Bega River catchment

River flow access and irrigated dairy farms

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The impacts of a set of proposed river flow access rules on irrigated dairy farms in the Bega catchment are examined. Three rivers within the Bega catchment are considered: Tantawangalo, Bemboka and Brogo.

The effect of water access restrictions on the level and variability of pasture production and subsequently farm cash income are simulated, using historical climatic data and based on existing farm dairy structures and market conditions.

The results indicate that, for the scenarios examined, farm incomes and pasture production were affected only in moderately dry periods.

River management

River flows, water quality and resource sustainability are key issues being examined for river systems across New South Wales. An important part of this process involves assessing the impacts of proposed changes in river management on water users in each catchment. In agricultural areas the potential cost of water use restrictions to meet environmental objectives will depend on the level and variability of rainfall, the intensity of water use along rivers, and the management options available to irrigators in the face of shortfalls in water supplies.

Background

The Bega River catchment is located on the far south coast of New South Wales. The catchment mainly supports irrigated dairying, beef cattle grazing and the grazing of sheep and lambs. Agricultural water use in the region is predominantly for irrigating perennial pastures to provide fodder for dairy cows.

Irrigated dairy farms located along the three principal rivers within the catchment — Tantawangalo, Bemboka and Brogo — occupy just over 3600 hectares of irrigated land. The farms are relatively similar in size, irrigated area and pasture types. The average area of irrigated properties in the catchment is 280 hectares, with 72 hectares sown to irrigated rye grass and white clover pastures (table 1). Estimates of the average financial characteristics of dairy farms in the region are also provided in table 1.

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The research presented in this article was prepared for the New South Wales Healthy Rivers Commission Inquiry into the Bega River Catchment. The results represent one of a number of inputs that the commission is considering in preparing its final recommendations. Hence, the findings do not necessarily reflect the views of the Healthy Rivers Commission.

As part of an inquiry into river flows and water extraction in the Bega River catchment, the Healthy Rivers Commission developed three alternative river flow access rules for the catchment. Under each river flow access scenario, water is shared between the environment and irrigators in proportions that depend on natural flows.

1 Irrigated dairy farms, Bega River catchment, 1996-97

		Average per farm	
Physical characteristics			
Cows	no.	200	
Heifers	no.	50	
Calves	no.	50	
Area sown	ha	280	
			summer
Area irrigated **a**	ha	72	
Ryegrass/white clover	ha	68	41
Kikuyu	ha	–	27
Sorghum	ha	4	
Dryland area	ha	209	
Ryegrass/white clover	ha	95	
Paspalum	ha	107	
Oats	ha	7	
Production characteristics			
Milk yield per cow	kL		5.55
Milk price			
Market milk	$/kL		517
Manufacturing milk (Sept–Jan)	$/kL		240
Manufacturing milk (Feb–Aug)	$/kL		311
Herd energy requirements **b**	GJ/month		1 208
Labor units **c**	no.		3.9
Financial characteristics			
Shed, herd and overhead costs **d**	$		488 675
Imputed labor costs	$		39 236
Depreciation	$		21 260
Inventory changes	$		6 331

a During summer, on average 40 per cent of area sown to irrigated ryegrass and white clover is taken over by kikuyu. **b** Energy requirement derived from the daily energy requirement outlined in Ashwood (1991). **c** One labor unit is defined as 1760 work hours a year (220 work days x 8 hours a day). **d** Includes imputed labor costs and depreciation.
Sources: NSW Dairy Industry Corporation (1998); FarmStats Australia (1998) – financial characteristics. Obtained from the following sources based on changes advised by New South Wales Agriculture after discussion with dairy farmers.

