Production, economic and environmental benefits of leucaena pastures

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Abstract

The rate of adoption of leucaena (Leucaena leucocephala)-grass pastures is rising rapidly in northern Australia as graziers realise the extent of the triple-bottom-line benefits. Leucaena pastures are suited to >13 M ha of Queensland, with a current estimated 150 000 ha producing 37 500 kg of liveweight gain valued at >$69 M each year. Despite high costs of establishment, this area is expected to expand to 300 000–500 000 ha by 2017. The main factor driving high levels of adoption is the ability of leucaena pastures to meet graziers’ needs for a highly productive and profitable system that meets market requirements for grass-fed beef of superior quality. Production benefits include: increased animal production/ha (up to 4-fold) resulting from a combination of greater animal liveweight gains and increased carrying capacity; longevity (30–40 yr); and potential to intensify production within the constraints of recent changes to the Queensland Vegetation Management Act and escalating land prices. Other benefits are: increased marketing flexibility; superior capital appreciation of leucaena pastures; and positive animal welfare outcomes.

Social factors are also important, with many farmers converting marginal dryland cropping cultivation to leucaena pasture owing to concerns about the impact of drought, global warming, and decreased profitability and sustainability of dryland farming. Importantly, technical information regarding the establishment and management of leucaena pastures is now available to graziers, giving them the confidence to adopt the technology.

Environmental benefits include: dryland salinity mitigation; soil erosion control and improved water quality; improved soil fertility through biological nitrogen fixation; and greenhouse gas mitigation. Given an average season, existing leucaena pastures fix approximately 7500 t N and reduce cattle methane emissions by approximately 91 000 t carbon dioxide equivalent carbon (CO₂-e) annually. These pastures also have the potential to sequester >4 M t of CO₂-e. However, leucaena is an environmental weed in northern Australia, largely as a result of its historical introduction and use as an ornamental and for slope stabilisation. While most current weed infestations are not due to grazier plantings, a voluntary Code of Practice, where graziers take responsibility for any spread from their properties, has been developed to limit seed production and dispersal. Soil acidification will not be a problem on the alkaline clay soils (high pH buffering capacity) in Queensland where most leucaena pastures are planted. There is need for greater factual appreciation of the environmental aspects of large-scale leucaena plantings, and for a thorough cost:benefit analysis to be conducted.

Background

Current developments with leucaena in Australia

Leucaena leucocephala (leucaena)-grass pastures are the most productive, profitable and sustainable ‘pasture-fed’ option for cattle production in northern Australia. There are currently >120 000 animal equivalents (AE = 450 kg steer)/yr grazing approximately 150 000 ha of leucaena in Queensland. At the current rate of adoption, the area planted is expected to reach 300 000–500 000 ha within the next 10 years. GIS analysis of the principal catchments in Queensland shows that there are approximately 13.5 M ha suitable for planting leucaena.
represented by the Burdekin (2.8 M ha), Fitzroy (4.7 M ha), Burnett (0.9 M ha), Mary (0.3 M ha), Brisbane (0.5 M ha), Condamine (3.6 M ha) and Border Rivers (0.7 M ha) catchments (M. Shelton, unpublished data). These data are based on the areas of soil types of moderate-high fertility to which leucaena is best suited, e.g. (a) deep loam and duplex soils of moderate fertility; (b) deep highly structured soils of high initial fertility; (c) calcareous soils; (d) cracking clays; (e) non-cracking clays; and (f) uniform soils.

While most of the leucaena planted to date is located in central Queensland, increasing areas of leucaena are being planted in southern Queensland, particularly around Wandoan, Chinchilla, Tara/Meandarra and as far south as Goondiwindi. The psyllid insect pest (Heteropsylla cubana) has restricted the expansion of leucaena pastures into humid (>800 mm annual rainfall) coastal areas of the state. The release of new psyllid-resistant varieties of leucaena in 2010 will overcome this problem (Dalzell et al. 2005), allowing graziers to realise the full production potential of the system in an additional 1.2 M ha of coastal Queensland (Coates 1997).

The area of irrigated leucaena is also increasing in Queensland. Irrigated leucaena increases beef production by 3–6 fold, compared with dryland plantings, to 1000–1500 kg liveweight/ha/yr (Petty et al. 1994). This is achieved through increased carrying capacity. Leucaena irrigators are planning to use 4–6 ML/ha/yr to strategically supplement rainfall (Dalzell et al. 2006), similar to average water application rates to pastures for hay/silage making (4.9 ML/ha/yr), sugarcane (5.3 ML/ha/yr) and cotton (6.9 ML/ha/yr) in Queensland (Trewin 2006) and much less than the 29 ML/ha/yr used in the Ord River Irrigation Area during the 1990s (Petty et al. 1994). Irrigated leucaena is an evolving production system and graziers are tackling technical issues such as: planting configuration (row spacing); maintaining adequate grass cover and level of roughage in the diets of cattle at high stocking rates (4 AE/ha); balancing dietary protein:energy ratios by providing energy supplements (hay, silage or molasses); and evaluating a variety of grazing strategies, e.g. cell grazing, rotational grazing and access to adjacent grass paddocks.

The successful adoption of leucaena in Queensland can be directly related to the same 5 key factors highlighted by Shelton et al. (2005) in their review of adoption of tropical forage legume technology around the world. These are: the technology meets the needs of farmers; relevant partnerships have been developed between farmers and R&D&E agencies; the socio-economic context and skills of farmers have been understood; participatory involvement with rural communities has occurred; and there has been commitment from long-term champions of the technology. Specific issues for leucaena adoption are now discussed.

Large areas of leucaena are being planted into previously cropped country, much of it productive farming land, e.g. the cultivated downs country around Emerald, Capella and Clermont, which was previously used for wheat/sorghum cropping. This change in land use is being driven by a number of factors including: (a) recent unreliability and poor profit margins from dryland cropping compared with good returns from a buoyant beef industry with a good medium to long-term future; (b) increasing market demands and price incentives for premium grass-fed beef (domestic MSA and export market price grids); (c) a growing need to intensify production as escalating land prices make pasture improvement more attractive than buying more land to expand beef enterprises; and (d) State Government Vegetation Management Act regulations which limit further development of pastures by prohibiting tree clearing. Leucaena pastures are also well suited to economically marginal lands not suitable for large-scale mechanised cropping, due to small property or paddock size, steep slopes subject to soil erosion, run-down in soil fertility (particularly N) and marginal/unreliable rainfall. One major advantage of leucaena is its drought tolerance, with its deep roots giving it the ability to produce high quality leaf during dry times. This gives graziers flexibility to handle drought and reduces their dependence on protein/urea supplementation during the winter dry season.

