Sustaining multiple production systems
5. Sown pastures for marginal cropping lands in the subtropics

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Abstract

Fertility and structure of surface soil is declining throughout the marginal dryland croplands of eastern Australia. The incorporation of a pasture phase in the cropping sequence appears to be the most promising option for developing a sustainable cropping system. However, special problems currently restrict the use of sown pastures in these lands in sub-tropical Queensland and NSW.

For much of the region, productive and persistent pasture species have been identified. These include the native grasses, *Astrebla lappacea* and *Dichanthium sericeum*. Perennial grasses are still needed on the lighter textured infertile soils and there are still no adapted summer growing legumes for frost prone areas.

Unreliable establishment is currently the main technical constraint limiting wider use of the available pasture species. Strategies for overcoming this constraint are discussed and include decision support packages using climatic and biological models, improving establishment by means of aerial seeding, mulches and stubbles, and management for improving the supply of soil moisture.

Resumen

La fertilidad y la estructura de la superficie de las tierras marginales para el cultivo a temporal del este de Australia se están deteriorando. La incorporación de una fase de pastura en la secuencia de cultivos parece ser la opción más prometedora para desarrollar un sistema de cultivo sostenible. Sin embargo los problemas especiales restringen actualmente el uso de pasturas sembradas en estas tierras de la región sub-tropical de Queensland y NSW.

Se han identificado especies de pasturas persistentes y productivas para gran parte de la región. Estas incluyen las gramíneas nativas, Astrebia lappacea *y* Dichanthium sericeum. *Aún se requieren gramíneas perennes para los suelos infértiles de textura ligera y todavía no hay leguminosas de crecimiento en verano adaptadas a las áreas propensas a heladas.*

En la actualidad, la falta de seguridad en el establecimiento de las especies de pasturas disponibles es la principal limitante técnica para la ampliación de su uso. Se discuten estrategias para superar esta limitante las cuales incluyen paquetes dè programas computacionales que utilizan modelos climáticos y biológicos para el apoyo a las decisiones y la investigación de las formas prácticas de mejorar el establecimiento utilizando la siembra aèrea, el abono orgánico, el rastrojo y el manejo para mejorar el abastecimiento de la humedad del suelo.

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Introduction

In northern New South Wales and southern Queensland dryland cropping has expanded westwards and north several hundred kilometres over the past 20 to 30 years. This expansion has preceded the development of sustainable farming systems. Most expansion has been on the cracking clay soils of the brigalow country and *Astrebla* grasslands but some fertile duplex soils in the poplar box woodlands have also been cropped. Typically, once the native vegetation has been cleared, the land is usually cropped annually to wheat incorporating a fallow for moisture conservation in the majority of cases.

With regular cropping, problems of decline in soil structure, loss of fertility and erosion are common in these areas (Dalal and Meyer 1986; Chan *et al.* 1988) resulting in lower grain yields and grain protein levels. There are an estimated 600,000 ha of marginal wheatland with over 30 years of cultivation in Queensland and this will double by the year 2000 (Weston 1987). An even greater area could be expected in New South Wales.

The incorporation of a pasture phase in marginal cropping systems has the potential to restore soil organic matter, maintain soil structure, increase availability of soil N, suppress crop weeds, and minimise the risk of erosion. However, these potential benefits need to be weighed against the costs of developing a ley farming system. For marginal croplands, low and variable rainfall dictate that economic inputs are minimised (Clarke and Russell 1977). It will therefore be important to minimise the cost of reliably establishing the pasture phase, that is, the inputs of seed, fertiliser and herbicide, for future ley farming systems in this region.

In this paper we specifically address the dryland cereal cropping lands of sub-tropical eastern Australia between about 22° and 31 °S. The paper focuses on the problems associated with pasture establishment as this is the major limitation to wider use of ley pastures in these environments. We review the availability of species, some recent experimental results on grass establishment, list current recommendations and suggest priorities for future research aimed at developing more reliable sowing methods.

