A CALCULATOR FOR ESTIMATING THE PROFITABILITY OF IRRIGATION ON NEW ZEALAND DAIRY FARMS

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Abstract

Few issues are as important, topical or problematic in New Zealand agriculture as irrigation. Central government is currently championing irrigation for its potential to dramatically increase dairy production, or as a way of introducing dairy farming to previously marginal areas.

There is a general consensus that applying irrigation to pasture with significant soil water deficits over summer will increase pasture production. However, there is much less agreement on the profitability of irrigating dairy pastures.

A calculator has been developed to help dairy farmers explore issues associated with an investment in irrigation. Farmers considering the adoption of irrigation can use this calculator to predict the likely profitability of irrigation. Inputs to the Calculator are few and simple.

The calculator has three modules; the first module is a pasture production model; the second is an expenses model which calculates the expenses associated with irrigation, the third is a model which compares a base farm (without irrigation) to an irrigated analogue. The results from these three modules is information such as cost per kg of extra dry matter from irrigation, the profitability of a particular irrigation scenario, as well as other financial information.

The calculator has been demonstrated on three contrasting Manawatu dairy farms. The main conclusions drawn from the use of the calculator on these case study farms are; the likely profitability of an investment in irrigation is not easy to identify (and may be unexpected); the amount of extra grass grown under irrigation is an obvious consideration in an irrigation investment analysis but arguably how this grass is utilized is just as important; there is a large 'production cost' associated with increasing the stocking rate on irrigated dairy farms and this can affect the financial feasibility of irrigation; in the Manawatu region, irrigation is likely to be more profitable on dairy farms that can grow more than 2 t/ha^{-1} additional dry matter and harvest this with current cow numbers.

Introduction

On dairy farms in many parts of New Zealand (especially the east coast), evapotranspiration during the summer months exceeds rainfall, causing large soil water deficits (SWD) to develop. Eventually the SWD will get to a point where it is the major factor limiting pasture growth rates (Baars and Coulter 1974). The consequence of this is that farmers cannot meet the nutritional requirements of their dairy herd from pasture alone, thus milk production can be severely reduced. However, irrigation can allow a farmer to fill this water deficit and gain significant yield responses (D. Rickard 1976), which in turn increase pasture production and negates the effect of the summer climate on the farming system (Mcbride 1994).

The profitability of an irrigation system is determined by the difference between on-going running costs and the money earned from the extra production that irrigation provides. However, this difference can vary markedly across regions and between farms according to variations in summer rainfall and soil profiles.

Many dairy farmers may be considering investing in irrigation to increase production, but due to the variations in reponse rates found across the country, the costs, plus the lack of decision support tools and any recent research studies on this subject are unsure of the economic benefits of doing so. Farmers need a clear idea about how much extra pasture can be grown on their farm, how much this extra pasture costs to grow, and the usefulness or role of this extra grass growth in their system.

A calculator has been developed to help dairy farmers assess the financial implications of an investment in irrigation. This calculator consists of three modules, which are dependent on each other. The first module is a pasture production model based on thirty two years of climate data and soil type. The second is an expenses module which calculates the expenses incurred in the use of irrigation including the setup cost of the system and yearly running costs. The third module is a model which compares a base farm (without irrigation) to an irrigated analogue over the 32 year period. The results from these three modules is information such as cost per kg of extra dry matter from irrigation, the profitability of a particular irrigation scenario, as well as other financial information. This calculator has been designed to be a relatively simple tool that requires a minimum of input information from the user. The use of the Calculator is demonstrated on three contrasting case study farms in the Manawatu.

Case study farms

Three contrasting Manawatu dairy farms have been used as case study farms (Table 1). These farms have been chosen as they represent a broad range of micro climates within the greater Manawatu region. They encompass the dry (Himatangi), average (Milson) and wetter (Shannon) rainfalls for the region.

Table 1: Details of case study farms

	Himatangi	**Milson**	**Shannon**
Rainfall (mm)	870	970	1200
Soil type (readily available water mm)	Himatangi sand (25 mm)	Te Arakura fine sandy loam (60 mm)	Manawatu fine sandy loam (50 mm)
Irrigation system	Centre pivot	K-Line	K-line
Current average herd production (kg MS/cow)	320	430	463
Stocking rate (cows/ha)	1.55	3	3.3
Max MS production by herd(Kg/MS/cow)	400	500	590

Methods

This calculator has been designed with simplicity in mind and most importantly to be user friendly, therefore, the information needed to drive the calculator is kept to a minimum. The user is required to input (at a user interface) simple details like region of NZ their farm is located; what kind of irrigation system they will run; their herd's current production and SR (Table 1). This is information that farmers should have 'at their fingertips'. Furthermore the costs of the irrigation project needs to be inputted into the calculator, however the calculator has a range of default cost values which, in the absence of exact costs, allow the user to determine the approximate financial feasibility of irrigation. From this initial result, the user can then determine if it is worth obtaining professional quotes, which they can then input into the calculator to obtain a more realistic output for their farm.

