Pasture research and development in northern Australia: an ongoing scientific adventure

R.J. CLEMENTS AND E.F. HENZELL

Abstract

A historical review of pasture research and development in the Australian tropics and subtropics identifies the key role that pastoralists have played in developing the twin objectives of: observing, utilising and conserving the native pasture resources; and introducing and exploiting exotic plant species that could improve livestock production. These two objectives were established during the earliest days of settlement by Europeans, were maintained during an era of intense scientific activity from about World War II (WW II) until the 1990s and will probably continue for some time. The scientific activity led to the publication of thousands of scientific papers and to the commercial release of approximately 150 cultivars of a range of pasture species, notably in the genus *Stylosanthes,* which, in terms of sown area, is now the predominant legume genus in tropical pastures globally. Research on the natural resource base enhanced our understanding of the structure and function of Australia's savanna lands and tropical grasslands and provided a scientific foundation for decisions on land use. For a period of almost 50 years, the Tropical Grassland Society of Australia provided a forum for interaction between graziers and scientists and its journal, *Tropical Grasslands*, recorded the rapid growth in knowledge of tropical pasture science and provided a medium for the publication of the results of research that had a practical focus.

The contribution of livestock producers, farmers and seed producers

We have long recognised the role of farmers and graziers in southern Australia in leading the subterranean clover revolution. The first 7 named varieties (Mt Barker, Dwalganup, Tallarook, Bacchus Marsh, Woogenellup, Yarloop and Clare) were all discovered and/or promoted by farmers during the period from 1889 to about 1935 (Oram 1990), and farmers devised the methods for harvesting the seed. Commercial seed of Mt Barker was sold by a farmer, Amos Howard from 1907. When his son Cecil Howard developed mechanical harvesting techniques in 1923, seed supplies of subterranean clover increased rapidly from 41 tonnes in 1923–24 to 259 tonnes in 1929–30 (Crofts 1985).

In contrast, we have been slow to recognise the northern parallels, perhaps because the northern effort was much more successful with grasses than legumes and because of the significant early role played by the Queensland Acclimatisation Society. H.G. Clements (1999; the quotations in the following sections are from her thesis) has provided a history of the Acclimatisation Society, which was established in 1862 with economic botany as its prime focus. By 1865, it was testing forage sorghum, Maltese clover (probably *Hedysarum* sp.), lucerne (*Medicago sativa*, already well-known in the colony) and temperate/Mediterranean grasses at its site at Bowen Park (now the Brisbane Exhibition Grounds); by 1869, guinea grass (*Panicum maximum*) had been introduced[1] and distributed to 22 locations; and by 1905, the Society had introduced more than 500 accessions of tropical grasses and legumes (Eyles *et al*. 1985).

Importantly, however, the Queensland Acclimatisation Society had hundreds of members during the 1870s and 1880s, and only about half of them lived in Brisbane (H.G. Clements, personal communication), as many were livestock producers and farmers. They included well-known pastoralists such as: William Archer (Gracemere); James Atkinson (Mt Surprise 1862–70; Farnham, near Ingham 1870–; Wairuna 1880–); J.P. (later Sir Joshua) Bell (Jimbour, Darling Downs); the Clark brothers (George and Charles: West and

Correspondence: Bob Clements, 29 Holmes Crescent, Campbell, ACT 2612, Australia. E-mail: clements@netspeed.com.au

East Talgai, near Warwick); C.R. Haly (Taabinga, Kingaroy); C.L. Hill (Isis Downs); John Macansh (Canning Downs); D.C. McConnell (Cressbrook, Darling Downs); Thomas Murray-Prior (Hawkwood, near Chinchilla, 1854–58; later Maroon, near Boonah); and Walter Scott (Valley of Lagoons, Upper Burdekin). The Society distributed literally thousands of items in the form of seeds and cuttings each year, and it is safe to assume that at least some of these ended up in the hands of pastoralists.

