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Managing water as a scarce resource in beef feedlots

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Abstract

Water is the single largest nutritional component in the diet but is commonly overlooked in most intensive animal enterprises in terms of actual intake and cost. This phenomenon has come about as water is not considered to be limiting in terms of supply and price. However, with the developing scarcity of water, competition for water allocation will increase along with decisions regarding expenditure on treatment and reuse of water. Hence, decision makers will require a more detailed knowledge of water requirements for the intensive livestock industry, if it is to be considered as a consumer of scarce water in the future. Using a bio-economic model, H_2OBeef, that includes traditionally considered parameters associated with running a beef feedlot but also incorporates aspects associated with water, changes that can alter water consumption and or price are examined. The results indicate that when water does not incur a cost, the net benefits of the feedlot used as the example in this paper, are in excess of one million dollars (Australian) over a 20 year period. However, with the inclusion of reasonable water costs ($1.20 to around $1.90/kL) and/or slight changes in water use within the feedlot, due to temperature changes from Greenhouse effects, the net benefits can fall to zero. Although water makes up a relatively small proportion of the total feedlot cost, if changes to water demand, supply and/or policy drive up price, then water can play a significant part in determining the economic viability of a feedlot.

Keywords: water, beef feedlot, management, economics

1. Introduction

Water is becoming less available and in many global regions, a constraint for agricultural production (John and Kingwell, 2004; Ward and Michelsen, 2002; Rijsberman, 2006). Hence, if water provision and use are to be thought of in a systems framework then decisions regarding potential treatment and reuse of water, and water allocation will require knowledge of water requirements for agricultural industries such as the intensive livestock industry. Furthermore, if the whole ‘water system’ is to generate net benefits then decision makers will have to consider the economic viability of enterprises, and their ability to effectively manage water usage to cope with changes in water supply, demand and price.

In Australia water is becoming scarce with issues of burgeoning salinity and limited rural water supply being discussed by authors such as Sexton (2003). In an attempt to address such issues the Rural Towns Liquid Assets project is evaluating abstracting and treating saline water that lies beneath several Western Australian towns (Pluske *et al*., 2004). However, it is likely that such a water management plan will only be economically viable if there is a market for the extracted water to recover water extraction, processing and distribution costs. As explained by Johnston et al. (2005), the introduction of new enterprises to inland rural Western Australia, such as beef feedlots, that have the capacity to utilize the treated water, could be a viable proposition.

Under such a scheme water will come at a cost and hence understanding water usage in beef feedlots is a necessity. However, water demand is a factor that is currently overlooked in most intensive animal enterprises. This situation has occurred because water is not generally considered to be a limiting input and its cost is often seen as being insignificant when compared to the costs of other inputs. It is common in crop science research to consider water as a major resource associated with production and hence to study a host of associated issues as explained by Sinclair et al. (1984). Even so, research associated with the economic implications of water use in animal production has not been as forthcoming. Beckett and Oltjen (1993) considered water consumption in a feedlot but from the perspective of the whole beef supply chain and not on what might affect demand. Parker et al. (2000) analysed water use in a feedlot with the emphasis on increasing efficiencies associated with water supply, while Brown and McNinch (1996) acknowledged water use in a beef feedlot business plan but not how changes may affect that plan.

There is also the added challenge that the changing weather patterns that may result from environmental changes predicted by Greenhouse Gas effects is a basis for a possible change in water utilization. Ash (2001) suggests that temperature may increase by two degrees Celsius and rainfall decrease by 20 per cent in South-western Australia over the next 30 years as a response to Greenhouse Gases. With the predicted climatic change, cattle may experience increased levels of heat stress (Howden and Turnpenny, 1998) and hence the amount of water required by cattle for intake, spraying for dust control and cooling would be expected to increase.