Social factors also drive the adoption of leucaena pastures with many aging farmers wanting a more relaxed lifestyle by moving away from high-risk, labour-intensive farming to become cattle managers. Some farmers have increasing concerns over frequent/persistent droughts and the impact that global climate change might have on the future of dryland cropping.

In the past, high rates of establishment failure deterred graziers from attempting to plant leucaena for the first time (Lesleighter and Shelton 1986), but technical advances in establishment
practices have overcome these problems. This information has recently been made available to graziers through training courses and the publication of the practical manual *Leucaena — A guide to establishment and management* (Dalzell et al. 2006). In the last 4 years, more than 380 graziers, natural resource managers, consultants and extension workers have attended *Leucaena for Profit and Sustainability* training courses co-ordinated by The University of Queensland.

Environmentally, leucaena can deliver a number of benefits, including prevention of dry-land salinity, carbon (C) sequestration, reduction in soil erosion and enhanced quality of runoff water. Some catchment groups now provide financial incentives for farmers to engage in community catchment landcare programs such as converting vulnerable marginal cropping paddocks (sloping degraded land) into productive permanent pasture, e.g. cash subsidies for pasture seed provided by the Jimbour-Brigalow Floodplain Group.

**Production benefits**

*Improved animal nutrition and pasture growth*

Tropical grass pastures, even on fertile soils, do not contain enough protein to enable cattle to gain weight quickly and consistently throughout the year. For instance, to achieve a target of 300 kg LWG/hd/yr, 12–13% crude protein (CP) in dietary dry matter (DM) is required. Crude protein levels in tropical grasses rarely exceed 10% DM and only following the break of the season. Both CP and digestibility drop dramatically to 5–8% DM and 45–50% DM, respectively, as the pastures mature. By contrast, leucaena forage contains 20% crude protein, is highly digestible, and provides a consistently high quality diet throughout the year.

Another limiting factor is the shortage of soil mineral nitrogen (N). All Australian soils are deficient in N, even those which previously carried brigalow (*Acacia harpophylla*) scrub and were of high initial fertility. Most agricultural systems have experienced soil nutrient depletion after decades of cropping or grazing and erosion of topsoil. Furthermore, soil N under grass pastures becomes immobilised and unavailable in carbon-rich soil organic matter that accumulates over time. This process is called pasture run-down. Higher animal production can be temporarily achieved by mineralising soil organic matter, for example when brigalow pastures are blade-ploughed. Applying N fertiliser is another option where adequate soil moisture enables the grass to efficiently utilise the added N. However, a longer-term, more-sustainable and cost-effective solution to pasture run-down is to add a vigorous forage legume to the pasture to boost soil N levels by biological N fixation. Leucaena pastures can fix >75 kg N/ha/yr (equivalent to 150 kg urea/ha/yr) some of which is cycled to the pasture via animal dung and urine during grazing.

**Rapid animal growth rates**

Australia’s major beef export markets such as Japan, Korea and the European Union require cattle that grow quickly throughout their lives and reach target weights at a young age. Typical market specifications for grass-fed animals in Australia (2006) are shown in Table 1. For example, a premium 600 kg Jap Ox steer 2–2.5 years of age must grow at an average of 0.6–0.8 kg/d. This is difficult for graziers in northern Australia to achieve without significant protein and energy supplementation, as animal nutrition fluctuates widely throughout the year due to highly variable rainfall, severe annual dry seasons and the typical decline in forage quality (protein concentration and digestibility) of tropical grasses with maturity. Steers in central Queensland grazing brigalow pastures of buffel grass (*Cenchrus ciliaris*), rhodes grass (*Chloris gayana*) and green panic (*Panicum maximum*) gain only 140–190 kg LW/yr, while leucaena-fed steers gain 250–300 kg LW/yr (Table 2). Thus, steers grazing leucaena pastures can grade Jap Ox at 24–30 months of age (2- or 4-tooth), 6–12 months earlier than those on straight buffel grass. Typical ‘kill sheets’ of cattle fattened on leucaena-grass pasture from throughout Queensland illustrate the ability of leucaena pastures to achieve these targets (Table 3). While the majority of cattle slaughtered for export in Queensland do not graze leucaena, leucaena-fed animals have significantly increased carcase value and businesses utilising leucaena have a higher rate of steer turnover, which combine to significantly boost enterprise profitability.
Increased carrying capacity

Leucaena pastures can be grazed at higher stocking rates than grass pastures, resulting in levels of beef production per hectare up to 4 times that from rundown buffel grass pasture (Table 2). Very high values for annual liveweight gain off dryland leucaena pastures have been obtained. Robert Ryan, ‘Kelor Downs’, Taroom, grazed 150 steers on 150 ha of prime leucaena-buffel pasture for 12 months in an average rainfall year starting February 2004. The steers, with hormonal growth promotant implants (HGPs) and receiving no other supplements, gained 357 kg/hd over 374 days (0.95 kg/hd/d or 348 kg/ha/yr). It is likely that lower levels of animal production (kg LW/ha) will result from leucaena pastures grown in southern Queensland, where leucaena forage supply will be constrained by a shorter active growing season due to cooler ambient temperatures and a longer period where frosts may defoliate leucaena.

Table 1. Australian market specifications for grass-fed cattle (as at mid-2006).

<table>
<thead>
<tr>
<th>Market</th>
<th>Live wt (kg)</th>
<th>Dressed wt (kg)</th>
<th>Fat (^1) (mm)</th>
<th>Age (months)</th>
<th>Dentition (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jap Ox</td>
<td>518–800</td>
<td>280–440</td>
<td>7–22</td>
<td>&lt;42</td>
<td>0–4</td>
</tr>
<tr>
<td>EU</td>
<td>440–780</td>
<td>240–420</td>
<td>7–22</td>
<td>&lt;30</td>
<td>0–4</td>
</tr>
<tr>
<td>Korean</td>
<td>520–750</td>
<td>280–400</td>
<td>7–22</td>
<td>&lt;42</td>
<td>0–4</td>
</tr>
<tr>
<td>Domestic</td>
<td>250–550</td>
<td>130–300</td>
<td>4–15</td>
<td>&lt;16</td>
<td>0–2</td>
</tr>
</tbody>
</table>

Feedlot entry
- Jap: 350–500
- Domestic: 280–350

Table 2. Average commercial steer performance from a range of pasture systems.

