# The benefits and challenges of crop-livestock integration in Australian agriculture

Michael A. Ewing[1,2] and Felicity Flugge[1]

[1] Cooperative Research Centre for Plant-Based Management of Dryland Salinity, University of Western Australia, Crawley, WA 6009, Australia. www.crcsalinity.com.au Email mewing@cyllene.uwa.edu.au and fflugge@agric.wa.gov.au
[2] West Australian Department of Agriculture, Baron-Hay Court, South Perth, 6151

## Abstract

Integrated crop-livestock farming systems continue to dominate broadacre agriculture in southern and eastern Australia. A shift in the last decade to a more diversified production system based around an increased proportion of cropping is evidence of the flexibility of the farming system to respond to innovation and to economic signals. The nature and extent of changes has been regionally variable, depending on the current production potential of crop and pasture elements and suitability of emerging technologies.

The physical and financial stability of crop-livestock production systems arises from the complementary interactions between components of the production systems. This produces a whole-farm financial outcome that is buffered against economic fluctuations with similar profits generally achieved for a range of physical strategies. This allows producers to implement measured responses to a trend, making changes only when they are convinced the trend will persist.

Resurgence of livestock prices, combined with difficulties with weed management in all crop systems and the need to deal with sustainability challenges such as salinity and acidity increase the likelihood that pasture and livestock components of mixed systems will retain their importance. Long term financial viability of crop-livestock systems will depend on steady increases in productivity, through innovation in all components of the system.

## Media summary

Crop-livestock systems are here to stay but producers must innovate continuously and evolve their systems to maintain profitability whilst their resource base is maintained or improved.

## Key words

Farming systems, crop, livestock, pasture, legume, profit

## Introduction

Farms that integrate cropping and livestock enterprises within a single business dominate broadacre agricultural production system in Australia. However, sitting below this commonly adopted enterprise framework is a wide array of farm level strategies which accommodate the range of climates, soils and social settings in which broadacre agriculture is conducted in Australia. We are interested in why this approach to land-use has been so broadly applicable and what issues and trends can be discerned that could guide our understanding of its future.

The wide application of farming systems involving crop-livestock integration has resulted in the linked naming of the zone where such activity is concentrated (Wheat-Sheep Zone (WSZ) - Figure 1) and this is the zone of focus for this paper. The WSZ sits between a High Rainfall Zone (HRZ) where specialist livestock enterprises dominate land use and a Pastoral Zone (PZ) which is also dominated by livestock production activities, in this case low input rangeland production systems.

Climate is a key factor explaining some of the observed variation within the WSZ which extends over almost 35 m ha. Climatic variation within the zone is substantial, but all the areas fit within the general category of warm, seasonally wet/dry climates (Hutchinson *et al.* 2004). Annual rainfall varies between 300 and approximately 600 mm with the proportion falling in the summer increasing in the northern zones. Average farm size is influenced by rainfall, being substantially higher in low rainfall areas.

