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Estimates of achievable milk production on subtropical dairy farms in Queensland

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Abstract. A knowledge-based decision support system called DAIRYPRO was applied to farm survey data to provide estimates of the achievable milk production for dairy farms in Queensland. The survey data were obtained from personal interviews conducted in 1994–95 involving 37–86% of farmers in 4 dairying districts in Queensland. Farms that had higher levels of milk production and a history of adopting proven management aids such as herd recording had production levels closer to achievable milk production. Measured milk yield relative to achievable milk production for 2 regions was significantly different from the other 2, while the age of the main decision maker was also a significant factor, with farmers aged 30–59 years producing closer to achievable milk production than any other age group ($P<0.05$). Seven percent of farms had measured production levels greater than the model's estimation of achievable milk production.

Introduction

The object of this paper is to estimate a realistic production potential for the Queensland dairy industry using a knowledge-based decision support system called DAIRYPRO, and to compare this potential with actual production. In this study, industry potential is referred to as achievable milk production (AP). This term is used rather than potential as it is based on expert opinion of realistic levels of production on dairy farms and not the hypothetical potential that could be obtained based on research results. Factors that may affect the industry not reaching AP are also discussed.

DAIRYPRO is a combination decision support and expert system, designed to help dairy farmers in Queensland make strategic decisions relevant to the productivity of their farms. Dairy extension officers can use it as a consultation package for farmers. The system is based on a combination of statistical models developed from real farm survey data and opinions from experts in the field of dairy farming. DAIRYPRO gathers together the data needed to run the predictive models and the system of rules that enable the program to make estimates of regional average production (using predictive statistical models) and AP of an individual farm (using heuristic models based on expert rules of thumb).

AP is derived from the sum of the expert's estimates of the milk production expected from each physical input on the farm, for example, tonnes of grain or hectares of pasture. AP for each physical input is given as a single estimate based on the expected milk production from an ideal farm with average soil fertility and using best management practices in industry as determined by the experts (i.e. optimum stocking rates, fertiliser rates, average soil conditions and correct agronomic practices). AP was calculated as point estimates only by the experts. A decision was made not to attach probability or certainty factor estimates (Buchanan and Shortliffe 1984) to these milk production estimates. This decision was based on the findings from Kidd and Cooper (1985) and Tonn *et al*. (1992), who suggest that it is difficult to extract probabilities from experts as they are either unwilling or unable to assign numerical precision to the

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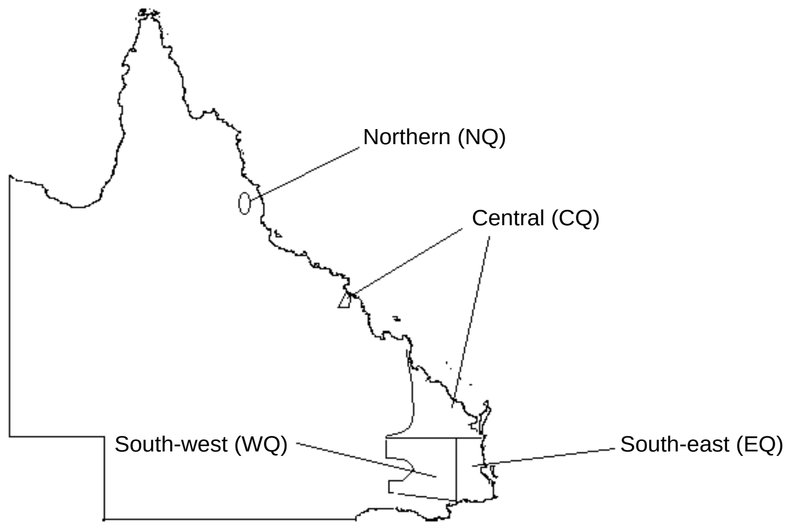

Figure 1. Regions of dairying in Queensland.

accuracy of an estimate. These authors further suggest that when experts are forced to assign precision, the reliability of the probability is low.

A description of the development and validation of DAIRYPRO is provided by Kerr *et al*. (1999*a*, 1999*b*).

The dairy industry in Queensland is situated in 4 main regions, they are south-east Queensland, south-west Queensland, central Queensland and northern Queensland (Fig. 1). The industry has been categorised by Kerr *et al*. (1999*a*) into 2 systems, namely the pasture-based system and the cropping system. The pasture-based system consists of introduced tropical summer grasses such as Setaria (*Setaria anceps*) or Kikuyu (*Pennisetum clandestinum*) with an annually sown temperate pasture component in winter. Winter pastures of ryegrass (*Lolium* spp.) and clover (*Trifolium* spp.) are grown when the dry matter production of summer pastures falls (from autumn to late spring).

