Problems of maintaining pastures in the cereal-livestock areas of southern Australia

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Introduction

Australian agriculture is constrained by five major factors, viz.:

- the general aridity and variability of rainfall - in over 70% of Australia the rainfall is too low or too unreliable for cropping or sown pastures;
- the generally poor soils - low in nutrients, shallow, rocky or saline;
- large distances from major world markets, increasing the cost of imported inputs and decreasing the profitability of export commodities;
- high costs of labour in primary, secondary and tertiary industries and
- high tariff burdens - the cost of tariff and quotas in 1975-76 averaged $11,600 for every sheep, cattle and grain producer in Australia. Today this figure exceeds $15,000 (D.B. Trebeck, personal communication).

These five dominating features of Australian agriculture are reflected in farm decisions and are certain to have a continuing profound influence on competition between crop and pasture-livestock production in Australia. There is a relentless cost-price squeeze in the rural industries which requires sustained efforts to either increase production and profitability, or decrease purchased inputs and maintain production and profitability, or save labour and maintain profitability.

One feature of Australian agriculture has been the heavy dependence on legume nitrogen (N). In recent years Australia has had some 40 million (M) ha of crop and sown pasture lands that rely on legumes to maintain or improve levels of soil N and to guarantee the quantity and quality of livestock feed. Using a mean figure of 70kg N/ha/annum for 28M ha of pasture in any one year, the increment of soil N plus savings on application costs is worth $1500M/annum. Furthermore, the improved quantity and quality of feed for some 170M sheep equivalents is worth another $1000M annually, making a total value of $2500M/ annum in Australia(1). Thus pasture legumes, and to a much less extent grain legumes, are a vital component of Australian agriculture. As a renewable resource, these legumes are far more important to the Australian economy than many of the much-publicised mining ventures. However, in recent years our pasture legumes have been under threat from poor grazing management, new pasture pests and other causes which will be detailed later in this review.

There is widespread agreement in southern Australia that the decline of the annual self-regenerating *Medicago* spp. (medics) and Tri*folium* spp. (clovers) is the main problem of maintaining pastures in the cereal-livestock areas. Farmers and research workers should concentrate their efforts on re-establishing pasture legumes: there are enough self-sown cereals and volunteer annual species (ryegrass, barley grass, brome grass, capeweed, etc.) to ensure balanced pastures if needed and there is little or no justification for sowing grasses with pasture legumes except for specific purposes like erosion control where perennials like *Phalaris aquatica* may be useful. In brief, soil structure, infiltration and soil nitrogen levels to sustain crops, the quantity and quality of livestock feed and total farm income are all dependent on good pasture legume stands in most of the integrated cereal- livestock farming areas of southern Australia.

To provide perspective for this paper it is necessary to give some background on the Australian environment and agricultural history as these both influence current land use in the main agricultural zones.

Background and perspective

The Australian Environment

Australia is one of the oldest land masses and it is the flattest of the continents, the mean elevation being only 220m compared with the world mean of about 700m. This low elevation, coupled with the latitudinal position extending from 10?41'S in the north to $43^0$39'S in the south, contributes to the general aridity of Australia, which is the driest continent. This aridity, along with the generally poor soils resulting from the great period of weathering, has a major influence on potential agricultural production.

A general description of land forms, climates, soils, water and irrigation, native vegetation, the pastures of northern and southern Australia, the livestock industries, field crops, native and introduced forests and native fauna is provided by Leeper(2) in *The Australian Environment* while Gentilli(3) has given a detailed account of the Australian climate which has such a major impact on Australian agriculture. Information on all these physical and biological topics is also available in the ABS Australian Yearbooks.

Rainfall data for Australia are shown in Figures 1 and 2, also Table 1. It is important to realize that 38.5% of Australia lies in the Tropical Zone (Queensland 54%, Western Australia 37% and Northern Territory 81%) and that summer rainfall during periods of higher temperature is less effective for production of crops and sown pastures. In general, 500-750mm mean annual rainfall is regarded as minimal for reliable crop and sown pasture production in northern Australia whereas 250-375mm is the corresponding minimal rainfall in southern Australia, the latter figure of 375mm relating especially to southern New South Wales. These latitudinal, seasonal and reliability differences with respect to rainfall are reflected in the map of effective rainfall (Fig.2). This averages less than 5 months on the drier fringes of the cereal belt.

The Cereal-Livestock Areas of Southern Australia

For the purposes of this review we have considered southern Australia as the area south of Lat. 29? in the east and Lat. 27?30' in the west(4) and including all of the wheat belt of Western Australia, South Australia, Victoria and New South Wales but excluding Queensland. However, we recognize that the problems in the cereal belt of southern Queensland are similar to those of northern New South Wales.

The cereal-livestock zone equates with the long-standing BAE Wheat-Sheep Zone, i.e. the 250-500mm rainfall zone (Fig.3). The southern Australian guidelines on minimum rainfall for cereal cropping and pasture improvement, viz. 250mm in Western Australia, 300m in South Australia and Victoria, 375mm in southern New South Wales and 500mm in northern New South Wales must vary, of course, with soil texture - sands being more effective under low rainfall conditions - and also rainfall distribution.

Stratification of the agriculture of southern Australia into three main zones (Fig.3), with the irrigated areas comprising a fourth important zone (but quite minor area),evolved during the last 100 years when initially there were no weather records. Hence there were mistakes. Shrub steppe *(Maireana* spp. and *Atriples* spp.) in the Pastoral Zone was ploughed for wheat crops in the early days: other areas of shrub steppe were destroyed by overgrazing. Nowadays these areas are conservatively stocked by sheep and cattle and there is no rainfed cropping in the dry Pastoral Zone areas.