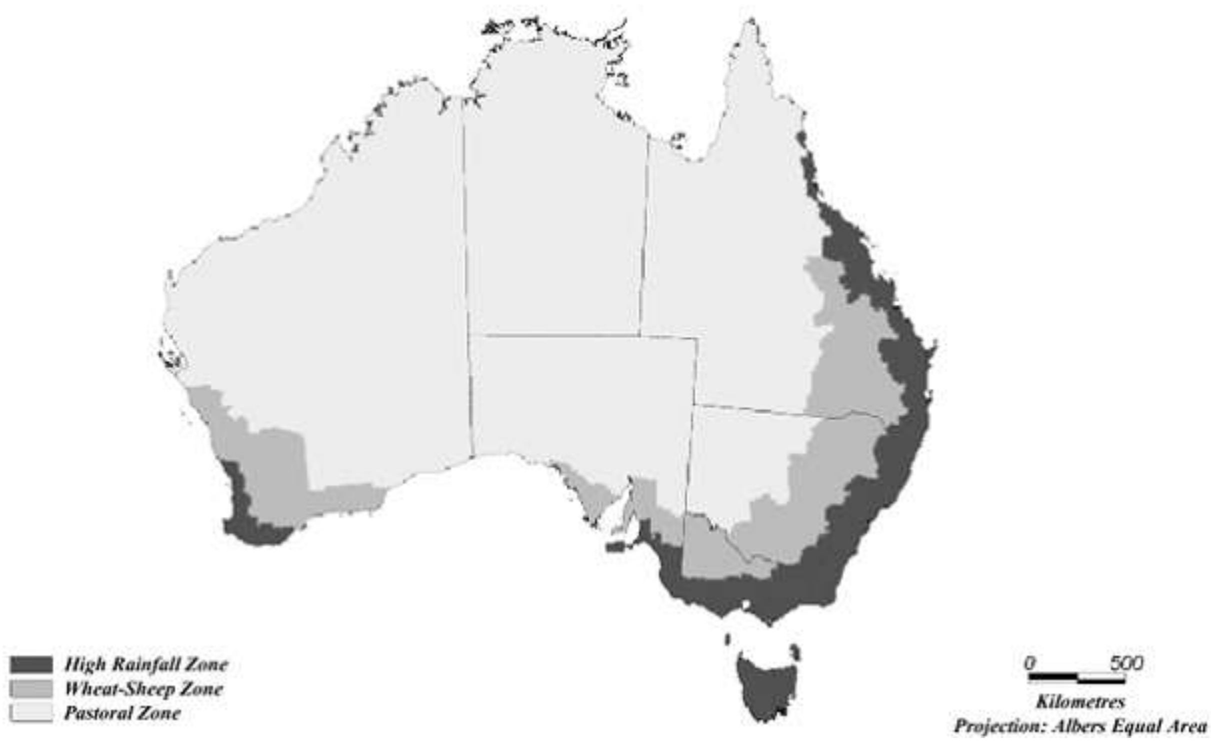


**Figure 1 - Sheep and wool production areas in Australia (from the Land and Water Resources Audit 1999)**

**The general farm context for decisions**

The naming of the WSZ reflects the historical land use, but has been an inadequate description of actual practices for some time (Reeves and Ewing 1993). Crop species other than wheat are now grown and cattle are of increasing importance. Table 1 gives an indication of the wider enterprise elements now integrated into the farming systems and some of the trends that occurred during the last decade. Despite considerable regional variation, there are some common and dominant features of the context within which crop-livestock producers make their decisions. These include:

- Large farms often with significant soil variation.
- A range of crop and pasture choices with yield and production variability across the land units within the farm.
- A history of past treatments that influence current resource status (fertility, soil structure, pasture seed pool, weed, insect and disease status).
- Farm infrastructure (physical and human resources) that is relatively inflexible in the short term but capable of being changed in the longer term.
- A price outlook for products that can fluctuate in both the short and longer term.
- A variable climate.
- Constraints on management influenced by the need to sustain or improve the productive resource base.

**Table 1. Summary of key farm statistics for the WSZ and trends for the decade 1991/2 – 2001/2 (Source ABARE 2003a)**

| **Average per farm** | **Year** | | |
|---|---|---|---|
| | 1991/92 | 1996/97 | 2001/02 |
| Area operated (ha) | 1776 | 1979 | 2078 |
| Total area cropped (ha) | 340 | 427 | 476 |
| Wheat area cropped (ha) | 153 | 224 | 248 |
| Grain legumes area cropped (ha) | 38 | 47 | 49 |
| Oilseeds area cropped (ha) | 8 | 17 | 29 |
| Sheep and lambs shorn (no.) | 1997 | 1770 | 1728 |
| Beef herd (no.) | 151 | 171 | 175 |
| Number of farms | 44052 | 41056 | 38600 |

It is clear from the temporal trends shown in Table1 that farm systems have inherent capacity to change over time. Key recent changes have been:

- An increase in average farm area and an associated reduction in numbers of farm operators.
- An increase in the proportion of farms sown to all classes of crop (cereals, legumes and oil seeds).
- A reduction in the numbers of sheep per farm (nationally flock at 50 year low).
- A modest increase in cattle numbers.

**Table 2. Summary of farm statistics indicating enterprise importance by state for the WSZ for the year 2001/02 (Source ABARE 2003a)**

| **Average per farm** | **New South Wales (NSW)** | **Victoria (Vic.)** | **Queensland (Qld)** | **South Australia (SA)** | **Western Australia (WA)** |
|---|---|---|---|---|---|
| Area operated (ha) | 1595 | 869 | 4263 | 1727 | 2680 |
| Total area cropped (ha) | 321 | 350 | 230 | 590 | 1149 |

| | | | | | |
|---|---|---|---|---|---|
| Wheat area (ha) | 171 | 138 | 83 | 325 | 660 |
| Grain legumes area (ha) | 27 | 44 | 16 | 34 | 156 |
| Oilseeds area (ha) | 27 | 28 | 15 | 18 | 60 |
| Sheep & lambs shorn (no.) | 1791 | 1477 | 529 | 1208 | 3507 |
| Beef cattle (no.) | 172 | 60 | 526 | 29 | 80 |
| Number of farms | 14665 | 6752 | 6120 | 5032 | 6031 |

A whole of zone analysis masks some of the regional differences in farm operations across the WSZ. Some of this difference is captured by looking at individual state summaries where the influences of climate, soils and past histories are more clearly evident (Table 2).

Key differences documented in Table 2 include:

- Farm size differences. In particular, Vic. has substantially the lowest farm size but highest crop yields.
- High crop proportion in WA, SA and Vic. compared to Qld and NSW.
- Wheat proportion highest in WA and SA.
- Grain legumes (in particular lupins) most important on WA farms.
- Cattle enterprises most prominent in Qld and NSW.
- Oilseeds (mostly canola) of growing importance (from Table 1) and regionally most prominent in Vic., NSW and WA.

**Nature of integration**

The national or regional summary of land uses gives limited insight into the nature of the crop-livestock integration that exists on farms or its biophysical and economic drivers. Such insights are best obtained though analysis of individual farm level processes. Some aspects of integration are captured at paddock scale but additional integrative elements occur at the whole-farm level.

At paddock scale the broad choices are between:

- Continuous crop
- Crop-pasture rotation
- Continuous pasture

This simple choice belies the array of options and configurations that are possible for an individual paddock in any year. For a particular paddock, the choice of crop type would be influenced by yield, cost and price factors as well as rotational transfer factors (Table 3 (a) and (b)).

