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## Case-study forty-year historical analysis of production and resource use on northern Victoria dairy farming

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**Abstract.** Recent analysis from surveys of dairy farms has shown that despite large increases in production, the productivity gains on these farms have been modest. Productivity gains are important for farm viability, farmers have made production gains through adoption of technologies and increases in scale. This long-term farm case study of an irrigated dairy farm over a 40-year period provides an in-depth analysis of system changes and management complexity. Detailed records of milk production, herd, farm area and infrastructure, water use, supplementary feed, and labour were collected and pasture consumption was estimated. Changes in milk production were analysed in relation to individual resources, particularly farm inputs. Increases in production were associated with the use of more resources, including cows, land, water, fertiliser, feed and labour. However, measures of partial productivity indicated that there has also been a trend towards more efficient use of these resources. This long-term study can provide an insight into production impacts from changes in farm resource use and illustrates the short and longer term impacts of changes to farming systems.

**Keywords:** dairy farming systems, productivity, long-term case study, farm production measures

### Introduction

Australia's dairy farm businesses need to be profitable and improve total factor productivity (TFP) growth in order to overcome impacts of the cost-price squeeze. Through embracing technological advances, and increasing scale, dairy farmers have on average made production gains in their business. However, recent analyses from ABARE (2002) suggest average TFP gains over the two decades from 1978-79, were modest at about 1.8%, with little productivity improvement in the second half of this period. Over the corresponding period, the decline in terms of trade was 1.2% p.a. Declines in the terms of trade make gains in productivity important.

The observed low average TFP on dairy farms in the 1990's can be attributed to factors such as increasing farm complexity with the use of new technology, expansion of farm area and concentrate feeding. The use of less productive land associated with farm expansion and the time taken to develop skills needed for managing increasingly complex systems, result in inefficiencies when farm development options are undertaken.

An insight into farm management complexity, particularly changes in farm inputs, is needed to better understand impacts on farm

production and productivity in the short to medium term. To account for and understand the nature of farm management changes a detailed analysis of production and productivity gains made over 20 years, or more, on a real case study farm has been undertaken.

In measuring changes in individual farm productivity, it is inappropriate to apply the TFP approach used by ABARE (2002). Total Factor Productivity estimates average productivity of the whole dairy industry and criticisms have been made about its application to individual farms (Watson 2004). Partial productivity measures can be useful in this context, as they attribute farm output to units of individual inputs. By attributing production to individual resources some understanding of factors associated with productivity changes can be gained.

In this paper changes in productivity over a 40-year period on an irrigated dairy farm are described. The key biophysical and infrastructure factors associated with the changes in productivity are discussed.

### Method

Several aspects of the approach will be discussed in this section. Further details can be found in Melsen et al. (2005).

### **Case study farm**

A case study approach was chosen because understanding farm management decisions requires detailed consideration of the complex combination of human, production, environmental, economic, and financial components of the business (Makeham and Malcolm 1993). Case studies over a long time enable an in-depth analysis of changes in production and resource use.

The analysis of the farm business reported in this paper focused on the production changes while identifying systems changes and investments.

The owners of the farm business that was investigated had very detailed physical and biological management records dating back 40 years. Extensive personal interviews were conducted to understand farm records and to gather additional information. Some data collected were based on memory re-call, particularly in the earlier years of the case study, introducing potential inaccuracies. The sources of data and assumptions used in generating a complete data set have been fully documented (Melsen et al. 2005). Once compiled, data, including estimated values, were checked with the farm manager and business members to guard against any inaccuracies.

### **Measures used**

The measures reported in this paper are changes in technical efficiency (quantities of physical output per quantity of physical input) on a dairy farm over a long time. The changes in physical inputs and outputs of the farm contribute to the changes that occurred in the economic performance of the business. A farm consists of numerous 'response functions' – relationships between the inputs that are of a physical, financial and human nature that, in combination create, ultimately, outputs of milk and livestock. The main indicator of the efficiency with which these resources are combined to produce output and meet farm goals are the economic indicators, profit and return to capital (also called economic efficiency). While maximum technical efficiency will not maximize economic efficiency, the physical relationships between inputs and outputs, and the changes in these relationships over time, are part of the basis for improving economic efficiency over time.