Land use for crop and livestock enterprises on typical cereal-livestock farms of Australia varies greatly but the close integration of crop and livestock enterprises on these farms is normal(5). The emphasis on the various farm enterprises changes according to market demand. This integrated system of crop and livestock production has considerable inbuilt flexibility. Furthermore, the four land-use zones are interdependent and integrated, which improves the stability of farming systems within the zones(6).

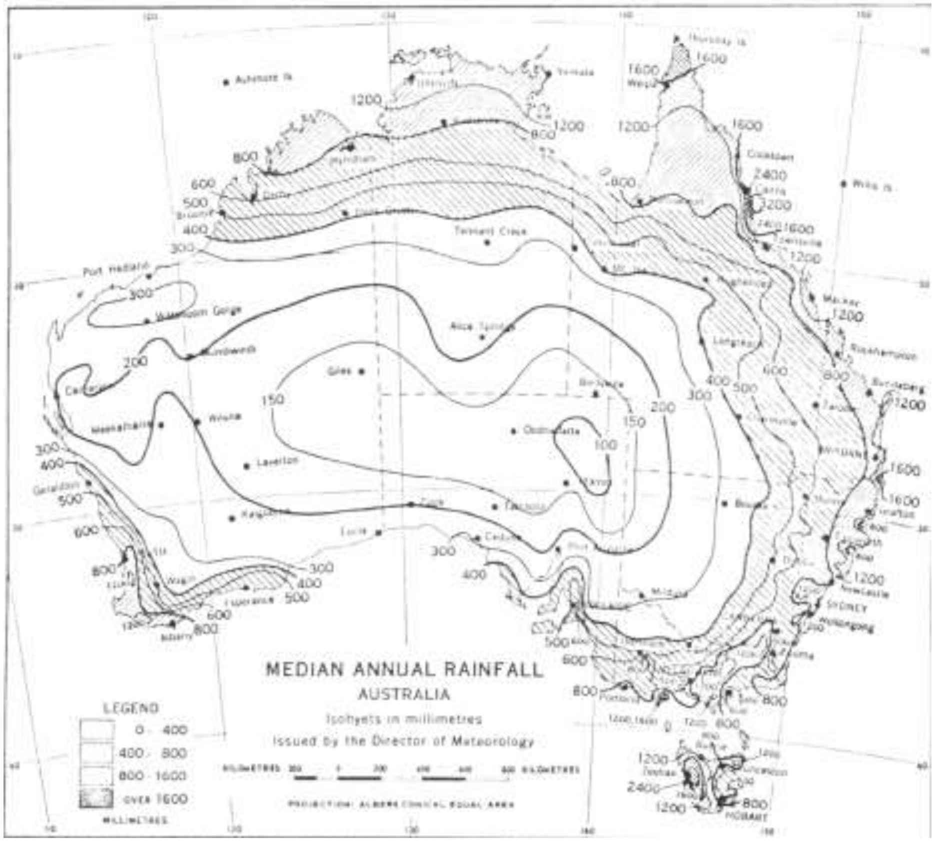

Fig.l. Annual rainfall isohyets (mm) for Australia showing the 50 percentile (median) values.

Table 1. The areas of states and territories and the distribution of rainfall throughout Australia

*Rainfall distribution included in figures for New South Wales Source: *Australian Bureau of Statistics Yearbook* 1973.

State or Territory	Area (1000ha)	Percentage of Area Receiving				
		<250mm	250-375mm	375-500mm	500-750mm	>750mm
New South Wales	80,160	19.7	23.5	17.5	23.3	16.0
Victoria	22,760	Nil	22.4	15.2	35.9	26.5
Queensland	172,720	13.0	14.4	19.7	30.4	22.5
South Australia	98,400	82.8	9.4	4.5	3.0	0.3
Western Australia	252,550	58.0	22.4	6.8	7.4	5.4
Tasmania	6,780	Nil	Nil	0.7	22.4	76.9
Northern Territory	134,620	24.7	32.4	9.7	15.9	17.3
Aust.Cap.Territory	240	*	*	*	*	*
Australia	768,230	39.0	20.6	11.2	16.2	13.0

Fig. 2. Effective rainfall map of Australia from Bureau of Agricultural Economics *Rural Industry in Australia,* 1975.

Brief History of Southern Australian Agriculture

Following colonization, the agriculture of New South Wales was constrained by the barrier of the Blue Mountains, but after the official South Australian settlement in 1836 cultivation of soils for wheat growing and the grazing of native perennial grass pastures (e.g. *Themeda, Danthonia* and *Stipa* in savannah woodland communities) or chenopodiaceous shrub steppe (e.g. *Atriplex* and *Maireana)* spread rapidly. However, the initial native fertility of the soils was soon depleted and yields of wheat declined through nitrogen and phosphorus deficiencies. Donald (7,8) showed a decline in the Australian mean decennial wheat yield from 861kg/ha in 1870 to 491kg/ha in 1900 (Fig.4) while the yields were even lower in South Australia(9).

Australian farmers are renowned as innovators, and though this first phase of cropping history was one of exploitation it also saw the development of Ridley's stripper (1843), Smith Bros. stump-jump plough (1876) and McKay's stripper-winnower (1885). Because of these and other innovations there has been a steady rise in agricultural machinery manufacturers in Australia(10).

Farrer, Australia's pioneer wheat breeder, recognized the value of legumes and writing in 1893 of his experiences with crimson clover *(Trifolium incarnatum)* suggested this species for growing with wheat or in rotation with wheat. He wrote ... *we could hit upon a leguminous plant that can be economically grown with wheat, the yield of the latter would be so greatly increased that wheat-growing would become a highly profitable industry ...(11). It* is significant that in South Australia Amos Howard recognized the potential of a naturalized subterranean clover (later cv.Mt Barker) in the same decade(12).

The second definable phase in Australian cereal-crop history was the period from c.1900-1930, which period saw the impact of Farrer's new wheat varieties, and bare fallowing (Fig. 4).