The aim of this paper is to provide an example of how changes in one part of the whole water management system for a rural town, in this case a beef feedlot, can influence the net benefits of the system. A model, H_2OBeef, has been developed to determine the net benefits of a beef feedlot enterprise and for the purpose of this paper, to explore the issues associated with water demand. A feedlot would only buy a particular source of water if it is in its best interest to do so. Furthermore, for the whole water management system to work, demand for water must be reliable otherwise the viability of the system will be in jeopardy. It is beyond the scope of this paper to discuss in detail, the other components of the model that address feedlot structure, feed intake and liveweight change, waste management, the loans schedule and non-market benefits and costs (see Pluske and Schlink, 2005). Likewise, the abstraction and treatment of saline water, and subsequent environmental and infrastructural changes that may occur in the whole system will not be discussed in this paper (see: Pluske et al., 2004; Pluske 2006).

Demand for water by a feedlot will be contingent on the size of the feedlot, feed intake, and changing climatic conditions. In the following sections, details describing how water demand is calculated in H_2OBeef are provided, together with a description of the water sources for the feedlot and water balance. The economic analysis is then described before some case studies are presented and discussed.

2. Methods

2.1. Model

H_2OBeef is a simulation model integrating economic and biological components. For economic aspects, the time step is annual. For biological processes, cattle input can be varied and so the length of time cattle are in the system depends on management plans that are selected by the user. It is possible to generate results from H_2OBeef for either a 10 or 20 year time period. For the purpose of this paper, the town of Wagin (Latitude:-33.3075 S and Longitude: 117.3403 E) was selected as the location for the beef feedlot because it is one of the towns involved in the Rural Towns Liquid Assets project. The model is implemented in a spreadsheet program, Microsoft Excel®. It relies on inputs of economic and biological data to produce outputs that can then used to calculate net benefits for the specified feedlot operation (Figure 1).

