FARM SYSTEM RISK ANALYSIS, BUILDING A FARM RISK PROFILE TO IMPROVE FARM ECONOMIC OUTCOMES

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Abstract.

Agricultural production systems are subject to a multitude of risks which must be managed or mitigated by farmers. Traditionally, a farm budget is fixed, and is based on expected farm outcomes. Limited variance analysis takes place, if so, usually around price of outputs and a limited number of inputs such as interest rates and perhaps some major expenses like fertiliser or grain drying which varies with autumn rainfall.

A budget does not describe the financial risk profile of a farm production system at all well. There are always a number of factors which have an influence on a farm's bottom line, climate, for example has a huge influence on yield, price and the quantity, components, timing and cost of many inputs. Sometimes there is a correlation between factors which improve farm incomes and *vice versa*.

Frequent summer - autumn rainfall events, for example, generally allow sheep and beef farmers to finish more stock, reduces the cost and increases the production of feed, will help maintain pasture cover and reduce weed germination and, or invasion, and prevent rye grass staggers. Whereas a drought will decrease income and increase expenses. The impacts are greatest if wet summers and droughts are felt on a national, rather than a regional scale.

Palisade @Risk software, is a risk profiling plug in tool for Microsoft Excel. It undertakes Monte Carlo simulations on inputs and outputs, based on the distribution type and parameters selected by the profiler. This paper runs simulations on model farm budgets for a typical Western Lower North Island sheep and beef property and a Canterbury dairy farm to demonstrate the risk profile of each farm type and the value of using this technique in farm planning.

Keywords: Monte Carlo simulations, risk profiling, frequency distributions, correlations

Introduction

Farm production systems provide financial opportunity but are fraught with risk. Some farmers may experience luxury profits, whilst others experience a total crop loss even if they are using similar production systems and like crops. Events such as a badly managed frost can eliminate a grape harvest or a hail storm an apple or kiwifruit crop. Misfortune to producers in one region can reduce supply and increase the price received by unaffected producers of the same commodity in another region.

Farmers like all business people have to manage risk. However, many of the factors that generate financial risk are outside the control of the farmer. For some farmers, risk mitigation is possible, irrigation for example can reduce risks associated with drought or hail cover insurance may be purchased to reduce the risk of a large reduction of income in an orchard.

The risks associated with an agricultural production system, as with most risks can be modelled by a frequency distribution. Palisade @Risk provides a large range of distributions which maybe fitted to spreadsheet inputs, from a typical farm budget. For example a normal distribution maybe fitted to annual rainfall, which can then be positively correlated to price achieved for stock sold, and negatively correlated to cost of stock feed. Distributions can be either continuous, for variation in income output, or discrete, say for the number of cows. Some costs such as repairs and maintenance can be fitted with log normal distributions, where there is a possibility of the costs being under budget, but if so are usually close to budget but with a chance, albeit slim, of a large budget blowout. These situations occur due to floods or other natural disasters from time to time.

Once the distributions are fitted to the inputs and correlations established, then a simulation may be run and the resulting effects on the operator selected outputs can be shown. Outputs are usually items such as total revenue, grouped expenses and profit. The software can record and summarise up to 2 billion random sampling iterations of the distributions or "Monte Carlo" simulations to provide a risk profile of a system.

Case studies

Two model farm budgets are examined, one a sheep and beef budget from the Western lower North Island (Anon, 2010), the other a Canterbury dairy farm (Journeaux, 2013). See Tables 1and 2.

Table 1 shows base budget of a Canterbury dairy farm under irrigation.

Rainfall (mm)	**625**		
Year ended 30 June	Number	Expense	Income
Effective area (ha)	210		
Milk solids per cow milked	410		
Milk solids per hectare	1,396		
Total milk solids	293,150		
Milk solids advance to end June ($/Kg)	4.92		
Milk solids deferred payment ($/Kg)	1.08		
Cows wintered	769		
Cull cows	180		90,720
Replacement heifers (head)	180	25,200	
Cows milked 15 December (head)	715		
Net cash income			1,824,420
Farm Expenses			
Total labour expenses	243,122		
Animal health breeding	102,960		
Dairy shed/ electricity	85,085		
Feed all sources	392,100		

Fertiliser, Ag lime and freight	154,440	
Regrassing, weed and pest control	18,590	
Fuel, Vehicle costs and R & M	144,430	
Communication and sundry costs	15,558	
Accountancy, Legal administration	11,440	
Water (Irrigation) rates	39,325	
Insurance ACC	25,039	
Total farm working expenses		1,232,089
Interest	330,000	
Dividend on wet shares		94,421
Stock value adjustment	-	
Depreciation	35,780	
Farm profit before tax	320,972	
Taxation	89,872	
Farm profit after tax	231,100	
Allocation of funds		
Add back depreciation	35,780	
Reverse stock value adjustment	-	
Drawings	85,000	
Cash Surplus/Deficit	181,880	

Table 2 shows base budget of a lower North Island sheep and beef farm.