Note that the measures of technical efficiency are annual average levels of performance that were achieved in the case study business. The law of diminishing marginal returns dictates that as more of an input is

added to the fixed resources of the farm, the addition to output eventually declines (called diminishing marginal product). The effect of diminishing marginal product is to cause average production per unit of input to decline. The profit maximizing rule for the use of inputs is to use inputs up to the level where marginal cost from an extra unit of input nearly equals the marginal return. This level of input use will be somewhere between the level of input use where the average product of the input (total product/total input) is maximum and where the total production reaches a maximum and the marginal product of an extra unit of the input becomes negative. Between these two levels of input use – where average product is maximum and marginal product is zero, any level of technical efficiency (total output/total input) could be the most profitable, depending on the prices of the input and the output.

The main output produced by this business was milk. Milk income is largely determined by milk fat and protein production. Hence, partial production efficiencies were calculated as the amount of milk fat and protein produced per unit of input.

To determine the productivity of particular resources, partial productivity measures were calculated as listed below.

#### **Cows:**

- kg milk fat and protein/cow

#### **Land:**

- kg milk fat and protein/ha total farm area (titled area including outblocks)
- kg milk fat and protein/ha milking area
- estimated t DM pasture consumed/ha milking area

#### **Water:**

- kg milk fat and protein/ML irrigation water applied on the milking area
- kg milk fat and protein/ ML irrigation water + estimated effective rainfall on the milking area
- estimated t DM pasture consumed/ML irrigation water + estimated effective rainfall on the milking area

#### **Feed:**

- concentrate: kg milk fat and protein/t DM concentrate

#### **Labour:**

- kg milk fat and protein/labour unit

### **Data collection**

#### Milk production

Farm production records provided milk volume, fat and protein concentrations. Data was available for milk volume and milk fat in all years except 1969-70 and 1970-71. Milk production for these two seasons was

estimated from a trendline established from previous and subsequent years. Milk protein was not measured in Victoria before season 1985-86 and protein records on the farm were kept from 1987-88. Milk protein concentrations between 1963-64 and 1986-87 were estimated from farm records and herd recording scheme data. The average differential between farm values and the recording scheme data was applied to the recording scheme data prior to 1987-88 (taking into account breed) to calculate missing data.

#### Herd details

Farm records were used to establish cow numbers. Cow liveweight was estimated using farm records and historical data for the relevant breeds. A stock trading schedule was developed with records of milking herd number, calf, heifer and bull records. The herd was self-replacing and stock purchasing was minimal.

#### Farm area, expansion and infrastructure

With the aid of a current farm map, a timeline of farm expansion and infrastructure improvements was developed. The milking area was defined as the area of pasture grazed by lactating cows and excludes laneways, irrigation infrastructure, buildings and yards. This area was sown to perennial pasture species, no annual pastures were grown on the milking area. Total farm area was used to express the total input of land to the business and was defined as titled area including non-grazed areas and outblocks.

#### Water

Department of Primary Industries (DPI) staff had collected data on irrigation water use on the milking area of this farm from 1995-96. Goulburn-Murray Water (G-MW) provided irrigation water use data for most other years in the study period. Expenditure on irrigation water from farm records and tax returns was divided by the relevant water price to provide an alternative estimate of irrigation water use. This method of estimating water use from expenditure and price was used for years when data was not available from G-MW and when the data from G-MW appeared less accurate. No data were available for the first 4 years of the study period.

The farmer provided estimates of the amounts of water obtained from drainage diversion and groundwater pumps on the milking area.

Effective rainfall was estimated using climate data from DPI Kyabram as described in Armstrong et al. (2000).