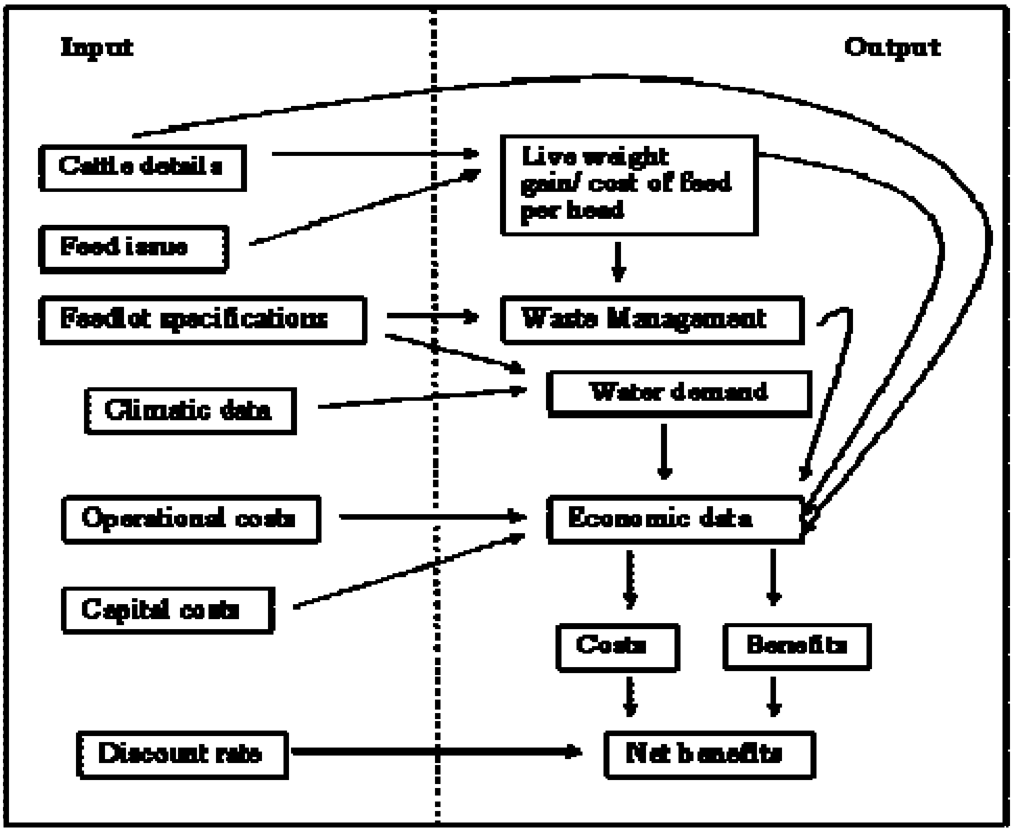

Figure 1: A simplified flow diagram showing the inputs (on the left side of the figure) required to produce the output from the H_2OBeef model (shown on the right side of the diagram)

2.1.1 Water demand

Rainfall and temperature data specific for the feedlot location is required to estimate the amount of water needed for dust control and water intake for cattle. Water required for dust prevention depends on several factors such as the nature of the soil type and the type of diet that is fed to the cattle. While the model can accommodate changes to this parameter, for the purpose of the analyses performed in this paper the assumptions are based on Watts and Tucker (1994), where it is assumed that watering would be required to maintain the manure surface moisture content at 25 to 35 per cent. Assuming one millimeter per hectare is equivalent to ten thousand litres, it would be necessary to spray three litres per square meter to ensure the equivalent rainfall of three millimeters per day.

Therefore the litres of water required for dust control for cattle in the feedlot in any one month ($\overline{W}$) is contingent upon the area of the feedlot in hectares (A), the number of cattle in the feedlot (N), the millimeters of water required for dust control on a daily basis ($\overline{w}$) and the number of days each month where the rainfall is less than three millimeters ($\hat{w}$) where:

$$\overline{W} = A\,N\,\overline{w}\,\hat{w} \qquad (1)$$

Winchester and Morris (1956), Hicks et al. (1988) and Doreau et al. (2004) have developed separate models to calculate daily water intake for cattle and each generate different daily requirements.

Hicks et al. (1988) estimated the litres of water required for a cow each day ($\hat{W}$) based on maximum daily temperature in degree Celsius (T), kilograms of dry matter intake per head per day (D), average daily precipitation in millimeters (I), and the percentage of salt added to the diet (s) where:

$$\hat{W} = -6.1 + 0.708T + 2.44D - 0.387I - 4.445s \qquad (2)$$

This prediction of water intake needs to be treated with caution for salt inclusions in the diet of greater that 0.5 per cent because the equation predicts decreasing water intakes with increasing salt content in the diet. This relationship is contrary to findings by Murphy et al. (1983) for dairy cows where increasing salt content in the diet resulted in increased water consumption. Moreover, the sodium content of drinking water can significantly reduce liveweight gains in feedlot cattle (Saul and Flinn, 1985). However, if it is assumed that the diet used in the feedlot does not exceed 0.5 per cent salt content, then Equation 2 which includes all four parameters can be used to generate water intake estimations within the imposed limitations. Winchester and Morris (1956) also provide predictions of daily water intake for both Bos taurus (W_{BT}) and Bos indicus (W_{BI}) cattle. As there is provision within H_2OBeef to have both cattle types in the feedlot this alternative estimation of daily water requirements is referred to as ‘Option 2’ while that developed by Hicks et al. (1988) is referred to as ‘Option 1’. The equations suggested by Winchester and Morris (1956) are:

$$W_{BT} = D\left\{3.413 + 0.01595\left(-e^{0.1739\hat{T}}\right)\right\}$$

$$W_{BI} = D\left\{3.076 + 0.008461\left(-e^{0.1739\hat{T}}\right)\right\}$$

where $\hat{T}$ is the average maximum temperature for the day.