Fig. 3. Map from The Australian Sheep Industry Survey 1970-71 to 1972-73 (Aust. Govt. Publish. Service Canberra, 1976) showing land use zones. and the use of superphosphate

Though wheat yields increased from 1900 to the 1920's they were falling again in many areas by 1930. In these areas the wheat-fallow rotation had depleted soil organic matter levels, soil structure had deteriorated and soil erosion was common.

The third phase of southern Australian agriculture developed following the recognition of the benefits of incorporating annual, self-generating species of *Trifolium* and *Medicago* into our cereal crop rotations. Though Howard had discovered and commercialized subterranean clover (*Trifolium subterraneum)* during the period 1894-1907, it took another 17 years before there was full official support from the South Australian Department of Agriculture (12, 13). This marked the turning point for subterranean clover as a commercial legume in Australia (and in the world). The recognition that subterranean clover was not necessarily suited to the drier and more alkaline soils of the cereal belt (14) and Trumble's paper on barrel medic (15) paved the way for commercialization of barrel medic *(Medicago truncatula)* in South Australia.

It is important to stress that both the annual *Trifolium* species and annual *Medicago* species were originally accidental introductions from the Mediterranean Basin to Australia, just as were most of our weeds. Furthermore, it is important to emphasize that edaphic factors as well as climatic factors have had a major influence in determining the natural spread of accidentally- introduced, self-regenerating annual pasture legumes in southern Australia.

In South Australia, following the widespread sowing of superphosphate with wheat and the topdressing of native perennial grass *(Danthonia-Stipa)* pastures in the 1920's, there was a rapid spread of *Medicago spp.* on the calcareous soils of the wheat belt and of *Trifolium spp.* on the neutral to acidic soils in the higher-rainfall areas. Hence there were tens of thousands of hectares of naturalized *Medicago spp.* (especially *M. polymorpha, M. truncatula* and and M. *minima)* and *Trifolium* spp. (especially *T. subterraneum* and *T. glomeratum)* long before there were any named cultivars of these species in Australia.

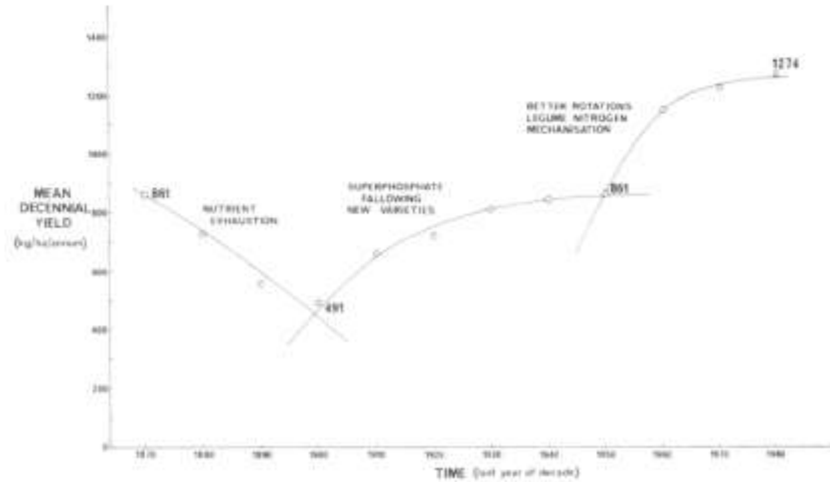

Fig. 4. Australian wheat yields, 1870-1980 updated from Donald (1963) by C.M. Donald in 1981 and used in Donald (1982).

At present both subterranean clover and barrel medic play a vital role in our cereal crop rotations - subterranean clover for the wetter areas with neutral to acidic soils and barrel medic and other medics for the drier areas with neutral to alkaline soils (16-21).

Though the value of legumes as nutritious food crops and forages, and for soil rehabilitation, has been recognized for thousands of years, the use of these self-regenerating annual species of *Trifolium* and *Medicago* in our cereal crop rotations is an Australian development (5, 6).

This legume-cereal rotation (or ley farming system) in southern Australia started in the 1930's, developed in the 1940's and became well-established in the 1950's. Prior to this period the cereal lands had been exploited with frequent cropping on fallow, soil fertility was depleted, soil structure had deteriorated and soil erosion was common. The development of the ley farming system was possible through reduction in the fallow, increased use of superphosphate and increased areas of barley (and relatively less wheat). In part, the reduction in wheat growing was due to the economic depression of the 1930's. This ley farming system gave increased yields of cereals and greatly increased livestock numbers, and it ensured better protection of soil and a far mare stable farm income.

The net increment of soil nitrogen resulting from symbiotic nitrogen fixation varies with the productivity of the leguminous sward, and under southern Australian conditions it frequently exceeds 100kg N/ha/annum or 3 to 4kg N/kg P205 applied (22, 23). However, a fair estimate of a mean value is 70kg N/ha/ annum for the cereal-livestock zone of southern Australia (24, 25, 26), despite many poor legume stands. This nitrogen is utilized by cereal crops in rotations such as the following:

- Medic - wheat - medic – wheat)
- Medic - barley - medic - barley) (short rotation: medic not re-sown)
- Medic - barley - barley - medic)
- Sub-clover - sub-clover - sub-clover - wheat - barley - barley (long rotation: sub-clover generally re-sown)

In the higher rainfall regions, the legume nitrogen is utilized by sown or volunteer pasture grasses or non-leguminous weeds.