Continuous crops sequences would now include crop legumes (Siddique and Sykes 1997) and oilseeds, as well as cereals. The recent adoption of such system means that long-term sustainability is yet to be established. Permanent pastures are complex entities but are generally established on areas unsuited for cropping due to factors such as slope, infertility, waterlogging and salinity. They vary greatly in their composition and productivity. Influential factors include whether they contain mainly native species or have been sown with exotic species and fertilized. Also of importance is the extent of perenniality and whether a significant legume component is present.

Paddock scale integration occurs with crop-pasture rotations. The extent of interaction between the crop and pasture phases of rotations depends on whether there is continuity between pasture elements of the rotation. In the past it has been common for the pasture, once sown, to regenerate following crop without re-sowing. This was called ‘ley farming’ and has been distinguished from ‘phase farming’ where the expectation is that pasture will be re-sown at the commencement of each pasture phase. Phase farming allows more flexibility in the length of the crop sequence and allows legume and oilseed crops to be sequenced with cereals without impacting on the ability of pasture to grow following the crop phase (Reeves and Ewing 1993). Pastures sown into a phase system can be either annual or perennial but will generally contain a legume because of the advantages for subsequent crops of any nitrogen fixation.

**Table 3. Categories of information needed for decisions on integrated crop-livestock enterprises (adapted from Pannell 1995)**

| Information type | Information needed for decision |
| --- | --- |
| (a) Short term paddock level option development | 1) Crop yield (and related input responses) |
| | 2) Crop residue (quality and quality) |
| | 3) Pasture production |
| | 4) Input costs for production systems |
| | 5) Output prices for products |
| (b) Inter-year transfer and rotation factors (positive and negative) | 1) Nitrogen fixation |
| | 2) Positive yield benefits (disease, insect soil structure related) |
| | 3) Weed seed pool |
| | 4) Fertiliser residual |
| | 5) Pasture density and seed reserve (-ve following crop) |
| (c) Whole farm factors | 1) Farm size and distribution of soil units |
| | 2) Machinery size and crop/pasture planting windows |
| | 3) Labour availability and cost |

| | |
|---|---|
| | 4) Farmer knowledge and skills |
| | 5) Finance (extent of availability and cost) |
| | 6) Animal feed (quantity and quality distribution pattern) |
| (d) Risk factors | 1) Yield variation (climatic and biotic factors) |
| | 2) Price variation (market) |
| | 3) Risk profile (personal) |
| | 4) Response capacity (flexibility) |
| (e) Sustainability factors and constraints | 1) Pasture (persistence and re-sowing requirement) |
| | 2) Weed (herbicide resistance and herbicide residues) |
| | 3) Soil degradation (salinity, acidification, wind and water erosion, nutrient decline, loss of biological activity, non-wetting) |
| | 4) Off site impacts (salinity, biodiversity) |

**Farm level decision making and MIDAS analysis**

The full benefits of integrated crop-livestock enterprises are not captured unless management decisions encompass the full array of complexities outlined in Table 3. Traditional economic comparison of options undertaken as paddock scale gross margins would typically concentrate in areas covered in section (a) of Table 3 and may include some consideration of aspects of section (b).

MIDAS (Model of an Integrated Dryland Agricultural System) and a closely related model (PRISM) have been developed (Morrison *et al.* 1986) to accommodate the complexity outlined in Table 3. For a case study farm with a specified set of physical, financial and human resources, the MIDAS model selects the profit maximizing set of activities from the wide array of options (Kingwell and Pannell 1987). Model analysis has shown that interactions play an important role in the selection of optimum strategies and should not be ignored (Pannell 1987). MIDAS deals comprehensively with issues outlined in parts (a), (b) and (c) of Table 3 and sustainability is added, in part, by constraining the model to solutions that minimize soil losses from erosion (stipulate minimum surface residues). Price and personal risk issues, as well as flexible response strategies are analysed through model output that investigates sensitivity to changes in key variables such as product price (Ewing *et al.* 1987).

In this section we use MIDAS model simulation outputs as examples of typical crop-livestock farm strategies. Two West Australian regional versions of the model are used. The Central Wheatbelt Model (CWM) is a case study of a low rainfall farm (350 - 400mm annual average rainfall) while the Great Southern Model (GSM) is typical of the high rainfall crop-livestock zone (550 - 600mm annual average rainfall).