2 River flow access scenarios

	Natural flow condition **a**					Irrigator access to natural flow
						%
Base	Available flow					100
Likely			flow	<	5th percentile	0
	5th percentile	≤	flow	<	20th percentile	50
	20th percentile	≤	flow			100
Lenient			flow	<	2nd percentile	0
	2nd percentile	≤	flow	<	10th percentile	50
	10th percentile	≤	flow			100
Stringent			flow	<	5th percentile	0
	5th percentile	≤	flow	<	20th percentile	30
	20th percentile	≤	flow			100

a For example, the 5th percentile of natural flows is that flow for which 5 per cent of natural flows are less than that amount.
Source: Healthy Rivers Commission, May 1999.

The proportions of flows available to irrigators under each scenario are provided in table 2.

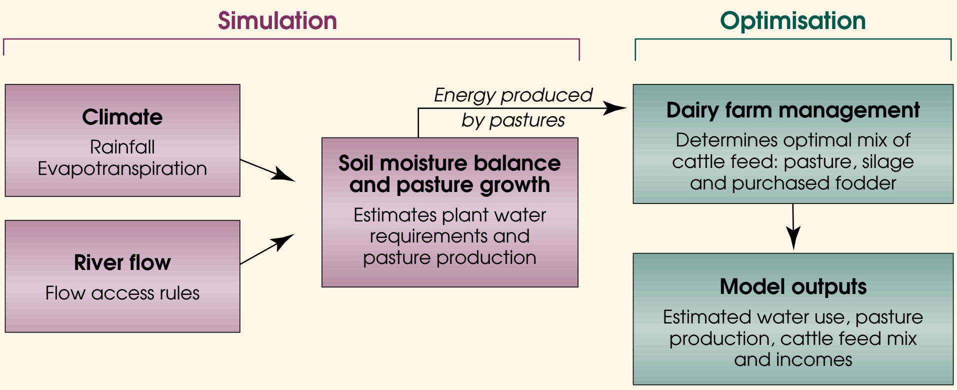
Each scenario was examined and compared against a base case in which access to flows for irrigation was always available, even during low flow events. For this study, the river flows examined were based on the assumption that the current operating procedures for Brogo and Cochrane dams are not altered. However, it is likely that changes to the operating procedures of Brogo dam could be made to allow for environmental flows.

Modeling river flow access scenarios

The impact of each river flow access scenario on irrigated dairy farms in the Bega catchment is assessed using a simulation model adapted from Brennan (1997). The model has four modules representing the biophysical and economic elements in the farm production environment (figure A):

- Climate module
- River flow module
- Soil moisture balance and pasture growth module
- Dairy farm management module.

A Structure of irrigated dairy farm model



In the simulation phase of the model, factors affecting fodder production, principally water availability, are considered. Rainfall, evapotranspiration and the volume of irrigation water available per hectare are simulated on a weekly basis. The climatic conditions are used to determine soil moisture availability, and river flow conditions determine the volume of irrigation water available to meet plant water requirements.

Based on the extent to which water requirements are satisfied, energy available from pastures is estimated and passed to the dairy farm management module. In this module an optimisation procedure is used to select the on-farm practices that best deal with meeting herd energy requirements given any shortfall in pasture production. More detailed descriptions of each module are provided in box 1.

Impact of river flow access scenarios

The impact of the river flow access scenarios varied between the subcatchments, principally depending on the rainfall pattern, river flow heights and the number of licence holders along each river. While the average impact of the flow scenarios over time was similar between the three subcatchments, the distribution of the impacts varied considerably. In the Brogo and, to a lesser extent, the Bemboka subcatchments, irrigators were likely to be affected by water use restrictions more frequently but less severely on most occasions than irrigators along the Tantawangalo River.