Rainfall (mm)	**921**		
Year ended 30 June	Number	Expense	Income
Ewes hogget's to lamb	1940		
Cattle 1 year rising	150		
Lambing (%)	132		
Lamb sales	2561		203,968
Sheep sales	473		28,380
Sheep replacements	480	42,374	
Cattle sales	145		129,050
Cattle replacements (weaners)	150	21,000	
Wool (Kg)	14929		32,845
Grazing income (hay and silage)	5000		37,500
Other income cash crops			40,000
Net cash income			408,368
Farm Expenses			
Total labour expenses	3,852		
Animal health	10,650		
Breeding	723		
Electricity	4,931		
Feed all sources	18,952		
Fertiliser, Ag lime and freight	68,678		
Regrassing, weed and pest control	10,995		
Cash crop expenses	18,823		
Shearing expenses	11,672		
Fuel, Vehicle costs and R & M	38,364		
Communication and sundry costs	5,031		
Accountancy, Legal administration	7,765		
Rates	14,904		
Insurance ACC	8,936		
Total farm working expenses		223,276	

Interest	95,261
Rent grazing leases	4,390
Stock value adjustment	-
Depreciation	28,092
Farm profit before tax	57,350
Taxation	16,058
Farm profit after tax	231,100
Allocation of funds	
Add back depreciation	28,092
Reverse stock value adjustment	-
Drawings	58,512
Cash Surplus/Deficit	10,871

Risk analysis using Palisade @Risk software begins with fitting suitable frequency distributions on the inputs which have an effect on the output cells. This requires a frequency distribution type to be entered and a standard deviation to be input, although @Risk defaults to a standard deviation of ten per cent of the mean. Commodity prices for; mutton, lamb, bull beef, cow beef, steer and heifer beef and milk solids for the previous ten years were obtained (Anon., 2014). Commodity prices obtained were compared to New Zealand climate data (Fauchereau *et al*, 2013).

All commodity prices have fluctuated, however, mutton and lamb prices have moved together and all cattle beef prices are also highly correlated. Figures 1 – 3 show the fluctuation in commodity prices which were used to fit normal distributions to farm income streams. Sheep meat prices and milk solids prices fluctuated more than beef prices. Sheep meat prices peaked during 2011 which was a wet year throughout New Zealand with frequent summer rainfall. The coastal lower west North Island (LWNI), recorded 1,297mm of rain, which is considerably more than the 30 year average of 921mm. This was followed in 2012 by a nationwide drought, where the LWNI recorded 778mm of rainfall and little summer rainfall (Fauchereau *et al*, 2013). In the summer of 2012/2013 sheep meat prices were depressed; there is about a $100 difference in price per lamb between the peak and trough.

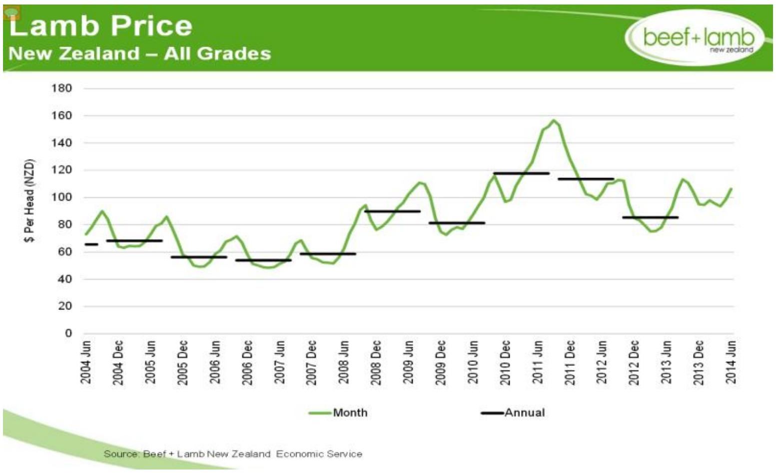

Figure 1: Lamb price over time courtesy beef + lamb New Zealand Economic Service

Although beef and dairy farmers were also subject to drought, prices remained less affected by drought. Although, farm incomes may have been equally affected; by the need to purchase feed, or to dry off cows early. However, for the case study of the Canterbury dairy farm, irrigation is available to mitigate the effects of drought. Canterbury is considerably drier than the LWNI and has a mean annual rainfall of 625mm so some sort of irrigation is required to enable productive dairy farming in any case.