The calculator has been developed using Microsoft Excel 2007; and is driven by information which the user is required to input (see above). The calculator is designed as a tool to predict the financial feasibility of an investment in an irrigation system. It does this by comparing a base system (the current farm as defined by the user) against an irrigated analogue, giving outputs such as profitability in $/ha and return on investment.

The calculator uses three individual modules that are driven by the data given by the user at the user interface. These modules are:

1. A soil water balance and pasture growth module

2. An expenses module

3. A current farm production vs. new system module

Soil Water Balance and Pasture Growth Module

Pasture production in the current and irrigated analogue is simulated for the past 32 years using a modified version of the model of Moir et al (2000). This model is driven by a growth constant and daily evapotranspiration rates. A value of 18 kg DM/ha/mm of evaporation was selected for the growth constant in order to reflect the high soil nutrient status of most dairy farms. Daily evaporation was determined by a soil water balance, both with and without irrigation. Accordingly, the annual irrigation requirement was also determined using the soil water balance. The procedure for the soil water balance is described by Scotter et al. (1979).

Expenses Module

The expenses module is driven by information provided by the user. The main function of this module is to estimate the total annual expense incurred from running an irrigation system over a defined period (for this calculator it is 32 years). The module uses two types of variables; those that change each year depending on irrigation usage (variable costs), and those that do not change or stay static whether the irrigator is used or not (fixed costs). The variable costs include; electricity costs; labour and bike costs. The fixed costs include; depreciation costs on hardware; opportunity cost of capital on total project cost; water consent costs.

The module takes the irrigation usage from the soil water balance module for a particular season and calculates the variable costs incurred in that specific season, and then adds these to the pre calculated fixed costs to give a total cost of irrigation for that season. This is done for each of the last 32 years of irrigation. The module works on the assumption that the user is using best irrigation practice (BIP). The total expense for each year is then used as an input in the 'Current Farm Production vs. Irrigated System Module'.

Current Farm Production vs. New System Module

This module calculates and compares the financial performance of the base farm system (without irrigation) vs the irrigated analogue farm. The module is split into two sections; a base system which is formulated on inputs provided by the user and a new farm system (with irrigation) which calculates the changes in production and farm expenses that result from the adaption of irrigation. Each year, these two farm systems are compared against each other (i.e. net difference between them) over a range of different MS pay-outs. The production information provided by the user is incorporated with the costs (fixed and variable) associated with the irrigation system to give an overall picture of the economics of irrigation. This is then displayed in the output screens, providing information such as how much the extra pasture produced will cost; how much extra money the pasture could be worth; possible increase in stocking rate and return on investment.

Identifying the base system

This module uses the pasture growth model (run for 32 years) to simulate the grass production in Kg/DM/ha for the base farm. This module then takes the simulated grass production and sorts it from lowest to highest. The base farm's median year for pasture production (50 percentile value) is identified. The calculator now looks at the effects of increases and decreases in grass growth on the farm over the last 32 years. This explores the effects of climate over the 32 year period on pasture production.

An important feature of this module is the bounded max and min milk solid production on farm. Annual milk production on a dairy farm varies from year to year for a number of reasons: the vagaries of the weather will account for most of this variation. In dry and/or cold years, less grass will grow and milk production will decline. In contrast, if favorable weather conditions are experienced, milk production will increase. However, on many farms production is bounded. In the very best years, the herd may not be able to eat all the extra grass that is grown. Conversely, in the most adverse years, many farmers will purchase extra supplements to prevent production falling below some minimum level. Some features that determine the range of the farm's annual milk production are gathered for input into this module and these are used to simulate the current and irrigated farms MS production.

The irrigated system

This section of the module, like the base system, uses the pasture growth module; however it now includes a simulated pasture response to irrigation for the last 32 years. The model partitions the extra grass grown under irrigation as follows. Firstly the calculator allocates grass to the current herd to a maximum value set by the production worth (PW) of these cows. Secondly; the SR is increased to utilize any remaining pasture.