Pasture production

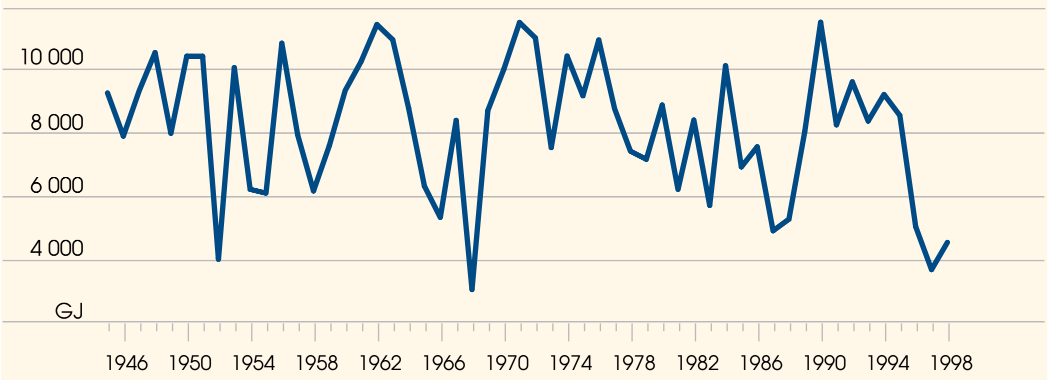
Dryland pasture production in the Bega catchment is highly variable and is closely correlated with rainfall. In the Bemboka subcatchment, estimated energy produced from dryland pasture over the period 1945-98 varied widely while irrigated pasture production changed little from year to year (figures B, C). Overall the pattern of energy availability from total pasture production largely reflected that of dryland pasture.

Irrigated pastures play an important role on dairy farms through the provision of a more stable and reliable energy source than dryland pastures. This source is particularly valuable to dairy farmers during dry seasons.

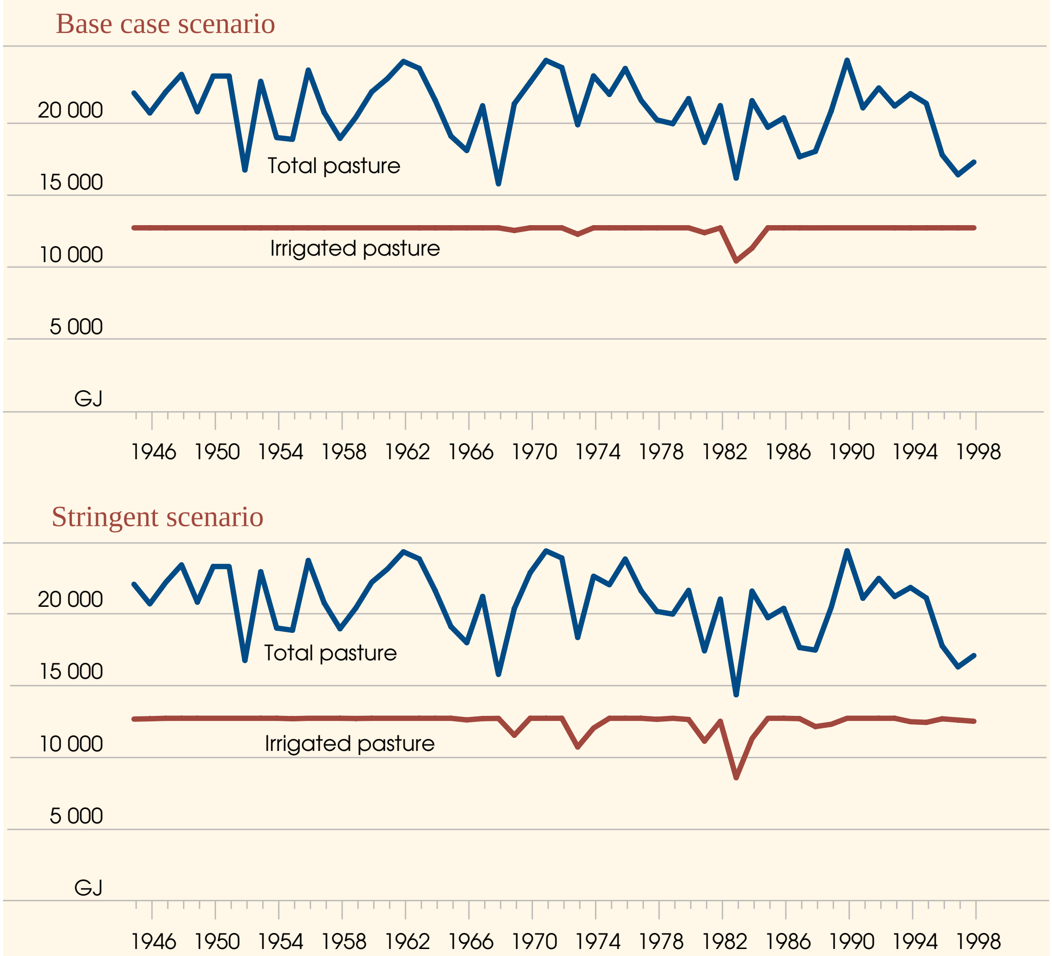
In figure C, irrigated pasture yield relative to total pasture yield is shown for the base and stringent river flow access scenarios in the Bemboka subcatchment. Over the period examined, irrigation provided considerable security through a reliable pasture yield. The amount of fodder produced from irrigated pasture remained relatively stable in all but extremely low river flow periods across all access scenarios.