Current pasture problems in the cereal-livestock areas of southern Australia

General

Pasture production in southern Australia requires a careful blend of science and art which compounds into the skills of the farm manager. In the intermediate-rainfall, cereal-livestock areas the problems of maintaining these pastures relate to the climate, soil, plant species and cultivars and socioeconomic conditions which determine the relative emphasis on crop and livestock enterprises. The problem of the decline of pasture legumes is especially serious in the cereal-livestock zone because these legumes not only have to survive the cropping phase of the rotation but also generally take second place to the cereal crop in farm decisions for the simple reason that in recent years cereal growing has been far more profitable than sheep or beef production. At the 1982 National Agricultural Outlook Conference Kingma (27) gave the following rates of return (including capital gain) for the 1981-82 season in Australia as follows: Sheep only = 8.5%, Beef only = 3.0%, Sheep-beef = 4.4% and Wheat = 14.1%. Consequently there has been an expansion of 3M ha in cereal crop (mainly wheat) and a corresponding decline in the area of sown pasture in Australia during the period 1975-76 to 1980-81 (28). The profitability of cereal crops at present is a disincentive to pasture improvement in the cereal-livestock areas of southern Australia.

Examination of Donald's data on trends in the Australian wheat yields (Fig. 4) shows an apparent yield plateau despite improved varieties and advances in cultural practices especially in weed control. We suggest that the recent decline in the legume component of pastures in southern Australia is a key factor in the disappointing trend in wheat yields. Unfortunately many farmers in the cereal-livestock zone of southern Australia are complacent or, at least, inadequately informed as to the potential benefits of pasture legumes in terms of feed quantity and quality, nitrogen fixation in the soil and control of cereal diseases. In some cases there has been inadequate extension advice because the evaluation of legumes did not include the all-important assessment of total seed production and seed survival by way of hard-seededness and/or dormancy mechanisms.

Unfortunately many of the present generation of farmers across southern Australia have so taken for granted the leguminous pastures established by their fathers or grandfathers that, through lack of practice, they have little skill in pasture establishment. Furthermore, modern, large-scale sowing implements (e.g. air seeders) are far less satisfactory for precision sowing of pasture legumes than were the drills of the last generation (10).

Why Have Pasture Legumes Declined?

In considering why pasture legumes have declined the most common reason is the failure to grasp the fundamental principle that persistence of pasture legumes is far more important than potential yield in spring, yet too many research workers spend a disproportionate amount of time measuring yield in spring and little or no time assessing seed production of annual legumes and seed-seedling dynamics through the year: however, recent research (1, 29-35) has highlighted problems of inadequate seed production and survival in medic and subterranean clover.

High seed production with adequate levels of hard seed, and preferably physiological dormancy to minimise out-of-season germination following summer rains, is essential not only for persistence but also productivity of annual legumes, which is linearly related to density in the early part of the growing season of annual pastures. There is no doubt that some of the farmer apathy and despondency concerning the role of pasture legumes in the cereal-livestock areas of southern Australia (31, 32) stems from a lack of relevant research on this vital issue.

We must accept drought and poor seasons and choose our pasture legume species and cultivars to ensure a range of maturities for survival, yet there are numerous examples of the wrong choice of cultivars - selected on potential hay yield in good seasons and not on the vital total seed production, percentage hard seed (medics and subterranean clover cultivars) and percentage burr burial and dormancy in the case of subterranean clover cultivars.

Table 2. Some factors causing decline of medic stands in the cereal-livestock zone of south Australia

- Reduced spraying to control red-legged earth mite and lucerne flea
- Reduced application of superphosphate to pasture
- Spread of Sitona weevil
- Increased cropping intensity and consequent grazing pressure
- Poor grazing management and fodder conservation practices
- Increased use of herbicides in the cropping phaseof the rotation
- Reduced undersowing of medic into cereal crops
- Rapid spread of pasture aphids (SAA, BGA, PA)
- Increased use of nitrogenous fertilizers
- Apathy and despondency concerning value of medics.

In a symposium on *The Medic Crisis in Cereal-Livestock Farming Systems of South Australia,* Carter (31) listed ten factors causing decline of medics in South Australia (Table 2). These factors, roughly in chronological order, pre-supposed that the correct choice of cultivars in relation to soils and climate had been made and that shallow tillage practices were adopted to avoid burial of legume seeds too deep for subsequent emergence (23). Adem (36) using *Medicago truncatula* cv. Jemalong, *M. littoralis* cv. Harbinger, M. *rugosa* cv. Paragosa and *M. scutellata* (Commercial) showed clearly that emergence declined with decrease in seed size, increased depth of sowing, and in heavier soils with greater soil strength.

There is little doubt that the causes of medic decline (Table 2) apply right across southern Australia and relate not only to medic but also to subterranean clover. However, in the case of subterranean clover the choice of cultivars and mixtures is even more critical than in the case of medics because subterranean clover generally has a far lower percentage of hard seed and is much less tolerant of water stress during flowering and seed development than the medics (33). Furthermore, fungal diseases, e.g. clover scorch *(Kabatiella caulivora)* and *Pythium* root rot contribute to decline of subterranean clover in some areas.

Reduced spraying of red-legged earth mite and lucerne flea resulted from the need to reduce farm expenses in the early 1970's. Similarly superphosphate applications to pasture were reduced - in the overall plan to reduce farm costs but also because of the sharply increasing price of this fertilizer.

While superphosphate use on crops has been static the decline in superphosphate use on pastures between 1973-74 and 1975-76 was unprecedented: the area fertilized dropped from 18.5M ha to 8.9M ha while the superphosphate used declined from 2.8M t to 1.1M t. Though reduced application of superphosphate probably tended to perpetuate legume dominance in the higher rainfall areas (37) there is evidence from the South Australian cereal belt that reduced phosphate applications may well affect total legume production (38).

<u>Increased Cropping Intensity</u>

While there has been a general increase in the area of cereals in Australia accompanied by an overall decline in both sheep and beef cattle (Fig. 5), which trend has also occurred in South Australia, in some areas there has been a <u>substantial increase in cropping without a corresponding reduction in livestock numbers</u> (Table 3). Hence grazing pressure has greatly increased and this has led to a dramatic decline of pasture legumes (1, 30-32).