Pasture species for marginal cropping lands

The dryland farming areas of Australia's subtropics have a summer dominance of rainfall. For example, at Walgett (30°S, AAR 450 mm) 60% of annual rainfall falls during the October-March period, while at Emerald (23 °S, AAR 640 mm) 75% falls in this period. However, as significant rainfall can occur at other times of year, pasture mixtures require an ability to respond to favourable growing conditions in all seasons. Productive and persistent pastures for the region consist of temperate annual legumes (especially *Medicago* spp.) combined with warm season perennial grasses. The annual medics provide high quality forage during winter and spring and add N to the ecosystem. The perennial grasses produce bulky feed in the summer and provide landscape stability during drought. A ley pasture phase for much of this region would probably need to be of longer duration (5 to 10 years) than those common in southern Australia (1 to 5 years). We believe this would be needed for two reasons. Firstly, because the rate of improvement in soil structure and fertility is proportional to the amount of plant growth and the rate of incorporation of that growth into soil organic matter; the hotter and drier the climate, the slower this process. Secondly, the need for landscape stability and efficient utilisation of warm-season rainfall precludes the use of pastures comprised solely of winter growing annuals. Ley pastures involving perennial grasses will be of long duration (5 to 10 years) due to the high cost of sowing, the need to resow after each cropping phase as these grasses are not self-regenerating, and the high risk of establishment failure.

A number of perennial grasses and annual legumes are currently recommended for the heavier textured soils of the region (Table 1). Lucerne (*Medicago sativa*) is an excellent short term (1-4 years) grazing option either alone or mixed with tussock grasses such as Silk sorghum (*Sorghum* hybrid) and purple pigeon grass (*Setaria incrassata*). Barrel, burr and snail medics grow well on heavy clays with snail medic (*M. scutellata*) being very productive in the first 2 years in wetter regions when mixed with tussock grasses. Barrel and burr medics (*M. truncatula, M. polymorpha*) are also well adapted to lighter slightly acid soils but do not spread easily.

Although not combining as well with legumes as many other grasses, Bambatsi panic (*Panicum coloratum* var. *makarikariense*) is very persistent and well suited to gilgai and seasonally swampy sites. There is scope for using the native grasses Curly Mitchell grass (*Astrebla lappacea*) and Queensland bluegrass (*Dichanthium sericeum*) on heavy clays, where the latter is a common natural coloniser after cropping. There are fewer options on the lighter textured soils but buffel grass (*Cenchrus ciliaris*) and *Bothriochloa* (bluegrasses) show promise (R.G. Silcock, unpublished data). Buffel can be sown in a mix with barrel medic cultivars such as Paraggio and Cyprus. Yellow seradella (*Ornithopus compressus*) and Premier digitaria (*Digitaria smutsii*) are being evaluated for the very sandy soils. Further information on recommended pasture species is given by McDonald and Watson (1990) and Thompson (1988).

Seed of Curly Mitchell grass (*A. lappacea*) has been successfully harvested using existing wheat

Table 1. Pasture species currently recommended or under advanced evaluation for ley pastures in marginal cropping lands of northwest New South Wales and southwest Queensland

Species	Cultivar	Common name	Country of Origin	Duration of pasture phase
Perennial tropical grasses				
Heavy texture soils				
Astrebla lappacea	none	Curly Mitchell	Australia	long
Cenchrus ciliaris	Biloela	Buffel	Africa	medium
Dichanthium sericeum	none	Queensland Blue	Australia	medium
Panicum coloratum var. *makarikariense*	Bambatsi	Bambatsi Panic	Africa	long
Setaria incrassata	Inverell	Purple Pigeon	Africa	medium
Lighter texture soils				
*Bothriochloa insculpta**[1]	none	Creeping Bluegrass	Africa	medium
*Bothriochloa glabra**	none		India	medium
*Digitaria milanjiana**	none	Finger Grass	Africa	medium
Urochloa spp.*	none		Africa	medium
Cenchrus ciliaris	Gayndah	Buffel	Africa	long
Eragrostis curvula	none	African Lovegrass	Africa	short
Digitaria smutsii	Premier	Premier digitaria	Africa	long
Annual temperate legumes				
Heavy texture soils				
Medicago truncatula	Sephi, Paraggio	Barrel Medic	Israel, Italy	short
Medicago scutellata	Sava, Kelson	Snail Medic	Germany, Hungary	short
Medicago polymorpha	Serena, Santiago	Burr Medic	Australia,[2] Chile	short
Lighter texture soils				
Ornithopus compressus	Madiera	Yellow Serradella	Spain	medium

[1]* Currently under evaluation and not yet available commercially.
[2] From naturalised ecotype.

harvesting machinery, while seed of Queensland Bluegrass (*D. sericeum*) can be harvested with a new machine incorporating a rotating nylon brush and strong air suction (Robotham and Loch 1990). The establishment requirements of Curly Mitchell grass and Queensland bluegrass (Watt 1978; Lambert *et al.* 1990) are similar to those of the adapted exotic grasses such as Bambatsi or Rhodes grass. There is scope for a plant improvement program to select native perennial grass genotypes with superior seed retention and/or greater seedling vigour following the example for *Danthonia* in New South Wales (Lodge 1990).