In the early years of the colony, the graziers and farmers showed a keen interest in the native pasture resources. It was a Queensland pastoralist/politician Charles Robert Haly[2] (who was also a member of the Acclimatisation Society), whose advocacy led the Queensland Government to establish a Board of Inquiry into the Causes of Diseases Affecting Livestock and Plants (1875–82). 'Stacked with Acclimatisation Society members', including Haly and McConnell, the Board of Inquiry supported 'practical scientific work' on agricultural issues, including the deterioration of native pastures. In 1875, it set up a committee to investigate this problem (Haly was a member) and engaged F.M. Bailey (a Brisbane nurseryman and honorary botanist to the Society since 1872, and colonial botanist from 1881) to collect and name indigenous grasses. The Board and the Acclimatisation Society 'arranged for local settlers to collect seeds and for propagation of indigenous grasses to be carried out at Bowen Park, the Brisbane Botanical Gardens, and in other parts of the colony, under the overall supervision of Bailey'. Bailey also travelled to collect native grasses, and published a List of the Grasses of Queensland in 1877, with notes on their value for grazing. After a rather haphazard start, the testing of introduced species under the auspices of the Board was mainly confined to Toowoomba (under the supervision of Edward Way, curator of the Toowoomba Botanic Gardens[3]) and New Farm (Brisbane).

Thus, by the late 1870s – less than 40 years after the first European pastoralists settled on the Darling Downs – the settlers had already established the two objectives of tropical pasture R&D that have persisted to the present time: observing, utilising and conserving the native pasture resources; and introducing and exploiting exotic plant species that could improve livestock production. To the extent that science follows well-established pathways (Raby 1996), these early 'cultivators' and 'practitioners' of science set the scene for the major research effort that followed in the 20th century.

Later, as the activities of the Society declined, between about 1900 and 1935 – the very period when southern farmers were popularising subterranean clover – northern graziers were vigorously promoting tropical grasses from the genera *Cenchrus*, *Chloris* and *Panicum* (Oram 1990). These grasses now occupy millions of hectares in northern Australia. The major role of graziers is most clearly seen in the development and spread of buffel and Birdwood grasses (*Cenchrus ciliaris*, *C. pennisetiformis* and *C. setigerus*). Buffel grass (*C. ciliaris*) is thought to have been introduced to north-west Australia accidentally in Afghan camel harnesses between 1870 and 1880. The grass was taken up vigorously by graziers near Port Hedland by the 1920s, and seed was available from at least 1924, supplied by a local identity, Joe Moore, who probably harvested it from the local aerodrome[4]. In Queensland, in 1926 A.M. Morrison, a Cloncurry grazier, obtained seeds of Cloncurry buffel grass (*C. pennisetiformis*) from Western Australia[5], and in 1928 plants were noticed near an old Afghan camel camp near the town of Cloncurry (Hall 1978). Seed from both locations was deliberately spread and, by the early 1930s, aided by natural dispersion, the grass was widespread in the Cloncurry district (Humphreys 1967c; Hall 1978). The Queensland Government obtained seed of *C. ciliaris* from about 1925[6] and was evaluating it by 1928, while the NSW Government probably obtained seed a few years earlier. An early Queensland variety of this species, cv. Gayndah, was promulgated by the teacher and students at Gayndah State School from seeds supplied by the Queensland Government in 1934; the grass quickly became the dominant grass species on the school grounds and was supplied to local graziers. *C. ciliaris* had reached Alice Springs by 1930, and was being planted by graziers in central Queensland by the late 1930s (Humphreys 1967b). Another early variety, cv. Boorara, was multiplied and commercialised by W.H. ('Bebe') Rich, from Yalleroi, central Queensland, who was probably the first grazier to plant buffel grass on cleared gidgee (*Acacia cambagei*) scrub during the 1950s (Ebersohn 1970; Oram 1990; Anon. 2009).

Rhodes grass (*Chloris gayana*) is said to have been introduced by Colonel Kenneth Mackay[7] in NSW, in about 1901. Following testing at Hawkesbury Agricultural College and Wagga Experiment Station, seed was distributed to farmers in 1903 and the grass reached Queensland by 1905. Seed was sold from 1904 and was widely advertised[8]. A farmer from Singleton, Sylvester Browne, had the largest area in 1905 and was a significant seed producer[9]. Rhodes grass was promoted strongly, especially by dairy farmers and seed producers. By the 1920s, it was widely planted in northern NSW (Eyles *et al*. 1985) and was the major sown pasture in the Queensland dairying areas south of the Tropic of Capricorn, especially in the Callide and Burnett (Skerman *et al*. 1988).