<table>
<thead>
<tr>
<th>Forage system</th>
<th>Average stocking rate (ha/steer)</th>
<th>Annual liveweight gain (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native pasture — northern Qld</td>
<td>10</td>
<td>80–100</td>
</tr>
<tr>
<td>Native pasture-stylo — northern Qld</td>
<td>5</td>
<td>130–165</td>
</tr>
<tr>
<td>Native pasture — central Qld</td>
<td>4</td>
<td>100–140</td>
</tr>
<tr>
<td>Native pasture-stylo — central Qld</td>
<td>3.5</td>
<td>140–170</td>
</tr>
<tr>
<td>Buffel grass — rundown</td>
<td>3</td>
<td>140–150</td>
</tr>
<tr>
<td>Buffel grass — good condition</td>
<td>2</td>
<td>170–190</td>
</tr>
<tr>
<td>Buffel grass — leucaena</td>
<td>1.5</td>
<td>250–300</td>
</tr>
</tbody>
</table>

Table 3. Summaries of kill sheets of steers fattened on leucaena pastures.

<table>
<thead>
<tr>
<th>Property location</th>
<th>No. steers</th>
<th>Market (^1)</th>
<th>Av. dentition (^2)</th>
<th>Av. fat depth (^3) (mm)</th>
<th>Av. carcase wt (kg)</th>
<th>Slaughter date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>24</td>
<td>EU</td>
<td>1.3</td>
<td>14</td>
<td>292</td>
<td>Nov 05</td>
</tr>
<tr>
<td>Wandoan</td>
<td>10</td>
<td>EU</td>
<td>1.6</td>
<td>15</td>
<td>330</td>
<td>Jan 06</td>
</tr>
<tr>
<td>Monto</td>
<td>33</td>
<td>EU</td>
<td>1.9</td>
<td>15</td>
<td>323</td>
<td>Feb 06</td>
</tr>
<tr>
<td>Mt Garnet</td>
<td>66</td>
<td>Jap</td>
<td>2.0</td>
<td>13</td>
<td>326</td>
<td>Sep 05</td>
</tr>
<tr>
<td>Home Hill</td>
<td>38</td>
<td>Jap</td>
<td>2.2</td>
<td>9</td>
<td>293</td>
<td>2006</td>
</tr>
<tr>
<td>Rolleston</td>
<td>65</td>
<td>Jap</td>
<td>2.6</td>
<td>22</td>
<td>368</td>
<td>May 06</td>
</tr>
<tr>
<td>Rolleston</td>
<td>61</td>
<td>Jap</td>
<td>2.8</td>
<td>15</td>
<td>362</td>
<td>Jun 06</td>
</tr>
<tr>
<td>Taroom</td>
<td>42</td>
<td>Jap</td>
<td>2.3</td>
<td>16</td>
<td>367</td>
<td>Apr 06</td>
</tr>
</tbody>
</table>

Source: Adapted from Dalzell et al. (2006).  
\(^1\) All EU cattle have no HGPs or additional supplements.  
\(^2\) Number of permanent incisors.  
\(^3\) P8 site (rump).
Longevity of leucaena

Leucaena is one of the few tropical legumes that can survive and remain productive for long periods of time (>30 years) under regular grazing (Jones and Bunch 1995). Jones and Bunch (2000) investigated plant mortality in a 40-year-old grazed leucaena pasture and found 74% of the original plants were still alive. Commercial stands are showing similar longevity. John O’Neill on ‘Nyanda’, near Carnarvon Gorge, central Queensland, was among the first group of graziers to invest in broadscale leucaena planting for cattle fattening and his leucaena is still highly productive after 25 years of grazing and annual frosting. This longevity sets leucaena apart from other forage legumes that are adapted to clay soils, such as lablab (Lablab purpureus), lucerne (Medicago sativa), burgundy bean (Macroptilium bracteatum) and butterfly pea (Clitoria ternatea). These legumes need to be replanted every 1–10 years depending upon species, drought incidence and grazing management (Whitbread et al. 2005; Collins and Grundy 2005; Cullen and Hill 2006).

Meat quality

Meat quality of beef produced from leucaena pastures rivals that of lot-fed cattle on the criteria of weight for age, fat depth, fat colour, lean meat yield, meat colour and marbling (Esdale and Middleton 1997). A comprehensive study to compare gains of steers grazing leucaena pastures or buffel grass only or buffel grass followed by a grain-based ration in a feedlot was undertaken in 1996–97 by the Callide-Dawson Beef Carcase Competition Committee as part of Beef ’97. The Beef ’97 Japanese Beef Carcase Feedback Trial involved 51 graziers providing 9–10 steers each (505 in total) comprising over 40 different genotypes (predominantly Bos indicus and B. indicus × B. taurus crossbreds) to the competition. The steers were randomly allocated to 3 feeding systems: 150 days grazing buffel grass (151 steers); 150 days grazing dryland leucaena-grass pastures (153 steers); and 50 days grazing buffel grass followed by 100 days on a grain-based ration in a commercial feedlot (201 steers). Steers were slaughtered in a commercial abattoir and their carcases scored using standard commercial grading methods (Table 4). Seasonal conditions for the trial were good and the pastures were in excellent condition. There was little difference in the carcase attributes of the leucaena cattle and those finished on grain in a feedlot. Fat colour for grass-fed and leucaena-fed carcases was similar, dispelling fears that leucaena causes yellow fat colouration, which downgrades carcases and incurs price penalties. This trial demonstrated that dryland leucaena pastures, in a good growing environment, can produce beef of similar quality to grain-fed animals that meets all export weight-for-age and carcase quality requirements.

