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Regional Economic Implications of Water Allocation and Reliability

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Abstract

The understanding of how allocation decisions can maximise the economic returns to the community from water for irrigation has received little attention, but is a significant issue for regional councils, those interested in water allocation policy development, and for irrigated farmers. There is a tradeoff between the amount of irrigated area and the reliability with which it can be undertaken. Overseas studies have generated a curve with optimum levels of allocation which maximise the economic return to the community from the resource. The study on which this paper is based used a single case study to model the individual and regional economic outcomes for four scenarios of water allocation, using daily time step simulation models of the hydrological, irrigation, farm and financial systems over the 1973 – 2000 period. The results show that there is an increasing return to the region as the allocation from the resource increases, at the expense of lower returns to existing users.

Key words: Irrigation, reliability, regional economic impacts.

Background

Water is an important resource for many stakeholders, having value both in stream and out of stream. The allocation of water has obvious environmental dimensions, but it has received little attention in terms of understanding how allocation decisions can maximise the economic returns to the community from the resource.

At a given minimum flow in a river, there are different levels of allocation which can be made to users. As more water is allocated, the allocation becomes less reliable because the river is less frequently at the flows required to sustain the total allocation. There is therefore a trade off between the amount of irrigation which can take place and the reliability with which it can be undertaken – less area irrigated more reliably, or more area irrigated at lower reliability.

Overseas studies have generated curves with "optimum" levels of allocation which maximise the economic return to the community from the resource. Three studies (Verdich and Bryant; Jones, Musgrave and Bryant 1992; Dudley and Hearn, 1993) which directly tried to assess this trade off, each indicated that the community net benefits were optimised at a level of reliability lower than the level which optimised the individual net benefit. Net benefit to the community was increased at the expense of an increased variability to the individual and in some cases to the community.

Reliability can be characterised (Kuczera, 1987) by the *probability* of a failure, its *duration*, and its *magnitude*. *Predictability* of failure may also be an important descriptor from a user point of view. The concepts of reliability can also be extended to include characteristics of the receiving use – the *vulnerability* of the receiving system to the water loss and its *resilience* in terms of its ability to recover following loss. Incorporating all these dimensions of reliability into a single measure can be difficult, and irrigation manager and policy description of reliability need to relate to users perceptions of reliability.

A number of attempts have been made to develop indicators of reliability (e.g. Robb and McIndoe, 2001), although it is not clear the degree to which these have proven useful for allocation purposes. Furthermore the use of indicators does not allow quantification of changes which occur, and therefore the point at which allocation becomes optimal. Little other work on assessing the economic implications of irrigation reliability appears to have been undertaken in the NZ context.

Method

This study has used a modeling approach to determine the regional and individual farm economic outcomes for four scenarios of water allocation from the Rangitata River, with all scenarios having the same minimum flow regime. The four scenarios were:

- a very reliable[1] allocation, (irrigating 29,000 ha)
- the current allocation, (irrigating 64,000 ha)
- a less reliable allocation, with an additional 26% of water, (irrigating 81,000 ha)
- a least reliable allocation, with an additional 59% of water. (irrigating 102,000 ha)