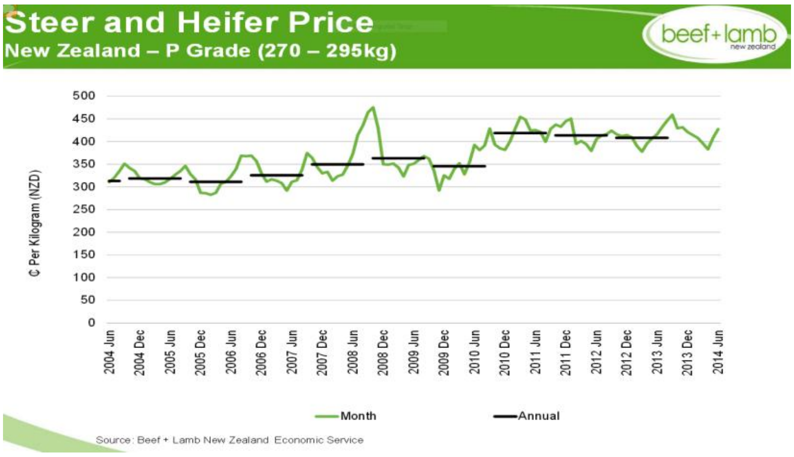

Figure 2: Beef price over time courtesy beef + lamb New Zealand Economic Service

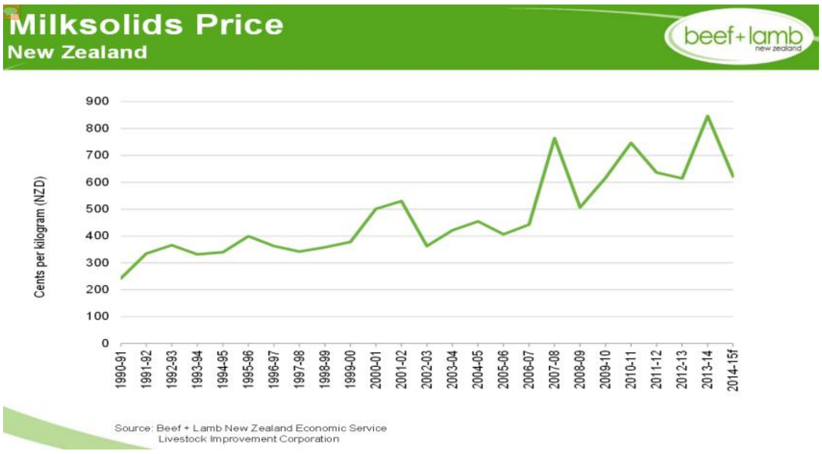

Figure 3: Milk solids price over time courtesy beef + lamb New Zealand Economic Service

It is evident that there is a correlation between climate and income and expenses, which needs to be considered in risk profiling farm systems. The @Risk software allows for the input of both positive and negative correlation matrices to be input. The software analyses the correlation matrix and reports error messages for correlations which are mathematically impossible, providing the nearest mathematically possible option to that inputted by the operator as a default option.

For these case studies the following correlation assumption inputs were made:

Dairy

- Feed cost is negatively correlated with rainfall by 0.7
- Regrassing costs are positively correlated with rainfall by 0.6

Sheep and beef

- Stock prices are correlated to rainfall by 0.48
- All sheep prices are correlated by 0.76
- Beef stock purchase and values are correlated to lamb price by 0.42
- Beef finished 2 year old sale price correlate to lamb price by 0.48

The other input distributions and assumptions for the Canterbury dairy model are shown in Table 3, post simulation at 5,000 iterations. The mean differs slightly from the base budget, which is set as the median 50% percentile level.