Table 4. Liveweight gain and carcase quality attributes of Jap Ox steers grazing buffel grass for 150 days, leucaena-grass pastures for 150 days or buffel grass pasture for 50 days followed by 100 days in a commercial feedlot.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Buffel grass</th>
<th>Leucaena-grass</th>
<th>Buffel + Grain-fed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial weight (kg)</td>
<td>481</td>
<td>463</td>
<td>407</td>
</tr>
<tr>
<td>Final weight (kg)</td>
<td>604</td>
<td>648</td>
<td>618</td>
</tr>
<tr>
<td>Total weight gain (kg)</td>
<td>123</td>
<td>185</td>
<td>211</td>
</tr>
<tr>
<td>Average daily gain (kg/hd/d)</td>
<td>0.83</td>
<td>1.26</td>
<td>1.41</td>
</tr>
<tr>
<td>Dressing %</td>
<td>55.2</td>
<td>54.6</td>
<td>56.4</td>
</tr>
<tr>
<td>Weight for age (points)</td>
<td>9.0</td>
<td>10.6</td>
<td>11.9</td>
</tr>
<tr>
<td>P8 fat depth (mm)</td>
<td>11.1</td>
<td>17.8</td>
<td>18.7</td>
</tr>
<tr>
<td>Rib fat depth (mm)</td>
<td>7.5</td>
<td>13.3</td>
<td>13.7</td>
</tr>
<tr>
<td>Eye muscle area (cm²)</td>
<td>91.8</td>
<td>90.9</td>
<td>82.6</td>
</tr>
<tr>
<td>Estimated lean meat yield (points)</td>
<td>60.3</td>
<td>58.1</td>
<td>57.4</td>
</tr>
<tr>
<td>Fat colour¹</td>
<td>6.3</td>
<td>6.2</td>
<td>7.0</td>
</tr>
<tr>
<td>Meat colour²</td>
<td>13.7</td>
<td>13.3</td>
<td>13.8</td>
</tr>
<tr>
<td>Marbling³</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Total relative point score</td>
<td>88.0</td>
<td>95.4</td>
<td>100.0</td>
</tr>
</tbody>
</table>

1 Fat colour (highest score of 7 = white fat).
2 Meat colour (highest score of 15 = excellent).
3 Marbling (highest score of 5 = highly marbled).
Economic benefits

Marketing flexibility

As described above, the superior quality of leucaena-fed beef enables graziers to capture price premiums. In addition, the continuity of forage supply from the deep-rooted leucaena trees enables graziers to hold cattle in excellent condition over the dry season (winter) and then to sell when the availability of finished cattle for abattoirs is limited (P.H. Larsen, personal communication). Leucaena is suited to the production of organically certified or EU-accredited beef as cattle perform well without the use of HGP's and do not require additional protein/urea supplementation or excessive use of synthetic agrochemicals (fertiliser or pesticides). Furthermore, leucaena pastures rate highly for animal welfare and environmental impact compared with feedlots; these factors may command future price premiums as consumers become more ethically astute.

Economic analyses of dryland leucaena

At a State level, the predicted gross value of all cattle and calves slaughtered in Queensland in 2006–07 will be $3.15 billion (QDPIF 2006). The gross value of the 120 000 AE/yr that graze leucaena is already estimated at more than $120 M annually, of which >$69 M is directly attributable to LWG from leucaena. As leucaena adoption accelerates over the next 10 years, these figures can be expected to more than double.

At the farm level, investment in leucaena typically involves a high initial outlay of funds to plant the pasture, a period of lower returns as the pasture is establishing, followed by a long period of relatively stable production and returns. The value of planting leucaena pastures to a beef business depends upon: (a) the cost of pasture establishment; (b) productivity of the established pasture; (c) the productive life of the pasture; and (d) the income forgone (opportunity costs) from alternative land uses, e.g. dryland cropping or irrigated agriculture (F. Chudleigh cited in Dalzell et al. 2006). Establishment costs vary with method of ground preparation, seeding rates and cost, and method of pre- and post-plant weed control. Total planting costs are around $375–400/ha at contract rates, but $250–350/ha when graziers use their own equipment and labour (Dalzell et al. 2006). These costs exclude the provision of additional infrastructure such as fencing and stock water. Therefore, establishment failures are expensive and it is vital that graziers use correct practices to ensure they succeed.

Table 5. Gross margins for leucaena pasture in the establishment year and when fully established.

<table>
<thead>
<tr>
<th></th>
<th>Establishment year ($/ha)</th>
<th>Established leucaena ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking rate (1 steer/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 kg steer @ $1.85/kg</td>
<td>555</td>
<td>555</td>
</tr>
<tr>
<td>Freight to property</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Interest on steer (7.5% pa)</td>
<td>10.25</td>
<td>30.80</td>
</tr>
<tr>
<td>Animal health</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total costs</td>
<td>585.25</td>
<td>605.80</td>
</tr>
<tr>
<td>Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 kg/hd/d for 90 days</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>1 kg/hd/d for 270 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final weight (kg)</td>
<td>390</td>
<td>570</td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sale of steer @ $1.75/kg</td>
<td>682.50</td>
<td>997.50</td>
</tr>
<tr>
<td>less: Livestock levy $5/hd</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Freight to yards</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Gross income</td>
<td>657.50</td>
<td>972.50</td>
</tr>
<tr>
<td>Total costs</td>
<td>585.25</td>
<td>605.80</td>
</tr>
<tr>
<td>Gross margin</td>
<td>72.25</td>
<td>366.70</td>
</tr>
</tbody>
</table>

Source: F. Chudleigh in Dalzell et al. (2006).
Economic analyses calculating gross margins and returns on investment were conducted by Fred Chudleigh (cited from Dalzell et al. 2006). Gross margins of $72/ha and $367/ha were calculated for the establishment year and for established leucaena, respectively (Table 5). It was assumed that the leucaena pasture was continuously grazed for only 3 months of the first year (90 kg LWG/ha/yr) and grazed for 9 months each year once established (270 kg LWG/ha/yr). A second analysis estimated the return on investment when converting 500 ha of buffel grass pasture to leucaena-buffel grass pasture at a rate of 100 ha/yr. Assumptions made included no additional infrastructure costs (water and fencing), carrying capacity increased from 3 ha/hd to 1.5 ha/hd, liveweight gain increased from 50 kg/ha/yr to 200 kg/ha/yr, productivity of the leucaena declined at 5%/yr after 25 years and the enterprise was sold after 30 years. The leucaena development returned 30% on funds invested with the initial investment repaid in the 7th year. The total return on investment included capital gain in land value proportional to increased carrying capacity, but did not include a price premium for the established leucaena pasture. All analyses were particularly sensitive to the prices paid for cattle bought and sold by the enterprise and did not include any price premiums for leucaena-fed steers derived from marketing flexibility described above.

Other economic benefits

Planting leucaena increases the value of the land compared with buffel grass pastures. These increases in value exceed the increased carrying capacity of the land and indicate that graziers are prepared to pay a premium for established leucaena pastures. Recent land sales in central Queensland indicate that values for established leucaena pastures were more than twice those of buffel grass pastures. This represents a substantial capital gain from establishing leucaena. It is also possible that in future there may be payments to graziers for carbon credits associated with C sequestration in leucaena stems and roots, and the reduction of methane (CH₄) emitted from cattle grazing leucaena.

Environmental benefits

Environmental benefits from growing leucaena can be realised at the farm, catchment and global levels.