#### Supplementary feed and estimated pasture consumption

Concentrate feeding commenced during season 1988-89. Details of concentrate use were available from records with the exception of seasons 1993-94 and 1994-95. In these seasons, data from the previous and subsequent years were used to estimate concentrate use. It was assumed concentrates fed in the dairy had zero wastage, dry matter content of 90% and an estimated metabolisable energy (ME) of 12.5 MJ/kg DM. It was assumed that the associative effect of adding concentrate to the diet resulted in a 10% decline in ME of concentrate.

Consultant's records of the amount of off-farm conserved fodder fed to cows were obtained for 1966-67 to 1972-73. Very little fodder was brought-in during this period. Prior to 1966-67, all conserved fodder fed to cows was harvested on farm. Brought-in conserved fodder was estimated to be approximately 0.6 t DM/cow in years 1974-75 to 1983-84. An accurate record of brought-in conserved fodder fed to cows was obtained for years 1995-96 to 2002-03. However, estimates were required for seasons 1984-85 to 1994-95 when consumption of brought-in conserved fodder was assumed to be 0.4 to 0.8 t DM/cow. Conserved fodder fed in paddocks was assumed to have a 25% wastage factor and an estimated ME of 8.5 MJ/kg DM. It was assumed that all fodder conserved on the milking area was consumed on the milking area and not sold or accumulated.

Direct measures of pasture consumption were not available. Hence, pasture consumption was estimated using the production efficiency analysis (D. Earle unpubl.) with modifications as described by Armstrong et al. (2000) and Heard et al. (2004). This method involved estimating the amount of energy required for milk production and stock requirements (SCA 1990). Estimated energy from 'brought-in' supplements was subtracted. An average pasture ME value of 10.8 MJ/kg DM (Cohen and Doyle 2000) was then used to calculate the amount of pasture consumed (t DM).

#### Labour

There were good records of labour input on the farm in any year. For the purpose of this study, one labour unit was defined as 40 hours per week. Estimates of hours worked by each employee and changes in hours worked throughout the study period were explained in depth.

## Results and Discussion

### Farm outputs

Milk production on the farm increased approximately 15-fold between 1963-64 and 2001-02 (Fig. 1). During this same period total milk production for Victoria increased approximately 2.4 fold (ADC 1999). The most significant drop in annual milk production occurred in 2002-03 in association with a drought. Interestingly there was no significant drop in milk production associated with the 1982 drought or the 1993 floods in the region.

The increase in milk production of the business was much greater in the second 20 years. For example, milk fat production increased from 10,700kg in 1963-64 to 41,700kg in 1983-84 and 155,900kg in 2001-02. Estimated milk protein production increased from 8,300kg in 1963-64 to 30,400kg in 1983-84 and actual production was 120,800kg in 2001-02 (see Figure 1).

This large increase in farm outputs resulted from the use of more inputs/resources and/or through more efficient use of these inputs.

### Farm assets and inputs

#### Cows

Herd size has steadily increased from 90 Jersey cows (350kg) in 1963-64 to over 500 Jersey X Holstein-Friesian and Jersey cows (450kg) in 2002-03, this represents about a 6-fold increase.

#### Farm area and land development

Over the past 40 years the milking area increased from 30 to 104 ha of irrigated perennial pasture (Table 1). Stocking rate on the milking area has increased from 3.6 cows/ha in 1963-64 to approximately 5 at present. Cow liveweight has also increased so that increases in effective stocking rate are higher than indicated by cow numbers/ha.

An 11 ha block was leased from 1985-86 to 1995-96, to agist dry cows and heifers. The most recent land purchase, in 1996, was a 200 ha outblock used for dry stock, heifers and contract agistment.

Table 1. Changes in the area of an irrigated farm between 1963-64 and 2002-03

Season	Milking Area (ha of irrigated perennial pasture)	Total titled area (including outblocks)
63/64	25	36
65/66	44	59
72/73	50	65

78/79	50	76
79/80	73	100
83/84	86	115
85/86	104	135
96/97	104	324
02/03	86*	324

\*Irrigated area reduced due to drought/ water allocation.