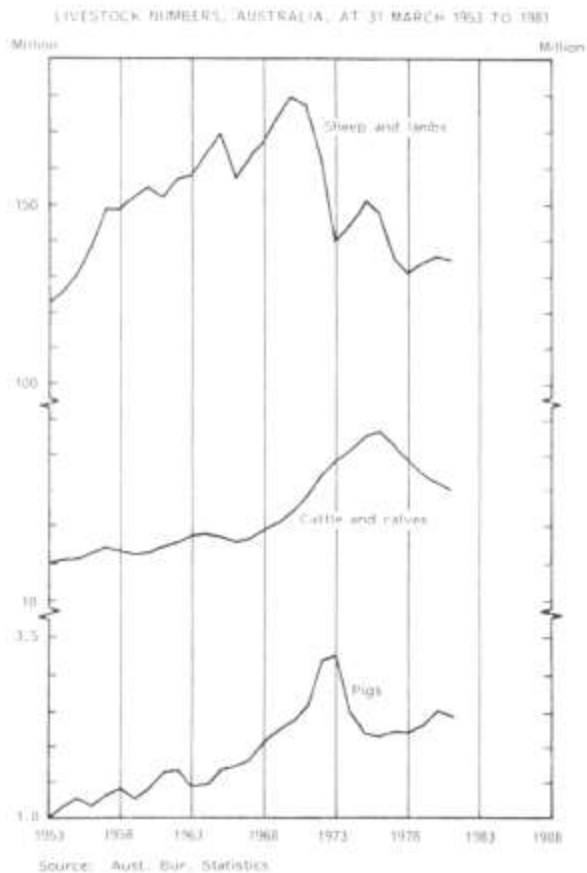

Fig. 5. Trends in livestock numbers, Australia.

Table 3. Crop and livestock changes in a wheatbelt area of South Australia (data are totals for Counties Lawler, Stanley and Victoria)

		Three-year Periods 1959-61	1979-81	Change (%)
Wheat	(ha)	131,335	177,821	+ 35.4
Barley	(ha)	84,610	142,709	+ 68.7
Total crop	(ha)	283,956	359,067	+ 26.5
Total sheep		1,383,272	1,481,060	+ 7.1
Total cattle		30,368	28,106	- 7.4
Sheep equivalents*		1,595,848	1,677,802	+ 5.1

* Sheep number +7 (Cattle number)

Specific Examples of Problems in Medic and Subterranean Clover Areas

The general problems of the declining legume component of pastures in the cereal-livestock zone of southern Australia are typified by the medic data of Carter (1, 30-32) in South Australia and the subterranean clover data of Wolfe (33-35) in New South Wales. Both of these are examples of study of seed- seedling dynamics of annual legumes rather than of pasture production. These studies show the less-obvious, insidious, decline of medic and subterranean clover as seed reserves are exhausted, as distinct from the dramatic loss of lucerne that has frequently occurred following attack by aphids. In view of the relatively minor area of lucerne in the cereal-cropping areas of southern Australia we will not review specific problems related to its decline and re-establishment.

The detailed studies on seed-seedling dynamics of medic pastures undertaken in South Australia by Carter at the Waite Institute and in the Mallala district on the Adelaide Plains have highlighted the generally poor medic pastures and some of the causes - the chief cause being grossly inadequate medic seed reserves. This research has shown that generally there is less than 2% survival of medic seed following ingestion of whole pods by sheep (30) and that under prolonged autumn grazing sheep can virtually eliminate medic pods on the surface of red brown earth soil. The largest pods containing the most seed and the largest seed are selected first. Hence, as grazing continues, the declining residue of small pods contains fewer, smaller seeds: in other words this seed is the least able to emerge from depth when pods are buried by tillage in preparation for the cereal crop (1, 31).

Of 35 paddock sites sampled in the Mallala area in 1981 (Table 4) there were only seven paddocks with satisfactory levels (i.e. >200kg/ha) of seed reserve in the top 5cm of soil in March (32). A most important point is that though the mean seed reserve was 97.7kg/ha in March (range 0-343kg/ha) the mean hard seed reserve was 65.4kg/ha in September (range 0-303kg/ha), representing a 33% loss of seed of which cumulative emergence of medic could account for only 7.4% of the original seed reserve. Thus there has been considerable loss of seed by germination without emergence even though these data were collected in an excellent growing season.

The poor state of most of these Mallala pastures, which once had excellent medic stands, may be judged from Table 4 and the following percentage (and range) values for botanical composition near the end of August 1981, as follows: Legumes 32.7% (0-94.0); Grasses 29.3% (1.2-67.4); Soursob 24.5% (0-89.1); Three-corner jack 6.1% (0-62.5); Capeweed 1.2% (0-13.0) and Other Species 6.2% (0-41.8). Clearly these pastures are generally not good enough. The Mallala district had a record or near-record winter rainfall in 1981 yet these same paddocks showed a mean of 26.9% Bare Ground with a range of 0-63%. The various pasture pests no doubt were a problem but other factors including farmer apathy had contributed to the very poor reserves of medic seed in the soil and consequent poor medic stands. It is worth noting that while hard seed reserves in September were highly correlated (r = 0.96***) with initial seed reserves in March, seed production was more poorly correlated with the initial seed reserves and unrelated to cumulative medic emergence. Of course, seed production at the various sites reflected individual farmer management (or mismanagement) during the growing season.

This research has shown conclusively that medic seed reserves in the top 5cm of soil are a reliable indicator of potential density (r = 0.86***) and productivity of medic pastures, and core-sampling techniques are being developed to enable farmers to assess their needs for sowing additional medic seed before the autumn rains. Farmers need to improve green pasture management to ensure better medic seed production, and to regulate summer-autumn grazing more carefully to ensure adequate residues of pods for replenishment of seed reserves through pod burial by the shallow tillage used for cereal cropping. To maximise seed production in subterranean clover and medic species a continuous grazing to keep the sward at no more than 8-10cm height up to flowering is desirable.