Table 3: Shows the fitted distribution, mean and 90% confidence spread of input values for the Monte Carlo simulations of the model Canterbury dairy farm

Input Parameter	Distribution Type	Mean	5% Confidence	95% Confidence
Rainfall (mm)	Normal	625	522	728
Cows milked	Normal discrete	709	688	742
Cows wintered	Normal discrete	763	740	800
Feed grazing ($)	Normal	240,803	201,166	280,363
Feed other ($)	Normal	149,440	124,855	174,007
Milk solids per cow (kg)	Normal	410	376	444
Milk solids price ($)	Normal	6.00	4.68	7.32
Price cull cows ($)	Normal	180	150	210
Price milking cows ($)	Normal	1,000	835	1,164
Price weaner heifers ($)	Normal	140	117	163
Regrassing costs ($)	Log Normal	13,370	12,373	15,532

Whilst the input parameters for the LWNI model sheep and beef farm after 5,000 Monte Carlo simulations is shown in Table 4.

Table 4: Shows the fitted distribution, mean and 90% confidence spread of input values for the Monte Carlo simulations of the model LWNI sheep and beef farm

Input Parameter	Distribution Type	Mean	5% Confidence	95% Confidence
Rainfall (mm)	Normal	921	770	1,072
Cull Ewes ($)	Normal	60.00	43.55	76.49
Average lamb[1] ($)	Normal	88.28	66.90	109.67
Average lamb[2] ($)	Normal	87.30	65.92	108.69
Average store lamb	Normal	72.00	53.91	90.10
Rising 2 year old steer ($)	Normal	890	597	1,183
Wool Kg ($)	Normal	2.20	2.04	2.36
Rising 1 year old steer ($)	Normal	450	376	524
Grazing income hay ($)	Normal	5,000	4,178	5,823
Hay bales ($)	Normal	7.50	5.03	9.97
Lambing (%)	Normal	132	119	145
Other income (Cropping)	Normal	40,000	39,013	40,987
Weaner steers ($)	Normal	140	117	163
Wool production (Kg/sheep)	Normal	5.83	4.88	6.78

Other costs are considered as budget and are therefore assumed to be fixed in terms of this case study. Although, the percentage of fat and stored lambs sold was also correlated to rainfall for the sheep and beef farm.

The risk profile is obtained by examining the effect of the Monte Carlo simulations on the output cells, which report the financial performance and cash flow projections of the spreadsheets.

Results

Dairy

Risk profiling of the Canterbury dairy farm was undertaken as per the budget (Journeaux, 2013) and again after goal seeking a break even milk solids price (price plus deferred pay-out) that achieves no cash surplus after drawings of $85,000. This occurs when farm profit before tax is $68,360 which when taxation of $19,141 is deducted and depreciation of $35,780 added back in, assuming no difference in opening and closing stock values leaves $85,000 for drawings.

Palisade @Risk allows goal seeking of a cell that is not an output file based on changes to a cell that is not an input cell for Monte Carlo simulation. To allow this to occur, milk solids was disabled as a variable and a price established for 50% percentile breakeven. The software estimates this to occur when total milk solids price is $5.21. This figure is higher than the forecast pay-out for 2015, outputs using this price are also presented.

The risk profile in terms of funds for reinvestment, net profit after adding back depreciation and deducting drawings for the farm as per budget, using the variable parameters in Table 3, after 5,000 Monte Carlo simulations is shown in Figure 4. At budget the farm cash surplus for reinvestment has a mean of $159,494, although the median is $160,140 has a standard deviation of $227,097 a minimum a deficit of $649,690 and a maximum surplus of $1,004,321. The effect variations in input parameters have on the mean are ranked in order of importance in Figure 5.

The risk profile at goal seek breakeven price for milk solids at $5.21, which is a fixed variable for this analysis is shown Figure 6. For this simulation the mean farm cash surplus for reinvestment is a deficit of $7,121, the median is a deficit of $6,040 the minimum is a deficit of $547,169 and the maximum is a surplus of $586,059 with a standard deviation of $149,634. The tornado graph of this simulation is shown in Figure 7.