#### Water

Irrigation water applied on the milking area increased from 348 ML in 1967-68 to about 900 ML in recent years (Fig. 2). The increase in total irrigation water applied is generally consistent with the increases in the area of irrigated perennial pasture (Table 1). However, climatic conditions result in significant variation between years. The low irrigation water use in 1992-93 and 1993-94 was due to high rainfall. The storage capacity of the re-use system installed in 1980 probably meant that the amount of effective rainfall in these wet years was higher than estimated. There is no logical explanation for the low irrigation water use in 1977-78 and 1978-79; it appears more likely that the data for these years is inaccurate.

It is difficult to establish the impact of laser-grading, the re-use dam and automatic irrigation on irrigation water use due to the variation in climatic conditions, but there does not appear to be a substantial reduction in irrigation water use as a result of irrigation development (see Fig. 2).

Currently, the water right of the business is 688 ML. In addition to the water right, the case study farm has held an 86 ML drainage diversion licence on the milking area for the past 40 years. Groundwater pumps were installed in 1979-80, 1982-83, and 1990-91 and extract approximately 90 ML in total each year. The water from the drainage diversion and groundwater pumps, which were generally not metered accurately, adds a degree of uncertainty to the data but is a relatively small proportion of total water used on the milking area.

#### Supplementary feed and estimated pasture consumption

Pasture consumed per cow averaged 3.0 t DM/cow over the study period. A drop in pasture consumption per cow occurred with the introduction of grain feeding and was related to increased stocking rate, but may also indicate some substitution of grain for pasture.

Concentrate fed to cows on the case study farm was a mix of barley, wheat and triticale. In the years since the introduction of concentrate feeding, total DM intake has

more than doubled from 1200 t to almost 3000 t at present (Figure 3). Concentrate was fed at 0.7 t DM/cow in 1988-89 increasing to approximately 1.5 t DM/cow.

Brought-in conserved fodder use increased from zero in the early years of the study period to over 1 t DM/cow in recent years (see Fig. 3).

#### Labour and milk harvesting facilities

Labour has increased from 1.8 to approximately 6 labour units (40 hours/week) over 40 years.

The management of the farm has gradually transferred through family members over the 40-year period. Two brothers currently manage the farm. Their father managed the farm in the earlier years of the study period and still has some involvement in the business.

Milking facilities have been updated in order to cope with herd and land expansion. Dairy updates and improvements have progressed from a walk-through in 1964 to an eight-a-side herringbone dairy, a 12 then 16-a-side double-up system. Quick release technology was installed in 1987 and the current 50-unit rotary dairy was built in 1989.

#### **Productivity – Resource efficiency**

##### Cows

Average milk fat and protein production has increased from 120 to 290 kg/cow and 92 kg to 225 kg/cow, respectively. Milk volume increased from approximately 2500 L/cow in 1963-64 to peak at 6000 L/cow in 2001-02. This represents about a 2.4 fold increase in milk production per cow. The increase in milk production per cow appears to be associated with the introduction of supplementary feeding.

##### Land

Average milk fat and protein production over the total farm area (titled area including outblocks) has fluctuated from a low of 206 and 159 kg/ha in 1965-66 to a high of 862 and 627 kg/ha respectively in 1994/95. Since the acquisition of the 200 ha outblock in 1995-96, milk fat and protein production over the total farm area has been about 400 and 300 kg/ha respectively. This outblock was used less intensively than the milking area (dryland and irrigated annual pastures) and does not contribute directly to milk production. Hence, it is unlikely that this partial productivity measure will reach the level achieved in 1994-95 with current land and resource use.