Farm-level benefits

Leucaena can withstand occasional heavy grazing and provide a buffer against unexpected drought or extended dry periods. Being deep-rooted, it is less affected by drought than shallow-rooted grass and herbaceous legumes and is an ideal drought mitigation strategy. This has proven to be one of its greatest benefits. Leucaena pastures also have high water use efficiency compared with other pasture types, such as buffel and native pastures (Dalzell et al. 2006). Other farm-level benefits include enhancement of soil fertility through the cycling of biologically fixed N. Assuming that 50 kg N/ha/yr is fixed from 150 000 ha leucaena pastures, an extra 7500 t/yr N (equivalent to >16 000 t/yr urea valued at >$9 M/yr) is being fixed and cycled onto the soil of these properties. This N fertiliser promotes grass growth and strong ground cover, which helps prevent soil erosion and control weeds, e.g. planting leucaena into native bluegrass (Dichanthium spp.) pastures on downs soils in central Queensland has reduced parthenium (Parthenium hysterophorus) populations (J. Chamberlain, personal communication). N accretion under long-term leucaena on Brian Pastures Research Station at Gayndah has promoted a voluntary understorey of green panic.

Ecosystem benefits are delivered on-farm by enabling graziers to intensify cattle production on robust leucaena pastures, thereby enabling them to spell and better manage fragile native ecosystems, preventing habitat destruction, loss of biodiversity and soil erosion, while improving water quality. In this way, graziers can address environmental issues on their properties while improving the profitability of their beef enterprises.

Catchment-level benefits

One of the most significant impacts of large-scale adoption of leucaena pastures is their ability to mimic the water use of the original native woodland vegetation and maintain the hydrological balance of
large areas of catchments by reducing deep drainage of water that can lead to dryland salinity.

There are considerable levels of stored salt in soils in cropping regions, especially in blackwood, brigalow and brigalow-belah soils (Webb 2001) (Figure 1). Since large areas of this land have been cleared for pasture and dryland cropping, occasional episodic deep drainage events will ensure that dryland salinity will occur over an extended time period. To date, most saline discharges in Queensland occur within local groundwater systems. After clearing, water tables can rise and small-scale saline discharges occur in nearby down-slope zones within 20–30 years of a water imbalance being created through the change in land use. The recharge area is easily identifiable and modified management practices such as returning annual cropping land to perennial pasture would achieve amelioration of the problem.

An example of the use of leucaena to control salinity outbreaks occurred on the 3710 ha breeding and prime finishing beef cattle property, ‘Mountain View’, currently owned by Graeme Acton (previously owned by Jeff Hume and Glenmary Swan). A localised saline outbreak occurred at the base of a hill after the 1974 wet season. Leucaena was planted into 220 ha of the recharge area in 1980 and the saline seepage disappeared within 2 years. Over a 6-week period early in 1991, when more than 1000 mm of rain fell, leucaena was able to soak up the extra moisture and no obvious signs of salinity re-occurred.

However, most groundwater flow systems in high salinity hazard areas of Queensland’s cropping regions are either intermediate or regional in nature posing difficulties for management of groundwater levels (Webb 2001). These larger groundwater flow systems have high storage capacity, saline discharge may take >100 years to occur after agricultural development, and farm-scale management options are unlikely to be effective in preventing dryland salinity outbreaks. Large-scale replanting of deep-rooted perennial vegetation will be required to arrest or reverse these processes.

There is a considerable body of evidence demonstrating the beneficial impact of leucaena hedgerows on the hydrological characteristics of catchments. In the Himalayan region of India, an agroforestry land use involving leucaena exploited water to 3 m depth compared with 1.5 m depth for annual crops (Narain et al. 1998). Hence, groundwater recharge in appreciable quantities was unlikely. The study showed that leucaena had similar hydrological impact to eucalypts. From a salinity amelioration viewpoint, this was an important result.

Studies of mature leucaena-grass hedgerows in central Queensland (Poole 2003) showed that leucaena systems mimic the original native forests and woodlands that covered the landscape prior to agricultural development in terms of rooting depth and water use. On a cracking clay brigalow soil near Rolleston, rooting patterns of brigalow regrowth were similar to those of leucaena, with roots reaching 5–6 m depth compared with 2 m for buffel grass. Similar results were obtained on an alluvial soil near Carnarvon Gorge (Figure 2). At this site, while leucaena roots were again measured to 5–6 m, the roots of native trees (Moreton Bay ash and apple gums) reached only 4.5 m depth. The roots of Rhodes grass interplanted between the leucaena rows reached only 1.5 m depth.

A computer modelling program, WaterMod3 (Johnson 2002), was used by Poole (2003) to predict the probability of occurrence of deep drainage under leucaena-grass pasture compared with buffel grass and an annual crop of sorghum on a dense and a permeable soil over a 100-year period. While limitations of the available input parameters meant that absolute values might not be accurate, the trends were likely to be realistic. Deep drainage events were directly related to episodic high rainfall events. On a permeable soil,
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the probability of annual deep drainage of 25 mm occurring over the 100-year period (1900–1999) was highest for annual sorghum (95%), much lower for buffel grass (30%) and lowest for leucaena (15%) (Figure 3).

A comparison of the leucaena suitability map (Figure 4) and the salinity hazard map for the various catchments, e.g. Fitzroy catchment (Figure 5), shows that there is considerable overlap, confirming that leucaena is an appropriate revegetation strategy for the high salinity hazard areas. These are also high-risk areas as landscapes have largely been cleared of deep-rooted woody vegetation.

Leucaena pastures also enhance ground cover compared with degraded grass pastures or annual cropping cultivation, minimising soil erosion and improving the quality of runoff water. Roose and Ndayizigiye (1997) showed that 2-year-old leucaena-setaria (Setaria sphacelata) stands in Africa reduced runoff to less than 2% of that from bare soil or from an annual cropping system. Soil erosion loss was only 2 t/ha/yr. In a trial in south-east Queensland, soil loss was reduced from ~12 t/ha from bare soil to <2 t/ha by the planting of leucaena hedgerows 4 m apart with no inter-row grass (R.C. Gutteridge, personal communication). Many graziers report the excellent erosion-control characteristics of established leucaena pastures. Even after high intensity rainfall, there is little runoff and water tends to be clear and free of debris and soil particles.
Global-level benefits

Leucaena pastures have the potential to have a positive impact on the global environment by providing the beef industry of northern Australia with a means of improving its greenhouse gas balance. Leucaena pastures store C in their woody frames and roots and in accumulated soil organic matter, and lower emissions of methane/kg LWG by cattle.