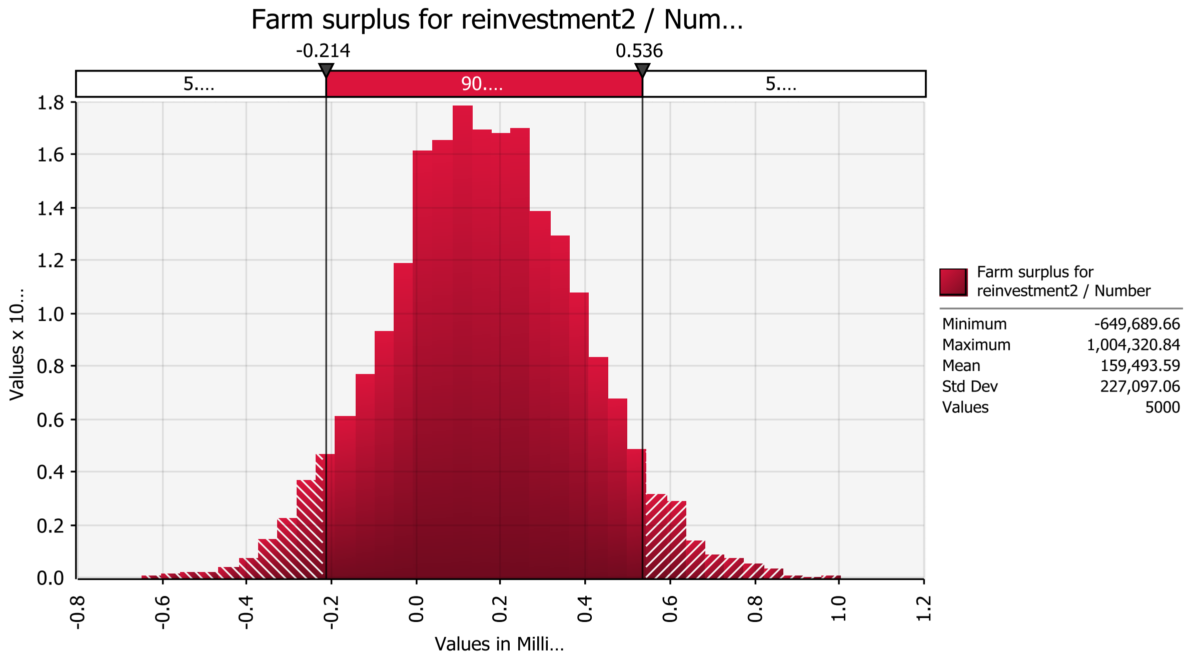

Figure 4: Shows the Monte Carlo simulations of the Canterbury dairy farm at budget, using frequency distributions fitted inputs result shows 5,000 simulations produced using Palisade @Risk software

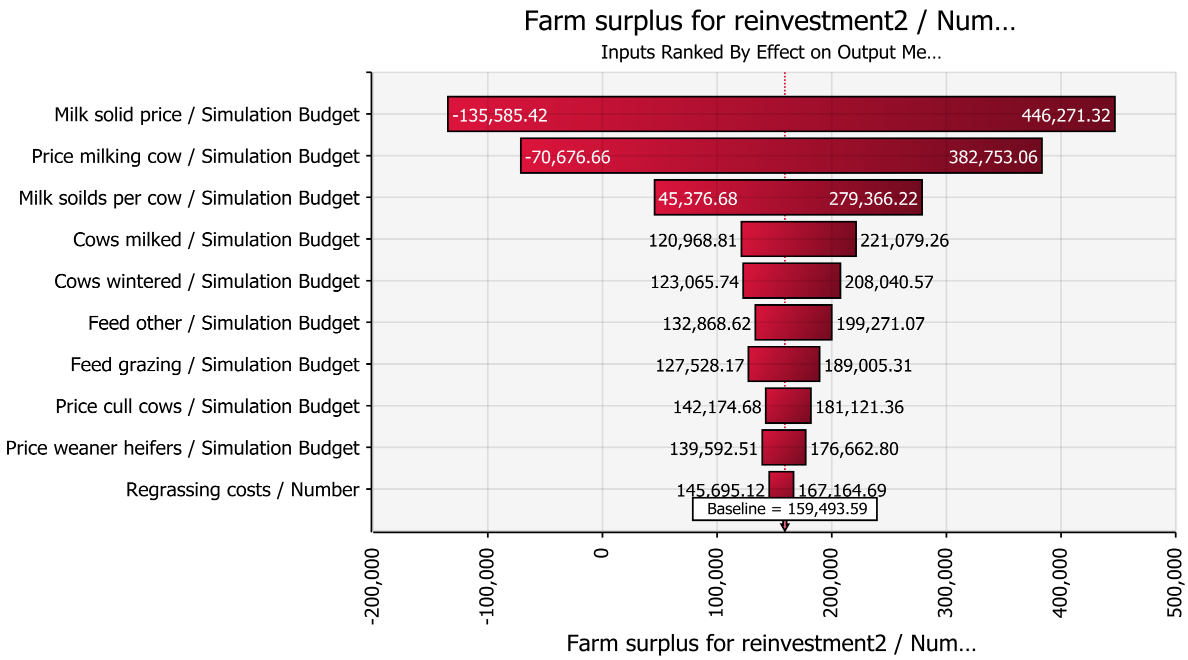

Figure 5: Shows the effect of the input variables on variations from the mean $159,494 as a tornado graph produced using Palisade @Risk software