The trend in milk fat and protein production per ha on the milking area was more consistent than milk fat and protein production over the total farm area. An approximate four-fold increase in milk fat and protein production per ha on the milking area occurred over the study period. The majority of this increase occurred since 1989 with the introduction of concentrate feeding and increased stocking rates. Milk fat production per ha on the milking area increased from 430 kg in 1963-64 to 530 kg in 1987-88 and 1500 kg in 2002-03. Over the same period, milk protein production increased from 330 kg to 370 kg and 1154 kg.

Initial inefficiencies associated with expansion in milking area indicate that developments involving expansion can lead to short-term inefficiencies (see Figure 4). This may be due to lower stocking rates and/or because the purchased land is less productive than existing land at the time.

While average milk production per ha of milking area has increased dramatically over the period examined, this is partly due to increases in the amount of supplementary feed given to the herd. The estimation of pasture consumption per ha provides an indication of how efficiently the land has been used to provide feed. The general trend has been for pasture consumption per ha on the milking area to double over the study period from approximately 7 to 15 t DM/ha (Figure 5). Peak consumption occurred in 2002-03 at 19.8 t DM/ha due to drought conditions and low irrigation water allocations. They led to some of the milking area being dried off (see Table 1) and a more intensive grazing system, which included young stock following the herd, being employed on the remaining area. It remains to be seen whether this level of pasture consumption can be maintained.

Initial reductions in estimated pasture consumption per ha were observed with increases in milking area. However, with increased stocking rates and time to improve pasture management, these inefficiencies were overcome. There also appeared to be a reduction in estimated pasture consumption per ha for about three years after the introduction of concentrate feeding in 1988-89 (see Figure 5).

##### Water

There was about a 3-fold increase in average milk fat and protein production/ML irrigation water applied (and per ML irrigation water and effective rainfall) on the milking area over the study period. The increase in efficiency primarily occurred from 1988-89

onwards and was partly due to increased supplementary feeding. The highest milk fat and protein production/ML irrigation water applied on the milking area occurred in the high rainfall years of 1992-93 and 1993-94. By including the estimated effective rainfall some of the variation due to climatic conditions was removed.

The general trend on the case study farm has been for pasture consumption per ML (combined irrigation water plus estimated effective rainfall) to almost double over the study period (Figure 6). The increase in efficiency of water use primarily occurred from about 1988-89 onwards. The increased pasture consumption per ML of water on the case study farm coincides with increased stocking rates and more intensive grazing management, in association with increased supplementary feeding.

It is difficult to establish any relationship between irrigation development and changes in pasture consumption per ML of water. The construction of the re-use dam and commencement of laser grading occurred in 1979-80. The following 10 years do not show an increase in pasture consumption per ML of water. However, it may have taken a number of years to capitalise on the benefits of these developments and they have probably provided labour efficiencies. The early laser grading methods (without topsoil replacement) were likely to have had a negative impact on pasture production (Kelly 1985) and consumption per ML of water. Much of the irrigation development coincided with expansion of the milking area in 1980-81, 1983-84 and 1986-87 which seems to have reduced the technical efficiency of pasture use for several years (see Figure 6).

#### Supplementary feed and estimated pasture consumption

Milk fat and protein production per unit of concentrate fed was highest in the year when the lowest quantity was fed (1988-89). Higher levels of concentrate feeding appeared to be associated with lower average milk fat and protein production per unit of concentrate fed, which suggests diminishing marginal responses were occurring when high levels of concentrate (over 1.5 t DM/cow) were fed.

The feeding of brought-in conserved fodder also increased from 1974-75 from 0.3 to over 1.0 t DM/cow. Milk fat and protein production per unit of conserved fodder decreased in association with increased feeding of conserved fodder in recent years. This suggests substitution and/or wastage may have occurred.

Average milk fat and protein production per t DM consumed (all feeds) increased slightly over the study period (Figure 7). This suggests that the estimated average feed conversion efficiency of the herd has not increased dramatically. Increases in milk production per cow appear to mainly be the result of increased DM consumption per cow. In total, DM consumption has increased from 3.0 to approximately 6.0 t DM/cow. This may be a result of breeding for a larger Jersey/Holstein-Friesian crossbred cow and a change in the type of feeds with the introduction of concentrates (see Figure 7).

