Successful integration of pastures in farming systems

D. L. Lloyd

Queensland Department of Primary Industries and Fisheries,
203 Tor Street, (PO Box 102), Toowoomba Qld 4350

Abstract. Ley phases in cropping systems are complex. Successful integration of ley phases is measured by the profitability of crop-pasture systems that have demonstrable natural resource benefits, compared with cropping systems. This paper identifies critical targets within the pasture phase that need to be managed effectively and efficiently to ensure successful and profitable integration with cropping.

Introduction

Fertility decline in the structurally stable, and inherently fertile heavy clay soils of the northern grain belt, now costs an estimated $450 M per year due to lower grain yield and quality (M. Probert, pers. com., from APSIM model). Integrating short-term pasture phases into farming systems is one option for restoring the productivity of cropping lands. However, successful integration demands that the ley benefits the profitability of the enterprise and sustains the resource that is used to create this profit.

"Integration" is defined as any pastures that are sown on land that is destined to be returned to crop in the short, mid or long term, and are a part of an integrated crop-pasture rotation system. Alternatively, pastures may be managed as "separate" entities in mixed grain and grazing enterprises if they are sown on soils that are not likely to be used for cropping.

Can ley pastures pay?

There is a perception in the northern grain belt that pasture-crop rotations sown on cropping land are not as profitable as continuous cropping. Livestock enterprises are nevertheless widespread and are based on native pasture, forage crop, stubbles and fallows, and sown pasture, established when animal product commodity prices were high.

If there is to be successful integration of ley pastures into the cropping system, it is imperative to accept that ley pastures "can pay" and then manage them to ensure that they "do pay".

Using an interactive economic spreadsheet model with farmer input developed for the GRDC-funded Leygrain project (Strahan and Scott 2004), crop-pasture rotations in the North Star area in northern NSW have been shown to be more profitable than crop rotations in >70% of years.

The focus of this paper is to identify key issues and limitations in ley pasture management that determine whether crop-pasture rotations will pay.

Ensuring that ley pastures do pay

The profitable integration of pasture leys into cropping systems demands that the pasture phase is managed as efficiently and effectively as a crop, and the transition between phases – the time that the land is out of production is minimised. Key issues are:

- Managing ley phases to overcome factors that limit crop yield and quality including low soil total nitrogen (N), organic matter (OM), weeds, pests and diseases and soil compaction.
- Selecting the most appropriate and well-adapted ley species.
- Establishing the pasture with precision and timeliness to minimise the duration of the crop-pasture interface.
- Integrating the forage provided by the ley with a range of other forages to meet profitable animal production targets.
- Timely removal of pasture to provide the necessary stored soil water and mineral N for the succeeding crop.

Overcoming problems caused by cropping

Improving soil N and crop yield and quality

Improvements to soil total N by legume or legume based pastures and the benefits to grain yield and quality are well understood (Littler1984; Whitehouse and Littler 1984; Littler and Whitehouse 1987; Holford 1980, 1981, 1989; Dalal *et al.* 1991; Hossain *et al* 1995*a*, 1995*b*).

Successful integration to maximise soil N improvement requires well-established, productive, adapted legumes that are used in 1-4 year phases depending on the N-improvement sought. Mostly, species issues are resolved, though new legumes including cultivars of *Hedysarum coronarium*, *Biserrula pelecinus* and *Ornithopus sativus* may find wide acceptance if their agronomy is resolved and they are well promoted.

Improving soil OM and soil structure

Grass-legume pastures rejuvenate soil OM (Bowman and Chan 1991) and, in turn, soil structure, with grass in particular very important in this process. Soil OM improvement occurs slowly – at least 5 years to effect improvement in the top 5 cm of soil. In turn, improved soil structure improves soil permeability and water infiltration, thus reducing runoff and erosion, and encourages soil biota and microorganisms.

Successful integration to improve soil surface conditions in hard-setting soils with will require the implementation long term, grass/legume pastures.

Controlling weeds

Weeds, controlled by cultivation and herbicide practices, particularly by herbicide in zero or minimum till systems, have always been an issue in cropping systems. New systems have resulted in herbicide resistant weeds and, as yet, we do not know if there are long-term detrimental effects of the on-going use of herbicide on crops. There are at least 10 crop weeds in the northern grain belt that are resistant to 1 of 4 herbicide groups (Walker 2002).

Well-managed ley pastures provide a cheap and effective means of controlling palatable weeds (Littler 1984). They also reduce the likelihood of herbicide resistance and the systemic costs of weed control. Not all weeds are palatable and their management using herbicide during the pasture phase is vital to prevent a bigger problem with weeds in following crops. However, there is a need to understand better the effects of herbicides on the pasture legumes, and of the grazing management needed to achieve that control.

Knowledge of the longevity of weed seeds in the soil is important in choosing the duration of a ley phase for weed control. For example, after 4 years, 5-7 % of the seed bank of turnip weed (*Rapistrum rugosum*) will remain in the soil, but <1 % of wild oats (*Avena* spp.) or sowthistle (*Sonchus oleraceus*) (S. Walker, pers. comm.).