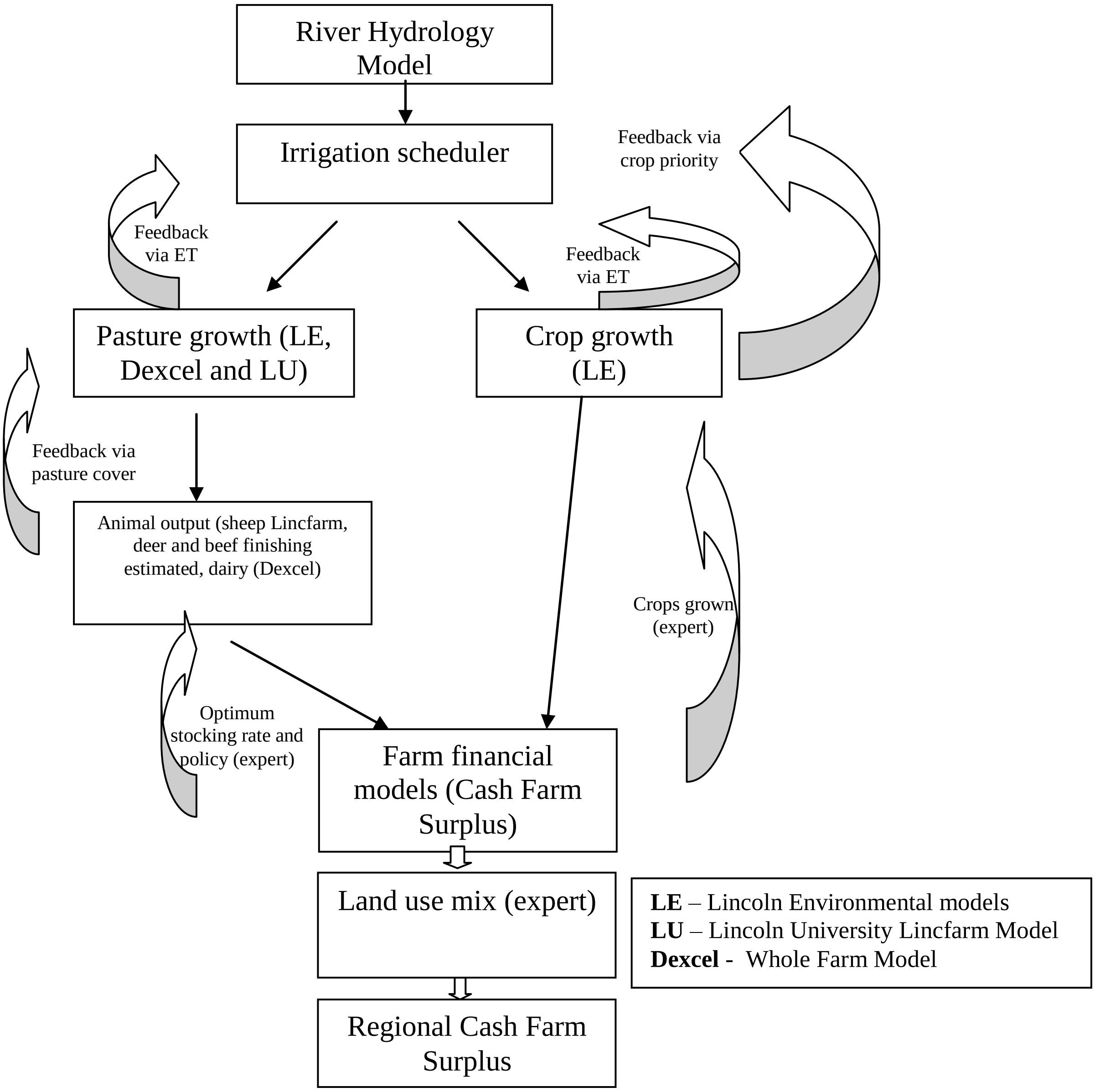
The modeling used daily time steps for 1973 – 2000 period, with simulations run in sequence through

- a hydrological model (John Bright, Aqualinc, pers comm.)
- an irrigation scheduling model (John Bright, Lincoln Environmental, pers comm.)
- 7 farm systems models (Cacho et al, 1999; Thorrold et al, 2004; Bright, Aqualinc, pers comm.)
- financial models (Ford, The Agribusiness Group, pers.comm.)

The arrangement of the models is shown in Figure 1.

[1] Refers to the availability of water on farm. In fact Scenario 1 has twice as much water allocated to it at the same reliability as Scenario 2, so the probability that some water will be available is significantly higher. Using this approach allowed us to also test the impact of the amount of water applied on the overall outcome.