Figure 4. Areas suitable for growing leucaena in the Fitzroy Catchment based on suitable soil types (Shelton and NRMW).
It is estimated that leucaena hedgerows store 600 kg C/ha/yr in the stems for the first 5 years after establishment (B.F. Mullen, personal communication). Additional C, equivalent to 30% of that stored above-ground, is stored in the root system of leucaena hedgerows, giving an estimated total of 780 kg C/ha/yr. Once fully established, it is assumed that the pastures are in a steady state where C storage in leucaena plants equals C release via respiration and the decomposition and decay of leucaena biomass. Therefore, the 150 000 ha of leucaena pastures currently planted in northern Australia (assuming >5 years of age) have stored a total of 585 000 t C, or 2.15 Mt CO$_2$ equivalents (CO$_2$-e).

Similar amounts of extra C are stored in soil organic matter beneath leucaena pastures. Results from a study of 20-, 30- and 37-year-old grazed leucaena pastures growing on a calcareous basaltic vertosol soil at Gayndah, Queensland, indicate that soil organic C in the 0–15 cm layer of soil increased by 0.12–0.22% of soil DM compared with adjacent grazed native grass pastures (A. Radrizzani, personal communication). Using these data, with an assumption of an increase in soil organic C of 0.2% soil DM, and a soil bulk density of 1200 kg/m$^3$, an extra 3.6 t/ha C, or 13.2 t/ha CO$_2$-e, would be stored under leucaena pastures compared with native grass pastures. Based on the assumptions

![Figure 5. Salinity hazard map for the Fitzroy Catchment (NRMW).](image)
described above, an estimated 1.98 Mt CO$_2$-e would be stored in extra soil organic matter that has accumulated in the top 15 cm alone under 150,000 ha of leucaena in northern Australia. This calculation of increased soil organic C under leucaena pastures is conservative for the following reasons: a) C storage has been calculated only in the top 15 cm of soil, whereas buffel grass and leucaena roots reach up to 2 and 6 m into the soil profile, respectively; and b) much of the leucaena established in Queensland has been planted into old run-down cultivation, where increases in soil organic C of >0.5% could be expected within 10 years of pasture establishment (Cullen and Hill 2006; Silburn et al. 2007).

Combining estimates of C stored in leucaena biomass and soil organic C suggests that existing leucaena pastures could potentially have sequestered a total of 4.13 Mt CO$_2$-e. To put this figure in context, current projections of Australia’s annual average total net greenhouse emissions (CO$_2$, CH$_4$, nitrous oxide etc.) for the period 2008–2012 will average 603 Mt/yr CO$_2$-e (Australian Greenhouse Office 2006).

While global CH$_4$ emissions are dwarfed by CO$_2$ emissions on a mass basis, CH$_4$ has a much greater radiative impact on the atmosphere (CO$_2$ = 1; CH$_4$ = 23) and is an important contributor to global warming (IPPC 2007). Ruminant livestock produce CH$_4$ in the fermentation process of digesting roughage (enteric CH$_4$) with further small emissions arising from decomposing manure. Most (>80%) of the enteric CH$_4$ is produced by bacteria in the rumen and is released by eructation, with the remainder produced in the lower digestive tract and emitted via the rectum (Clark et al. 2005). Reducing the fibre content of animal diets usually reduces the amount of CH$_4$ produced; likewise, increasing digestibility of the diet reduces CH$_4$ production/kg animal product as less feed is required by the animal to maintain the desired level of production. There are very few measurements of enteric CH$_4$ emissions from cattle grazing tropical pastures. Reductions of 74% in CH$_4$ emissions/kg LWG have been observed from Brahman cattle fed a lucerne chaff-grain diet ad libitum (DMD 70%, CP 19.4%, LWG 1.3 kg/hd/d) compared with those fed Rhodes grass hay (DMD 60%; CP 8.8%; LWG 0.6 kg/hd/d) (Kurihara et al. 1999). In another study, Kurihara et al. (1998) investigated CH$_4$ production from beef cattle fed grain-based diets (15–30% roughage) at different levels (1–2 × maintenance requirements) to give a range of animal performance (LWG). Cattle gaining weight at 0.41 kg/hd/d, the equivalent of average buffel grass pasture productivity (150 kg/hd/yr), produced 325 g CH$_4$/kg LWG. However, cattle fed a higher quality ration and gaining 0.68 kg/hd/d, equivalent to leucaena pasture productivity (250 kg/hd/yr), emitted only 219 g CH$_4$/kg LWG. Thus, the improvement in animal gross energy intake (quantity of the grain-based diet) and subsequent animal performance (LWG) in this study resulted in a 106 g CH$_4$/kg LWG (33%) reduction in CH$_4$ emission. Assuming similar reductions in CH$_4$ emissions occur when cattle graze leucaena pastures, compared with poorer quality tropical grass pastures, and assuming that the 150,000 ha of leucaena pastures produce 250 kg LWG/ha/yr, then 37,500 t/yr LWG would be produced. Using the data from Kurihara et al. (1998), to produce the equivalent amount of beef from buffel grass pasture, an extra 3975 t/yr CH$_4$ would be emitted. Given that CH$_4$ has 23 times the global warming potential of CO$_2$, the reduction in CH$_4$ emissions resulting from producing beef from leucaena pastures is equivalent to 91,425 t/yr CO$_2$. Leucaena also contains secondary plant metabolites called condensed tannins (CTs) in its foliage (Dalzell and Shelton 2002). Condensed tannins enhance the nutritive value of leucaena forage by preventing bloat and promoting bypass protein for efficient protein utilisation by cattle (McNeill et al. 1998). The presence of CTs in temperate forages appears to reduce CH$_4$ emissions/kg digestible DM intake and per kg animal product. This was demonstrated in dairy cattle fed Lotus corniculatus silage (Woodward et al. 2001) and fresh sulla (Hedysarum coronarium) forage (Woodward et al. 2002) and in sheep fed fresh L. pedunculatus (Woodward et al. 2001; Wagborn et al. 2002) and sulla (Wagborn et al. 2002) forage compared with those fed a range of CT-free forages and silage in New Zealand. One study observed a direct reduction of 16% in CH$_4$ emissions attributed to the activity of CTs in L. pedunculatus (Wagborn et al. 2002). Therefore, adding leucaena to the diet of cattle grazing tropical grass pastures of low inherent forage quality will not only increase overall digestibility of the diet but also improve the efficiency of LWG/kg CH$_4$ produced. The presence of CTs in leucaena may further inhibit methanogenic bacteria and protozoa in the rumen as a mode of action to reduce methane emissions.
Environmental risks from growing leucaena

Leucaena pastures can produce 2 adverse environmental impacts without careful management.