This result was consistent for all three subcatchments. However, the magnitude of the decline in fodder production during low flow periods varied considerably between subcatchments (figure D).

B Estimated dryland pasture yield, Bemboka



C Pasture yield, Bemboka



1 Irrigated dairy farm model

Climate module

The climate module simulates rainfall based on weekly rainfall data for the period 1945–98 for Bemboka and Tantawangalo and 1978–98 for Brogo. Evapotranspiration rates for Bega are based on average weekly evapotranspiration rates, between October and March, over the past eight years (earlier data were not available). Evapotranspiration rates for Nowra and adjustment ratios supplied by the Department of Land and Water Conservation were used by the Healthy Rivers Commission to approximate the required weekly rates.

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River flow module

The river flow module simulates river flow heights and contains the access rules underlying each scenario. Using this information, the module determines the volume of water available to irrigators. Weekly flow data were provided by the Department of Land and Water Conservation based on historical flows at gauging stations along the Bemboka, Tantawangalo and Brogo rivers. The historical flow data were used to approximate natural flows by adding back estimated extractions by upstream irrigators along each river.

Access to flows along each river varied depending on the flow and the minimum and maximum flow percentiles set for each scenario. If weekly historical flow was below the minimum cutoff, no access was allowed. If the flow was beyond the maximum cutoff, full access was granted to irrigators. Flow sharing with the environment occurred if flow fell within the specified range (see table 2).

To obtain the volume of irrigation water available per hectare, the irrigators' share of river flow was divided by the total installed area in each subcatchment. Installed area represents the portion of licensed area actually irrigated along each river. Having derived the quantity of irrigation water available on a per hectare basis, it is implicitly assumed in the model that the regional water authority can constrain irrigators, if necessary, to the predetermined maximum quantity of irrigation water available per hectare.

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Soil moisture balance and pasture growth module

Climatic data and available irrigation supplies are passed to the soil moisture balance and pasture growth module where plant water requirements, irrigation water use and pasture yields are estimated.

The soil moisture balance is calculated for each pasture type according to the following equation:

$$M_t = M_{t-1} + R_t + I_t - E_t - F_t$$

Where M is the moisture in the plant root zone, R is rainfall, I is irrigation, E is potential evapotranspiration, determined by pan evaporation multiplied by a crop factor, F is the level of water in excess of field capacity, and t is the time period.

If available soil moisture falls below a set level of depletion, irrigation water is applied to refill the soil profile to field capacity. Rainfall in excess of field capacity is assumed to run off. The level of depletion tolerated was set at 85 per cent of plant root depth.

Pasture growth is linked to a moisture index that tracks the proportion of moisture available in the plant root zone for each pasture. The moisture index is used to determine a growth index for pasture during the simulation period. The growth index varies between zero and one and is multiplied by potential yield to estimate pasture production for each month. The relationship between the moisture index and the pasture growth index, based on the GROWEST model of pasture growth, was obtained from Brennan (1997).