The cropping system consists of grazing forage sorghum (*Sorghum* spp.) during summer and oats (*Avena sativa*) during winter. Some farms also grow lucerne (*Medicago sativa*) and lablab (*Lablab purpureus*).

Materials and methods

Estimates of AP on dairy farms in Queensland were predicted using DAIRYPRO (Kerr *et al*. 1999*a*, 1999*b*). These estimates were obtained for a cross section of dairy farms from an industry survey conducted in 1994–95 (Kerr *et al*. 1996). The survey was designed to be a representative sample of all dairy farms in Queensland with a sample size 37–86% of farmers in the 4 dairying districts (Kerr *et al*. 1996). Sample size was determined using a stratified random technique based on 3 strata of total farm milk production, namely 50 000–350 000, 350 001–750 000 and >750 001 L/year. Data were collected by personal interviews and physical inputs and outputs such as paddock areas, number of cows milked, supplements fed etc. were collected for each farm. In addition, farmers were asked to answer some social, attitude and financial questions. The main components of the farming system as determined by Kerr *et al*. (1999*a*) were extracted from the survey database and used in the DAIRYPRO model to estimate AP.

Comparisons between measured and AP were calculated as measured milk yield to AP expressed as a percentage. Measured milk yield relative to AP from forage was also analysed. This estimate was obtained by subtracting the production expected from supplements from total farm production as described by Kerr *et al*. (1999*a*).

Comparisons were made for a number of managerial factors. Data were compared for the production category for the farm based on the 3 production categories used in the sampling technique shown above, and for the use of herd recording (HR), as this is the most easily recognised management decision-making tool in the northern dairy industry. This variable is considered an indicator of a farmer's propensity to adopt other productivity-increasing technologies such as irrigation and supplementary feeding (Kerr 1993; Kerr *et al*. 1995). Based on this evidence, the survey data was divided into farms that recorded the milk production of their herd and those that did not.

The data were also compared for the irrigation status of the farm using the same categories as those described by Anon. (1988) and Kerr *et al*. (1996). Farms were considered fully irrigated when the irrigation area per cow was greater than 0.132 ha, partial if between 0.04 and 0.132 ha and non-irrigated if less than 0.04 ha/cow. These areas were based on expert extension officers' opinion and on previous surveys and were derived to be a reflection of effective irrigation areas and stocking rates on farms. Seventy-five respondents did not provide an irrigation status for their farm. Rather than discard these data a 4th category of unknown irrigation status was included in the analysis.

Table 1. Mean achievable milk production (AP), measured milk yield relative to AP for farms grouped by production category and adoption of herd recording

The 95% confidence limits are in parentheses (calculated from the means of $\log_e$-transformed data)
Categories within the same group of herd-recording status followed by the same letter are not significantly different at $P = 0.05$

Farm category	Achievable milk production (×1000 L/farm)	Measured milk yield relative to AP (%) All feeds	Forage only
Low production farms (50 000–350 000 L/year)			
No herd recording	555 (501–616)a		
Herd recording	620 (557–690)b		
All farms		40 (37–44)a	18 (13–25)a
Medium production farms (350 001–750 000 L/year)			
No herd recording	1053 (935–1187)c		
Herd recording	930 (853–1013)d		
All farms		51 (47–55)b	28 (21–38)b
High production farms (>750 001 L/year)			
No herd recording	1795 (1512–2131)e		
Herd recording	1664 (1500–1845)e		
All farms		61 (55–67)c	35 (26–48)b
All farms			
No herd recording		48 (44–52)a	
Herd recording		52 (48–56)b	

The data were also divided on the basis of 5 age categories of the main decision maker on the farm. These age categories were <30, 30–39, 40–49, 5059 and >60 years of age.

Farms were also divided into 6 categories of debt level. These were 0, 1–100 000, 100 001–200 000, 200 001–300 000, 300 001–500 000 and >500 000 dollars.