Queensland graziers planted common guinea grass (*Panicum maximum*) for more than 100 years before a cultivar was eventually selected from it and named Riversdale (Oram 1990). Another cultivar, Hamil, spread from the farm of Jack Hamil of Daintree, from seed he had received from the Queensland Government botanist in 1935. Green panic (*Panicum maximum* var. *trichoglume*) was grown in about 1930 by A.A. Petrie (Madoora, Gayndah) from uncertain sources of seed; he promoted it vigorously and the commercial cultivar (cv. Petrie) was eventually named after him (Humphreys 1967b).

The role of farmers and graziers in promoting tropical legumes before WW II was much less significant. Many of the Australian species were intolerant of grazing and we are unaware of any early record of their vigorous promotion by northern Australian landholders. While the 'subtropical' legume, *Kummerowia striata* (Japanese lespedeza), had been introduced by the Queensland Acclimatisation Society via Baron von Mueller (Government botanist of Victoria) in 1886, by 1890 Bailey was able to list only a handful of truly 'tropical' introduced herbaceous legumes in Queensland, namely: *Aeschynomene falcata* (joint vetch), *A. americana* (American joint vetch), *Arachis hypogaea* (peanuts), *Clitoria ternatea* (butterfly pea), *Crotalaria alata* (rattle pod), *Indigofera argentea* (probably *I. tinctoria*, common indigo – a small shrub), and *Macroptilium lathyroides* (phasey bean; listed as *Phaseolus psoralioides*). Most of the tropical pasture legumes that were commercialised during the life of the Tropical Grassland Society of Australia were not introduced until the 20th century. There is evidence that from the outset graziers regarded these exotic tropical legumes with mixed emotions.

Townsville lucerne (*Stylosanthes humilis,* now known as Townsville stylo) was first noted in 1903 on the Townsville common by 'Ted Blackman and Joe Lynam' (Humphreys 1967a). It was promoted by staff of the Queensland Department of Agriculture and Stock as well as some graziers during the 1920s and 1930s. Seed of Townsville stylo was first produced commercially in 1932. The methods used for seed production by Bob Enever on the Townsville common observed by one of us during the 1950s probably did not differ much from those used in the 1930s. Dry litter was swept by hand and shovelled into an ingenious seed cleaning device that Enever had constructed from bits of an old bicycle and surplus household hardware. The hooks on the *Stylosanthes* seed pods caught on the inside of an inclined revolving wire gauze cylinder. The pods were then swept off with an old road broom into a piece of galvanised iron guttering and slid into a sack. The rubbish (trash) fell out of the lower end of the cylinder and was discarded. Thirty years later, the 'Enever' principle was still being described (Humphreys and Riveros 1986).

Although the input by professional scientists increased after WW II, graziers continued to provide critical support. They played a vital part when funds were short and field stations were few and far between, often contributing far more than their land and knowledge of the industry. While they did not always choose to invest in pasture improvement themselves, they were amongst the scientists' staunchest supporters. There were so many of them that it is unfair to single out individuals; many of them feature in the records of the Tropical Grassland Society. However, it is worth recording that three generations of the Wilson family (J.L. Wilson, Calliope Station; R.S. [Dick] Wilson, Calliope; and Richard Wilson, Banana Station) provided support for tropical pasture research. Much more recently, graziers like Peter Larsen and Don Heatley are playing a key role in the current increase in plantings of leucaena (*Leucaena leucocephala*).

The role of pastoralists has been highlighted here partly because most of the early supplies of grass seed were supplied by graziers 'selling it over the fence'. However, it is also important to record the role of professional seed producers and merchants since WW II. Two groups, one on the Atherton Tableland (notably including John Rains in partnership with researcher John Hopkinson) and another in southern/central Queensland, made particularly valuable contributions. Both groups deserve to be on a special honour board in the history of the Tropical Grassland Society.