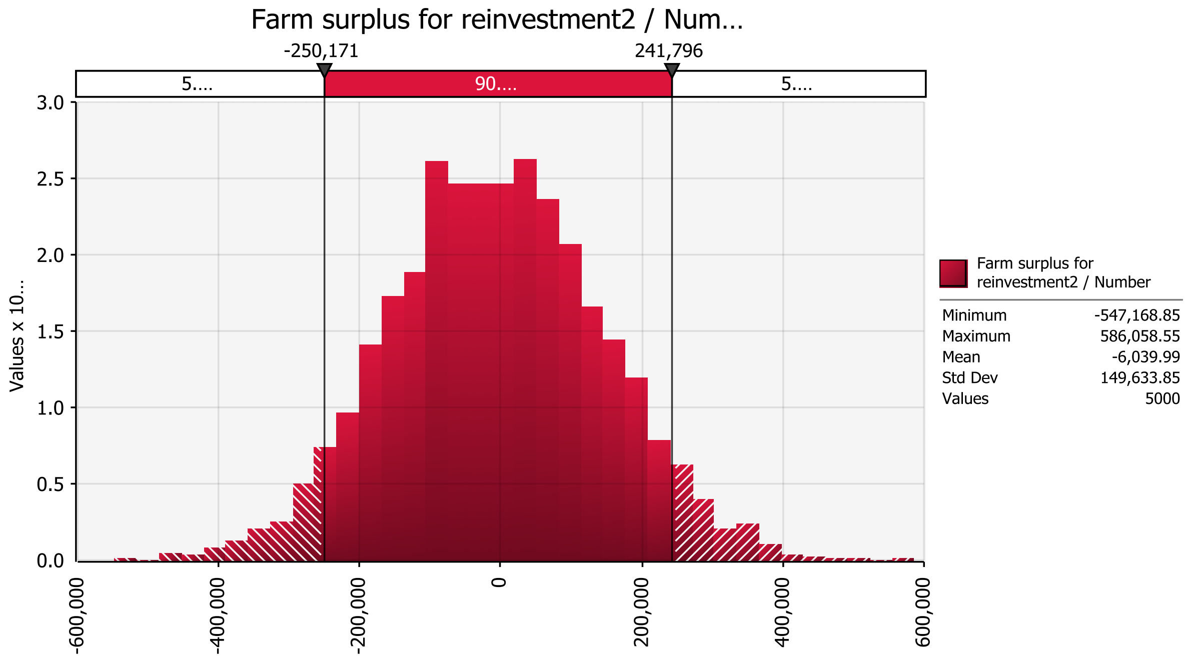

Figure 6: Shows the Monte Carlo simulations of the Canterbury dairy farm at break even, using frequency distributions fitted inputs result shows 5,000 simulations produced using Palisade @Risk software