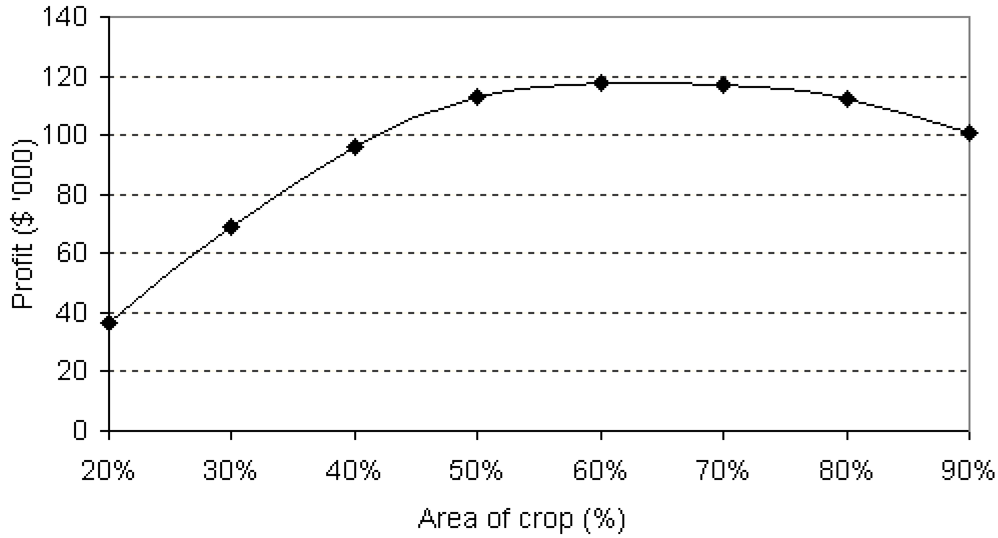


**Figure 2. Relationship between area of CWM farm sown to crop and whole-farm profit at 2004 commodity prices (see Table 5 for price details).**

Profit is maximized for the CWM at a cropping proportion of 60%, in line with current practices in the target zone (Figure2). The profit maximizing strategy selected for each of the key soil units identified are shown in Table 4. Figure 2 shows the maximum profit achievable for the CWM when it is constrained to set ratios of crop and pasture.

**Table 4. Soils types of the low rainfall cropping zone (CWM) in Western Australia, and land use and annual profit associated with the most profitable rotation.**

| Soil Description | Soil Texture | Typical surface pH range ($CaCl_2$) | % occurrence on typical farm | Optimum rotation selected | Shadow price of land* ($/ha) |
|---|---|---|---|---|---|
| Poor sands | Sand | 5 - 6 | 7% | P | 70 |
| Average sandplain | Sand | 5 – 6.5 | 11% | P / WWL | 82 |
| Good sandplain | Loamy sand | 5 -6.5 | 18% | P | 180 |
| Shallow duplex soil | Sandy loam over clay | 5.5 - 6.5 | 11% | WWFp | 128 |
| Medium heavy | Sandy loam | 6 - 7 | 10% | P | 181 |
| Heavy valley | Clay | 7 - 8.5 | 10% | WWFp | 172 |

| | | | | | |
|---|---|---|---|---|---|
| floors | | | | | |
| Sandy surfaced valleys | Sand over clay | 6 - 7 | 15% | WWFp | 119 |
| Deep duplex soil | Loamy sand over clay | 6 - 7 | 19% | WCWL | 139 |

P – Continuous annual pasture; C – Canola; W – Wheat; Fp – Field pea; L – Lupins
* shadow price is the increase in whole-farm profit from the addition of one extra ha of the soil type.

Several features emerge from this model simulation. Land uses strategies vary for the different soils identified for the model farm (Table 4) and include continuous crop, crop pasture rotations and continuous pasture. These were associated with contrasting profitability (range $70 to $181). While profit was maximized at 60% of the farm as crop, there was little profit difference in the range 50-80% of the farm as crop (Figure 2). If the current strategy falls in this range there is little financial incentive to change. The commonly observed plateau of profit allows producers to adopt a conservative strategy to change, only adjusting their plan when there is there is clear evidence of a substantial and sustained redirection in underlying conditions (economic or technological). This profit stability across a range of activity mixes is likely to be increasingly important, since increased price volatility has been predicted to occur in the future (Kingwell 2002).

Not all farms have soils in the proportion of the model farm and this can produce differences in the farm level strategy. Adjusting the proportion of soil types in the CWM to include a higher proportion of heavier textured soils results in a higher optimal crop level than for the standard above. Conversely, altering the proportion to include a higher proportion of light textured sandy soils results in a lower optimum crop percentage (data not shown).

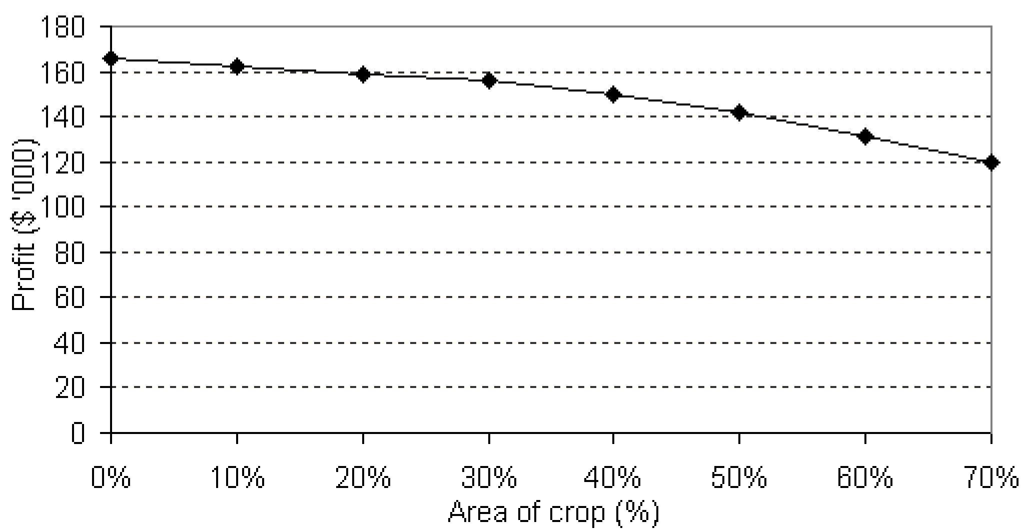


**Figure 3. Relationship between area of GSM farm sown to crop and whole-farm profit at 2004 commodity prices (see Table 5 for price details).**

The GSM output (Figure 3) produces a contrasting result to the CWM, with the highest profit occurring with no cropping at the high rainfall edge of the crop-livestock zone. However, like the CWM profit changes are small over a substantial range, in this case up to 40% of the farm as crop. This outcome reflects the poor crop yield potential in this region compared to pasture production despite significant technological advances with cropping in high rainfall zones (Poole 1998).