The contribution by professional scientists

Northern Australia in the 19th century was on the scientific periphery, isolated from both the European centre and southern Australian science (H.G. Clements 1999). Between 1770 and 1850, commencing with Joseph Banks and Daniel Solander, those who explored the country and described the vegetation in broad terms included a few men with training in natural history or some other field of science. The Queensland Philosophical Society had provided 'cultivators of science' from 1859 but its *Transactions* reveal little interest in pastures or even botany (H.G. Clements 1999). It was not until the establishment of the Acclimatisation Society (1862), the Royal Society of Queensland (1883), the Queensland Department of Agriculture and Stock (1887), the Wollongbar Experiment Farm of the NSW Department of Agriculture (1894) and the Queensland Agricultural College (1897) that what could called be called 'practitioners' of science became active in research on tropical pastures. Even then, only a handful of professional scientists studied tropical pastures, notably Ernest Breakwell[10] in NSW (Eyles *et al*. 1985). In Queensland, it was not until the 1920s and 1930s that there was a resident nucleus of pasture and natural resource scientists in the Queensland Department of Agriculture, the Queensland Agricultural College, the University of Queensland (after 1927) and CSIRO (from 1935). By the late 1930s, the Queensland group had grown to include Stan Blake, Wilf Bryan, Chris Christian, Selwyn Everist, John Miles, Terry Paltridge, Dick Roe, John Schofield and Charles Winders (Eyles *et al*. 1985). Together with a few individuals in NSW, Western Australia (Kim Durack part-time) and the Northern Territory, there were fewer than a dozen 'full-time researcher equivalents' working on tropical pastures immediately before WW II.

After WW II, Research Stations were established in the Kimberley Region (Western Australia) in 1945 and at Katherine (Northern Territory) in 1946 and a build-up of professional pasture researchers commenced in those regions as well as in Queensland and northern New South Wales. The number of tropical pasture scientists in northern Australia increased rapidly, peaking at about 125 (excluding technical staff) during the 1970s (E.F. Henzell, unpublished data). More recently there has been an equally significant decrease and Lowe (2007) suggested that only about a dozen of the scientists employed in northern Australia in 2007 were undertaking pasture research.

Until quite recently, tropical pasture science in Australia had a utilitarian focus: the emphasis was on the use of pastures for livestock production. For a long period (until the 1990s) the prime focus was on improved pastures for livestock production. Since that time the investment on native pastures may have held up better than that on sown pastures, with a consequent shift in the balance of the research towards native pastures and perhaps towards an increased emphasis on environmental values and services.

In relation to the natural resource base and native plants, the research commenced with the earliest descriptive studies by botanists such as Joseph Banks and Daniel Solander, Robert Brown, Allan Cunningham, Ludwig von Leichhardt and F.M. Bailey. Topographical mapping in Queensland commenced in 1886. Soil mapping in agricultural areas dates from the early days of CSIR (the Council for Scientific and Industrial Research, which later became CSIRO). The description of land systems and soils in northern Australia, particularly in the Northern Territory, was bolstered in 1945 when CSIRO established a Northern Australian Regional Survey Section, which operated under various other names until the 1980s. Another early soil map was Skerman's unpublished map of the soils of the Darling Downs region of Queensland soon after WW II. The development of an Atlas of Australian Soils (Northcote *et al*. 1960–68) during the 1960s also stimulated and guided a good deal of research.

Crude maps of the vegetation were first developed during the first two decades of the 20th century by Griffith Taylor and others, and large-scale maps of the pastoral resources in northern Australia were available by the 1930s (*e.g*. McTaggart 1936). Skerman (1953) produced a rough map of the brigalow (*Acacia harpophylla*) region; a more accurate map was available within a decade. Building on the Atlas of Australian Soils, during the 1970s a survey of the agricultural and pastoral potential of Queensland was undertaken by Weston *et al.* (1981). In turn, Tothill and Gillies (1992) built on this survey and provided a detailed description of the state of the pasture lands of northern Australia. These and many other studies (including autecological research on particular grassland species such as *Heteropogon contortus* and *Themeda triandra*) led to a better understanding of the structure and function of Australia's savanna lands and tropical grasslands (*e.g.* Mott *et al.* 1985). Despite these advances, in 1993 the Australian Science and Technology Council (ASTEC) pointed to ongoing 'environmental decline' in arid and semi-arid regions, stated that 'baseline knowledge of tropical ecosystems is incomplete and is often not adequate for resource management and environmental regulatory purposes' and regarded 'the tropical savanna and woodlands ecosystem as being the highest priority for focused research in tropical Australia'. The picture has probably not changed much since then.

By 2010, the combined efforts of countless individuals had led to the widespread availability of relatively detailed descriptive information on the natural resources of northern Australia, and much of this information was available on-line (*e.g.* currently in the Australian Soil Resource Information System and the Australian Natural Resources Atlas). It provides a lasting scientific foundation for decisions on land use by Government agencies, communities and individual landholders.