The search for reliable methods for perennial grass establishment

Poor establishment has long been recognised as a major limitation to greater utilisation of sown pasture grasses on cracking clay soils in low rainfall country (Winders 1936; Donald 1946; Leslie 1965; Silcock 1977; Younger and Gilmore 1978; Watt and Whalley 1982). A recent survey of landholders reveals it is still the greatest constraint to better pasture production (Bourne 1987).

While low and erratic rainfall is the major limitation, other important technical limitations include:

- Decline in soil structure following organic matter depletion, leading to poor seedling emergence because of excessive soil strength and the formation of surface crusts.
- Intense competition from annual weeds on old cultivation areas.
- Frost which can cause high mortality rates of perennial grasses sown in late summer or autumn; winter being the most reliable time for adequate soil moisture for seedling growth.

Perennial grass establishment using existing technology is still unreliable as shown by the results from grass evaluation trials sown on five occasions at 11 sites across north-west New South Wales (Table 2). The few successes in 1986/87 were all sown onto good subsoil moisture with moderate post-sowing rainfall from patchy summer storms. The widespread success of 1988 was largely due to a long sequence of rain days beginning in late March. There were also some successful sowings in autumn 1989 following above-average rainfall. Very dry conditions in the

Table 2. Summary of outcomes from grass variety sowings[1] throughout the north west wheat belt of New South Wales and rainfall during the establishment period

	Date of Sowing				
	Nov 1986	Oct 1987	Mar 1988	Feb 1989	Oct 1989
Outcome[2] (Number of sowings)					
Failure	8	6	1	5	9
Marginal	2	3	0	0	0
Success	1	2	10	4	0
Total	11	11	11	9	9
Rainfall[3] (mm)					
Oct-Feb	142	195	—	—	81
Mar-Apr	—	—	196	157	—

[1] Seed sown at 1 cm depth using a bandseeder followed by a rubber tyre roller.
[2] Failure: Almost no plants establish.
Marginal: A few plants establish, may thicken upon time.
Success: Adequate plants to ensure a productive pasture.
[3] Rainfall data for Walgett.

summer of 1989 resulted in complete failure of all sowings.

Overall, there were only 17 successes from 51 sowings, an unacceptably low level of success considering the costs involved. These costs have been recently calculated at $44/ha for grasses only (Benson *et al.* 1990) and increase slightly if a legume is included. Reliable grass establishment, combined with a significant legume component could recoup these costs in three to four years through increased livestock production alone. Management practices which may improve the reliability of establishment include the timing of sowing, weed control, and seeding into stubble.

Time of sowing

It has not been possible to predict the optimum time for sowing perennial grasses in the marginal cropping areas. Most experiments have been short term and are very dependent on the rainfall events during the experimental period (Leslie 1984). However, the relationships between specific rainfall sequences and seedling emergence and survival can be determined from such studies. This information is essential for understanding the process of establishment and for constructing decision support packages based on an analysis of historic rainfall records. However this information alone is insufficient to predict establishment success and other factors such as temperature, evaporative demand, pests, diseases and weeds must be considered. Seedling losses due to grass hoppers are likely to be greater in spring than in autumn in southern Queensland because of greater spring populations of these obligate grass feeders (Silcock 1987). Grass weeds are regarded as a bigger problem in spring than in autumn in southern Queensland (Thompson 1988).

Some recent research with Curly Mitchell grass highlights the problems of predicting successful establishment. Seed of Curly Mitchell grass was sown either as spikelets (the natural dispersal unit) or as caryopses (clean seed) along with seed of Bambatsi panic. The complex pattern of emergence for seed sown in November 1987 is presented in Table 3. Under the marginal rainfall conditions experienced, emergence was not synchronous but staggered over a range of rainfall sequences. The relatively high emergence from Mitchell grass spikelets after the April 1988 rain demonstrates the importance of possessing some resistance to 'false starts' in this environment. On another occasion a significant fall of 51 mm (1.12.89) onto a very dry soil profile, followed by two days of hot dry winds, was not effective for seedling emergence. The results demonstrate that establishment cannot be predicted from rainfall data alone.

Table 3. Emergence of successive cohorts from seed sown in November, 1987 (W.D. Bellotti and C.R. Watson, unpublished data)

Date of emergence count	Rainfall preceding emergence	Mitchell caryopses	Emergence[1] Mitchell spikelets	Bambatsi seed
	(mm)		(%)	
15.12.87	51	0.2	0.2	<0.1
3.01.88	26	0.1	0.9	<0.1
2.02.88	10	<0.1	0.1	<0.1
24.02.88	34	<0.1	0.9	0.2
20.04.88	121	0.4	7.6	2.1

[1] Expressed as percentage of remaining seed.