Decisions to replant and supplement pasture yields with summer plantings were also represented in the pasture growth module. If soil moisture falls below the tolerated level of depletion for two weeks, due to a lack of available irrigation water and/or rainfall, irrigated pastures are assumed to die and cannot be replanted until soil moisture recovers.

Establishment costs are incurred on replanting. Pasture production is supplemented with sorghum plantings if spring yield is low. The replanting costs incurred together with the total amount of energy produced in each season are passed to the

1 Irrigated dairy farm model *Continued*

dairy farm module, as an input to the income maximisation problem.

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Dairy farm production module

A linear programming model is used to simulate dairy production decisions aimed at maximising cash income at the beginning of each season in response to realised climatic conditions. Key decisions to deal with any reduction in available energy from pasture are considered, such as buying in feed, keeping reserves of silage and reducing milk production. Production and hired labor costs, herd energy requirements, milk yield, utilisation rates of pasture and silage, and milk and fodder prices are taken into account in the decision process.

Certain parameters in the model are updated at each step of the simulation to reflect seasonal conditions (available energy and fodder prices) and past farm management decisions, such as silage carried over from previous seasons and the effect of cow nutrition on potential milk production.

Fodder prices are linked to a drought trigger based on minimum rainfall levels during each season. If these rainfall conditions occur fodder prices are assumed to double. However, the model can be modified to read in price time series for fodder and grain.

Over the periods examined, river flows dropped to such low levels in some years that there was very little between the effects of the lenient, likely and stringent scenarios, particularly for the Bemboka and Tantawangalo subcatchments. This can be seen for the Bemboka subcatchment in 1973 and 1983.

In less extreme years, pasture production declined as access to river flows was restricted. For example, during 1981 along the Bemboka, irrigated pasture production declined by 10 per cent under the stringent scenario, compared with the base case. The declines in production for the likely and lenient scenarios were 6.4 per cent and 3.6 per cent respectively, reflecting the higher access to flows under these regulations (table 2).

The magnitude and frequency of impacts arising from the water use restrictions are also important. On average, impacts were similar between the subcatchments; however, farms along the Tantawangalo River were estimated to incur large but less frequent impacts compared with other catchments. Along the Brogo River the impacts were smaller but much more frequent.

The more moderate but frequent impacts along the Brogo and Bemboka Rivers compared with the Tantawangalo River may reflect the potential effect of flow regulation through the management of Brogo dam — used mainly for irrigation purposes — and Cochrane dam in the western headwaters of the Bemboka River. While Cochrane dam is operated mainly to generate hydroelectricity, it can also maintain a flow in the Bemboka River during drought.