As the research on augmented pastures and exotic species built up after WW II a notable milestone was the demonstration by Schofield, Graham and their colleagues at South Johnstone Research Station that sown legume-grass pastures in the wet tropics could support high levels of livestock production (Summerville 1951; Graham 1951). This 'proof of concept' was encouraging. Another significant scientific contribution was the research of Norris (1956) on the evolution of legumes and their associated symbiotic root nodule bacteria; this reminded pasture researchers that the legume family and its associated rhizobia originated in the tropics, and remained overwhelmingly tropical in adaptation, and that this had practical implications for the selection and management of both exotic legumes and the strains of appropriate root nodule bacteria for them. Early evidence that tropical legumes in grazed pastures could fix large amounts of atmospheric nitrogen was also encouraging. Proof came in three steps, showing that: they could fix enough N for good growth when they had to (Henzell 1962); most of the N in their tissues, when grown in competition with grasses, was fixed from the air; and the rates of addition of N under grazing were consistent with legume yields and N contents, and a high proportion of fixation. The second step took many years of research using ^{15}N, and the field evidence was not summarised until 1977 (Vallis *et al.* 1977). The third step took even more work and the main results were published by Vallis in 1972.

During the 50 years from 1945–95 there was a concerted effort in northern Australia to assemble, characterise and evaluate a tropical forages genetic resource collection. Many Australian researchers travelled overseas to collect seeds, and many more were involved in the seemingly endless tasks of quarantine, species description and characterisation, seed multiplication (and regeneration), seed distribution, regional testing and information storage and retrieval. By 1996, the collection contained about 17 000 legume accessions and almost 5 000 grass accessions and was a globally significant resource (*e.g.* Williams 1983; Hacker 1997). This work and the associated evaluation of promising accessions under grazing led to the commercial release of approximately 150 registered cultivars of grasses and legumes (to 2010). Notable among the plant varieties were 15 cultivars of *Stylosanthes* (*S. humilis*, *S. hamata*, *S. scabra*, *S. seabrana* and *S. guianensis*). In terms of sown area, this is now the predominant legume genus in tropical pastures globally (Shelton *et al.* 2005), and its deliberate use was pioneered in Australia. The research also provided an extensive knowledge base on this genus and on the associated fungal pathogen *Colletotrichum gloeosporioides*, including molecular genetic research since the 1980s.

Leucaena was another notable success in the development of exotic species. While the release of new cultivars was important, the pivotal research was the discovery by Raymond Jones (Jones and Lowry 1984) that a specialised rumen bacterium (*Synergistes jonesii*) could degrade DHP (3-hydroxy-4(IH) pyridone), a breakdown product of mimosine and the causal agent of leucaena toxicity. This discovery led to a practical means of controlling leucaena toxicity, underpinned the current surge in leucaena plantings in northern Australia, and opened a new field of genetic manipulation of rumen microorganisms.

With a few exceptions the research on viny (twining) tropical legumes did not lead to their widespread and sustained use in sown pastures. The exceptions included *C. pascuorum* in the Northern Territory (Cameron 2005), *Clitoria ternatea* (butterfly pea) in central Queensland (Conway 2005) and perhaps *Centrosema molle* (centro) in the wet tropics. Siratro (*Macroptilium atropurpureum*), the first artificially bred tropical pasture legume (Hutton 1962), released in 1960, did not persist for long under grazing despite ample evidence of its initial productivity. It could not tolerate frequent close cutting or heavy grazing (*e.g.* Jones 1967) and could not regenerate adequately from seed when the first-established plants died (Jones and Bunch 1998a; 1998b). In contrast to prostrate legumes such as white clover (*Trifolium repens*), its elevated growing points were susceptible to destruction by livestock (Clements 1989). Moreover, despite the bulk of feed it produced and the excellent beef cattle production achieved in a range of environments, its leaves were so dispersed that cattle simply could not get a decent mouthful (Stobbs 1973).

The search for legumes broadly adapted to the Australian subtropics also met with limited success. All the trailing/twining legumes suffered from the same flaws as Siratro. Eventually some other kinds were found with genuine persistence but with other deficiencies (*e.g.* limited environmental adaptation or difficulties with commercial seed production). When Wynn cassia (*Chamaecrista rotundifolia*) – a cultivar with a genuinely broad adaptation to a wide range of Australian subtropical environments – was released in 1984 (Oram 1990), its relatively low palatability and weedy characteristics greatly reduced its attractiveness to pastoralists. Time will tell whether it eventually occupies a large area in subtropical Australia.