Furthermore, Doreau et al. (2004) suggested that daily water intake should be supplied at 25.3 millilitres per kilogram live weight (doubled if cattle are fed at ad libertum). This work provides an additional check (‘Option 3’) in predicting the minimum litres of water required by the cattle ($\tilde{W}$) and serves as warning, in cases where cattle are placed on very restricted levels of feed intake, resulting in the weather conditions becoming the prime determinant of water intake where:

$$\tilde{W} = \left(\frac{a+b}{2}\right)\left(\frac{25.3}{1000}\right)$$

with a and b being liveweight in kilograms at purchase and sale, respectively.

To illustrate any differences in water intake that may be predicted by these equations, the following data was used: climate data for the upper Great Southern Region of Western Australia (around Latitude:-33.3075 S and Longitude: 117.3403 E); purchase weights of 220 kilograms per head of cattle; and predicted daily live weight gains of 1.24 and 1.29 kilograms for Bos taurus and Bos indicus cattle respectively over an one hundred day period (as generated by H_2OBeef using a daily dry matter intake figure of 5.22 kilograms; and the ration composition as shown in Table 1).

Table 1: Ration components selected for the diet used in the example presented in this paper

Component	Percentage in the diet
Wheat grain	45
Barley grain	5
Lupins	10
Silage	15
Fat	10
Wheat straw	5
Oat grain	10

NB: This diet is not necessarily optimal nor recommended but represents commonly used ingredients

Compared with Option 1, estimates generated from Option 2 indicate that there is a difference in water intake for Bos taurus cattle but not for Bos indicus cattle whilst the predictions from Option 3 generate a lower expected water intake value for both cattle types (Table 2).

Table 2: Daily water consumption of Bos taurus and Bos indicus cattle for the model options

Option	Water consumption Bos taurus (L/day/hd)	Water consumption Bos indicus (L/day/hd)
1	16.0	16.0
2	22.7	16.1
3	14.3	14.4

Given that under normal circumstances there is little difference in water intake between the models and that the Hicks et al. (1988) equation is the most inclusive and the temperature range is appropriate for the Western Australian environment, it has been selected to find the default water intake values in H_2OBeef. However, solutions to the models suggested by Winchester and Morris

(1956) and Doreau et al. (2004) are also presented in H_2OBeef and used to check that the water intake estimations produced using the Hicks et al. (1988) model are reasonable especially when temperatures are high.

Water intake required by the feedlot for any month is therefore the daily water intake for cattle multiplied by the number of cattle in the feedlot at that time and the number of days in that month. Total feedlot water requirement for each month (W) is then the sum of water required per month for all cattle in the feedlot and for dust control.

2.1.2 Cost of the water

For the purpose of this paper, it is assumed that water is sourced from saline groundwater that has been treated to a level that will not to impede cattle production. The total cost of desalinated water per month (C) (Australian dollars) is the quantity of desalinated water used in the feedlot in a particular month multiplied by the price of water per kilolitre (p). As the water is produced in a treatment plant some distance from the feedlot there is the additional cost for water transport. This cost is calculated as the quantity of water required, multiplied by the price of transporting the water from the desalination plant to the feedlot ($\overline{p}$) where:

$$C = Wp + W\overline{p}$$

2.1.3 The economic model

The underlying economic methodology in H_2OBeef is benefit cost analysis. There are variable and fixed costs to be accounted for over a twenty year period with facility in the model to adjust for cost and benefit streams varying across years. As outlined in numerous texts such as in Robison and Barry (1996), long-term investments are analysed by adding all costs and benefits for each year of the project (as present values) and using a discounting approach to calculate the net present value. The net present value (NPV), in Australian dollars, is the sum of the net benefits (B) for each year (t), discounted using a discount rate (r) where:

$$NPV = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t}$$

The preferred strategy has the highest NPV or highest internal rate of return (IRR) (which is the interest or discount rate required for the NPV to equal zero).