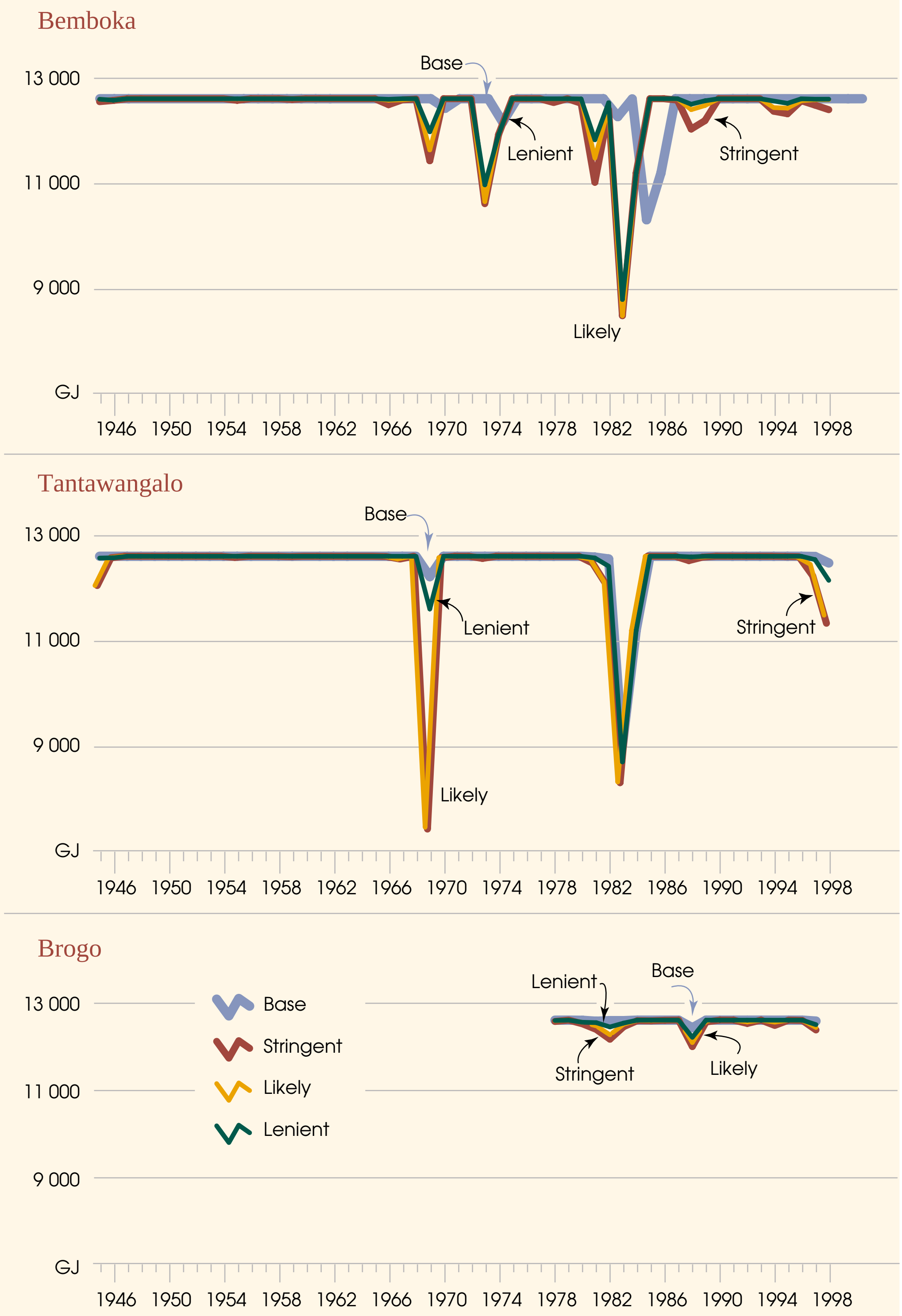
In the Brogo subcatchment, declines in pasture yields relative to the base case occurred more frequently than in the other subcatchments. However, the overall effect on irrigated pasture yields was smaller. While the management of Brogo dam may have influenced this result, it is important to note that the Brogo subcatchment was also examined over a shorter and relatively wetter period than the other regions, 1978-97.

Financial performance and water use

The impact of the river flow scenarios on farm income was very similar to the effect on pasture production. Incomes were largely unchanged in most seasons compared with the base case. Only during exceptionally low flow seasons were there substantial impacts on incomes. However, the magnitude and frequency of impacts on incomes varied between the three subcatchments.

The change in average farm cash income is shown in table 3. Average farm cash

D Impact of river flow access scenarios on irrigated pasture production



income in the base case was similar in each of the subcatchments. Under the stringent river flow scenario, average farm cash income declined by $1100 for farms along the Brogo River, compared with declines of over $1200, on average, for farms along the Tantawangalo and Bemboka rivers.

The impact on farm cash income during the year in which the river flow scenarios had the greatest impact is also shown in table 3. It should be noted that this was not necessarily the lowest income year and that the farm incomes with the water use restrictions in place generally fell within the range of incomes simulated under the base case scenario over time.

This feature of the simulated impacts arises from the fact that the timing and magnitude of the impacts of the river flow access restrictions are not closely linked to other factors affecting farm income, especially dryland pasture production. At times there was a close correlation between river flows and farm incomes but at other times they appeared unrelated. The future impact of any river flow access rules on income levels and variability would depend on these correlations, and the impacts are likely to differ between subcatchments.

