The changing nature of Australian agriculture has been associated with: (1) increased use of nitrogen fertilizer replacing nitrogen fixed by legumes grown in rotation with cereals; (2) increased use of herbicides; and (3) decreased cultivation.

The decline in sheep number has been largely associated with a decline in demand for wool. Another factor in considering the future of animal industries is the widespread concern within the Australian community regarding the welfare of live animal exports in importing countries. Countering these effects is the growth in population and income within developing economies in Asian countries. As income increases there is substitution of animal protein (both milk and meat) for vegetable protein. It has been estimated that increased demand for milk and meat will greatly improve the profitability of Australian animal industries. This in turn will place greater emphasis on grassland research.

Expansion of Australian agriculture, particularly in southern Australia, was associated with superphosphate application to legume-based pastures grown in rotation with cereals. The introduction and selection of well-adapted pasture legumes and their associated root nodule bacteria was a major factor in the success of legume ley agriculture in southern Australia. The advent of improved cereal varieties suited to early sowing associated with decreased cultivation and the use of herbicides accelerated the expansion of cereal production at the expense of animal production. A major factor in the decline in animal production has been the relative profitability of cropping and animal enterprises. Much of the research on pastures was funded from levies on wool, meat production and cereal production. In the 1980s and 1990s the Australian Wool Corporation and the Australian Meat and Livestock Corporation placed greater emphasis on funding research past the farm gate with much lesser emphasis on farm production research. With a decline in pasture phases

Table 2. Excellence in research for Australian universities (Australian Research Council 2012). For universities to be rated, 50 apportioned indexed journal papers had to be produced in a six year period. Ratings are 3 - world average; 4 - above world average; 5 - well above world average. FTE – full-time staff equivalent. Output is journal articles, conference papers, books and book chapters.

Discipline	Number of universities	Rating			FTE	Output
		3	4	5		
Agricultural and Veterinary Science	23	9	10	4	1102	11032
Crop and Pasture Production	11	5	3	2	233	2434
Animal Production	6	5	1	0	166	1697
Agriculture, Land and Farm Management	2	0	0	2	85	921

associated with cropping the Grains Research and Development Corporation appears to have decreased its funding of pasture research.

Who will do the research?

The major organisations involved are CSIRO, the State Departments of Primary Industry (very few Departments of Agriculture remain), universities, private enterprise and the Co-operative Research Centres. There has been a shift away from agricultural production research within CSIRO and a shift away from research in most State Departments of Primary Industry. Enrolments of Australian students in agricultural and related education within universities at both the undergraduate and post-graduate level have declined substantially (Office of the Chief Scientist, Health of Australian Science 2012). Australian and State Government research agencies conducted 22% and 53% respectively of agricultural R&D in 1995, but only 16% and 50% in 2009. By contrast universities increased their share of publically funded agricultural R&D from 14% in 1995 to 34% in 2009 (Australian Bureau of Statistics, 2010). Growth in public agricultural R&D expenditure averaged from around 7% per annum between 1952-53 and 1977-78 to around 0.6% per annum from 1977-78 to 2006-07 (Sheng *et al*, 2011). CSIRO expenditure on agricultural production R&D fell from 40% of its budget in the 1950s to only 20% in 1994 (Mullen *et al*, 1996), and has probably declined further since 1994. It has been estimated that public investment in R&D and extension between 1952/53 and 2006/07 generated rates of return as high as 28% and 47% per year respectively (Sheng *et al*, 2011). Total factor productivity (TFP) growth in broad acre agriculture has increased by 0.6% a year resulting from domestic R&D and extension (Sheng *et al*, 2011). These authors estimated that growth in foreign public R&D knowledge stocks accounted for a further 0.6% in TFP and that the growth in domestic and foreign knowledge stocks accounted for more than 60% of the total growth in annual broad acre TFP (1.96% a year). An analysis of Australian dryland farming systems concluded that growth in productivity in the last ten years (from 2000 to 2010) had slowed, partly as a result of extended dry conditions, declining investment in research, development and extension and was also linked to ageing of the farm population (Carberry *et al*, 2010).

Teaching in the narrow discipline of Agriculture for commencing students decreased by 18.3% between 2002 and 2010 (Health of Australia Science), and for continuing undergraduate students declined by 31.1%. Commencing higher degree by research (HDR) enrolments remained largely static during this period varying between 420 and 450 equivalent full-time students over this period. I have not been able to accurately estimate how many higher degree by research graduates studying pasture or grassland topics remained in Australia after completing their post-graduate research. However, I would estimate that fewer than five Australian students completed a PhD degree on a topic related to pasture or grassland production in any year.

Recently the Australian Research Council conducted the Excellence in Research to Australia exercise. For crop and pasture production, only eleven universities produced at least 50 apportioned indexed journal papers in six years (Table 2). Of these eleven universities the research output was rated well above world average in two universities, above world average in three universities and world average in five universities.