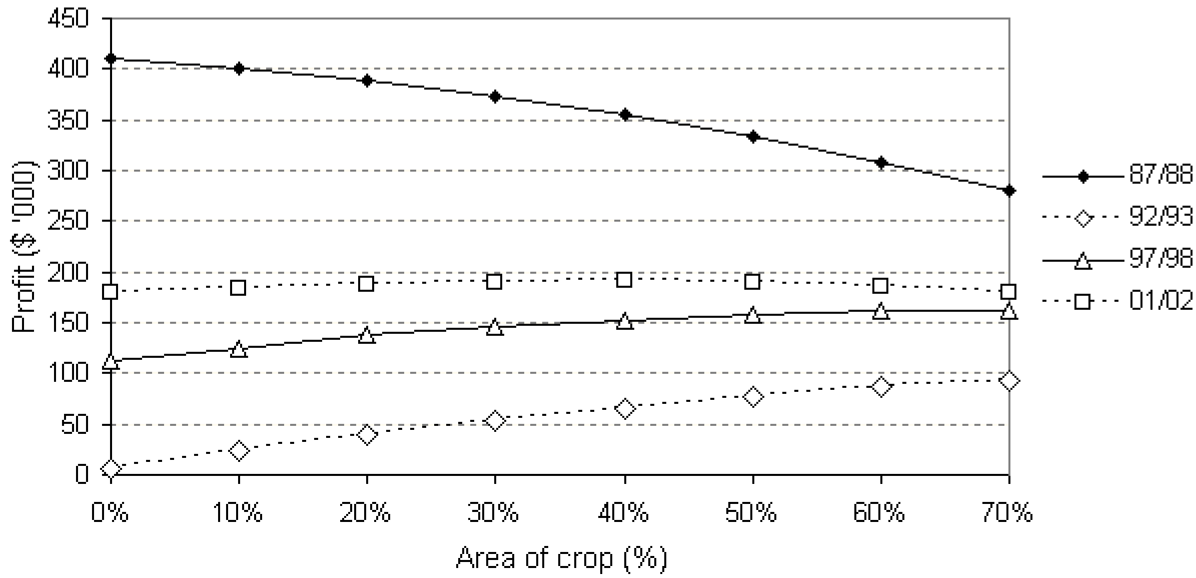


**Figure 4 Relationship between GSM whole-farm profit and area of crop using product prices prevailing at 4 times since 1987/88 (see Table 5 for commodity price details).**

The current relationship between percent crop area and profit for GSM (Figure 3) resembles the shape of the curve during the wool boom of the late 1980s (Figure 4), although the absolute whole-farm profit is different. However, in the intervening period livestock prices have been low in absolute terms and low relative to crops for a sufficient length of time for producers to change their system to include crops (Poole 1998). Having invested in equipment and the skills base to undertake cropping, these producers are now unlikely to return to a totally livestock enterprise unless the current relative price trends are sustained for a lengthy period. This supports the observed increase in cropping reported for the WSZ as a whole in farm surveys in Table 1.

The protracted period of unfavourable economic conditions for livestock during the 1990s resulted in reduced sheep numbers. However, the most recent analysis (Figure 2) indicates the likelihood of a change back to increased pastures and livestock. Product prices listed in Table 5 make it clear that meat production rather than wool production is responsible for the substantial profit improvements for both regions shown, a trend that is predicted to be sustained (CIE 2001).

**Table 5. Prices of key crop and livestock products for the period 1987/88 to 2001/02 adjusted for inflation to 2001/02 (Source: ABARE 2003b).**

| **Commodity** | **Prices (in 2001 $)** | | | | |
|---|---|---|---|---|---|
| | I987/88 | 1992/93 | 1997/98 | 2001/02 | Standard* (2004) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Wheat | $/t | 252 | 240 | 218 | 247 | 215 |
| Feed barley | $/t | 226 | 203 | 233 | 243 | 215 |
| Canola | $/t | 481 | 419 | 493 | 400 | 400 |
| Lupins | $/t | 278 | 244 | 221 | 240 | 210 |
| Oats | $/t | 172 | 132 | 193 | 191 | 145 |
| Field peas | $/t | 377 | 308 | 307 | 288 | 220 |
| Chickpeas | $/t | 480 | 475 | 552 | 500 | 320 |
| Mutton | c/kg DW | 68 | 36 | 85 | 146 | 122 |
| Shippers | $/hd | 36 | 18 | 30 | 60 | 50 |
| Lamb | c/kg DW | 202 | 165 | 226 | 266 | 300 |
| Wool EMI | c/kg clean | 1760 | 651 | 829 | 841 | 760 |

* Source: ABARE (2004)

**Challenges and opportunities for crop-livestock integration**

Dunlop *et al.* (2004) have comprehensively explored the challenges and possibilities facing broadacre agriculture using scenario analysis and highlighted hazards associated with predicting the future. Despite such difficulties a number of key challenges and related opportunities are likely to strongly influence the extent and nature of mixed crop-livestock farming systems.