2.2 Analyses

2.2.1 General set-up of the feedlot operation

In this paper, H_2OBeef is used to generate an initial long term investment analysis (Analysis 1) based on the data set as outlined below. All costs and benefits and hence net present value results are in Australian dollars. It must be noted that with just over 150 parameters in the model and the capacity to adjust real costs and benefits in any of the twenty years, a great number of scenarios could be developed. Therefore for the purpose of this paper, only the most relevant parameters will be mentioned. The structure of the feedlot, including number and type of cattle entering the feedlot, store weight, death rate, and time in the feedlot, is designated by the model user. From this information, the model determines the number of cattle in the feedlot for each month of the year. For the example presented in this paper, the feedlot has an annual output of ten thousand head with a starting weight of 220 kilograms per head and a length of confinement of one hundred days. Natural death rate is one per cent per year. For simplicity, in the case studies input/output over time will be kept constant.

Nutritional information is supplied in the model for over fifty different feed components with provision made for entry of additional feed components by the user. While there is capacity in the model to change the composition and nutritional values of feed materials, for this paper the information was derived largely from Sauvant et al. (2004). From this list, type and quantity of components making up the ration and feed intake are selected and then, dry matter intake and live weight gain are generated by the model. Estimates of growth and production are based on equations from AFRC (1993) and as feed intake drives end weight of cattle, in the initial analysis, feed, composed mainly of grains, silage and wheat straw, is rationed at 8.75 kilograms per head to give a reasonable end weight of cattle at around 420 kilograms per head (based on DPI 2006).

Details regarding assets, revenue and most costs are either based directly on data obtained from industry sources or derived from calculations based on cost, revenue or biological data within H_2OBeef. The discount rate is assumed to be seven per cent.

As explained by Pluske et al. (2004) the potential to use treated desalinated water in intensive animal industries is still being investigated and hence the desalinated water referred to in this paper is not currently traded in the market and no prices are currently available for this water. Pluske (2006) further explores this issue and suggests that industry will only use desalinated water if the net benefits of doing so are at least equivalent to the net benefits of using alternative available water sources. Therefore, the price of desalinated water in the initial analysis is assumed to be $1.20 per kilolitre which is equivalent to the average cost of water (first 300kL per year) provided for country commercial purposes by the Integrated Water Supply System (Water Corporation, 2005). It is assumed that the water is of high quality and does not decrease cattle growth rate or water intake. There will be delivery costs for the water because in the example used in this paper it is sourced off-farm. Due to the lack of piping infrastructure, for simplicity, the cost of transporting the water by truck is assumed to be $0.25 per kilolitre per kilometer with the distance between treatment plant and feedlot being five kilometers. However, in line with research carried out by Ghafoori et al. (2006), who looked at the cost of piping manure against transporting it by truck away from feedlots, there are a number of parameters that will influence the optimal transport of water and this could be the focus of further work.

2.2.2 Alternatives to be analyzed

The parameter values and assumptions of any economic model are subject to change and error and hence sensitivity analysis can be used to investigate any impacts of these derivations on conclusions to be drawn from the model (Pannell 1997). Hence in an attempt to determine how differences in water demand and price affect the results generated by the model, the values of the most relevant parameters pertaining to water are altered from those described for Analysis 1 (Table 3).

In Analysis 2, the feed ration is altered and hence new daily weight gains are generated by the model, and water intake also changes as water intake is primarily determined in the model by dry matter intake (Table 3). In Analysis 3, water price is simply increased until the NPV is around zero, while in Analysis 4 the price of water is set to zero (but includes transport costs) and in Analysis 5 the total cost of water is set to zero (Table 3). To estimate the effect of potential climatic impacts of Greenhouse Effects on the feedlot, a sixth analysis involves changing temperature and rainfall parameters for each month, and water required for dust control and cooling based on information provided by Howden and Turnpenny (1998) and Ash (2001) (Table 3). The final analysis includes these same physical changes arising from the Greenhouse Effect but also includes the increase in water price required to produce a NPV figure close to zero (Table 3).