Generalised linear models were fitted to the data with the best model being selected using backward elimination stepwise regression and the SELECT procedure in the GENSTAT statistical program (Genstat 5 Committee 1993). A normal error distribution was assumed. To satisfy the assumptions of a normal distribution with constant variance it was necessary to transform the data using logarithmic transformation. In the case of AP from supplement and forage, it was necessary to add a constant (15 000 and 60 000, respectively) to the data before transformation. Each prediction shown in this paper was adjusted for other effects. The effects considered were production category, irrigation status, herd-recording status, debt level and age. The mean values for each prediction eliminate the effect of the other categories and will be different from the average because the number of farms within different categories varied. For example, in the west region, 23% of farms were irrigated compared with 39% in the east region.

Results

A total of 67 farms from the survey data set of 596 were omitted from analysis due to anomalies in the data. In each case, the estimated volume of milk from supplements exceeded the measured total farm milk production. Closer inspection of these data indicated that larger than expected amounts of supplements were fed over the year, indicating that stockpiles of supplements remaining at the end of the survey period were not deducted from the total amount of supplement fed. A similar problem has occurred in other Queensland dairy surveys (Kerr *et al*. 1995) where end-of-year stockpiles of supplements were not deducted from the total but included as supplements fed to the dairy herd during the year.

Seven percent of farms produced more milk than the AP estimate (Table 1). Higher-production farms showed a significant increase in measured milk yield relative to AP and a significant increase for measured milk yield relative to AP from forages when compared with low- and medium-production farms (Table 1). Herd-recording farms had higher measured milk yield relative to AP than non-herd-recording farms (Table 1). The significant interaction between production category and herd recording for AP is an indicator of the natural resources of the farms and has no bearing on the adoption of technology (Table 1).

Measured milk yield relative to AP varied from 44% in the central Queensland region to 57% in south-east Queensland. Northern Queensland and south-east

Table 2. Mean measured milk yield relative to achievable milk production (AP) and AP from all feeds for farms grouped by region

The 95% confidence limits are in parentheses (calculated from the means of $\log_e$-transformed data)
Categories within a region followed by the same letter are not significantly different at $P = 0.05$

Region	Measured milk yield relative to AP (%)	AP from all feeds (×1000 L/farm)
Northern Queensland	54 (48-60)a	987 (882–1105)a
Central Queensland	44 (39–48)b	1131 (1015–1260)b
South-east Queensland	57 (53–63)a	875 (789–959)c
South-west Queensland	47 (43–51)b	1028 (946–1117)ab

Table 3. Mean achievable milk production (AP) and measured milk yield relative to AP for farms grouped according to irrigation status

The 95% confidence limits are in parentheses (calculated from the means of $\log_e$-transformed data)
Categories within the same group of irrigation status followed by the same letter are not significantly different at $P = 0.05$

Irrigation status	Measured milk yield relative to AP (%)	AP from all feeds (×1000 L/farm)
Non-irrigated	55 (51–59)a	872 (802–947)a
Partially irrigated	52 (45–61)a	1013 (863–1189)a
Fully irrigated	56 (52–61)a	920 (850–995)a
Unknown status	39 (35–43)b	1237 (1108–1380)b

Queensland were significantly higher than central Queensland and south-west Queensland (Table 2).

Apart from farms with an unknown irrigation status, there were no significant differences between measured milk yield to AP based on irrigation status (Table 3).

Measured milk yield relative to AP for the 5 age groups of farmers is shown in Table 4. Farmers in the age group 30–59 years are significantly closer to AP than farmers who are <30 and over 60 years of age ($P<0.05$). The younger managers apparently have a larger scope for improvement through development of the farm or management expertise.

Measured milk yield relative to AP for each debt category over the whole industry is shown in Table 4. There were no significant differences between farm debt and measured milk yield relative to AP.

In the interaction irrigation and herd-recording status, partially irrigated farms with no herd recording had significantly lower measured milk yield relative to AP from forage than those that did herd recording (Table 5). This could be due to farmers that do herd recording having a higher level of managerial expertise in other aspects of farming such as irrigation management, which is important in farms when irrigation is limited.