The gross income and costs (taken from the expenses module) associated with irrigation are formulated and then the net difference between the irrigated and non-irrigated farm is calculated as an end result.

Results and Discussion

The outputs

A summary of the final results from the three case study farms are compared against each other below (Table 2).

Table 2: Summary table for the case study farms with a side by side farm comparison.

	Milson	Himatangi	Shannon
Capital cost of installing irrigation	$276,335	$771,857	$450,547
Capital cost of installing irrigation/ha	$3,004	$3,979	$3,004
Median annual cost of irrigation/ha*	$626	$1,295	$522
Median extra income from irrigated farm	$47,207*	$61,293*	$729*
Median extra income from irrigated farm/ha	$513*	$316*	$5*
Median return on investment	17%*	8%*	0%*
Possible change in S/R cows/ha	0	0.32	0
% of the time that the irrigated farm out-preforms the base farm	76%*	65%*	50%*
Median irrigation depth (mm)	265	300	205
Range of increase in pasture growth (kg DM/ha)	0 – 4,000	1,200 – 6,000	0 – 4,000
Median increase in pasture growth (kg DM/ha)	2,250	3,700	1,130
Range of cost of increased growth ($/kg DM)	0.17 – 1.30	0.12 – 0.31	0.17 – 2.00
Median cost of increased growth ($/kg DM)	0.30	0.18	0.38

*At a $5.80 MS payout

The Himatangi farm has the largest capital set up cost at $771,857, because it has the largest irrigated area (194 ha) compared to Milson (92 ha) and Shannon (150 ha). When the per ha capital cost of the individual irrigation systems are compared, both Milson and Shannon cost $3,004/ha, whereas Himatangi costs $3,979/ha, which would be expected since pivot irrigation generally has greater start-up costs than K line irrigation.

The median annual cost of irrigation/ha (Table 2) shows that Shannon is the cheapest system to operate at $522/ha, with Milson second at $626/ha and Himatangi is by far the most expensive at $1,295/ha. The annual cost of irrigation/ha cost at Himatangi would at first seem extremely large given that this farm produces 1,500 kg/ha more grass than the Milson farm in a median year, and achieves this at a very reasonable cost of $0.18/kg DM. As Himatangi has a centre pivot, its much larger costs cannot be attributed to greater labour costs. Likewise, neither will increased electricity costs to pump this extra water account for such a large increase in annual irrigation cost. When these annual costs are investigated further, the answer for this seemly counter intuitive result becomes clear.

The reason for this result is mainly due to the way that the model partitions the extra grass grown under irrigation. The extra grass that is not utilized by the current herd is used to increase SR. It is when the SR is increased that the costs increase dramatically; this is because when a cow produces a kg of MS, this MS has a 'cost of production' attached to it. This 'cost of production' is the farms total expenses divided by the total of MS produced, ($/kg MS). Now any cow already on the farm (from the base system) is assumed to have this cost attributed to the MS they produce, therefore when they increase production (i.e. from the extra grass provided by irrigation) it is assumed that there is no additional cost associated with the extra MS the cows produce. However when the current herd (base system) is incapable of consuming all of the extra grass on offer, then new cows (an increase in SR) must be purchased and brought onto the property. There are two costs associated with this increase in SR; firstly there is the capital cost of the new cows, and this (capital cost) is accounted for as an opportunity cost of capital. Secondly each MS produced by the new cows incurs the cost of production. Furthermore, the new cows are assumed to have lower conversion efficiency (Holmes and Roche 2007), as some of the grass that they eat is needed for maintenance, compared with the current herd where maintenance has already been accounted for, but each MS solid they produce in theory is also worth less when compared to the base system. If we take the average inflation adjusted MS price of $5.80/kg MS (Dairy NZ 2013) and a typical cost of production figure of $4.00/kg MS, then each MS that the new cows produce is in theory only worth $1.80 ($5.80 - $4.00). It is this 'cost of production' which drives up the cost of irrigation on the Himatangi case study farm.