In New South Wales experience with subterranean clover provides similar results. Winter productivity is a function of initial plant density, which in turn is a function of the overall reserve of seed. To obtain a desirable minimum of 100kg/ha of seed available for germination in autumn, a seedbank at the end of summer of from 150-500kg/ha is required, the exact amount depending on the cultivar. The performance in New South Wales of many popular cultivars of subterranean clover, particularly the softer-seeded midseason cultivars such as Woogenellup and Mt. Barker, falls short of the ideal in unfavourable seasons. In 1981-82, these two cultivars accounted for 90% of the certified subterranean clover seed produced in New South Wales. However, since 1974 in southern and central New South Wales, Wolfe *et* al have conducted more than 30 experiments involving a range of subterranean clover strains. Only at one site (Cooma) have Woogenellup and Mt. Barker persisted well for more than two seasons. In the wheat belt they have failed. In the experiments at Dunedoo (650mm average annual rainfall country east of Dubbo) the harder-seeded, earlier-maturing cultivars such as Daliak, Northam and Nungarin regenerated well after the drought in 1980, whereas Woogenellup, Mt. Barker, Esperence and Meteora all failed (Table 5). Another example is shown in Table 6.

Table 5. the contrasting performance of soft-seeded (woogenellup) and hard-seeded (daliak) cultivars at Dunedoo, N.S.W., 1979-81.

	Woogenellup	Daliak
1979		
Seed yield (Dec.) (kg/ha)	900	1200
1980		
Seed yield (June) (kg/ha)	20	750
Seed yield (Dec.) (kg/ha)	10	620
1981		
Seedlings (June) (plants/m^2)	30	1050
Seed yield (Dec.) (kg/ha)	20	630

Source: E.C. Wolfe, N.S.W. Department of Agriculture (35)

Table 4. Medic survey data, Mallala district, south Australia, 1981 (Seed samples from 0-5cm soil)

Medic Status Class*	Number of sites	Seed Reserve March 1981 (kg/ha)	(#/m^2)	Cumulative Emergence (plants/m^2)	Hard Seed Reserve September 1981 kg/ha)	(#/m^2)
1	14	9	394	35	6	250
2	3	33	871	80	25	735
3	5	71	2914	215	48	2030
4	6	136	4745	387	100	3644
5	3	244	9409	475	139	5572
6	4	321	11625	985	218	7991
7	0	-	-	-	-	-

* For these classes see reference #32 (E.D. Carter, 1982)

In parts of the southern and central wheat belts of New South Wales there has been another serious consequence of the failure to persist of relatively soft- seeded cultivars of subterranean clover like Woogenellup. This has been the overall increase in the proportion of Dwalganup subterranean clover in formerly safe pastures. Dwalganup, like other cultivars that are high in the plant oestrogen, formononetin, causes a severe, progressive and cumulative reduction in ewe fertility.

Despite inherent oestrogenic problems some of the older cultivars of subterranean clover are extremely well adapted and persistent. On a red brown earth soil at the Waite Institute, Glen Osmond, an annual pasture including Dwalganup, Geraldton, Yarloop and Clare subterranean clovers survived heavy grazing (Table 7) while in Western Australia the data of Nicholas demonstrates very well the response of barley to clover-dominant swards of the highly oestrogenic, hard-seeded and persistent Dinninup and Dwalganup subterranean clovers (Table 8).

Table 6. Sequential seed reserves of some medics and subterranean clover cultivars at Goolgowi, N.S.W.

Species and Cultivar	Dec. 1979 (kg/ha)	Dec. 1980 (kg/ha)	Dec. 1981 (kg/ha)
Clovers			
Nungarin	850	460	250
Daliak	900	300	80
Seaton Park	840	190	50
Medics			
Jemalong barrel	220	50	40
Sava snail	440	270	100
Sapo gama	260	50	10

Source: E.C. Wolfe, N.S.W. Department of Agriculture

Table 7. Hard-seeded reserves of subterranean clover after 2, 3, 4 and 5 years of continuous grazing by sheep
(Waite Institute, South Australia)

Stocking	Hard Seed Reserves in Spring			
Rate (Sheep/ha)	1964 (kg/ha)	1965 (kg/ha)	1966 (kg/ha)	1967 (kg/ha)
7.4	272	581	356	399
12.4	197	444	222	179
14.8	120	393	206	132
17.3	113	368	157	123
22.2	98	202	65	49

Source: E.D. Carter, Waite Agricultural Research Institute

Table 8. Effect of pasture composition and/or clover cultivar on the yield of a following barley crop at North Bannister, W.A.

Cultivar	Pasture Composition Oct. 1978		Barley Yield 1979
	Clover %	Grass & Weeds %	(kg/ha)
Dinninup	98	2	3409
Dwalganup	77	23	2713
Seaton Park	56	44	2641
Daliak	63	37	2622
Uniwager	60	40	2509
Woogenellup	61	39	2432
Geraldton	63	37	2401
Midland B	58	42	2267

Source: D.A. Nicholas, W.A. Department of Agriculture

Some Regional Ecological Differences in Southern Australia

There are substantial differences within and between the cereal-livestock zones of Western Australia, South Australia, Victoria and New South Wales.

Subterranean clover, annual medic species and lucerne are all used in the wheat belt but the problems of maintaining pastures mainly concern the persistence and regeneration of subterranean clover and annual medic species.