In the Tantawangalo subcatchment the impact of the water use restrictions was concentrated around a single event in which farm incomes were estimated to fall by about $35 000. In the Brogo and Bemboka subcatchments, farm incomes declined by smaller amounts but these events occurred more frequently. As can be seen in table 4, although there is a higher probability of income remaining unchanged in Tantawangalo compared with the other two regions, there is also a higher probability of losses in excess of $15 000 being incurred.

It is interesting to note that the high loss event in the Tantawangalo subcatchment occurred in a year in which the pattern of rainfall permitted reasonable levels of dryland pasture production to be achieved. Hence farm income was maintained despite the considerable shortfall in irrigated production, brought about by a period in which river flows regularly fell within the bounds of the water use restrictions.

As the timing of low flow periods can be relatively independent of rainfall in an area,

3 Financial impact of access scenarios, by subcatchment

	Average farm cash income		Difference from base case	Cost per irrigated hectare a	Farm cash income in year of greatest impact
	$		$	$	$
Bemboka					
Base	128 450	(16.7)			126 650
Lenient	127 860	(17.1)	590	8.2	115 150
Likely	127 540	(17.4)	910	12.6	112 310
Stringent	127 180	(17.7)	1 270	17.6	111 960
Tantawangalo					
Base	121 810	(16.4)			126 250
Lenient	121 570	(16.5)	240	3.3	120 760
Likely	120 690	(17.2)	1 120	15.6	91 830
Stringent	120 580	(17.3)	1 230	17.1	91 530
Brogo					
Base	126 000	(14.9)			119 180
Lenient	125 730	(15.1)	270	3.8	117 210
Likely	125 320	(15.2)	680	9.4	116 160
Stringent	124 900	(15.4)	1 100	15.3	115 350

a Based on irrigated area of 72 hectares per farm (see table 2).
Note: Numbers in parentheses are standard deviations that are expressed as percentages of the estimates.

4 Probability of losses in cash income under river flow access scenarios a

	Probability		
	Lenient	Likely	Stringent
	%	%	%
Bemboka			
No loss	67	61	56
Loss up to $1000	24	22	20
Loss $1000–5000	7	9	15
Loss $5000–10 000	0	6	6
Loss $10 000–15 000	2	2	4
Loss over $15 000	0	0	0
Tantawangalo			
No loss	83	76	67
Loss up to $1000	9	13	20
Loss $1000–5000	6	6	7
Loss $5000–10 000	2	4	2
Loss $10 000–15 000	0	0	2
Loss over $15 000	0	2	2
Brogo			
No loss	65	25	20
Loss up to $1000	25	60	50
Loss $1000–5000	10	15	30
Loss $5000–10 000	0	0	0
Loss $10 000–15 000	0	0	0
Loss over $15 000	0	0	0

a Based on simulated incomes over the period 1945–98 for Bemboka and Tantawangalo and 1978–98 for Brogo.

it is possible for such periods to occur at a time when dryland pasture production is also low. In this situation the impact on farm incomes could be substantial.

However, as the Tantawangalo result was driven by a major event that occurred only once over the period examined, robust conclusions cannot be drawn about the frequency and impact of such an event on irrigated dairy farms.

The income estimates presented reflect an irrigator's best short term response to reduced seasonal pasture production. In figure E preferred sources of nutrition given seasonal conditions are shown for the year in which the river flow restrictions had the greatest impact.