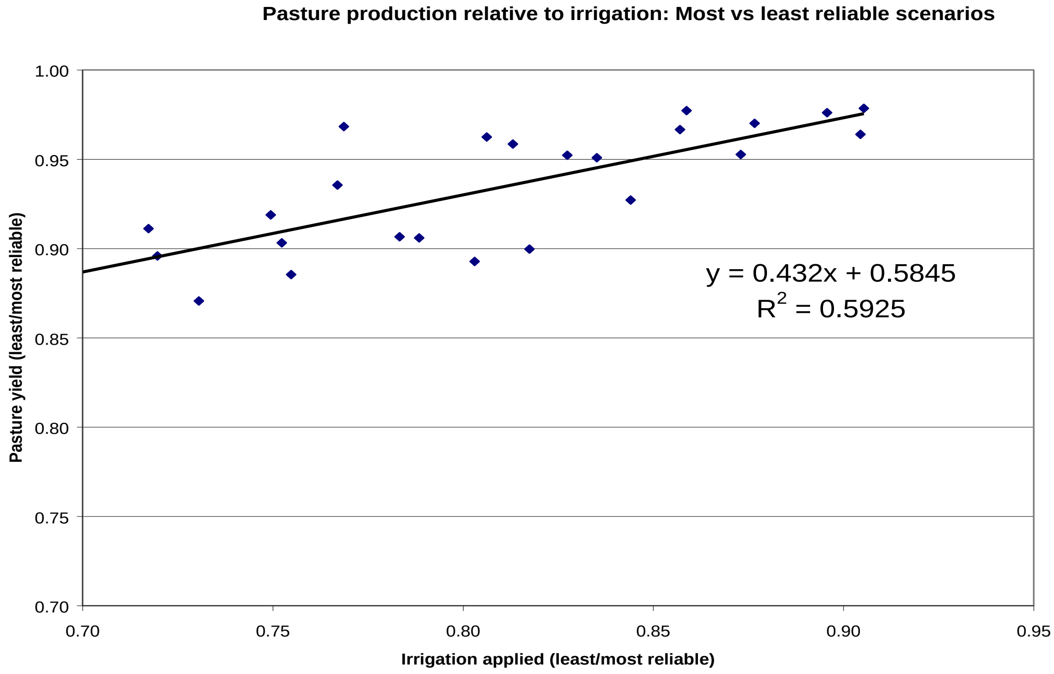
Figure 1: Outline of Water Reliability Study



RESULTS

The impact on production from lower reliability is significant, but does not appear to be proportionate to the loss in water. This is demonstrated in Figure 2 below which shows the relationship between pasture production in the most reliable scenario and that of the least reliable scenario. It demonstrates that the relationship between the amount of water applied over a year, and the pasture production is not linear – in fact the loss in pasture is only about 50% of the loss in water. The impact on production is even less in the case of cropping, and this appears to go some way toward explaining the relatively small differences in financial outcomes between scenarios.

Figure 2: Relationship between water applied and pasture yield: Least reliable scenario as a proportion of Most reliable scenario



Cash farm surplus (CFS)[2] results were generated for each farm model for the four scenarios. CFS decreases for all models from Scenario 1 to 4 (highest to lowest reliability). The results for the irrigated sheep and dairy farms are shown in Figure 3 and Figure 4 below, and exhibit low variability (coefficient of variation (CV) 4% - 14%). The arable models are intermediate in variability, and the dryland models are highest variability at 28% - 51%. The minimum CFS, or the worst year that farmers would face is in the order of 11% - 13% worse for the scenarios which are less reliable than the current allocation for the irrigated sheep model, 4% - 9% worse for the dairy models, and 1% to 3% worse for the crop models. The CV increases when capital costs of irrigation development are taken into account.

[2] CFS = Gross Farm Revenue – Farm Working Expenses. It does not include tax, interest, drawings, depreciation etc.