*Terms of trade*

Fundamental to an understanding of the future challenges facing crop-livestock farmers is the near certainty that current practices and strategies will be inadequate for the future because of the on-going downwards trend in terms of trade (Figure 5). The long-term trend is downward at an average of 2.2% a year.

While the general trend is downward, crop-livestock farm decisions are likely to be influenced by relative changes in input costs and prices of the key enterprise components which may not all decline at a uniform rate. For instance some analysts are predicting that meat price will rise in real terms during the coming decade (CIE 2001). Such a trend, if sustained over time, would result in a re-balancing of the crop-pasture ratio in favour of increased pasture.

There is substantial uncertainty and disagreement about the future direction of energy costs (Dunlop *et al*. 2004). High levels of mechanization and dependence on nitrogen fertilizer (Angus 2001) expose crop dominant systems to high energy costs. If energy prices increase, the crop-livestock system is likely to adjust to make greater use of leguminous pastures (i.e. less crop area and less nitrogen fertilizer).

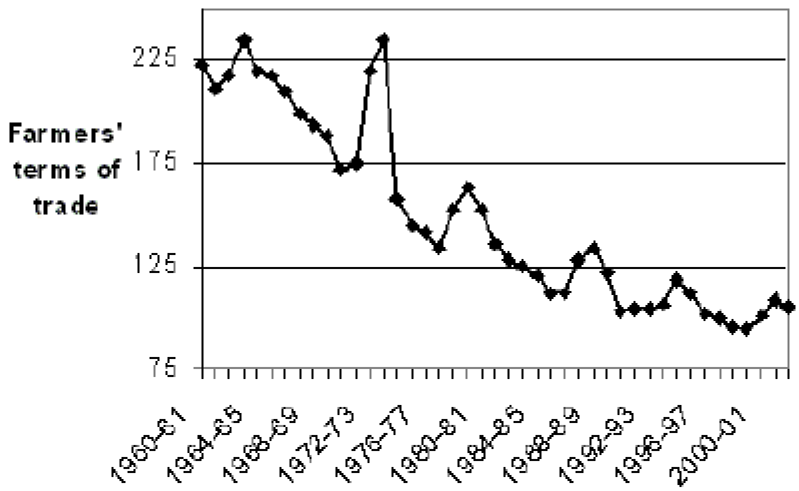


**Figure 5: Farmers' terms of trade. Base year 1997-8 = 100. (Source: ABARE, 2003b)**

*Requirement for innovation and diversification*

Productivity and profitability of farming systems are challenged by biotic pressures and threats, resource degradation and unfavourable terms of trade. To offset this, continuous innovation is required. Mullen (2002) has indicated that without productivity growth in the last 30 years, Australian agriculture would have declined to less than 30% of current levels. Sector productivity growth has been variable, with productivity growth associated with cropping being greater than that associated with livestock enterprises (ABARE 2003a).

In the past crop-livestock production systems have evolved rapidly to adopt innovation and increased diversity (Reeves and Ewing 1993). The introduction of alternative crops such as pulses (Siddique and Sykes 1997) and oilseeds has been a key element of improved productivity. The impact of such innovations and the clear profit-driven motivation for change are demonstrated in Figure 6. Without the grain legume option, in this CWM case study lupins and field peas, the predicted farm profit is more than $40,000 less and the optimum proportion of the farm as crop is 50% rather than 65%. For this case study canola has little profit impact but in other regions the adoption of canola has been important in increasing profit (Angus 2001).