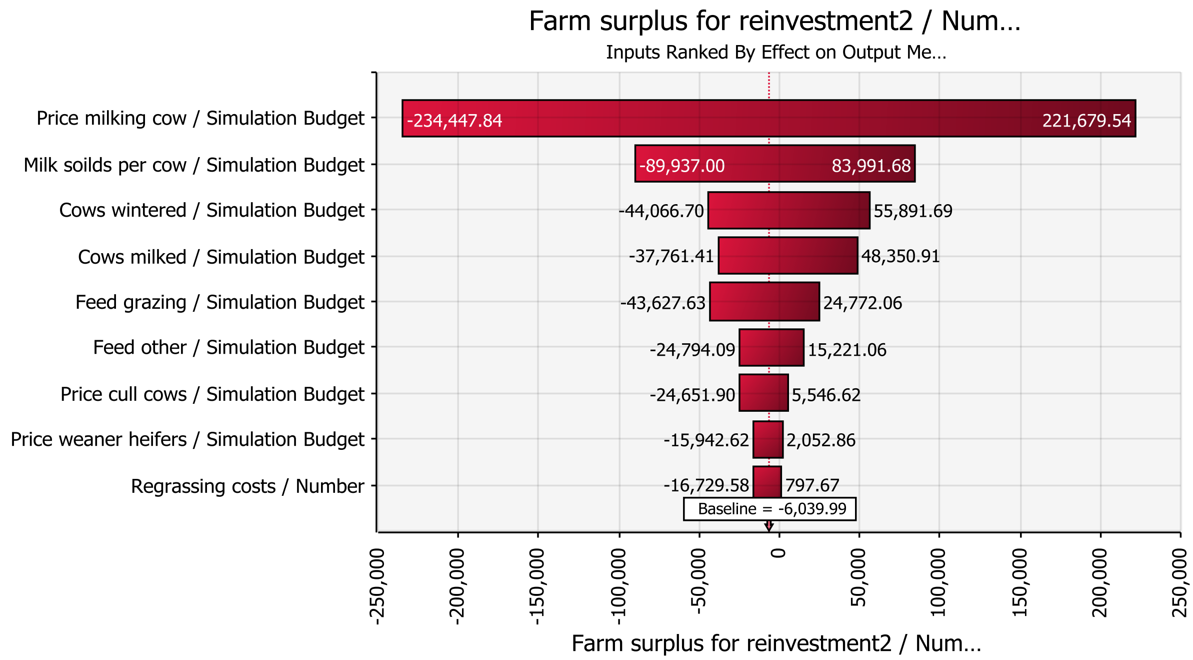

Figure 7: Shows the effect of the input variables on variations from the mean ($6,040) as a tornado graph produced using Palisade @Risk software

Sheep and Beef

Similarly a Monte Carlo simulation was run for the LWNI sheep and beef budget. Unlike the dairy farm situation there is no forecast pay out, however, farmers with contract meat prices could fix a price input. This would reflect the reduction in variability to the risk profile of their business. The farm surplus after drawings of $58,512, Monte Carlo simulation is shown in Figure 8. The mean surplus is $1,576 the median surplus is $1,372 the standard deviation is $61,696. The minimum is a deficit of $263,489 and the maximum is a surplus of $203,248. The tornado graph of this simulation is shown in Figure 9.

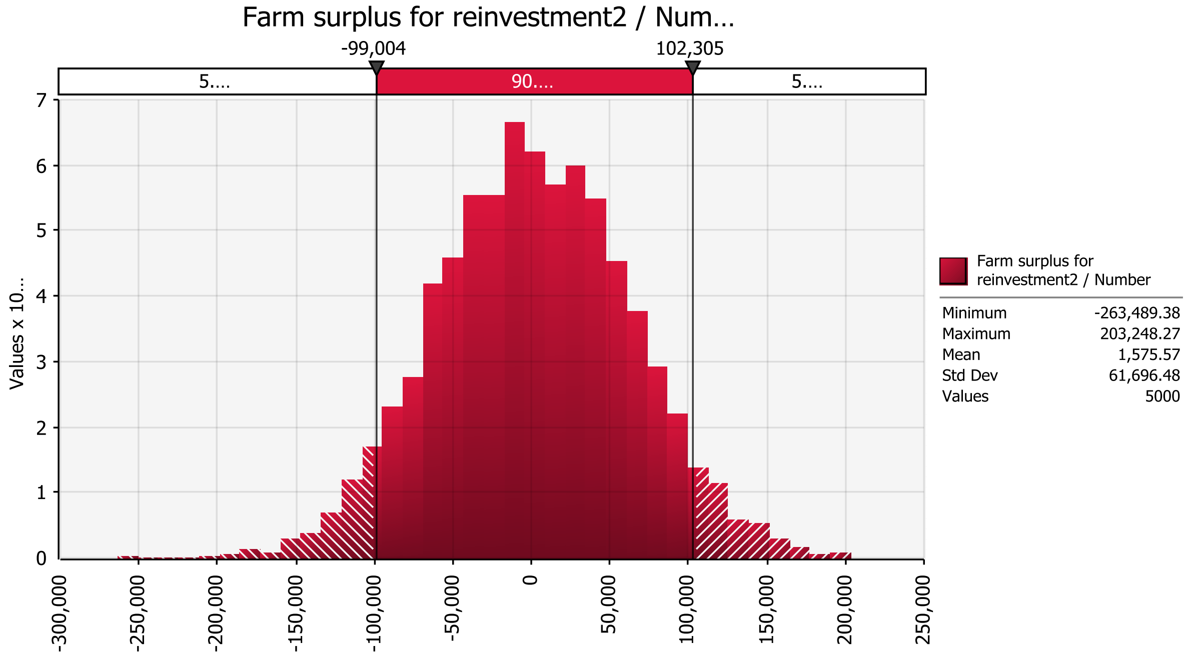

Figure 8: Shows the Monte Carlo simulations of the LWNI sheep and beef farm at budget, using frequency distributions fitted inputs result shows 5,000 simulations produced using Palisade @Risk software