Figure 3: Sheep Finishing Breeding (irrigated) CFS/ha

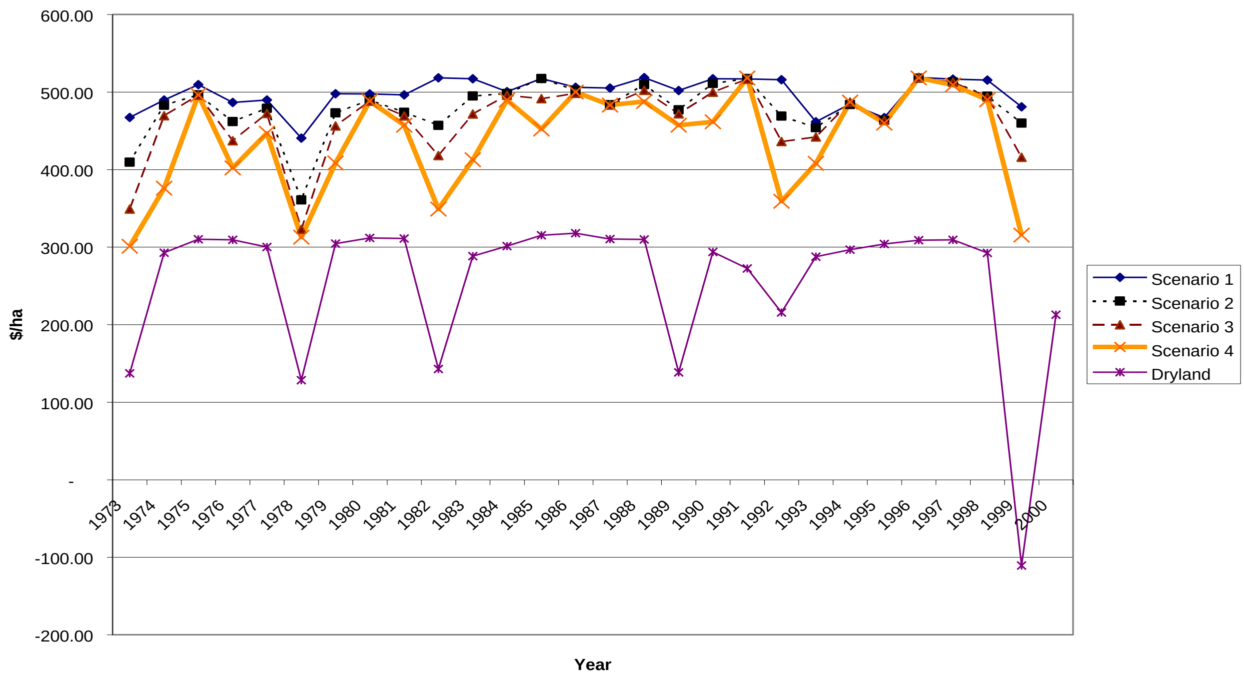