Table 4. Mean achievable milk production (AP), measured milk yield relative to AP from all feeds and from forage for each age group and for level of debt

The 95% confidence limits are in parentheses (calculated from the means of $\log_e$-transformed data)
Categories within the same age group followed by the same letter are not significantly different at $P = 0.05$
Percentage of farmers in each age group is shown in parentheses under each grouping

There were no significant differences between debt levels

Age or level of debt	AP (×1000 L/farm)	Measured milk yield relative to AP (%) All feeds	Forage only
	Farmers grouped by age (years)		
<30 (4%)	1251 (1059–1478)a	43 (36–50)a	20 (13–33)a
30–39 (16%)	928 (838–1027)b	52 (47–57)bc	24 (18–34)a
40–49 (28%)	906 (830–990)b	55 (50–60)bc	29 (22–39)a
50–59 (34%)	956 (872–1047)b	52 (48–57)bc	30 (22–41)a
>60 (18%)	1000 (902–1109)b	49 (45–54)ab	28 (20–38)a
	Farms grouped by level of debt ($A)		
1 (No debt)	1076 (1009–1148)	46 (44–49)	24 (18–30)
2 ($1–100 000)	940 (836–1057)	48 (43–54)	26 (18–38)
3 ($100 001–200 000)	974 (860–1103)	52 (46–58)	22 (15–32)
4 ($200 001–300 000)	1058 (908–1233)	47 (41–55)	25 (16–39)
5 ($300 001–500 000)	1015 (858–1201)	54 (46–63)	25 (15–40)
6 (>$500 000)	951 (759–1192)	54 (43–67)	37 (19–75)

Table 5. Mean measured milk yield relative to achievable milk production from forage for farms grouped according to irrigation status and adoption of herd recording

The 95% confidence limits are in parentheses (calculated from the means of $\log_e$-transformed data)
Categories within the same group of herd recording status followed by the same letter are not significantly different at P = 0.05

Irrigation status	No herd recording	Herd recording
Non-irrigated	27 (20–38)a	27 (20–36)a
Partially irrigated	10 (4–24)b	34 (23–52)a
Fully irrigated	33 (25–43)a	31 (25–38)a
Unknown status	17 (5–56)ba	49 (22–109)a

There were significant differences in measured milk yield relative to AP from forage for different irrigation categories within regions. These were most noticeable in south-east and northern Queensland, with lower measured milk yield relative to AP from forage on partially irrigated farms compared with fully irrigated and or non-irrigated farms (Table 6).

Discussion

A comparison of measured milk yield relative to AP provides an estimate of the effectiveness of use of resources on Queensland dairy farms. Seven percent of farms produced more milk than the AP estimate. This indicates that our estimates of AP are in fact achievable on dairy farms in Queensland. However, measured milk yield for most farms in Queensland is well below AP, particularly when milk is produced from forages. This could be due to the model overestimating the effects of supplements; however, this is considered unlikely, as the estimates provided are consistent with previous work (Davison *et al.* 1982; Cowan and Davison 1983; Ashwood *et al*. 1993; Davison and Elliot 1993; Moss and Lowe 1993).

The low measured milk yield relative to AP indicates an under-utilisation of forages in Queensland and this could be due to the low stocking rates (0.3–0.83 cows/ha over the whole farm) found on Queensland dairy farms (Kerr *et al*. 1996). This observation is consistent with results of other studies that indicate a reduced level of pasture utilisation with lower stocking rates. Kaiser *et al*. (1993) reported utilisation rates as low as 30% for ryegrass at a stocking rate of 3.75 cows/ha compared with up to 70% for ryegrass at a stocking rate of 7.5 cows/ha during the ryegrass growing period.

Ashwood *et al*. (1993) estimated the potential production on dairy farms in Queensland and northern New South Wales using data from an industry survey conducted in 1986–87 together with estimates of plot-trial yields and pasture-utilisation rates. Their estimates were 0.98 ML for farms with partial irrigation, with an average area of 180 ha milking 140 cows, and 0.90 ML per farm for farms with full irrigation with an average area of 100 ha milking 150 cows. By comparison, the estimates provided by the DAIRYPRO model are 1.07 ML for partial irrigation and 0.98 ML for full irrigation. The DAIRYPRO estimates were based on the more recent 1994–95 survey and use more conservative estimates of production levels for each component of the farm. Survey data show that farms with partial irrigation in general have more inputs from other sources than fully irrigated farms (Kerr *et al*. 1996), hence the higher AP. The higher total production per farm estimated by the DAIRYPRO model is a reflection of the increased use of farm resources between 1986–87 and 1994–95. For example, average herd size increased from 96 in the 1986–87 survey to 108 in the 1994–95 survey (Kerr *et al*. 1996).