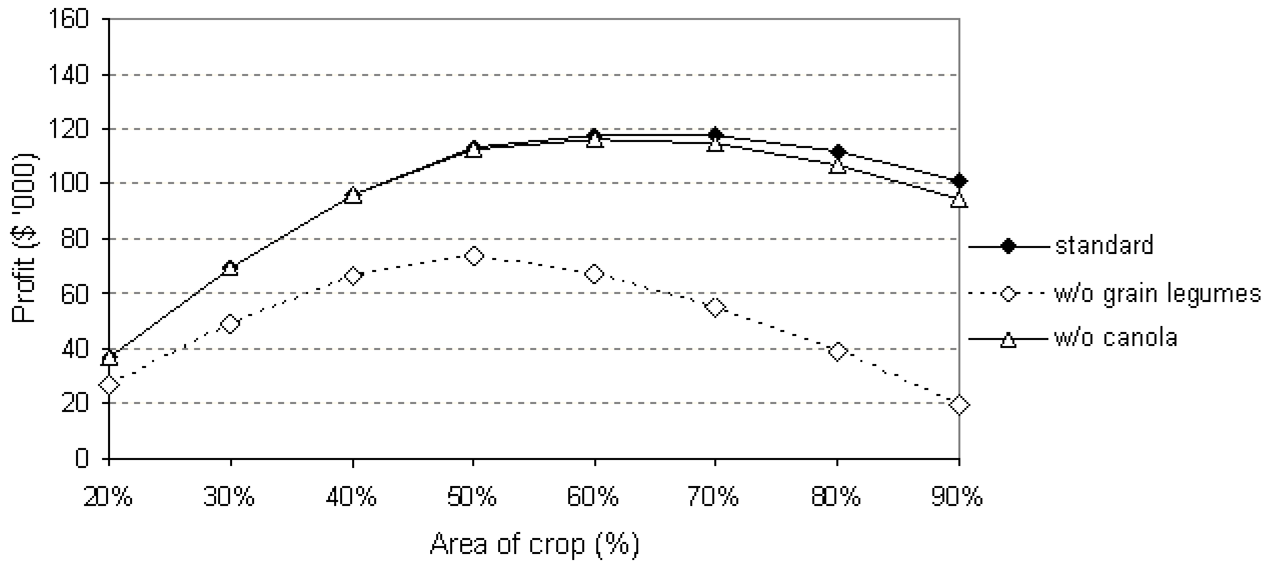


**Figure 6. Relationship between CWM farm profit and area of crop with and without canola and grain legumes included as production options (see Table 5 for current commodity price details).**

There will be a continuing incentive to seek new crop and pasture options within the crop-livestock production system to match innovations from the recent past. Some innovations offer immediate promise such as the possibility to increase production of forages for on-farm use and transfer from farm to farm or export (Zhou 2004). Outcomes of other options such as diversification into forestry and agroforestry will be dependent on the trends in commodity and energy prices and the development of markets and associated regional infrastructure (Bartle and Shea 2002).

*Herbicide resistant weeds*

Crop-only systems of production have emerged at both paddock and farm level as a result of economic influences and advances in crop technology (Angus 2001). Where such systems have been consistently in place for an extended period, challenges to productivity and profitability are emerging from increased difficulties associated with weed management. Herbicide resistant populations of weeds have been induced by repeated applications of commonly used herbicides. Preventing and combating this hazard requires a weed management strategy involving integration of an array of different weed control techniques (Pannell *et al*. 2004(a)). A key option amongst such strategies is the introduction of a pasture phase into the crop sequence. This allows weed populations to be drastically reduced using a combination of treatments involving cultivation, selective and non-selective herbicides, grazing and mowing. Modelling of such systems indicates that in many circumstances it will be difficult to sustain crop-only systems in the longer term and a phase of pasture with associated livestock will be required (Monjardino *et al.* 2004).

Natural variation in palatability amongst pasture plants can be used to enhance the weed control impact of grazing. Sowing species of low palatability compared to the target weed encourages selective weed removal and enhances competition from the sown plant. Use of the recently released annual pasture legume species *Biserrula pelecinus* L. cv. Casbah has been demonstrated to be effective in enhancing weed removal, compared to alternative annual legumes such as annual medics (Thomas *et al.* 2003) and this highlights an important future opportunity for pasture breeding. Use of a phase of perennial pasture species such as lucerne (*Medicago sativa* L.) allows targeted weed management opportunities associated with both differences in tolerance of the perennials, once established, to non-selective herbicides and differences in the palatability.

*Sustainable production systems*

Given the finite land resource in our target zone, the average length of exposure of the land to the degradative processes associated with farming is increasing steadily, undiluted by the addition of substantial areas of new land (Dunlop *et al.* 2004). As a result, problems associated with acidity, salinity, soil structural decline and erosion (Poole 1998) can be expected to increase. Active strategies will be required to maintain the resource base.

Greater use of perennial plants has been widely advocated because of their broad sustainability advantages (Lefroy *et al*. 1999) with particularly positive impacts on salinisation and soil acidification (Cocks 2003). In the short and medium term, large scale use of perennials is likely to be linked to livestock production systems because of the lack of perennial crop options. A move to greater use of perennial plants is thus likely to be associated with consolidation of integrated crop-livestock farming systems (Ewing and Dolling 2003).

Future adoption of perennial plants will be driven by both the availability of technologies (Bennett *et al*. 2003, Dear *et al.* 2003) and its profitability (Pannell *et al*. 2003(b)). Lucerne is the most developed and widely applicable species (Kingwell *et al.* 2003). Prospects for its wider use are supported by economic analysis of its profitability with the current CWM model farm, which is located in a zone in which lucerne is currently rarely used because its benefits have yet to be widely understood and demonstrated. Using production assumptions resulting from recent experiments and on-farm experience combined with current commodity prices, model outputs indicate a case for profitability driven adoption with approximately 12% of the farm sown to lucerne at the profit maximizing proportion ratio of crop and pasture (Figure 7).