Table 3: A description of changes made to specific model parameters for each of the 7 analyses presented in this paper

Analysis	The value of the relevant model parameters
1	Per unit water cost = \$1.20/kL; cost of feed = \$1.66/hd/day; live weight gain = 1.98kg/hd/day
2	Feed intake is reduced from 8.75kg/hd to 7.62kg/hd (cost of feed = \$1.45/hd/day; live weight gain = 1.83kg/hd/day)
3	Price of water increased by 61 per cent from \$1.20/kL to \$1.93/kL
4	Price of water decreased from \$1.20/kL to \$0/kL
5	Price of water decreased from \$1.20/kL to \$0/kL and price of water transport decreased to \$0 per year
6	Monthly temperature increased by 2°C, monthly rainfall decreased by 20 per cent and water sprayed for dust and cooling increased by 20 per cent
7	Changes as for Analysis 6 with price of water also increased by twenty two per cent from \$1.20/kL to \$1.46/kL

3. Results and discussion

3.1 The base case analysis

Given the data used to generate the output for the base case scenario (Analysis 1) the feedlot could be described as being an economically viable proposition given a NPV over twenty years of just under \$490,000 and an IRR that is five per cent greater than the selected discount rate of seven per cent (Table 4).

With an annual demand for water of just over 63,000 kilolitres, based on a WAGov (2003) figure of annual personal water consumption of 155 kilolitres per person in Western Australia, the feedlot consumes as much water on an annual basis as around four hundred people. The population in most inland southern Western Australian shires is between 500 and 1,500 people with a varying percentage of these people living in towns (ABS 2005), thus a feedlot may be using the equivalent of a town’s annual water supply. Furthermore, in rural areas water is scarce and there are often several options for water use and hence policy makers will need to obtain sufficient information about the social net benefits of a new feedlot if it is to be considered as a potential beneficiary of any new water that is to be made available. While this is beyond the scope of this paper, it is important for decision makers to know if a feedlot will be viable in the town’s water management system. If it is expected to be viable then it should be a steady long term investment and hence demand for treated saline water would be consistent so helping with the fight to reduce salinity in the nearby town site.

3.2 Altering the feed ration

In considering ways to reduce water usage in a feedlot, decreasing the feed ration is an option. However as a consequence, if the diet is left unchanged, growth rate will be compromised as will the finishing weights, and hence revenue generated by the feedlot. Analysis 2 (Table 3) was designed to demonstrate the effect of feed intake on parameters in the model that influence water intake, and on the economic outcome produced by H_2OBeef. Decreasing the feed ration by just over ten per cent in Analysis 2, decreased feed costs and also water consumption and hence water costs when compared to Analysis 1. However, predicted growth rate also decreased, as did the NPV, to around zero, and IRR to around that of the discount rate (Table 4). While a decrease of around ten per cent in feed allocation resulted in the finishing weight of cattle being only fifteen kilograms lighter, the model indicated that from an economic perspective, the output is more sensitive to the level at which cattle are fed and hence their finishing weights, than to the implications of a reduction in water in take. That is, the daily weight gain per head was still within the average range of around 1.3 to 2kg as described by Edmondstona et al. (2004), but the percentage of water cost to total cost decreased by only 0.01 per cent under this scenario which was significantly less than the decrease in revenue.

Table 4: Values of feedlot parameters and the Net Present Value (NPV) and Internal Rate of Return (IRR) for the base case analysis (Analyses 1) and an analysis showing a reduction in feed intake (Analysis 2)

Parameter	**Analysis 1**	**Analysis 2**
Water used in the feedlot per year (kL)	63,262	61,072
Annual cost of water ($)	75,915	73,286
Annual cost of water transport ($)	79,078	76,340
Water costs as a percent of total costs	2.26	2.25
NPV ($)	487,223	-1,692
IRR (%)	12	7

3.3 Changing the water price

As the price of desalinated water used in these analyses is assumed, it is imperative to have some understanding of how high this price can go before it affects the economic viability of the feedlot. When compared with Analysis 1, increasing the price of water by 61 per cent in Analysis 3 increased the percentage of water costs to total costs by less than one per cent, to just over 2.90. However, the NPV was reduced to around zero and the IRR to around the level of the discount rate (Table 5). The commercial water price imposed by Water Corporation (2005) for additional water usage over 300 kilolitres per year, is slightly greater than $2.20 per kilolitre. Hence should a feedlot have to pay for water then decision makers should be aware that this model indicated that with a price of water at well below this level, at around $1.90 per kilolitre, the feedlot was not economically viable.