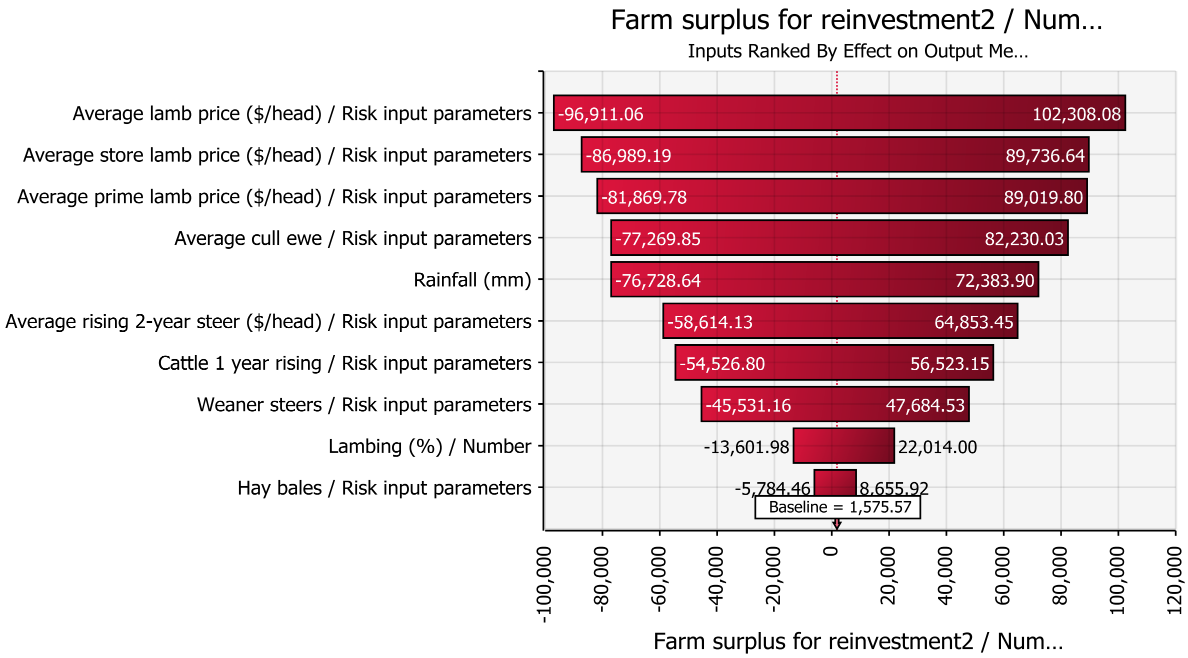

Figure 9: Shows the effect of the input variables on variations from the mean $1,576 as a tornado graph produced using Palisade @Risk software

Discussion

Producing a risk profile reflecting the parameters which vary and influence a farming enterprise's income is worthwhile. It shows the range of possible outcomes and spread of likely outcomes. In both farming situations there is a reasonable likelihood of farm deficit after drawings. Although this is more likely for the sheep and beef farm which budgets near breakeven surpluses, than that of the Canterbury dairy farm. However, at current forecast dairy pay-out the Canterbury dairy farm is more likely to operate a cash deficit than a surplus.

The use of tornado report graphs is also extremely useful as it ranks the factors which have an effect on the mean farm income in order of importance. Although, not all these factors can be managed, some important decisions such as sales mix, or stocking ratios could be influenced. In these case studies for example, increasing beef numbers and reducing sheep numbers would reduce the risk profile of the sheep and beef farm.

Similarly, fixed price contracts with meat processing firms may be viewed more favourably if the risk profile of the market price is better understood. In any case the farmer is better equipped to make an informed decision.

Conclusions

Risk profiling is much more comprehensive than variance analysis. It provides a means for randomly varying a large number of inputs, which have variable distributions assigned to represent a spread of possible values. These input parameters need to be carefully considered and the appropriate distribution representing the outcomes and a standard deviation from the mean assigned. However, if completed accurately a risk profile can be established. Palisade @Risk provides a means of undertaking this as an Excel spreadsheet add on.

Risk profiling is undertaken in many industries and is an integral part of exploration, civil engineering, quantity surveying and insurance. It is rarely undertaken in agriculture, although primary industries are some of the most variable and are invariably price taking commodity producers.

There is an opportunity for farm business advisers to use risk profiling to better advise their clients as to the risks associated with their businesses. Farmers may then have the opportunity to reduce or take on added risk when better informed of the likelihood and range of outcomes.

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