As we cross from west to east in southern Australia, not only does rainfall reliability decline in the cereal-livestock areas but also there is a declining percentage of sandy-surfaced soils. On the other hand, probability of receiving summer rains increases as we pass from the South Australian wheatbelt through Victoria into New South Wales. Winter temperatures are also lower in much of the New South Wales wheatbelt. All four factors may influence establishment and persistence of subterranean clover and medics. As stated before, 250mm annual rainfall is a guide to the lower limit of cereal cropping and pasture improvement in Western Australia, but this figure rises to 300mm in South Australia and north-west Victoria and say 375mm in southern New South Wales.

It is especially difficult to maintain good leguminous pastures on the hard- setting soils, especially if shallow or skeletal, in the marginal rainfall areas of the cereal-livestock areas of southern Australia; firstly, because of excessive run off with consequent loss of potential productivity of both herbage and seed of pasture legumes and insufficient burr burial by subterranean clover; secondly, because livestock can easily prehend clover burrs and medic pods and thereby effectively decimate seed reserves (1); and thirdly, because there is a high loss of seedlings by desiccation at the break of season through insufficient anchorage to the soil surface.

In these difficult environments mean rainfall is a poor guide to choice of cultivars and it is essential to choose very early maturing cultivars for inclusion in mixtures. Furthermore, small, hard-seeded species like cluster clover *(Trifolium glomeratum)* have a definite role to play in mixtures. A valuable management procedure is to give a very shallow scarification of the soil surface in late summer-autumn to ensure burial of burrs or pods,which greatly improves subsequent establishment of pasture legumes. This is especially important for ensuring rapid development of new legume stands.

In Western Australia the high proportion of acid soils in the wheat belt creates special problems in the selection of suitable cultivars of very early maturing subterranean clover for these low-rainfall acidic soils. However, the new cultivar of spineless burr medic (M. *polymorpha),viz.* cv. Serena,is extremely promising and withstands moderately acid soil conditions.

Subterranean clover persistence in the central wheat belt of New South Wales is constrained by insufficient hard-seededness and dormancy of current cultivars to avoid excessive loss of seed by germination with summer rains. Any farming system that prevents seed production by annual pasture legumes will exhaust the seed reserves. Recent dry years coupled with increased cropping intensity has shown the greater fragility of the subterranean clover ley farming system as against a system based on medics which are more stable in low rainfall environments.

Apart from the special needs of pure seed production, there is ample evidence of the benefit of using mixtures of subterranean clovers, and of medics, and sometimes mixtures of both genera. While it has been traditional to use two or three cultivars of subterranean clover, with perhaps cluster clover for skeletal sites (39), we see no reason for not sowing a mixture of four or five cultivars of subterranean clover in the wheat-belt. Such mixtures must cope with variation of site with respect to soil water availability (influencing growing season), soil pH, resistance to pests and diseases and, above all, ability to set large amounts of seed with a large proportion of hard seed to guarantee survival in the crop rotation.

Recent expansion of wheat growing in southern Australia is not without problems: certainly in South Australia there are clear signs of degradation of red brown earth soils associated with deterioration of soil structure and consequent erosion hazards and it, is difficult to envisage a successful alternative to the pasture phase of the rotation on these soils and many others. However, it is recognized that on some structureless sandy soils, especially in Western Australia, it may be a biological possibility if not an economic practicability to substitute artificial nitrogen for leguminous pastures, depending on the relative returns from cereal crop and livestock products. Furthermore, continuous cropping using lupins and oil seed crops in rotation with cereals offers some scope for developing stable and profitable farming systems. However, there is evidence that leguminous crops like lupins, peas and beans may be providing cereal yield benefits mainly through disease control rather than from net nitrogen fixation.

Future Prospects tor Better Pastures in the Cereal-Livestock Areas

Recent problems with pasture legumes (e.g. oestrogenic activity and clover scorch susceptibility of subterranean clover, and the spread of Sitona weevil and pasture aphids into medic and lucerne stands) though costly in terms of production, has had some impact in focussing attention on real research problems and priorities and has catalysed multi-disciplinary research efforts in southern Australia.

Thanks to the efforts of the National Subterranean Clover Program in Perth and the National Medic Program in Adelaide and the extensive regional testing in all states of southern Australia, we now have a much wider choice of medics, subterranean clover and lucerne to use in our various ecological zones (40-44). We have replacements for the oestrogenic cultivars of subterranean clover with a wide range of maturity, hard-seededness and resistance to clover scorch but more cultivars are needed: e.g. with maturity of Woogenellup but with much more hard seed and clover scorch resistance than Woogenellup (40, 41). With the medics and lucernes being developed at Adelaide an enormous amount of screening has taken place and new cultivars released, e.g. Hunterfield lucerne and Sava snail medic.

We believe that the self-regenerating annual pasture legumes (the medics and clovers) have an assured place in our farming systems for maintenance of the N economy and soil structure, and improving the quantity and quality of livestock feed; however, on some sandy soils soil structure is not limiting and continuous cropping is possible using lupins, oil seed rape, etc. as cash and break crops, but more cultivars of medic, subterranean clover and lucerne are needed to fit the various climatic and edaphic areas of the cereal belt of southern Australia.

Ongoing research is needed on the cost : benefit relations of all fertilizers, including micro-nutrients, for pastures in the crop-livestock farming system. Aspects of genetic control of nutrient efficiency need attention.

Specific problems like ryegrass toxicity (45) and increasing soil acidity (46) need to be resolved in specific areas of southern Australia.

Research and extension personnel must ensure that research is not only good but relevant: the farmer is generally only interested in practices that will make money, save money or save work having regard to preserving a stable ecosystem.

Finally, in future we expect that a much more professional farmer attitude to the sowing and managing of legume leys in the cereal belt will be normal. These will generally be mixtures of cultivars of medics or of subterranean clovers to ensure better persistence. We have to spend some money on re-establishing leguminous pastures to make money - not just wait for the perfect pasture legume to be developed as that may prove impossible as we expect the plant pest and disease problems to be quite dynamic. Despite recent problems there are some excellent leguminous pastures in most wheat belt districts which show that the technology is available. The greatest challenge in research and extension is to improve the general standard so that good to excellent leguminous pastures once more predominate in the cereal belt of southern Australia.