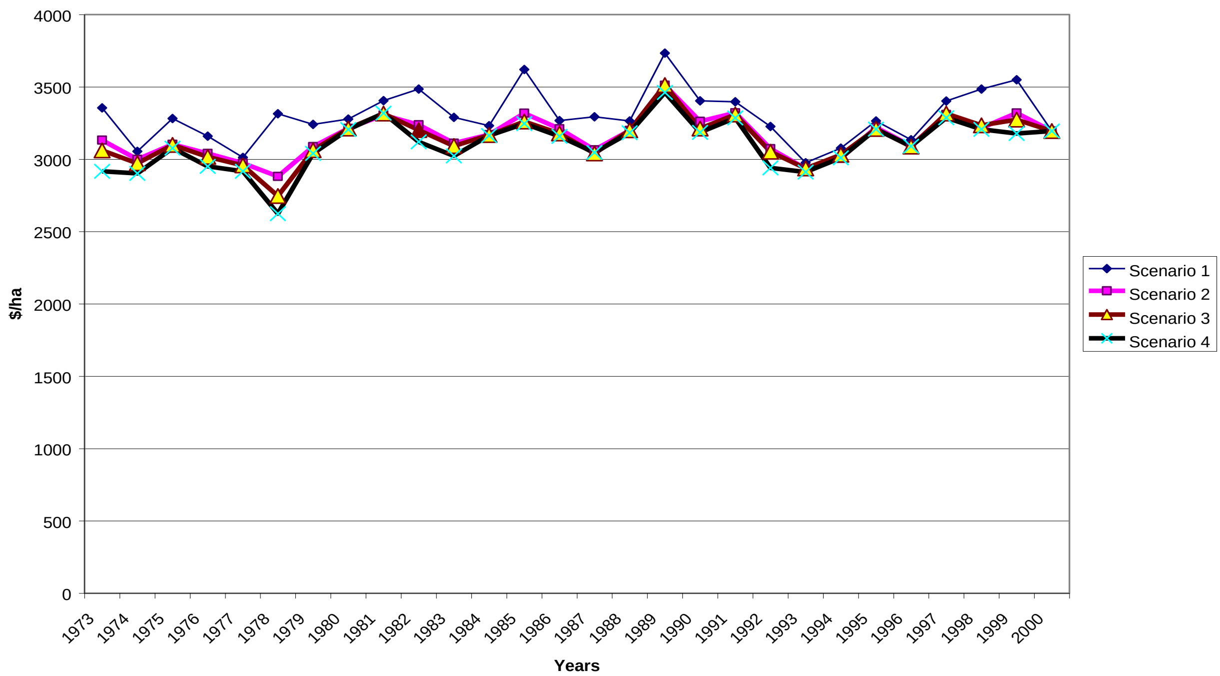
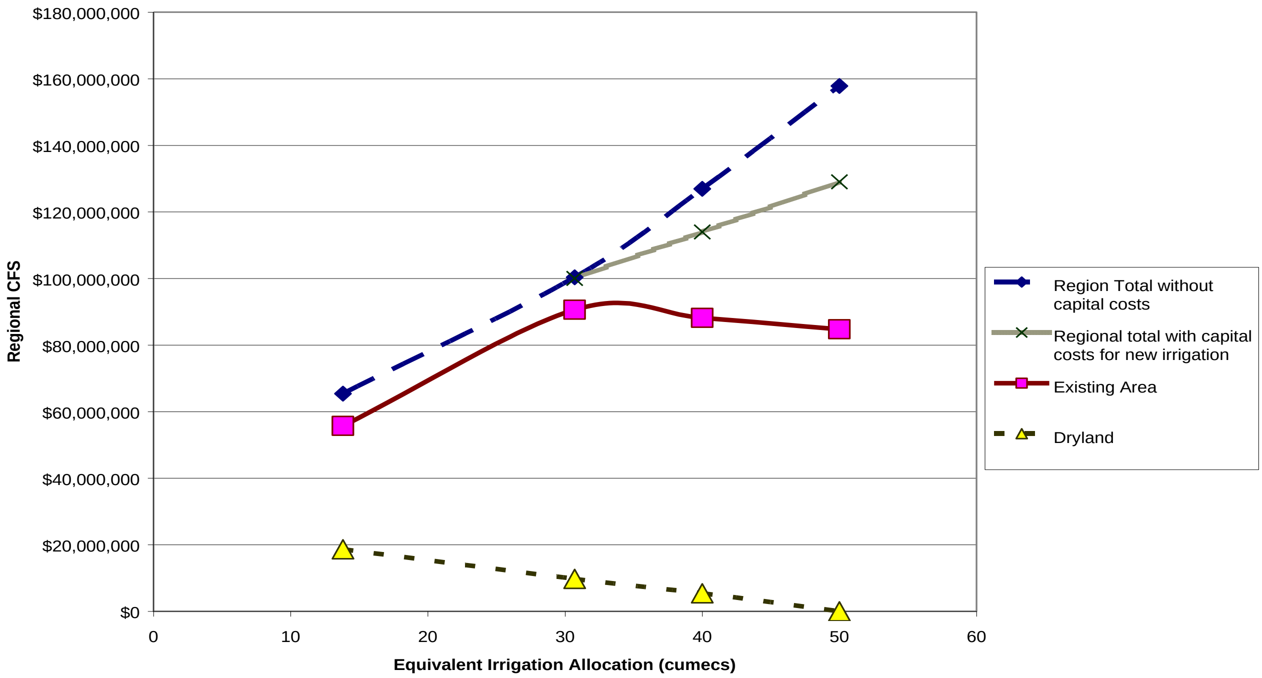