I examined the websites of Australian universities involved in agricultural education to assess the extent of research on pastures and grasslands. My assessment is that there are only three Professors in Australia whose major interests are in increasing pasture productivity. At several universities I could identify nobody who appeared to be active in pasture research other than adjunct appointments from other organisations. In three universities there were programs examining aspects of nitrogen fixation by legumes, including pasture legumes. At a very limited number of universities diseases of pasture plants were being examined without it appearing to be the major research interest.

This lack of emphasis in the research programs of Australian universities is off-set to some extent by activity in associated Co-operative Research Centres. For example, at The University of Western Australia there has been considerable emphasis on pasture research in the Co-operative Research Centre (CRC) for Legumes in Mediterranean Agriculture (CLIMA), the CRC for Dryland Salinity and the Future Farm Industries CRC. Currently in the Future Farm Industries CRC there are projects aimed at developing: (1) improved perennial grasses; (2) shrub-based systems; (3) improved saltbush production; (4) animal production systems involved the grazing of crops (Evergraze®); (5) productive, persistent tropical grasses; (6) commercial lotus cultivators; and (7) improved establishment practices for perennial pastures (Future Farm Industries CRC Annual Report 2011-12). This CRC is supported by Meat, Wool and Grains Research and Development Corporations and has a commercial partner. There are four university participants, five State Government agencies and CSIRO. In all there are sixteen

participants. There were six students who completed higher degrees in pasture research within this CRC during 2011-12.

Similarly, in the Dairy Futures CRC headquartered at LaTrobe University, there is a major program aimed at improving pastures by developing better grasses and legumes, by identifying novel endophytes for use with ryegrass and fescue, and by the use of DNA markers to improve the nutritive value of pastures (Dairy Futures CRC Annual Report). In this CRC the participants are divided into two groups – essential Victorian Department of Primary Industries, Dairy Australia and LaTrobe University; supporting Agriseed, Australian Dairy Herd Improvement Scheme, Barenbrug, Fortuna, Genetics Australia, Heritage Seeds, Holstein Australia, Jersey Australia, Murray Goulburn, PG Wrightson Seeds, Monash University and the universities of Melbourne and Sydney. In the Improving Pastures Program twelve PhD students were enrolled in 2012 (Annual Report).

My conclusion from this analysis is that there is relatively little grassland research in Australian universities outside the CRC's associated with universities. Pasture research within CSIRO appears to be closely related to increasing the sustainability of agriculture production with emphasis being placed in decreasing the emission of greenhouse gases, on the development and management of dual purpose crops, both grazed by animals and harvested for grain. There remains a long standing program to improve perennial grasses. Pasture research within State agencies appear to be largely related to the introduction of improved pasture species and then management.

Climate change and pasture research

There is no doubt that the climate is changing with the effects varying greatly within different regions in Australia. Temperatures have risen in much of southern Australia and there have been marked decreases in rainfall, particularly in south-western Australia. The changing climate produces many challenges for grassland research. In a comprehensive analysis of the effects of climate change on pasture production at six sites in southern-eastern Australia, it was concluded that warmer and drier climates led to lower pasture production with summer and autumn growth being most affected (Cullen *et al*, 2012). However, annual pasture production was largely unaffected until temperature rise exceeded 2°C.

The first challenge is to minimise those gaseous emissions (principally carbon dioxide and methane) leading to climate change. In limiting carbon dioxide emissions there is the very large effect in increasing these emissions by the substitution of fertiliser nitrogen for nitrogen fixed by legumes. Additionally, there is far more financial risk in drying climates when nitrogen fertiliser is purchased rather than being reliant on nitrogen fixed by either pasture or grain legumes. There is a major need to limit the production of methane by grazing ruminants. There are a number of approaches being researched (Department of Agriculture, Fisheries and Forest Climate Change website) involving animal breeding, manipulation of rumen microorganisms and the selection of plants for low methanogenic potential on livestock production. Successful outcomes from this substantial research effort are very important.

The second challenge is to develop production systems better adapted to a hotter, drier climate. The development and future prospects of both annual and perennial temperate pasture legumes have been extensively reviewed (Nichols *et al* 2007, Nichols *et al* 2012). This aspect of Australian pasture research has been exemplary and probably unmatched elsewhere in the world. There are 36 annual and 11 perennial legumes registered for use. The potential contributions of forage crops to economic returns and soil management in Australia dryland agriculture has recently been examined using bio-economic modelling (Monjardino *et. al* 2010). This study concluded that including perennial forage shrubs could increase farm profitability by an average of 24% with the optimal area being 10% of the farm. Benefits of forage shrubs included: (1) reduced supplementary feed costs; (2) deferred use of other feed resources; (3) improved water use through summer growing deep-rooted plants; and, (4) increased carbon storage. The growth of salt-tolerant forage shrubs allowed the use of soils too saline for the growth of annual pasture legumes and grasses.