The AP levels presented in this paper are still below the potential in controlled experimentation on research

Table 6. Mean measured milk yield relative to achievable milk production from forage for farms grouped according to region and irrigation status

The 95% confidence limits are in parentheses (calculated from the means of $\log_e$-transformed data)
Categories within the same group of irrigation status followed by the same lowercase letter are not significantly different at P = 0.05; categories within the same region followed by uppercase letters are not significantly different at P = 0.05

Region	Non-irrigated	Partially irrigated	Fully irrigated	Unknown status
Northern Queensland	43 (21–88)acAE	17 (7–39)aA	52 (37–74)aBE	45 (12–164)aAE
Central Queensland	20 (13–30)aA	17 (7–39)aA	24 (17–33)bA	26 (9–76)aA
South-east Queensland	51 (37–71)cA	15 (7–35)aBE	40 (31–51)aA	29 (4–203)aAE
South-west Queensland	12 (10–16)bA	27 (14–52)aBE	21 (16–28)bBE	22 (7–65)aAE

stations and below theoretical estimates of milk production from concentrates. Davison *et al*. (1988) obtained production levels of 8533 L/ha.year during a 2-year experiment on summer-dryland grass pasture while the estimate derived with DAIRYPRO was 5000 L/ha.year (Kerr *et al*. 1999*a*). Another experiment conducted by Moss *et al*. (1985) over 3 years obtained production levels of 10 183 L/ha.year on winter-irrigated grass pasture while the estimate derived with DAIRYPRO was 8800 L/ha.year. These examples further support the contention that the AP levels used in the DAIRYPRO model are realistic and achievable on dairy farms and that farm productivity could be improved considerably by implementing existing technologies.

These results have implications for extension services, as the greatest differences between current production and AP were recorded on smaller farms. It can be questioned, however, if concentrating the extension effort on farmers who are at the lower end of the production scale has the greatest effect on total industry productivity, even if they have the greatest capacity to increase production. Greater production increases may come from the larger producers. In addition, some dairy farmers have expressed their choice to maintain a satisfying lifestyle by not adopting technology that improves productivity. Frank (1997) contends that farmers may prefer not to adopt technology rapidly for a multitude of reasons and that slow rates of adoption may be a reflection of other factors such as limited resources or technology not fitting into their farming system rather than any negative attributes of farmers. He further contends that some farmers' attitudes to technological innovation may reflect dissatisfaction with the assumption that 'economic growth is a necessary part of modernisation'.

Central Queensland and south-west Queensland had the highest difference between measured milk yield and AP. In central Queensland this was thought to be due to the larger areas of summer-dryland grass pastures associated with larger farms in the region. The effect of factors such as thermal load (Davison *et al*. 1996), cattle ticks (*Boophilus microplus*) and variable rainfall can be reduced by good management strategies; however, they cannot be entirely eliminated, and regions such as central Queensland are more adversely affected by these environmental factors than other regions. South-west Queensland suffers from inadequate rainfall in many years and most farms in this region do not have irrigation.

Conclusions

Most farms in this study were producing under their AP, indicating that farmers are not adopting known and proven technology to maximise the productive capacity on their farms. There appears to be scope to increase production by the adoption of presently known technology and the greatest scope for relative increases appears to be with smaller dairy farms, although greater state-wide production increases could be achieved with larger producers, even though they are closer to AP.

Factors such as management (as measured by the adoption of herd recording) and economies of scale were associated with the farm's ability to realise AP. Farmers who do not herd record and have lower levels of total farm production are not as close to AP as farmers who do herd record and have higher levels of total production. This is further demonstrated in the interaction between herd-recording status and partially irrigated farms where it is contended that farmers who herd record may have a higher level of managerial expertise in other aspects of farming such as irrigation management.

Regional differences were also apparent with Central and south-west Queensland having the lowest production relative to AP. Environmental factors such as heat stress and cattle tick infestations in central Queensland and variable rainfall in both central and south-west Queensland may have an effect. The farmers' age appeared to be a contributing factor with the 30–59 year age group having production levels closest to AP.

The present industry in Queensland appears to have a capacity for large increases in milk production. At the farm level, an average farm has a milk production potential of 813×10^3 L/farm or 7900 L/ha compared with a measured production of 438×10^3 L/farm or 4250 L/ha. State-wide AP estimates indicate a milk production potential of 1.3×10^9 L compared with a measured production of 0.7×10^9 L.

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References

Anon. (1988) 'Queensland dairy farmer survey 1986–87.' Queensland Department of Primary Industries, Brisbane, Australia.