Many grasses exhibit a complex pattern of emergence and survival in response to low and erratic rainfall sequences (Silcock and Smith 1990). There is a need for a grass establishment simulation model to help explain this complex response and to help identify the sowing conditions most likely to lead to successful establishment.

Weed competition

The weed species which compete with sown pasture seedlings vary greatly from the north to the south of the review region as well as with time of germinating rains in any single area (Table 4). Most are annuals, some are short term perennials eg *Chloris truncata, Malvastrum americanium* and *Sclerolaena muricata* (black rolypoly), and a few are perennials e.g. green couch. Annual weeds such as barley grass (*Hordeum* spp.) and *Brassica* spp. can seriously reduce the establishment and growth of sown perennial grasses in the southern marginal cropping areas.

There are currently no herbicides registered for use as either pre- or post-emergent weed control for the perennial grasses recommended in these areas. However, the work of Scattini (1978) suggests there are useful tolerance levels to Atrazine in Hatch creeping bluegrass and Bambatsi panic. Preliminary screening has identified the potential of Ally (R) and Logran (R) for control of broadleaf weeds competing with perennial grasses during establishment (A. Bowman, unpublished data). Cool season annual grass weeds can be controlled with low rates of glyphosate applied in the winter months when warm-season perennial grassses are dormant.

Fortunately, the pasture grasses are perennial and, once established, will thicken up as the disturbance-induced weeds die back. They are also grazing tolerant, so strategic grazing will disadvantage palatable weeds such as wild turnip. However many problem weeds are unpalatable e.g. blue heliotrope, spiny emex and Maynes pest (*Verbena tenuisecta*) and grazing does not control them directly.

Aerial seeding into wheat stubbles

Aerial sowing perennial grass seed into standing stubble just before or after harvest is another method of reducing the risks associated with establishment of grasses. The standing stubble protects pasture seedlings by reducing evaporation and surface soil temperature fluctuations. In addition, the paddock should be relatively weed free and there is a reduced risk of soil erosion during heavy summer storms due to the stubble cover. The main disadvantage is that in most summers there is unlikely to be significant soil moisture left in the profile after the grain filling period.

Four grass species were surface sown by hand into newly harvested wheat stubble in November 1988 (Table 5). The stubble treatments consisted of a normal stubble height after heading (with straw) and a reduced stubble height with the trash removed (reduced straw). Although initial seedling numbers were quiet dense, high mortality rates during the first summer and winter reduced overall plant density to 1.6 plants/m^2 by August 1989. The main stress factors responsible for mortality were most likely soil mositure deficits during summer and exposure to low temperatures and frost during winter. Plant density had declined further when sampled in May 1990 indicating a further loss of plants during the second summer. There was no consistent difference between the stubble treatments. These results demonstrate the time needed for these establishing populations to stabilise. Despite low survival percentages for some species, the overall established plant density of 1.2 plants/m^2 is comparable to that of undisturbed native grasslands in the region.

Table 4. Common weeds of three marginal dryland farming areas in sub-tropical Eastern Australia for winter and summer sowings

Sowing Time	Emerald region (23°S)	Roma region (26°S)	Walgett Region (30°S)
Spring/early summer sowings	*Parthenium hysterophorus* *Tribulis terestris* *Corchorus triloculeris* *Abelmoschus ficulneus* *Crotalaria dissitiflora*	*Malvastrum americanium* *Verbesin encelioides* *Cynodon dactylon* *Urochloa pronicoides* *Chloris truncata* *Aristida* spp.	*Sclerolaena muricata* *Salsola kali* *Tribulis terestris* *Boerhavia diffusa* *Solanum esuriale*
Autumn/early winter sowings	*Salsola kali* *Parthenium hysterophorus* *Argemone mexicana* *Sonchus oleraceus* *Haloragis aspera*	*Rapistrum rugosum* *Lepidium* spp. *Helipterum* spp. *Emex australis* *Verbena tenuisecta* *Centaurea melitensis* *Pimelea trichostachya* *Ipomoea lonchophylla*	*Hordeum* spp. *Avena* spp. *Phalaris paradoxa* *Brassica* spp. *Salsola kali* *Centaurea melitensis*

Table 5. Survival of perennial grasses sown into wheat stubble in November, 1988. (A. Bowman, unpublished data)