Providing crop disease and pest breaks

Ley pastures break some disease and pest cycles of grain crops (G Wildermuth, M Ryley, pers. comm.). Our understanding of the cross-infectivity of crop and pasture diseases is limited and research is needed to improve the selection of pasture species to control identified disease targets. Nevertheless, successfully integrated systems:

- Use lucerne or medic to reduce common root rot and crown rot. Avoid grasses as they are generally susceptible to those diseases.
- Lucerne and medics do not provide an effective disease break for *Phytophthora* root rot following chickpeas.
- Ley legumes and grasses will not reduce the incidence of charcoal rot, *Sclerotinia*, *Sclerotium* and *Rhizoctonia* stem and root rots, which have a wide host range and can survive on pasture and crop residues for many years.
- Lucerne, medics and Bambatsi panic interrupt the life cycle of the root lesion nematode (*Pratylenchus thornei*) (R. Colbran, unpublished data).
- Lucerne and medics carry some virus vectors (e.g. leafhoppers and aphids) that can exacerbate insect and disease problems in some crops.

Improving soil biota and Vesicular Arbuscular Mycorrhiza (VAM)

There has been little rhizosphere research with pastures in the northern grain belt and this could be enhanced, particularly with VAM, to understand the benefits to the whole system.

Long term grass-legume pastures that improve soil OM should improve populations of both beneficial micro and macro fauna and microflora. Ley grasses and legumes generally stimulate both the number and type of large beneficial soil fauna such as earthworms, but do not increase the number of pests.

Lucerne stimulates soil VAM and is recommended in ley pastures preceding crops that are highly dependent on VAM including maize, sorghum, sunflower, linseed, a number of pulses and cotton (Thompson 1987).

Improving ground cover and infiltration and restricting water leakage through the profile

Continuous cropping has been responsible for soil loss related to erosion. By increasing ground cover from 20 to 70%, runoff is reduced from 160 to 10 mm/year and soil loss from 8.5 to 0.3 mm/year or from 85 to 3 tonnes soil/ha/year (derived from Wockner and Freebairn 1991). There is also an implied maintenance of soil fertility in reducing the loss of topsoil. The reduction in runoff is achieved through an increase in infiltration rate e.g. 38 mm/hr under grass pasture and 30 mm/hr under medic pasture, compared with 6 mm/hr in cultivated soil (R. Enright, unpublished data).

In reducing runoff from 10 to 3% of incident rainfall, deep rooting perennial pastures also improve infiltration and profile soil water use by the plants. The net benefit can reduce leakage of water in the profile from about 4 to 0.5% of incident rainfall (derived from Littleboy *et al.* 1989).

Benefits gained by using pastures will be superior to stubble management systems, only if careful and appropriate grazing management practices, aimed at maintaining the high level of ground cover for long periods of time are implemented.

Minimising soil compaction

High bulk densities (>1.4 Mg/m^3) in the top 30 cm of the soil, caused by machinery impacting at the soil surface and at the plough layer, retard root penetration and development, and soil water infiltration. Studies of different surface management regimes, have shown that soil bulk density under grazed grass and legume pasture is <1.4 throughout the surface profile (R. Enright and A. Harte, unpublished data).

This questions the popularly held view that grazing cropping soils causes compaction at the soil surface. Nevertheless, it is preferable to limit all practices that may cause compaction when the soil surface is wet. If grazing, the ground cover associated with grass would minimise that impact.

In addition, in integrating ley pastures to overcome the specific problems that affect the yield of crops in a cost-efficient way, the rotation system and its duration should be selected carefully. Consider the target and plan the rotation accordingly.

Using well-adapted species

In the northern grain belt, there are well-adapted, tropical and temperate, short, mid and long-term legume and grass cultivars for all climatic and edaphic environments in the region. Information about species has been developed by Queensland Department of Primary Industries and Fisheries and NSW Agriculture and effective integration should not be limited by suitable species or information about them.

As well, there are a number of new legumes that are being released through national pasture plant improvement programs (e.g. French and yellow serradella, and sulla).

There is an urgent need to understand the agronomy and management of these new legumes, and to fit them into farming and grazing systems.

Ensuring that establishment is precise and timely

Failures in the establishment phase occur as farmers often manage that phase poorly, hoping to succeed with limited preparation, inputs and cost. For success, rainfall variably must be managed skilfully and pasture establishment managed with the same precision as for crops, recognising that failure is often related to rainfall variability.

Successful integration demands the following:

During seedbed preparation:

- Avoiding paddocks with residual herbicides and meeting plant back standards.
- Preparing a seedbed that is fallowed to store water and mineral N.
- Controlling weeds to limit the loss of soil water.
- Applying fertiliser before sowing where necessary.

At sowing:

- Selecting high quality, soft or non-dormant seed.
- Sowing fluffy grass seed effectively, and inoculating and applying fungicide and anticide to legume seed where necessary.
- Sowing only when there is water in the soil profile, preferably to >30 cm.
- Sowing at a seeding rate that depends on target plant population and the quality of the seed.

Farmers need an inventory of seed sizes to enable this calculation.