As well as developing systems incorporating strategic shrubs there is a need to select pasture plants, particularly legumes, better adapted to the changed climate. Improvement traits will be appropriate patterns of seed softening and germination, greater responses to elevate atmospheric CO_2 and drought resistance (Revell *et. al* 2012). In drier climates, inputs of fertiliser, particular phosphorus, are likely to be less and pasture plants well adapted to lower phosphate levels will be advantageous. In a large study of genetic variation within subterranean clover in response to phosphorus it was significant that commercial cultivars were in general the least responsive indicating that perhaps their commercial success was in part related to their phosphorus supply (Robson, Collins and Snowball unpublished data).

Conclusion

A recent symposium examining Australian Legume Research identified major challenges for pasture research as sources of funding, the development of acid- tolerant perennial legumes for permanent pastures in higher rainfall zones and to improve the procedures for pre-modulation of legume seed (Virgona *et. al* 2012). These authors also focussed on "the need to develop a better model of collaboration within Australia and internationally". Many comments were made regarding the failure of Pastures Australia, lack of capacity and need for greater collaboration between private and public groups, across regions, across institutions and between conventional and biotechnological approaches to improvement.

I strongly agree with this analysis as relating to pasture research more generally. Australia will be unable to benefit from increased demand for animal protein and from sustainability measures associated with ley cropping unless these issues are addressed.

References

Australian Bureau of Statistics (2010) Research and Experimental

Development, All-Sector Summary Australia 2008-09 Cat No. 8112.0 Canberra.

Australian Bureau of Statistics (2013) Historical Selected Agriculture Commodities by State (1861 to Present), 2010-11 Cat No. 7124.0 Canberra.

Australian Research Council (2012) Excellence in Research for Australia 2012 National Report.

Carberry P, Keating B, Bruce S, Walcott J (2010) Technological innovation and productivity in dryland agriculture in Australia. A joint paper prepared by the Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences (ABARE–BRS) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Clements RJ, Henzell EF (2010) Pasture research and development in northern Australia: an ongoing scientific adventure. *Tropical Grasslands.* **44**, 221–230.

Cullen BR, Eckard RJ, Rawnsley RP (2012) Resistance of pasture production to projected climate changes in south-eastern Australia. *Crop and Pasture Science* **63**, 77-86.

Dairy Futures CRC (2012) Annual Report.

Department of Agriculture, Fisheries and Forestry Climate Change website (http://www.daff.gov.au)

Future Farm Industries CRC (2012) Annual Report 2011-12.

McIvor JG (2005) *Grasslands of the world.* Chapter 9, 343-80. Suttie J.M, Reynolds S.G and Batello C (eds). Plant Production and Protection Series FAO Rome 2005.

Monjardino M, Revell D, Pannell DJ (2010) The potential contribution of forage shrubs to economic returns and environmental management in Australian dryland agricultural systems *Agricultural Systems* **103** (4), 187-197.

Mullen JD, Lee K, Wrigley S (1996) *Agricultural production research expenditure in Australia 1953-1994.* NSW Agriculture, Orange, NSW.

Nichols PGH, Loi A, Nutt BJ, Evans PM, Craig AD, Pengelly BC, Dear BS, Lloyd DL, Revel CK, Nair RM, Ewing MA, Howieson JG, Auricht GA, Howie JH, Sandral GA, Carr SJ, de Koning CT, Hackney BF, Crocker GJ, Snowball GR, Hughes SJ, Hall EJ, Foster KJ, Skinner PW, Barbetti MJ, You MP (2007) New annual and short-lived perennial pasture legumes for Australian agriculture-15 years of revolution. *Field Crops Research* **104**(1-3), 10-23.

Nichols PGH, Revell CK, Humphries AW, Howie JH, Hall EJ, Sandral GA, Ghamkhar K, Harris CA (2012) Temperate pasture legumes in Australia? Their history, current use, and future prospects. *Crop and Pasture Science.* **63**(9), 691-725.

Office of the Chief Scientist (2012) *Health of Australian Science.* Australian Government Canberra.

Revell CK, Ewing MA, Nutt BJ (2012) Breeding and farming system opportunities for pasture legumes facing increasing climate variability in the south-west of Western Australia. *Crop and Pasture Science* **63**, 840–847.

Sheng Y, Gray EM, Mullen JD, Davidson A (2011) Public investment in agricultural R&D and extension: an analysis of the static and dynamic effects on Australian broadacre productivity. ABARES research report 11.7.

Virgona JM, Harris C, Kemp S, Evans J, Salmon R (2012) Australian Legume Research - synthesis and future directions. *Crop and Pasture Science* **63**(9), 918-26.