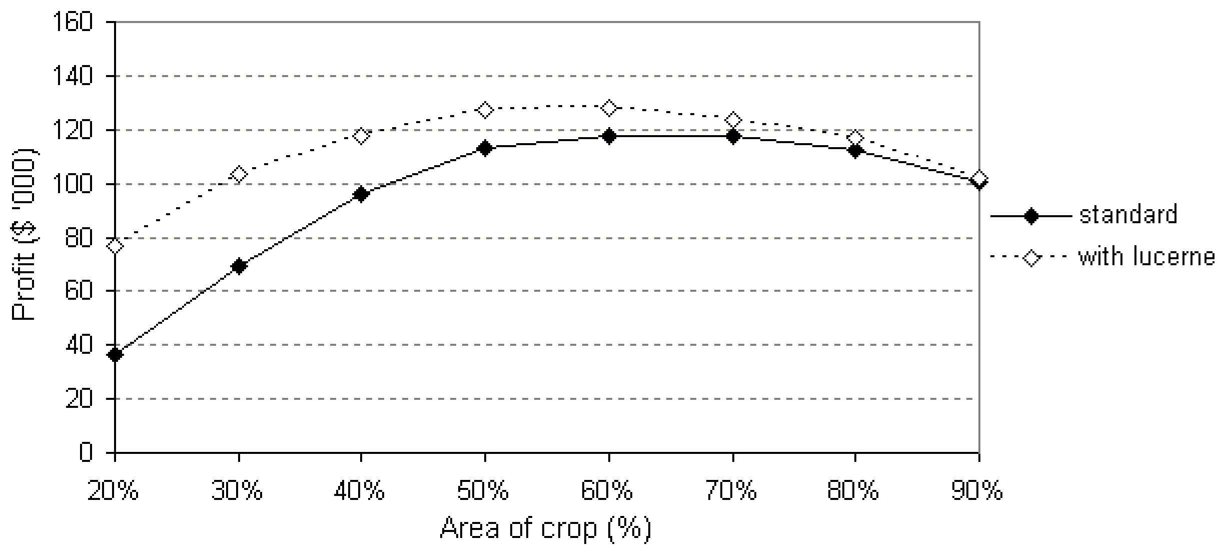


**Figure 7. Relationship between CWM farm profit and area of crop (%) with and without lucerne included as production options (see Table 5 for current commodity price details).**

The key challenges associated with the wider use of perennial pastures include:

- Development of an array of plants to compliment lucerne and provide profitable options for the full range of soils and climates where crop rotations are practiced.
- The development of perennial species and systems (herbaceous or shrubby) suited to low productivity areas where cropping is currently practiced to replace annual dominated systems.
- The modification of livestock production systems to maximize the profit impact of increased use of perennial plants.

*Responding to climatic variation*

Mixed crop-livestock production systems embody seasonal risk reducing elements, but it is possible to further reduce risks by tactical decisions made in response to emerging climatic scenarios (Kingwell *et al*. 1992; Sadras *et al*. 2003). Producers commonly adjust the extent and nature of their crop program in response to pre-sowing conditions and, post sowing, similarly adjust the level of inputs, particularly N fertilizer (Angus 2001). Indications are that profit can be enhanced by as much as 20% by responding logically to emerging seasonal scenarios (Kingwell *et al.*1993). More flexible and responsive systems will emerge from:

- Better methodologies for measuring pre-decision conditions and predicting the potential of alternative land uses (drawing particularly on experience in northern cropping systems, e.g. Keating *et al*. (2003)).
- Strategies that deliver more flexible year to year sequencing.
- Low input options that can be applied in years of particularly low potential.
- Better climatic predictions.

The wider use of phase pastures (Reeves and Ewing 1993) which disconnects one pasture phase from the next, allows greater flexibility in crop choice within a year and in the length of the crop phase. With a phase system it is possible to shift from a growing season length sensitive crop such as canola to a less sensitive crop such as wheat with a minimum of disruption. Additionally, it is possible to extend the cropping sequence by a year if pre-sowing conditions are favourable. Pasture re-sowing would then be postponed by a year. In self-regenerating pasture systems, extending the length of the crop phase may reduce seed reserves beyond the regeneration threshold, thereby disrupting the system.

In seasons with poor growth potential, generally associated with the late start of season rains, demand for forage is high and transfer of resources from crops to pastures can reduce losses. However, areas prepared for crop have low inherent potential as pasture if weed control preparation has been efficient. Traditional low density pasture sowing is unlikely to be economic and a low input, but responsive, system is required. The recent development of a new annual pasture legume, French serradella (*Ornithopus sativus* L.), has provided a model of a forage legume that can be established at high density but low cost from seed produced and stored on farm. Sowing can take place when it is clear that an economic crop is not possible. Tactical use of a forage legume in this way generates direct benefits from feed supply in a feed limiting scenario as well as providing nitrogen fixation and the potential for weed management. There is a need to develop other low input forage legumes that suit the full array of soils and climates of the mixed crop-livestock zone, for similar tactical use in farming systems.

**Conclusions**

Most mixed crop-livestock producers have made the logical decision to increase the proportion of their farms allocated to cropping following more than a decade of economic conditions favouring crop compared to livestock. At the same time, they have adopted an array of new technologies that have diversified their production base and increased productivity. A small proportion of farmers have ceased livestock production and some livestock producers have introduced cropping to their enterprises for the first time.

Economic conditions have now shifted to the extent that if current relativities applied for an extended period, increased livestock production would be anticipated. The market prospects for livestock-based commodities, particularly meat, make this a likely scenario. However, the complementarity between crop and livestock components means that low profit differences between a wide array of strategies buffer against rapid shifts, particularly where fixed investments in infrastructure are in place or required for change.

The economic advantages of increased cropping are also associated with emerging problems, the most notable being the emergence of herbicide resistant weeds. Effective management of this problem is greatly enhanced though the use of a phases of pasture, further emphasizing the complimentary links between crop and livestock production.

The increased need to deal directly with sustainability challenges and advantages associated with perennial-based production systems linked to livestock, are another driver towards evolving production systems that retain both crops and animals.

The integrated crop-livestock production system has been resilient, flexible and responsive to economic fluctuations and technical innovation, but must evolve further to meet the certainty of further change and the challenges of sustainable production.

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