It is impossible in this brief overview to do more than point to a few key research publications among the thousands that were generated by the research effort. Also, such an exercise is bound to be subjective. Fortunately Eyles *et al.* (1985) have reviewed the research activities up to the early 1980s. Walker and Weston (1990) described the history of pasture development in Queensland and provided estimates of the areas of attainable sown pastures, the areas actually sown by 1988–89 and the amounts of seed produced in 1986–87. In 1997 Walker and his colleagues from the Meat Research Corporation (now Meat & Livestock Australia) provided an analysis of priorities for sown pasture research in northern Australia at that time. Humphreys (1997) has reviewed the changing scope and direction of grassland science globally, using the International Grassland Congress as a framework for analysis and has positioned the Australian tropical pasture research effort in a global context. The book, edited by Tothill and Mott (1985), also provides a global context for the Australian work on the ecology and management of savannas. What can be said is that, in terms of quality and relevance of the research, the northern Australian activity during the period under review was world-class.

The contribution of the Tropical Grassland Society

The Tropical Grassland Society of Australia Inc. was formed in 1963 to ‘further knowledge of all aspects of the production, management and use of pastures and forages, and to provide members with opportunities for the interchange of ideas and experiences relating thereto’ (Pulsford 2010). Details of its organisation, membership, activities and achievements have been provided by Pulsford (2010), while Winks (2010) has provided an overview of the Society’s journal *Tropical Grasslands*. From the beginning, the objectives of the Society were designed to bring together everyone with an interest in tropical pasture improvement. Regular contact with farmers and graziers was seen as an essential way for scientists to keep their feet on the ground, both literally and figuratively, particularly as it was considered that southern pasture researchers, especially in CSIRO, were moving away from farmers’ practical problems and retreating into the laboratory. Field days and farm visits became a constant feature of the Society’s activities.

The Society’s *Proceedings* and its journal *Tropical Grasslands* reflect an evolution from reports of field days to the summarising of much of the knowledge that underlay northern Australia’s reputation as the global leader in tropical pasture science from about the time of the International Grassland Congress in 1970 to the 1990s. Of the ten volumes of *Proceedings* (published between 1964 and 1967, before the Journal was established), five recorded the contributions at regional meetings and field days of the Society (Pulsford 2010). The first paper published in the Journal was written by a grazier from the Mary Valley, D.E. Poulsen (1967), who described 60 years of pasture development on his family farm and noted that the first white clover 'came to the district in a match box'. The Journal published the proceedings of all the Australian Conferences on Tropical Pastures from the first (1975) to the 8th and last (2009), and published the records of a number of other key scientific meetings as the research effort wound down in the 1990s. More recently, it has provided a valuable service in recording the backlog of papers from more than half a century of research conducted by CSIRO, Queensland Government Departments and the University of Queensland. It has also provided a publication opportunity for tropical pasture researchers from other countries; more than 40% of the contributed papers (excluding those arising from Australian conferences) were contributed by non-Australian authors (Winks 2010).

The Tropical Grassland Society was a significant ingredient in the success of the northern Australian pasture research activities (Pulsford 2010). It brought together researchers from the various research organisations, and brought them into contact with pastoralists. It provided a clearing house for new ideas. Through its many communication activities it aided the flow of technical information.

We owe a considerable debt to those who kept the Tropical Grassland Society and its journal viable in recent years so that its work could be completed. In some ways the rise and decline of the Tropical Grassland Society mirrors that of the Queensland Acclimatisation Society. They were organisations of similar size. Each arose to meet a clear need. Each had a utilitarian focus. Each contained a mixture of pastoralists, researchers and others with a keen interest in tropical pasture R&D. Each made a major contribution to the scientific agenda of the day. Each provided useful communication mechanisms. The Acclimatisation Society declined and was abandoned when other organisations took over its role (H.G. Clements 1999). The decline of the Tropical Grassland Society may have been partly for similar reasons; it is interesting to contrast the declining membership of the Society and the declining attendance at its field days with the current strength of the (Australian) Leucaena Network and the attendance at field days run by organisations such as Meat & Livestock Australia. This suggests that the Society's communication/extension function has to some extent been superseded. However, the dramatic reduction in the number of pasture researchers in northern Australia provides another more compelling reason for the declining demand for the services provided by the Society. Consistent with Raby's (1996) analysis of the relative contributions that Governments and private individuals made to the creation and dissemination of scientific and technical agricultural knowledge during the period 1788–1860 in Australia, the Leucaena Network is very much the kind of organisation that one would expect to have arisen in place of the Tropical Grassland Society as the Government investment in tropical pasture research wound down and the balance of pastoralists and scientists in the technical creativity mixture changed during the 1990s.