To further emphasize the importance of water price for feedlot managers, in a sensitivity analysis (Analysis 4) water price was set to zero as it is considered to be the case for most livestock farmers. Given all other model parameters were kept constant, the NPV increased to over one million dollars (Table 5). On removing the water transport costs as well in Analysis 5, resulted in the NPV increasing further to around two million dollars (Table 5). Given that the internal rate of return in both of these latter examples was well in excess of the discount rate of seven per cent, a feedlot could go from a relatively lucrative proposition to one that is unacceptable just on the account of considering water costs.

Table 5: Values of feedlot parameters and the Net Present Value (NPV) and Internal Rate of Return (IRR) for the base case analysis and analyses showing the effect of a change in water price (Analyses 3, 4 and 5)

Parameter	**Analysis 1**	**Analysis 3**	**Analysis 4**	**Analysis 5**
Water used in the feedlot per year (kL)	63,262	63,262	63,262	63,262
Annual cost of water ($)	75,915	122,096	0	0
Annual cost of water transport ($)	79,078	79,078	79,078	0
Water costs as a percent of total costs	2.26	2.91	1.16	0
NPV ($)	487,223	-2,023	1,291,464	2,129,214
IRR (%)	12	7	19	26

3.4 Accounting for potential climate changes

Analysis 6 was set up to account for potential climatic changes due to the Greenhouse Gas Effect. As described in Table 3, the temperature was increased, rainfall decreased and water required for dust abatement increased. As a consequence water demand in the feedlot increased by around 17 per cent, so increasing the cost of water and decreasing the NPV to just over $200,000 when compared to Analysis 1 (Table 6). Increasing the water price by around twenty per cent (Analysis 7) while maintaining the same changes in model parameters as were used in Analysis 6 resulted in a small change in the percentage of water costs to total costs but saw the NPV drop to around zero (Table 6). Hence, if water is freely traded and increases in price due to its scarcity, by just a small margin, the effect on the viability of feedlots is significantly more dramatic. The impact of raising water prices will not only affect the economic viability of feedlots in general but will also significantly affect production of beef that currently relies on feedlot finishing to meet market specifications for beef products.

Table 6: Values of feedlot parameters and the Net Present Value (NPV) and Internal Rate of Return (IRR) for the base case analysis and analyses showing effects of climate change (Analyses 6 and 7)

Parameter	**Analysis 1**	**Analysis 6**	**Analysis 7**
Water used in the feedlot per year (kL)	63,262	74,135	74,135
Annual cost of water ($)	75,915	88,962	108,237
Annual cost of water transport ($)	79,078	92,669	92,669
Water costs as a percent of total costs	2.26	2.63	2.90
NPV ($)	487,223	205,017	816
IRR (%)	12	9	7

4. Conclusions

The case studies presented in this paper were designed to highlight the importance of considering water use and cost in a beef feedlot that would be part of a town infrastructure management plan. While the example is specific for a town in Western Australia, the model variables can be changed to those for any feedlot situation in any part of the world.

It is evident from these scenarios that while changes in major inputs in a feedlot, such as feed, significantly alter the economic viability of a beef feedlot, a largely forgotten input, water, can also have ramifications on the investment decisions. These findings emphasize that for informed decisions to be made, policy makers need to address water pricing specifically in rural areas because it can have an impact upon the economic viability of intensive livestock enterprises.

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