Ashwood A, Kerr DV, Chataway R, Cowan RT (1993) Northern dairy feedbase 2001. 5. Integrated dairy farm systems for northern Australia. *Tropical Grasslands* **27**, 212–228.

Buchanan BG, Shortliffe EH (1984) 'Rule-based expert systems: the MYCIN experiments of the Stanford Heuristic Programming Project.' (Addison-Wesley Publishing Company: Massachusetts, USA)

Cowan RT, Davison TM (1983) The supplementation of dairy cows at pasture in Queensland. In 'Recent advances in animal nutrition in Australia'. (Eds DJ Farrell, P Vohra) pp. 69–80. (University of New England: Armidale, NSW)

Davison TM, Elliot R (1993) Northern Dairy Feedbase 2001. Response of lactating cows to grain-based concentrates in northern Australia. *Tropical Grasslands* **27**, 229–237.

Davison TM, Cowan RT, Chopping GD (1982) Milk responses to supplementation under tropical pasture feeding systems. (in contract review—pasture systems for milk production in Queensland). *Proceedings of the Australian Society of Animal Production* **14**, 110–115.

Davison TM, McGowan M, Mayer D, Young B, Jonsson N, Hall A, Matschoss A, Goodwin P, Goughan J, Lake M (1996) 'Managing hot cows in Australia.' Queensland Department of Primary Industries, Information series QI 96102.

Davison TM, Orr WN, Silver BA, Kerr DV (1988) The effect of nitrogen fertiliser and season on milk yield and composition in cows grazing tropical grass pasture. *Proceedings of the Australian Society of Animal Production* **17**, 170–173.

Frank BR (1997) Adoption of innovations in the North Queensland Beef Industry. III. Implications for extension management. *Agricultural Systems* **55**, 347–358.

Genstat 5 Committee (1993) 'Genstst 5 release 3 reference manual.' (Lawes Agricultural Trust, Oxford University Press: Oxford, UK)

Kaiser AG, Havilah EJ, Chopping GD, Walker RG (1993) Northern Dairy Feedbase 2001. 4. Feeding systems during winter and spring. *Tropical Grasslands* **27**, 180–211.

Kerr DV, Cowan RT, Chaseling J (1999*a*) DAIRYPRO—a knowledge-based decision support system for strategic planning on subtropical dairy farms. I. System description. *Agricultural Systems* **59**, 245–255.

Kerr DV, Chaseling J, Chopping GD, Cowan RT (1999*b*) DAIRYPRO–a knowledge-based decision support system for strategic planning on subtropical dairy farms. II. Validation. *Agricultural Systems* **59**, 257–266.

Kerr DV (1993) 'Queensland dairy farm study 1990–91.' DPI Information series Q193015, Queensland Department of Primary Industries, Brisbane, Australia.

Kerr DV, Davison TM, Cowan RT, Chaseling J (1995) Factors affecting productivity on dairy farms in tropical and subtropical environments. *Asian–Australasian Journal of Animal Sciences* **8**, 505–513.

Kerr DV, Davison TD, Hetherington GD, Lake M, Murray AJ (1996) 'Queensland dairy farm summary report.' Information series QI96115. Queensland Department of Primary Industries, Brisbane, Australia.

Kidd AL, Cooper MB (1985) Man–machine interface issues in the construction and use of an expert system. *International Journal of Man–Machine Studies* **22**, 91–102.

Moss RJ, Lowe KF (1993) Development of irrigated forage systems for dairying in subtropical Australia. In 'Proceedings of the 17th international grasslands congress'. Hamilton, NZ/Rockhampton, Australia. (Eds MJ Baker, JR Crush, LR Humphries) pp. 1191–1193. (Keeling and Mundy Ltd: Palmerston North, NZ)

Moss RJ, Lowe KF, Chopping GD, Reason GK, Bowdler TM, Bird AC, McKeogh P, Duncalfe F (1985) Effect of stocking rate on milk production from irrigated annual temperate pastures in southern Queensland. In 'Proceedings of the Australia–New Zealand dairy production conference—The challenge: efficient dairy production'. Albury–Wodonga, March 1985. (Ed. TI Phillips) pp. 73–74. (Lucas Print Ltd)

Tonn BE, Goeltz R, Travis C (1992) Eliciting reliable uncertainty estimates. *Expert Systems* **9**, 25–33.

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