Leucaena as an environmental weed in northern Australia

The weed status of leucaena in Australia and elsewhere has been examined and reviewed (Hughes and Jones 1998; Middleton et. al. 2002; Shelton et al. 2003; Walton 2003). Leucaena does occur as a minor weed of disturbed areas in <10 000 ha of northern Australia, especially along creeks and ruderal areas in peri-urban environments (Shelton et al. 2003). Much of this leucaena is the ‘common’ type, L. leucocephala ssp. leucocephala (Hutton and Gray 1959), an unthrifty, prolific-seeding and weedy variety that was introduced to Australia in the late 1800s and had become naturalised by 1920 (White 1937). Commercial use of L. leucocephala ssp. glabrata did not commence until the early 1980s; therefore, weed infestations along the coast of northern Australia did not originate from graziers’ paddocks. A recent survey has shown that there has been little escape of leucaena from central Queensland grazing properties owing to the control of seedlings and seed production by grazing cattle (Shelton et al. 2003). There has been seedling recruitment between the rows on some properties when leucaena pastures have been overgrazed or no grass has been planted in the inter-row (Shelton et al. 2003). In another example, a study in 2002 found no leucaena had escaped from 40-year-old grazed leucaena pastures at CSIRO Samford Research Station (Jones and Bunch 2003) owing to prudent grazing management. Most of the weed leucaena in northern Australia has arisen from historic deliberate plantings by Government authorities and the general public for ornamental or land stabilisation reasons, followed by unintentional spread via contaminated soil/machinery in road maintenance.

Leucaena has been a slow ‘invader’ but is continuing to spread in ungrazed areas when not controlled, especially along riparian zones and roadsides. It can be controlled relatively cheaply and easily by chemical means. One grower successfully controlled all weed leucaena resulting from 1000 ha of planted leucaena in less than one day’s work for a chemical cost of $15.

Many graziers now recognise that commercial varieties of leucaena do have weed potential and have adopted a voluntary Code of Practice, which recognises their responsibility to the environment. The Code of Practice was developed by The Leucaena Network, a group of graziers, scientists and extension staff dedicated to advocating the responsible use of leucaena in northern Australia. The Code of Practice outlines basic tenets that, if followed when planning and managing leucaena pastures, will both maximise animal production and minimise weed risk.

The State Government of Queensland is concerned about the weed potential of leucaena and has prepared a review of the pest status of leucaena (Walton 2003). A tri-agency policy Policy to reduce the Weed Threat of Leucaena (LPG/2055/1910), formulated in 2004 by the departments of Natural Resources, Mines & Water, and Primary Industries & Fisheries and the Environmental Protection Agency, permits the ongoing use of leucaena as forage by graziers and endorses The Leucaena Network’s voluntary Code of Practice.

The environmental weed potential of leucaena could be eliminated by the development of sterile varieties and hybrids. Partial sterility exists within the Leucaena genus, as do the techniques to induce: (a) sterility by the generation of artificial triploid hybrids (Brewbaker and Sorensson 1990); and (b) cytoplasmic male sterility by chemical or irradiation mutagenesis. Research proposals to undertake this work have failed to gain financial support from environmental agencies or from the grazing industry. In the meantime, adoption of the Code of Practice and control of weed infestations by the Government authorities responsible, along with numerous natural control agents (including frost, the psyllid, a flower-eating moth Ithome lassula and the seed-eating bruchid beetle Acanthoscelides macropthalmus), should ensure that the rate of spread of leucaena is minimised.

Soil acidification under leucaena pastures

Rates and sources of soil acidification under temperate legume pastures in southern Australia are well documented (Porter et al. 1995). Less is known about the soil acidification potential of tropical legume pastures. Acidification occurs under pastures as a result of: (a) the accumulation and cycling of organic matter in the top-soil
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and the release of carbonic and carboxylic acids; (b) legume roots extracting base cations (Ca\textsuperscript{2+}, Mg\textsuperscript{2+}, K\textsuperscript{+}) from lower in the profile for use in biological N fixation and excreting H\textsuperscript{+} into the rhizosphere; (c) the removal from the paddock of organic anions in livestock product or manure/urine; and (d) leaching of excess N in nitrate or ammonia from the soil profile (Bolan and Hedley 2003; Tang and Rengel 2003). The high rates of N fixation and longevity of leucaena pastures have led to speculation that soil acidification may occur. The results of 2 studies of soil acidification under leucaena pastures have been published. The first investigated soil pH to a depth of 70 cm under a leucaena-Sabi grass (Urochloa mosambicensis) pasture growing in a poorly buffered sandy/clay-loam (CEC = 1.8 meq/100 g soil) in the seasonally dry tropics (840 mm annual average rainfall) at Townsville (Noble and Jones 1997). Soil pH was significantly lower at all soil depths under the leucaena pasture after 22-years grazing, compared with adjacent ungrazed Sabi grass pasture. The drop in soil pH was most pronounced in the top-soil (0–10 cm) where soil pH was 1 unit lower under leucaena than under the grass pasture control. Levels of exchangeable Ca\textsuperscript{2+}, Mg\textsuperscript{2+} and K\textsuperscript{+} were also lower under leucaena pastures to a depth of 70 cm, indicating that leucaena was very efficient at extracting base cations. An estimated 78% of the increased acidity under leucaena was due to N fixation/leaching and base cation uptake/removal, with the remainder attributed to an increase in soil organic matter. The second study to 90 cm depth on a loam-medium clay alluvial prairie soil (pH 1:5 soil:water = 5.9–6.4) in the humid subtropics (Samford, 1100 mm annual average rainfall) found that a leucaena-green panic pasture lowered soil pH by 0.3–0.4 units only in the top 0–50 cm of soil after 36 years of grazing compared with original soil samples taken prior to leucaena establishment (Noble et al. 1998). Unlike the Townsville study, 80% of the increased soil acidity was attributed to soil OM accumulation and the remaining 20% due to N fixation/leaching and cation uptake and removal. In contrast, recent research has found that the pH of a calcareous basaltic vertosol soil (pH 1:5 soil:water = 7–9.5; CEC = 65 meq/100 g soil; clay content = 60%) in the subtropics (Gayndah, 730 mm annual average rainfall) has not changed under a grazed leucaena-green panic pasture 37 years after its establishment (A. Radrizzani, personal communication).