- Sowing small seeded pasture species at or near the soil surface. For example, with lucerne, establishment on a clay soil will decline from 53% of the seed sown at 1.25 cm depth, to 13% when sown at 5 cm (McDonald *et al.* 2003).
- In the subtropics, the choice of drilling seed into profile water or sowing at the soil surface is a dilemma. With the temperate species, drilling in autumn may be preferred if climatic projections indicate that the autumn/winter season is likely to be dry and the probability of immediate follow up rain to germinate seed sown near the surface is low. With tropical species, sowing large seeded cultivars at depth is an insurance against the soil surface drying before germinating seed has established.
- Successful establishment can be achieved by undersowing with crops, providing the crop sowing-rate is at least halved. A better package to assist in making the decision to undersow or to sow as a sward is needed to answer questions such as, "To what extent is soil N accruement jeopardised by undersowing and how is this compensated by the value of the companion crop?"
- Timing sowing to maximise the probability of successful establishment in a variable rainfall environment poses challenges with species sown at or near the soil surface, particularly the tropical species that are sown between late spring and early autumn when evaporation rates are high. By using the computer program "RAINMAN Streamflow Version 4", the historical probability of follow-up rain falling during the establishment period can assist in deciding sowing time for all species.

Provide a continuum of high quality forage for livestock

Ley pastures are high value pastures that carry more livestock and produce more animal product per head than native pastures, but require more careful management to maintain their composition and productivity. These pastures can be successfully integrated with other forage sources to meet high value animal production targets (Gramshaw and Lloyd 1993). For example, by integrating ley pastures with forage crops, a steer can meet an EEC market weight 9 months before that target is met from the ley pasture alone. Using good quality native pasture only, an EEC steer target cannot be met.

By using pasture growth curves of adapted species, ley pastures can be integrated with other forages (native pasture, forage crops, stubbles, failed crops and fallows) to meet both those targets and the needs of non-growing stock. Adjusting stocking rates during the year and conserving feed are strategies that should be implemented to maximise production. There is a particular need for agronomic and management research with new legumes to fit them profitably into well targeted production systems.

Managing the pasture in the first year to create a seed reserve or to maintain a high reserve of carbohydrate in the crowns of key species, is vital to the on-going productivity of the pasture. Livestock should be managed to minimise anti-nutritional qualities of pastures. In particular, the bloat risk of legumes such as lucerne needs to be managed to maximise profitability. Many farmers fear lucerne but do not manage the risk. This is a challenge for extension.

Manage the transition back to crop

Replenishing the soil profile water profile for the succeeding crop

Perennial pastures, particularly grass and deep rooting lucerne, dry the soil below the crop root zone. On clay soils, this results in a reduction in the potential grain yield of 8 kg/ha for every 1 mm of plant available water less than a full profile to depth 1.2 m. On loamy soils, the reduction is less as the "bucket" is smaller and the plant available water content (PAWC) is less per unit soil depth. The extent of soil drying after lucerne is well understood (Holford and Doyle 1978) but there is a need to understand the soil water dynamics of other ley legumes and ley systems.

The soil water and its effects on subsequent crops can be managed by:

- Timing the removal of the pasture phase to maximise the probability of replenishing the profile.
- Choosing the most appropriate crop to sow following the ley, based on pre-plant soil water.

Using the soil water balance computer program, "Howwet", the timing of pasture removal to replenish soil water varies from place to place in the grain belt.

Using 50 years of historical rainfall data for, Tamworth, in northern NSW and "Howwet" simulations, only 70% of PAWC was replenished, on average, in a 1.2 m clay soil after lucerne was terminated 12 months prior to sowing. On a loamy soil, 90 cm deep, the profile was filled if the lucerne was terminated 10 months before sowing. The proportion of PAWC replenished if lucerne was terminated in September was 50 and 80%, respectively.

In a more marginal cropping environment at Roma in south-west Queensland, only 60% PAWC was replenished on a similar clay soil when lucerne was terminated 12 months before sowing and only 65% PAWC was replenished after the same time of removal on a loamy soil. The percentages were 44 and 55% if the lucerne was removed in September.

Once a decision is made to terminate the pasture is made, it must be regarded as a weed of the following crop rather than a source of high quality forage. Irrespective of the timing of termination, the pre-plant water should be monitored to facilitate the decision to grow a grain crop or a forage crop. For successful integration, these are further challenges for extension.

Replenishing soil mineral N for the succeeding crop

After a pure legume ley is removed, there is generally a large and rapid release of mineral N, which may be in excess of the needs of the following crop. After a grass-legume ley is removed, the release of mineral N is slower and release occurs over a longer period of time.

Denitrification losses can occur in fallows after legume-based leys, more so after grass-legume leys than after pure legume leys owing to the abundance of carbon in grass residues (Islam *et al.* 1992). While there is limited research on the management of denitrification, research has consistently shown long-term N benefits after lucerne, leading to the conclusion that denitrification losses are generally low, and large losses are infrequent.

As is good management practice, a soil test will determine the quantity of pre-plant soil mineral N and, by balancing this with the soil available water content, better decisions can be made of the succeeding crop to sow and if additional N fertiliser should be applied.

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