Figure 4: Dairy Spray Irrigated CFS/ha



Analysis of the CFS results suggests that no land uses are likely to be precluded because the extra variability is not significant enough to limit land use options. The average and minimum CFS figures are lower with lower reliability, suggesting that the land values for systems under less reliable scenarios will be lower.

Figure 5: Average Annual Cash Farm Surplus Aggregated for all Farms in Study Area



The results were aggregated for the whole command area based on surveyed land use mixes. This aggregation shows that the increasing allocation results in increasing Total CFS in the region (heavy dashed line, Figure 5, 'Average' row, Table 1). The increase in economic return to the region remains true whether or not capital costs of new investment in irrigation are included (shaded line with crosses, Figure 5). The regional variability increases in absolute terms, but as a proportion of the increased average CFS it remains stable. CFS without capital costs can be used as a proxy for direct estimates of contribution to Gross Domestic Product (GDP), and CFS with capital costs can be used as a measure of net benefit. Sensitivity testing with increased feed costs ($0.20/kgDM) and -20% on price assumptions did not change the overall shape of the curve.

Table 1: Aggregated Cash Farm Surplus for whole command area 1973 – 2000 (without capital costs)

Test	Scenario 1 (most reliable)	Scenario 2 (current)	Scenario 3	Scenario 4 (least reliable)
Mean	$65,000,000	$100,000,000	$127,000,000	$158,000,000
Change in average (relative to current)	65%	100%	126%	157%
Minimum	$38,000,000	$79,000,000	$105,000,000	$128,000,000
Coefficient of variation (CV = SD/Mean)	12%	9%	8%	9%

Increasing reliability relative to the current situation results in lower economic returns (-35%) to the region in terms of total CFS, and an increased variability when expressed as a proportion of the average. These changes arise because more dryland area is created within the study area to accommodate the smaller irrigated area which can be serviced at an increased reliability.

The existing irrigated area experiences a decrease in aggregate CFS with both increasing and decreasing reliability from the current allocation (Boxed line: Figure 5; Mean row: Table 2). Its variability also increases in all scenarios other than the current situation (64,000 ha irrigated).

Table 2: Annual Cash Farm Surplus for Existing RDR Area

	Scenario 1 (most reliable)	Scenario 2 (current)	Scenario 3	Scenario 4 (least reliable)
Mean	$56,000,000	$91,000,000	$88,000,000	$85,000,000
Change in average (relative to current)	61%	100%	97%	93%
Minimum	$42,000,000	$75,000,000	$73,000,000	$67,000,000
Coefficient of variation (CV = SD/Mean)	8%	7%	9%	11%

DISCUSSION

The results from this project point to an increased allocation increasing regional GDP and a net regional benefit, with a penalty to those existing irrigators from the resource and a gain to new irrigators converting from dryland. The changes we have introduced in terms of allocation are extreme, simply because more moderate changes to allocation resulted in differences which were too small to be resolved by the modeling. In this case study resource environmental constraints would limit the allocation before the upper allocation limits tested here. The conclusions regarding the increased regional GDP appear robust, with the trends consistent across all model results. The conclusions regarding net benefit are likely to be sensitive to the capital costs of irrigation development.

The results reflect a particular resource and relate mainly to regional impacts. The implications for individuals, particularly existing irrigators, is more severe in the extreme scenarios. In particular the decrease in reliability modeled here appears to increase the vulnerability of farms to changes in other factors such as product prices. As a result there are equity implications which need to be taken into account with significant increases in water allocation at the current minimum flow from this resource.

In methodological terms the approach has been proven as feasible, although complex and not well understood by potential users. Unfortunately the range of reliability studied here was not sufficiently great to preclude specific land uses. As a result we have not been able to answer questions regarding the relative importance of land use feasibility vs. the adverse effect of poor reliability in estimating the impacts of allocation on the community returns from a resource.

The model development process has been very extensive, and the individual model components have been tested against actual farm trials and they are reasonably capable of replicating production systems in tests of that nature. However the models are inevitably limited in the extent to which they are able to replicate physical and management systems. Farmers involved in the development and specification of this project expressed concern over the ability of the models to accurately represent farm systems.

The models require further work in reflecting management input into the physical systems, particularly in relation to management of variability. The models operate under a reasonably constant management system because this has to be set to allow the production system to operate regardless of the conditions it encounters. In the case of the dairy model this includes maintaining pasture production constant and varying feed inputs. In this way the model management may be more conservative, and will certainly be less sophisticated than an actual farm manager. While the level of conservatism was tested by changing the stocking rate plus or minus 2 stock units, the matching of demand to supply may operate at a more sophisticated level in the actual management of a farm. For this reason the actual variability experienced by a farmer may be greater – because farm managers are better able to take advantage of upside variability, or may be less, because farm managers are likely to be better at managing downside variability than the models. We are unable to define how actual management would relate to the model management, but it should be noted as an area for concern.

This approach to modeling reliability has taken considerable time, and has proven complex and not altogether transparent to users. However it has produced a set of results which give a definitive answer to the questions of whether an increased allocation in the case study area would increase regional GDP and produce a net benefit. Work should continue on developing and testing this methodology. This work could include:

- Development of the farm models to better reflect farm systems, and importantly the management inputs into those farm systems, so that models can be run under conditions of variability yet reflect in a reasonable fashion the types of management interventions which are used to optimise the farm system under that variability.

- Applying the method to an expanded range of situations. It should be applied to more resource types, preferably in conjunction with a river classification system which enables the work to be replicated by class rather than for each river. Equally importantly the resource allocations need to be "stress tested" to the point where land uses are no longer viable, so that we can understand why that happens and how the overall returns to the region change as allocations approach that point.

Acknowledgements

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