#### Labour

Average milk fat and protein production per labour unit increased from 4,000 and 3,000 kg, respectively, in 1965-66 to 25,500 and 19,700 kg, respectively, in 2001-02 (Figure 8). The volume of milk produced per labour unit increased from 81,000 to 536,000 L over the same period.

Production increased from 9,600 to 19,100 and 7,200 to 14,000 kg of milk fat and protein per labour unit after installing the rotary dairy and increasing cow numbers. Concentrate feeding and improved irrigation layout through laser grading and automatic irrigation are also likely to have contributed to gains in labour efficiency (see Figure 8).

#### **Conclusions**

The large increase (approximately 15-fold) in total milk production on this case study farm over the last 40 years came about through the increased use of inputs (cows, land, water, fertiliser, feed and labour). However, partial productivity measures indicated that there has also been a trend towards more technically efficient use of these resources. Between 1963-64 the following partial technical productivity measures increased substantially:

- kg milk fat and protein/cow;
- kg milk fat and protein/ha milking area;
- kg milk fat and protein/ML of water (irrigation and effective rainfall)
- estimated t DM pasture consumed/ha milking area;
- estimated t DM pasture consumed/ ML of water (irrigation and effective rainfall); and
- kg milk fat and protein/labour unit.

There were periods when some of these measures (milk fat and protein/ha, pasture consumed/ha) declined for a short time. These reductions in partial productivity were generally associated with expanding the area of land, and took several years to overcome. Therefore, it would be expected that

significant increases in these productivity measures across the dairy industry are unlikely during periods of widespread expansion. It should also be noted that many farms have less opportunity to expand their milking area in small increments, as occurred on this farm.

Milk production per cow has increased, due to increased feed consumption per cow, which has allowed a greater proportion of energy to be used for milk production. However, milk produced per estimated t DM consumed does not seem to have increased substantially, indicating that average feed conversion efficiency has not increased substantially.

Pasture consumed per ha and per ML has increased, indicating that land and water resources are being used more efficiently in a technical sense.

Introducing concentrate feeding enabled increases in stocking rate, milk production per cow and per ha, and labour efficiency through increased per cow production. However, as expected concentrate feeding appeared to have reached levels in some years where the marginal response was diminishing. The amount of brought in conserved fodder fed to milkers in recent years appeared to be associated with a decline in milk response to this input.

While these partial productivity measures are useful for analysing change in a farm business they can be misleading if they are considered in isolation. They need to be considered in the context of the whole farm system. An analysis of farm economic performance is necessary to determine whether the productivity changes have been profitable.

The management of the production system and input usage on this farm are relatively efficient. However the farm is not representative of the average farm in the region. It probably represents the direction in which many farms need to move to be profitable. This case study analysis provides a detailed understanding of changes in production efficiencies over an extended period of time, with some key messages for managers of similar businesses.

### Acknowledgments

We thank the case study farm family for their time, co-operation and willingness to share their farm data, which was crucial to the completion of this study. We appreciate the direction and support provided by our project steering committee and our colleagues. Funding through Dairy Australia/Murray