Impact

The impact of the ongoing scientific adventure in tropical pasture research outlined here can be judged only at some time in the future, and it will be assessed against changing criteria and values. However, some preliminary comments can be made.

While there are varying estimates of the area of land on which exotic grasses and legumes occur in northern Australia, in 1995 it was estimated that about 25% of the northern beef cattle herd and virtually the entire northern dairy herd were grazing sown pastures or forage crops at some stage in their lives (Clements 1995).

Chudleigh and Bramwell (1996) estimated that:

- in 1995 about 7.8 million hectares of grazing land used for beef cattle in northern Australia contained sown and naturalised exotic grasses and legumes;
- the present value of the benefits of the research and extension (extrapolated to 2020) was AUD 3.28 billion (expressed in 1995 dollar terms);
- the costs (extrapolated to 2020) were AUD 2.57 billion; and
- the benefit:cost ratio of the research was 1.28:1.

In addition, benefits from tropical grasses and legumes for dairy cattle were approximately AUD 128 million per year.

The analysis for beef cattle was significantly influenced by the relatively favourable returns for research on buffel grass and *Stylosanthes*. In the case of buffel grass, Chudleigh and Bramwell (1996) estimated that:

- the area in 2005 was about 5.3 million hectares (including about 2.6 million hectares on which buffel grass had spread naturally);
- the present value of the benefits was AUD 1.99 billion; and
- the benefit:cost ratio was 4:1.

In the case of *Stylosanthes*-based pastures, they estimated that:

- the area was about 1.15 million hectares;
- the present value of the benefits was AUD 0.65 billion; and
- the benefit:cost ratio of the research was 1.7:1.

A particular strength of this unique analysis is the extent to which Chudleigh and Bramwell validated published information using advice sought from experienced agronomists, particularly those working in the field. Although the authors expressed some caveats, and although some of their assumptions may not have been met, these estimates give a first approximation of the value of the research to Australia alone, ignoring the benefits to other countries.

Henzell (unpublished data[11]) has analysed the contribution of tropical pastures to the three-fold increase in beef production in Queensland since the first new tropical legumes were released in the early 1960s. Impact was estimated by analysing the period in two phases: 1960–1974, and 1984 to the recent past.

Increased beef production during the first phase was due predominantly to growth in cattle numbers; output per head grew no faster than it had in the past. The additional 4 million head of beef cattle were attributable to, in decreasing order of importance: (a) the switch from wool and butter-fat dairying to beef production; (b) heavier stocking of traditional cattle country; (c) clearing of brigalow country for sown grasses and fodder crops; and (d) legume-based pasture improvement. Category (d) accounted for no more than a tenth of the gain, and (c) + (d) for no more than a quarter of it.

The increase during the second phase was due mostly to improvements in productivity per head; numbers grew by only about 1.9 million head. Just over a quarter of the extra beef was attributable to lot feeding (this is a relatively firm figure based on data from Meat & Livestock Australia); in contrast, the effect of converting woody vegetation to pasture was difficult to assess. Clearing for this purpose continued at a significant rate until the end of 2006, and about half was old growth – or what looked like old growth based on satellite imagery. It may even have contributed as much extra beef as lot feeding did. Lesser factors included the demise of the wool industry (*i.e.*, a further shift to beef production), legume-based pasture improvement (no more than a seventh of the total), and improvements in station management. During this second phase, the industry was able to maintain the rate of flow of cattle directly to the meatworks while finding an additional 1.2 million head a year to stock the feedlots. Native pastures stabilised, but there is no evidence that they had improved to any significant extent.