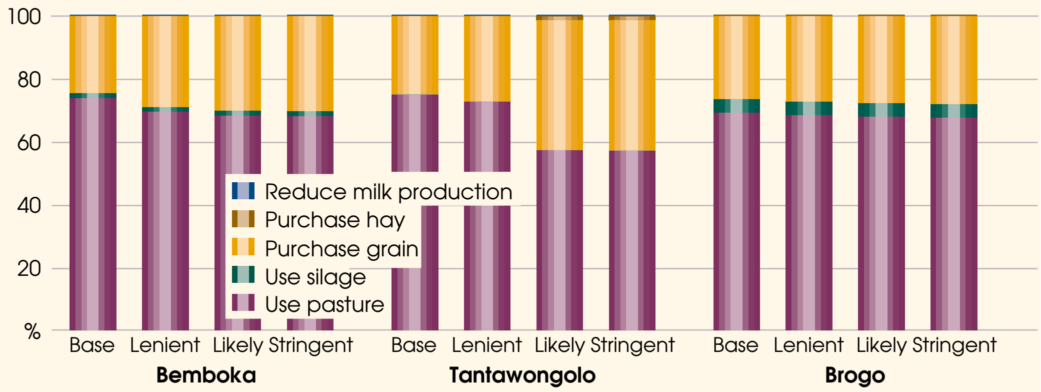
Depending on seasonal conditions, pasture was grazed and, when possible, cut and stored for silage. Along the Tantawangalo River, seasonal conditions did not allow for silage production. As pasture availability declined, preference was given to purchasing grain, a relatively cheaper source of energy than hay. However, the requirement that a minimum level of fibre consumption be maintained resulted in purchases of hay being forced into the model solution at times. Reduced milk production to alleviate nutritional needs was never chosen by the model.

The decline in income in the year of greatest impact in the Tantawangalo subcatchment was brought about by the need to buy in hay to meet herd fibre requirements as silage was unavailable.

For the other subcatchments in the year of greatest impact, fodder supplies carried over from previous seasons were available,

E Short term response to flow restriction in year of greatest impact

Contribution to total herd energy requirements per farm



5 Estimated average water use and dairy farm profit

	Water use		Farm profit a	
	ML/ha		$	
Bemboka				
Base	7.2	(21.6)	73 700	(29.7)
Likely	6.7	(23.8)	73 380	(30.2)
Stringent	6.5	(25.9)	73 020	(30.8)
Tantawangalo				
Base	7.9	(19.3)	67 650	(29.5)
Lenient	7.7	(21.5)	67 400	(29.8)
Likely	7.6	(24.0)	66 530	(31.2)
Stringent	7.3	(26.3)	66 410	(31.4)
Brogo				
Base	6.3	(16.0)	71 840	(26.2)
Lenient	6.2	(16.7)	71 560	(26.4)
Likely	6.0	(17.8)	71 150	(26.8)
Stringent	5.9	(18.6)	70 730	(27.2)

a Farm cash income less depreciation and imputed labor costs plus inventory changes.
Note: Numbers in parentheses are standard deviations that are expressed as percentages of the estimates.

which enabled them to restrict their need to purchase fodder to grain only (figure E). During dry seasons, purchasing grain and hay to supplement on-farm fodder supplies was always chosen in preference to reducing milk production.

Average estimated water use and farm profit for farms in each subcatchment are shown in table 5.

Conclusions

While the impact of the water use restrictions between the three subcatchments was similar on average, the magnitude and frequency of impacts varied considerably. It is this variation that provides an insight into the adjustment pressures faced by farms in each subcatchment.

For farms in the Bemboka and Brogo subcatchments, the water use restrictions examined imply that farm incomes will be affected quite frequently, but the decline in income experienced in most years will be small.

In the Tantawangalo subcatchment, irrigators could expect income to be unchanged in most years, with a relatively large loss incurred in about one in fifty years. However, conclusive findings cannot be drawn from a single event such as this.

Of potential interest to river managers is that periods in which river flows regularly trigger access restrictions can be independent of dryland pasture growth and farm incomes. As such, future impacts will depend on the frequency and timing of these events in relation to rainfall patterns.

The river flow access scenarios examined have an impact on farm incomes and pasture production only during moderately dry seasons. During extremely dry periods, low river flows meant that access was similarly restricted under each of the flow scenarios examined, particularly for Bemboka and Tantawangalo.

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