At Himatangi, unlike Milson and Shannon, it is predicted that the farm will have to increase SR by 0.32 cows/ha (Table 2). The reason for the increase in SR at Himatangi is directly related to the low current SR (1.55 cows/ha) and the low maximum production of the current herd (400 kg MS/cow) (Table 1). The low SR and low maximum production of the cows on this farm have contributed to the increase in SR of 62 cows (opportunity cost of capital charge of $18/ha). These cows produce 31,000 kg MS (at a cost of $636/ha). If this 'cost of production' ($18/ha + $686/ha) is subtracted from the current annual cost of irrigation on Himatangi, it would now only be $609/ha which compares more directly with Milson and Shannon (Table 2). It can therefore be seen that increasing the SR on a farm converted to irrigation detracts from the profitability of irrigation. However as a point to note, when further development of this calculator is undertaken the 'no cost of production' assumption attributed to extra MS produced by the current herd may need to be further investigated as there may be small increases in this cost of production and these may need to be accounted for.

When the median extra income from irrigation (Table 2) is investigated (at a $5.80 pay-out), the Milson farm has the biggest net difference between the base and irrigated farms at $513/ha (a 17% return on investment) compared to Himatangi at $316/ha (8% return on investment) and Shannon at $5/ha (0% return on investment). For the Milson case study, the irrigated farm is the more profitable system and it 'breaks even' or better 76% of the time. The reason that Milson is the most profitable case study farm is due to the fact that it is well stocked (3 cow/ha) with cows capable of eating (max production 500 kg MS/cow) all the extra grass (2,250 kg DM/ha) made available by irrigation. On the Shannon farm even though the SR is high (3.3 cows/ha) and even though they are capable of eating all the grass on offer from irrigation, at a median of 1,130 kg DM/ha there is simply not enough extra grass grown on this farm to make irrigation a viable option. This can been seen in the fact that irrigation will only break even or better 50% of the time, or five years in ten (at a $5.80 pay-out). The small net different between the irrigated and base a farm at Himatangi is obviously attributed to; the low SR on the farm, low PW of the cows, the consequent need for an increase in SR, and the cost associated with this. However when the Himatangi case study is re-run through the calculator, but with Milsons cows and SR, a very different result occurs. Under this scenario, Himatangi now only needs to increase its SR by 0.19 cows/ha, meaning it now has a net difference of $700/ha, a return on investment of 18% and it will break even or better 92% of the time when compared to the base system.

This has shown that when investigating irrigation it is not only important to consider how much extra grass irrigation can grow, but equally important is how this grass is utilized. The ability to efficiently utilize the extra grass grown under irrigation is constrained by numerous factors not least of all is the skill of the farmer. It can be assumed that good farmers will be able to produce more MS from their cows than less competent farmers.

This calculator is designed for use by either farmers who are thinking about irrigation, but do not have accurate quotes for capital and running costs, or farmers who are further along the investigation process and have more accurate industry quotes. At the Himatangi farm, they have made substantial progress in identifying the unique capital costs associated with establishing a centre pivot on this farm. If the more accurate industry quote (which includes costs such a test bores and re-grassing etc.) of $1,160,000 (provided by the farmer) is run through the calculator then this farm is predicted to have a net median difference between the irrigated and base farms of only $196/ha and will break even or better only 53% of the time or five years in ten. This shows how the calculator can be first used to investigate if it is worth contacting industry professionals for quotes.

It is important to remember that this calculator is not designed to, and cannot give, a definitive 'yes' or 'no' answer to whether it is feasible to invest in irrigation: rather, it as a tool to assist in the decision making process. This is because it will always depend on the individual farmer and how he perceives the risks, financial returns and convenience of irrigation. Irrigation can take the uncertainty out of variable pasture production over the summer period and this may be more important than financial gain? Therefore, the calculator will let farmers explore different scenarios and how their farms may perform under irrigation, and then use the information provided by the calculator to make an informed investment decision depending on what is important to them.

Conclusion

A calculator to predict the feasibility of an investment in irrigation on dairy farms in New Zealand has been developed and three contrasting case study farms in the Manawatu have been use to investigate the outputs of the calculator. From the results and discussion above the following conclusions can be drawn:

- The likely profitability of investment in irrigation is not easy to identify (and may be unexpected)
- The amount of extra grass grown under irrigation is an obvious consideration in an irrigation investment analysis, but arguably how this grass is utilized is just as important.
- There is a large 'production cost' associated with increasing the stocking rate on irrigated dairy farm and this effects the financial feasibility of irrigation.
- The Calculator's analysis of the case study farms in the Manawatu suggested that irrigation in this region is likely to be more profitable on dairy farms that can grow more than 2 t ha^{-1} additional DM and harvest this with current cow numbers.

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