References

1. Carter, E.D. 1981a. Proc. XIV Int. Grassl. Cong. Lexington, U.S.A. (In press

2. Leeper, G.W. (ed) 1970. The Australian Environment CSIRO/MUP, 4th ed. 163p.

3. Gentilli, J. (ed) 1971. Climates of Australia and New Zealand. World Survey of Climatology, Vol. 13. Elsevier, Amsterdam.

4. Donald, C.M. 1970. In The Australian Environment CSIRO/MUP, 4th ed. 68-82.

5. Carter, E.D. 1975. Report to FAO/UNDP Lahore Pakistan 35p + appendices.

6. Carter, E.D. 1978. Report to ICARDA, Beirut Lebanon, 120p.

7. Donald, C.M. 1963. Aust. J. Sci. 25: 386-395.

8. Donald, C.M. 1982. In Agriculture in the Australian Economy SUP, pp. 55-82.

9. Cornish, E.A. 1949. Aust. J. Sci. Res. Series B 2: 83-137.

10. Carter, E.D. and Saunders, D.A. 1970. Proc. Nat. Agric. Mach.Workshop, University of New South Wales, Sydney 1969. pp. 25-42.

11. Farrer, W. 1893. Agric. Gaz. N.S.W. 4: 859-862.

12. Symon, D.E. 1961. A Bibliography of Subterranean Clover, Com. Agric. Bur.

13. Spafford, W.J. 1924. J. Dep. Agric. S. Aust. 27: 634-646.

14. Trumble, H.C. and Donald, C.M. 1938. J. Aust. Inst. Agric. Sci. 4: 206-208.

15. Trumble, H.C. 1939. J. Dept. Agric. S. Aust. 42: 953-958.

16. Amor, R.L. 1965. J. Aust. Inst. Agric. Sci. 31: 25-35.

17. Amor, R.L. 1966. Aust. J. Exp. Agric. Anim. Husb. 6:361-364.

18. Andrew, W.D. 1962. Aust. J. Agric. Res. 13: 212-219.

19. Robson, A.D. 1969. J. Aust. Inst. Agric. Sci. 35: 154-167.

20. Scott, B.J. and Brownlee, H. 1970. Agric. Gaz. N.S.W. 81: 62-69.

21. Cocks, P.S., Mathison, M.J. and Crawford, E.J. 1980. In Advances in Legume Science (eds) R.J. Summerfield and A.H. Bunting, Roy.Bot.Gdns, Kew. 569-596.

22. Carter, E.D. 1970. M.Ag.Sc. Thesis, The University of Adelaide.

23. Carter, E.D. 1974. Report to CIMMYT Mexico and MARA Algeria, 54p.+ append.

24. Ford, G.W. 1968. Ph.D. Thesis, The University of Adelaide.

25. Greenland, D.J. 1971. Soils and Fertilizers 34: 237-251.

26. Papastylianou, I., Puckridge, D.W. and Carter, E.D. 1981. Aust. J. Agric. Res. 32: 703-712.

27. Kingma, O. 1982. Quart. Rev. Agric. Econ. 4: 10-19 (Supplement).

28. Aust. Bur. Statistics. 1975-76 to 1980-81. Govt. Printer, Canberra.

29. Carter, E.D., Challis, S. and Ridgway, I.G. 1977. Proc. XIII Int. Grassl. Cong., Leipzig, G.D.R. Vol. II. pp. 735-738.

30. Carter, E.D. 1980. Proc. Aust. Agron. Conf., Lawes, Qld., p. 178.

31. Carter, E.D. 1981b. Proc. Symp. Roseworthy Agric. College.The Medic Crisis... 32,

32. Carter, E.D. 1982. Proc. Aust. Agron. Conf., Wagga Wagga, N.S.W., p. 32.

33. Wolfe, E.C. 1981. Report on Reserve Bank of Australia Research Fellowship (Agriculture) at the University of Western Australia. Govt. Printer, N.S.W.

34. Wolfe, E.C. 1982. Proc. Aust. Agron. Conf. Wagga Wagga, N.S.W. p. 34.

35. Wolfe, E.C. 1982. Address to N.S.W. Seedgrowers Assoc. Conf. Forbes, July 1982. The Improvement of Pasture Plants, 7p.

36. Adem, L. 1977. M.Ag.Sc. Thesis, The University of Adelaide.

37. Carter, E.D. and Day, H.R. 1970. Aust. J. Agric. Res. 21: 473-491.

38. Rudd, C.L. 1972. Aust. J. Exp. Agric. Anim. Husb. 12: 43-48.

39. Carter, E.D. and Wigg, P.M. (1963) J. Dep. Agric. S. Aust. 66: 464-475.

40. Quinlivan, B.J. and Francis, C.M. W.A. Dept. Agric. Bull. 4012, 1977.

41. Southwood, O.R. and Wolfe, E.C. 1978. N.S.W. Dept. Agric. Bull. P473.

42. Mathison, M.J. and Kobelt, E.T. 1980. Aust. P1. Br. and Gen. News.30: 78-82.

43. Mathison, M.J. 1981. Aust. P1. Br. and Gen. News.31: 89-92.

44. Kaehne, I. and Lake, A. 1982. Dept. Agric. S. Aust. Fact Sheet No. 9/82.

45. A.M.R.C. 1982. Report of an A.M.R.C. Workshop on Annual Ryegrass Toxicity, Feb. 1982. Waite Agricultural Research Institute.

46. Cregan, P.D. (1980) AGbulletin No. 7, N.S.W. Dept. Agriculture.