This study investigated soil pH to a depth of 3 m under the leucaena pasture and that of an adjacent grazed native grass pasture control treatment. As this calcareous clay soil is more typical of the alkaline, highly buffered cracking clay soils in which most leucaena is planted in Queensland, it appears that soil acidification will not threaten the long-term sustainability of leucaena pastures. However, leucaena established on lighter, poorly buffered soils of lower initial pH, particularly in high rainfall areas or under irrigation, may require regular applications of lime to prevent soil acidification suppressing leucaena growth and damaging soil chemical properties.

Other challenges to growing leucaena on marginal cropping lands

Lack of cold and frost tolerance

Leucaena is a tropical plant and cool temperatures (minimum temperatures <15–20°C) limit growth in southern Queensland for 3–5 months of the year (Cooksey et al. 1988; Mullen et al. 2003). Above-ground growth is also damaged by frost. Light frosts (0 to –3°C) kill leaves, while heavy frosts (<–3°C) kill stems to ground-level but plants survive, regrowing vigorously from the root crown in spring (Dalzell et al. 1998; Middleton and Clem 1998). Thus, winter forage production from leucaena in southern Queensland will be limited, while frosts will prevent graziers from saving summer growth in forage banks. Despite this limitation, graziers prefer productive leucaena pastures for 6–8 months of the year to no leucaena at all (A. Richardson, personal communication).

Establishment challenges on degraded soils

Leucaena seedlings are particularly vulnerable to soil crusting and weed competition during establishment. These are common challenges in degraded cropping soils that typically have low soil organic matter levels, poor surface structure and heavy weed populations. Soil crusting prevents seedling emergence and can cause complete establishment failure. Crusting can be overcome using rolling cultivators post planting and pre-emergence (e.g. yetter wheels) to gently break the soil crust and allow the fragile seedlings to emerge. A number of mechanical and
chemical options are available to effectively control weeds (Dalzell et al. 2006).

More intensive pasture and animal management

While highly productive, leucaena pastures do require more careful management of plants and animals than other pasture systems, particularly in regard to height management of plants and prevention of leucaena toxicity in cattle. Leucaena is a small tree and can grow out of reach of cattle in frost-free areas with inappropriate grazing management. Height can be regulated by planting twin rows, strategic rotational grazing, ‘crash-grazing’ taller trees or using trimming machines operated by contractors (Dalzell et al. 2006). In southern Queensland, annual frosting can effectively control the height of leucaena. Graziers need to prevent leucaena toxicity from affecting animal health and liveweight gain. Cattle must be inoculated with special rumen bacteria (Synergistes jonesii) that are capable of detoxifying mimosine and its rumen breakdown product 3,4-dihydroxyypyridone (Jones and Megarrity 1986). Failure to prevent leucaena toxicity can result in reductions of liveweight gain of 30–50% (Jones and Winter 1982; Quirk et al. 1988). Herds need careful management to ensure that inoculated animals have regular access to leucaena and that new animals introduced to leucaena remain in contact with those carrying the bacteria to ensure successful animal-to-animal transfer and complete protection of the herd. A leucaena toxicity test kit will shortly be available to assist graziers to monitor this problem and to take prompt action to prevent toxicity and liveweight gain reduction.

Soil fertility problems

Declining leucaena productivity in aging leucaena pastures (more than 10 years old) is an emerging problem (Radrizzani et al. 2007), particularly on marginal soils of moderate to low inherent fertility, such as brigalow, scrub, downs and forest soils. The cause of run-down appears to be a combination of: (a) severe competition for soil moisture from companion buffel grass during the droughts of the last 10–15 years; and (b) soil nutrient depletion, particularly phosphorus (P), sulphur (S) and zinc (Zn) (A. Radrizzani, personal communication). Leucaena run-down is manifest as poor plant growth and reduced N fixation (low plant N concentration, <3.5% N on DM basis). A recent survey of leucaena growers has revealed that very few leucaena pastures have ever been fertilised (Radrizzani et al. 2007). Estimations of nutrient removal from leucaena pastures via animal product and excreta transfer (to water points and shade areas etc.) suggest that 7.6 kg P, 1.7 kg potassium, 2 kg S, 9.6 kg calcium and 0.6 kg magnesium/ha are lost each year (A. Radrizzani, personal communication). When these rates of removal are compounded over 10–30 years, it is obvious that significant amounts of soil nutrients have been removed without replacement. Graziers wishing to establish leucaena on degraded marginal cropping soils should consider applying N, P, S and Zn ‘starter’ fertiliser at planting to ensure leucaena can establish rapidly, efficiently fix atmospheric N and reach its full growth potential (Dalzell et al. 2006). Graziers with established leucaena should consider a modest maintenance fertiliser regime to replace nutrients removed in beef production.

Conclusions and the future

The inherent profitability of the system, together with its environmental benefits, ensures that the leucaena-grass system will have a significant impact on the triple-bottom-line at local, regional, national and global scales.

The direct production and economic benefits from growing leucaena in Queensland are substantial. At present levels of adoption, the current planted area of 150 000 ha will more than double in the next 10 years, lifting the gross annual value of LWG generated from leucaena pastures to >$138 M/yr at current market prices. Indirect benefits will accrue at the farm level from drought mitigation, N accretion from the cycling of biologically fixed N, and ecosystem benefits owing to improved capacity of graziers to rest fragile areas.

Environmental benefits at the catchment level include improved hydrological balance leading to reduced deep drainage and dryland salinity risk, reduced soil loss and improved water quality. At a global level, greenhouse gases have been reduced through C storage estimated at >4 Mt CO₂-e, with an additional benefit from reduction in enteric CH₄ production equivalent to >91 000 t/yr CO₂-e from...
cattle grazing current plantings alone. These amounts are expected to double over the next 10 years.

However, there is continuing concern regarding leucaena as an environmental weed. While the potential for environmental weed spread is acknowledged, the current areas are small and largely the result of the activities of leucaena being planted for ornamental and soil-stabilisation reasons. Graziers have adopted a Code of Practice, although this may need to be enforced to ensure that this source of weed leucaena is minimised.

Researchers have been unable to obtain financial support for promotion of leucaena for its environmental benefits, e.g., salinity control, or for the production of sterile lines for planting in coastal areas where weed risk is highest. To address these concerns, a thorough cost:benefit analysis needs to be conducted. This would assist public and private decision makers to understand the balance between economic, social and environmental benefits of this controversial plant.

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