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### References

- ABARE 2002, *Australian dairy industry productivity and profit*, Australian Bureau of Agricultural and Resource Economics, Canberra.
- Armstrong D, Knee J, Doyle P, Pritchard K and Gyles O 2000, 'Water-use efficiency on irrigated dairy farms in northern Victoria and southern New South Wales', *Australian Journal of Experimental Agriculture*, 40:643-653.
- Cohen DC and Doyle PT 2000, 'A pasture database for Victorian dairy producers', *Asian-Australasian Journal of Animal Sciences* A(13):61.
- Heard J, Francis S and Doyle P 2004, *Tactical decision support systems for the dairy feed base*, GF/059, Department of Primary Industries, Kyabram, Victoria.
- Kelly K 1985, 'Effects of soil modification and treading on pasture growth and physical properties of an irrigated red-brown earth', *Australian Journal of Agricultural Research*, 36:799-807.
- Makeham J and Malcolm L 1993, *The Farming Game Now*, Cambridge University Press, Melbourne, Australia.
- Melsen M, Armstrong D, Doyle P and Ho C 2005, 'A case study of changes in production and resource use over 40 years on an irrigated dairy farm in northern Victoria', Department of Primary Industries, Kyabram, Victoria.
- Watson A 2004, *Productivity and the dairy industry*, unpublished paper prepared for Department of Primary Industries, Victoria, Dairy Program, Kyabram, Victoria.



Appendix

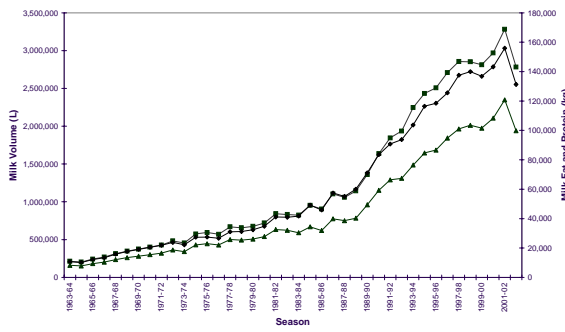


Figure 1. Changes in milk (□), milk fat (●) and protein (Δ) on an irrigated dairy farm between 1963-64 and 2002-03

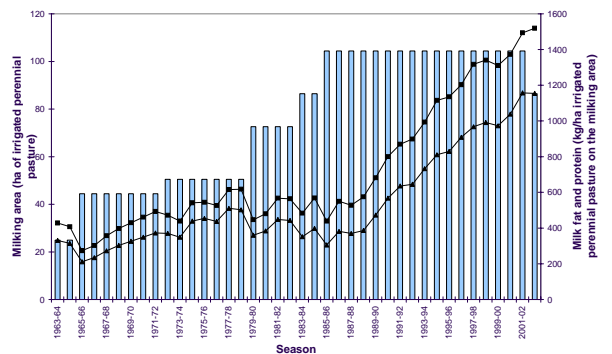


Figure 4. Changes in milk fat (□) and protein (Δ) production/ha of irrigated perennial pasture on the milking area (represented by columns) on an irrigated dairy farm between 1963-64 and 2002-03

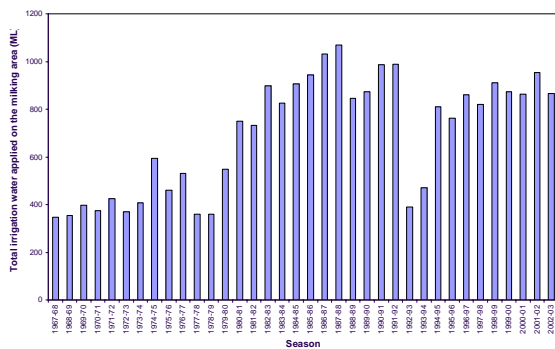


Figure 2. Changes in irrigation water use on the milking area of an irrigated dairy farm between 1967-68 and 2002-03. Data on irrigation water use was not available prior to 1963-64 to 1967-68

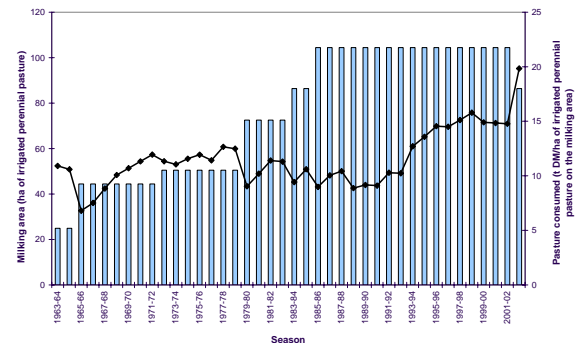


Figure 5. Changes in estimated pasture consumption (t DM/ha of milking area) (◇) and milking area (represented by columns) on an irrigated dairy farm between 1963-64 and 2002-03.