In summary, Henzell's analysis indicates that Queensland now produces more than three times as much beef as it did when the first 'new' tropical legumes were released in about 1960. No more than about 13 per cent of this increase is attributable to legume-based pasture improvement, while sown tropical grasses have accounted for at least twice as much.

Although grasses have been planted extensively throughout the world's tropical grazing lands, there has been uncertainty about the adoption of tropical legumes in other countries, and in 2001–04 a global survey was undertaken to investigate this issue. The survey indicated that: at least 5 million hectares of tropical legume-based pastures had been planted in farmers' fields; approximately two-thirds of this was in developing countries; and at least 500 000 farmers were benefitting (Shelton *et al*. 2005).

Conclusions

Two conclusions emerge from this brief review. One is that, because pasture R&D in northern Australia has to a considerable extent always been user-driven, it will probably continue in modified ways long after the Tropical Grassland Society ceases to exist. Farmers and livestock producers have long played a key role, and will likely continue to do so when the current scientists have moved on.

The second conclusion is that Australian tropical pasture science has been world-class in quality and in relevance to defined industry problems, and has provided benefits to Australian pastoralists and to end-users in other countries. While the economic, environmental, social and poverty-reduction benefits of the research are ongoing and will be assessed eventually by other generations, we can be optimistic that the impacts will be considerable and will more than justify the research costs.

If there has indeed been a shift in northern Australia away from the utilitarian tropical pasture research focus of the last 150 years towards a focus on resource conservation and the enhancement of environmental services, it will need to withstand the brutal reality of what is possible in an imperfect world. The emerging global view is that, if conservation of natural resources is to have any chance of success, intensification of production in favoured areas will be essential. In relation to feed supplies for the northern Australian beef industry, the inadequacies of the native pasture resource for livestock production have been recognised from the beginning of European settlement and, if the industry is to grow and if pasture improvement is to be excluded, there are not many development options other than the feeding of more grain and concentrates. There are limits to what can be achieved with legume technology without continuing research. It will be interesting to see where the ongoing scientific adventure leads us in the next 50 years.

Acknowledgements

We thank Dr Gail Clements for giving us access to her unpublished information concerning the Queensland Acclimatisation Society.

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Endnotes

1. 'Two sorts' of guinea grass were sent for 'testing' to Hon. J. Ellis (a Society member and Councillor) from Jamaica by his father, Lord Howard de Waldon, in 1865 (Minutes, Queensland Acclimatisation Society, May 29, 1865). Guinea grass was also grown at the Darwin Botanic gardens in the 1880s.
2. Charles Robert Haly was among the first pastoralists to vigorously publicise the dangers of over-grazing land. He was the Member for Burnett in the Queensland Legislative Assembly (1860–63, 1865–67, 1869–71).
3. *Phalaris aquatica*, although not a tropical species, is perhaps the best-known of the grasses to have been introduced through the Toowoomba Botanic Gardens.
4. *The West Australian*, January 25, 1924; *The West Australian*, September 23, 1924; *The Western Mail*, April 2, 1925; *The Western Mail*, May 21, 1925.
5. This seed was probably originally introduced from Afghanistan to Western Australia by General Birdwood after WW I (Humphreys 1967c). Cloncurry buffel grass is distinct from the Western Australian variety and is considered by some taxonomists to be a different species, *Cenchrus pennisetiformis* (Hall 1978).
6. *The West Australian*, April 2, 1925; *The Brisbane Courier*, October 29, 1932.
7. Colonel (later honorary Major General) Kenneth Mackay raised (1897) the 1st Australian Horse Regiment and commanded (1900–01) the NSW Regiment of Imperial Bushmen in the Boer War. The seed was probably provided by Cecil Rhodes, who was a passionate advocate for this species.
8. *Sydney Morning Herald*, April 28, 1904.
9. *Sydney Morning Herald*, August 1, 1905.
10. Ernest Breakwell (1885–1952) was an agrostologist in the NSW Department of Agriculture from 1912–22. He is said to have introduced kikuyu (*Pennisetum clandestinum*) to Australia and wrote an early book about tropical forage species (Breakwell 1923). He then rejoined the Department of Education as the first headmaster of Yanco Agricultural High School and was later inspector of schools. He was one of the founders of the Junior Farmer Clubs of NSW and was president in 1950.
11. E.F. Henzell, unpublished memoirs; copies will be deposited in due course with CSIRO and the University of Queensland.