	Date of sampling				
	10.1.89	18.4.89	16.8.89	17.5.90	Survival
	(Plant density/28 m²)				(%)
With Straw					
Buffel Grass	538	167	84	13	2.4
Curly Mitchell	258	171	84	71	27.5
Purple Pigeon	299	140	61	21	7.0
Bambatsi Panic	165	100	32	26	15.7
Reduced Straw					
Buffel Grass	442	166	59	10	2.3
Curly Mitchell	389	160	99	68	17.5
Purple Pigeon	203	52	35	23	11.3
Bambatsi Panic	186	74	35	23	12.4
Mean: with straw	321	144	32	33	10.3
Mean: reduced straw	305	113	57	37	12.1

Current recommendations

The principles of pasture establishment in marginal environments are little different from those for more humid environments but the need for farmer commitment and reseeding expertise are greater as rainfall decreases and the seedbed environment becomes more hostile. The landholder needs to prepare well in advance of the actual sowing operation in order to take full advantage of favourable environmental events. These events should be viewed as 'windows of opportunity' where delays in sowing time of just one day can mean the difference between success or failure.

We see pasture establishment as having three main stages over a two year duration.

(i) Careful site preparation to improve the chances of success, in particular soil moisture conservation and grass weed control.
(ii) Sow an adequate number of viable seeds at the correct depth to give seedlings the maximum chance of emergence.
(iii) Defer grazing until the plants are firmly rooted and cannot be pulled from the ground. A short, light grazing in the year of establishment is usually beneficial to grasses by encouraging tillering and controlling weeds. Seed set by annual legumes in the first year is crucial and also desirable for the perennial grasses.

More detailed guidelines can be found in McDonald and Watson (1990) and Thompson (1988).

Future research priorities

Research needs to identify ways to improve soil-seedling moisture relations and to enhance seedling survival through the first summer and/or the first winter. During summer the major hazard is severe moisture stress in young plants due to the rapid drying of the surface soil layers. For seedlings sown in late summer or autumn, the advantage of slightly improved chances of good soil moisture conditions must be weighed against the additional risk of death due to frost exposure. The following list suggests research topics which could lead to the development of more reliable sowing methods.

Aerial seeding into crop stubbles

This option warrants greater attention given the success so far achieved on commercial farms (e.g. 'Kindon' near Wyaga) and that noted by Rickert (1973) and Younger and Gilmore (1978). The probability of success should improve with the increasing reliability of summer rainfall in northern areas. Further south, one option would be to control weeds with herbicides, conserve moisture over summer and sow into standing stubble in February. This has the advantages of aerial seeding into stubble, a full soil moisture profile and increasing probability of favourable soil moisture conditions in autumn.

Avoidance of frost damage

More work is needed to assess the positive and negative effects of cover crops on grass establishment. Another option is to select grass genotypes with greater frost tolerance. Warm season perennial grasses differ in their cool-season growth potential and selection between and/or within species for seedling frost tolerance may enhance our ability to use autumn sowings. There is a need to determine whether grass seedlings are less frost tolerant before or after they develop tillers and whether competing weeds or moisture stress affects this tolerance.

Seeding directly into moisture

Establishing grasses without the need for follow-up rainfall to ensure survival would remove some of the risk associated with current methods. Possible ways of achieving this include furrow seeding, water injection, and the use of artificial mulches. While potentially technically feasible, these methods are unlikely to be economic for broad-scale application.

Prediction of abnormal rainfall events from global circulation patterns

The chances of doing this are improving with the discovery of relationships between regional rainfall and the Southern Oscillation Index. Using this relationship it should be possible to predict seasons of above or below average rainfall. The application of this information to improve the reliability of pasture establishment requires investigation.

Amelioration of poor soil surface structure

Ways of reclaiming soil structure will be required on soils degraded through depletion of organic matter or the exposure of poorly structured subsurface soil. In these situations ameliorants such as gypsum or mulches may be needed to improve soil surface properties before pastures can be sown.

In addition to these priorities there will be a continuing demand for information on the potential for using herbicide, insecticide, or fertilizer to enhance establishment, and for guidelines for grazing management in the first year.

Conclusion

The expansion of the wheat belt into marginal environments has preceded the development of sustainable grain production systems. Soil fertility and surface structure is declining. While the development of a ley farming system holds promise, there are special problems restricting this concept in marginal environments in eastern Australia. These problems include low and variable grain yields which restrict expensive inputs and unreliable establishment of current grass species.

The available species are productive and persistent once successfully established. However, the high risk of establishment failure, and the high cost of seed, act to deter more widespread use of these grasses in commercial leys.

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