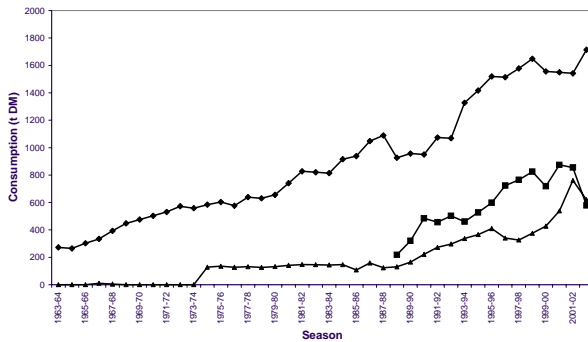


Figure 3. Changes estimated pasture consumption (◇), amounts of concentrate (□) and brought in conserved fodder (Δ) on the case study farm between 1963-64 and 2002-03

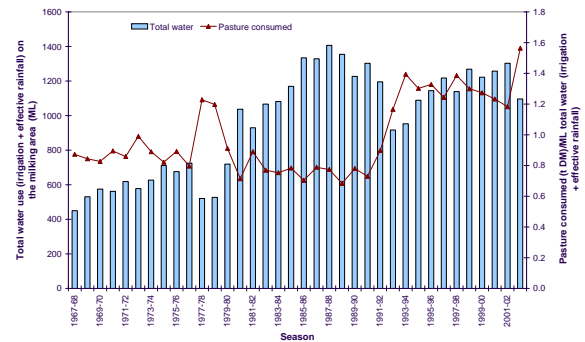


Figure 6 Changes in pasture consumption t DM/ML irrigation water and effective rainfall on the milking area (Δσ) and total ML of irrigation water and effective rainfall (represented by columns) on the milking area on an irrigated dairy farm between 1967-68 and 2002-03

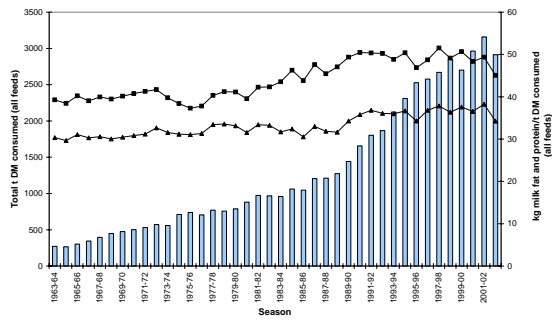


Figure 7. Milk fat ( $\Delta$ ) and protein ( $\square$ ) production per t DM consumed (all feeds) and total DM consumption (represented by columns) on an irrigated dairy farm.

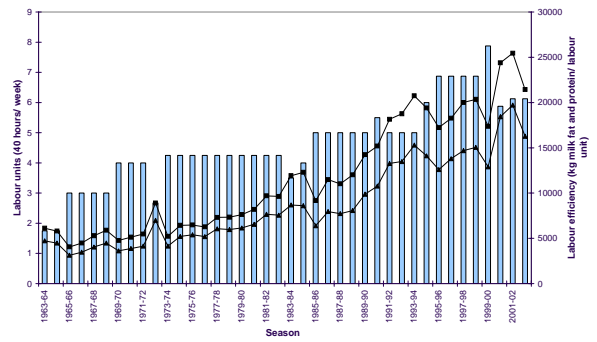


Figure 8. Changes in milk fat ( $\Delta$ ) and protein ( $\square$ ) production/labour unit and labour units (1 labour unit = 40 hours/week) (represented by columns) on an irrigated dairy farm between 1963-64 and 2002-03