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Economics of supply reliability of irrigation water

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SUMMARY

In this study, we have assessed the economic impact of potential increase in supply reliability of irrigation water in the Hinds Plains Area in the Ashburton district. The Hinds catchment has a number of irrigation schemes namely, Rangitata Diversion Race (provides water for Mayfield Hinds and Valetta Schemes), Barrhill Chertsey, Eiffelton and Lynford Schemes. All these schemes have varying supply reliability which ranges from 40% to 80% approximately. First, we estimated the relationship between water availability and pasture growth using experimental data. We then employed this relationship to estimate the potential incremental pasture growth with assumed increased supply reliability (95%) at farm level. We estimated the farm level benefit of increased pasture production in terms of saved costs in supplementary feed. These farm level estimates were used to assess the catchment level farm income gain. The catchment level income gain was then employed to assess the regional level economic gain (GDP and employment) by the socio-accounting matrix input-output model (SAMI-O) simulation. Income gain at catchment level is estimated to vary from $16 to $17million. This implies an additional gain in regional level income (GDP) of $85 to $91million and additional employment of 137 FTE to 207 FTE. The study indicates the importance of an increase in irrigation efficiency at farm level for the local and regional economy and also discusses the potential environmental impacts of increase irrigation efficiency at catchment level.

Key Words: water, supply reliability, SAMI-O input-output modeling, irrigation

INTRODUCTION

Irrigation water reliability is defined as the ability of the water supply to meet demand from one or more abstractors, when operating within its flow and allocation regime (Ritson and Stapleton, 2013). Irrigation water supply reliability is a burning economic issue especially in the Canterbury Region of New Zealand because of the irrigation based dairy expansion in the region. In fact, the dairy industry contributed 9.7% to the District GDP in 2011, up from 4.2% in 2001 (Brawley, 2011). Meanwhile as per the recommendations by the Land and Water Forum (LWF, 2012), all regional councils in New Zealand are supposed to set catchment level water quantity and quality limits to achieve water quantity and quality targets. In this process, LWF suggests that regional councils should consider the tradeoff among economic, environmental, social, and cultural impacts of the limit setting process. In this study we discuss a method to estimate the farm, catchment, and regional level economic impact of change in supply reliability of irrigation water. Snow et al (2010) assessed the farm level financial impacts of irrigation water availability by considering the impact on water availability on pasture growth and managing the deficit of on farm pasture through buying additional feed or through other farm management options. Thorrold et al (2004) studied the effects of irrigation water reliability on pasture growth in a dairy system in Canterbury Region in New Zealand and indicated the need to consider the role of water storage, climatic patterns, feed storage, use of run-off blocks and the regional balance of water demands as important factors in reducing production variability on the farm and in the region. Our study differs from the aforementioned studies because we assessed the regional level economic impact of change in supply reliability through use of socio-accounting matrix input-output modelling. The study area was Hinds catchment in the Ashburton District of Canterbury region.

METHOD

The general method used involves a number of steps. First we have estimated the relationship between the pasture growth and irrigation water availability using experimental data. Then we calculated the potential pasture volume lost for various farm types at catchment level under different irrigation schemes with different water supply reliability levels. For this calculation we assumed that the optimum supply reliability level is 95% and we estimated the value of lost pasture volume in terms of costs incurred by the amount of additional supplementary feed required. The catchment level pasture loss value was then employed in a socio-accounting matrix input-output (SAMI-O) model to estimate the regional level economic impacts in terms of loss in GDP and FTE employment.

Estimating relationship between water availability and pasture production

The relationship between pasture dry matter production and amount of irrigation was derived using data from the Winchmore flood irrigation trials (Rickard & McBride, 1986; Richard, 1972; Schipper et al., 2013). The initial trial had 6 flood irrigation treatments replicated 4 times in a randomized block design. The treatments were No Irrigation, Irrigated when soil moisture dropped below 20%, Irrigated when soil moisture dropped below 10%, Irrigated at 3-weekly intervals, Irrigated at 6 weekly intervals, Irrigated at 3-weekly intervals in alternate seasons only. In 1957, the trial design was changed to the following 5 treatments: No Irrigation, Irrigated when soil moisture dropped below 10%, 15%, 20%, and Irrigated at 3-weekly intervals. By employing this experimental data, the relationship between pasture dry matter (DM) production and the amount of irrigation and rainfall was estimated using a Bayesian smoothing algorithm (Upsdell, 1992). The initial model fitted was:

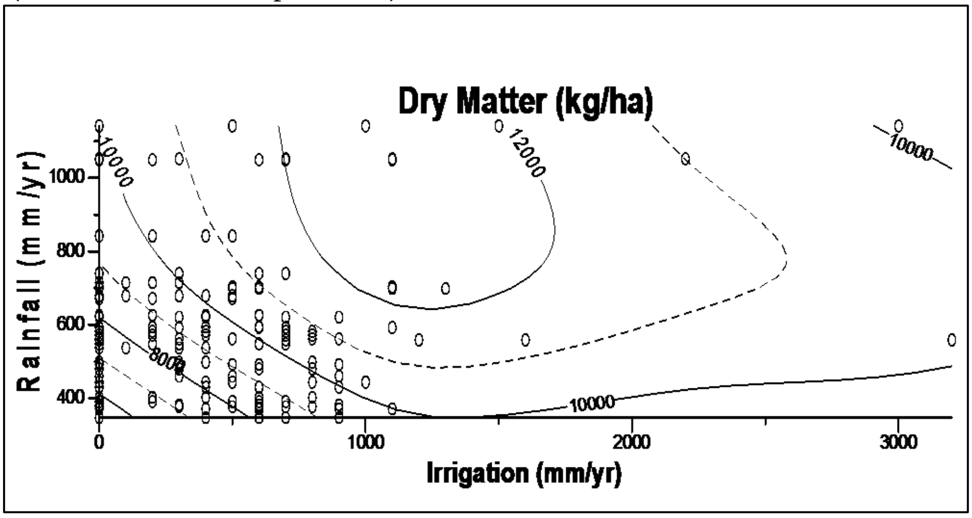
$$DM = \text{function (Irrigation, Rainfall)} + \text{function (Year, Trial, Treatment)} \quad (1)$$

The terms in Year, Trial, and Treatment are included to allow for the correlations that these terms induce in the data. Third order interactions were needed in the model as judged by the Akaike Information Criterion (AIC). The curves with irrigation consisted of a straight line up to irrigation=1000 mm with irrigation having no further effect at higher values (figures 1 and 2). It was decided to restrict our region of interest to irrigation amounts < 1000, where a simpler equation was adequate. Both irrigation (IR) and rainfall (RF) provided a good fit in this region as judged by the AIC. The non-linear parts were non-significant ($p>0.05$). The resulting equation was:

$$DM = 5.6\ (\pm 0.6) \times IR\ (mm/yr) + 6.8\ (\pm 1.1) \times RF\ (mm/yr) + 6538\ (\pm 1844) \quad (2)$$

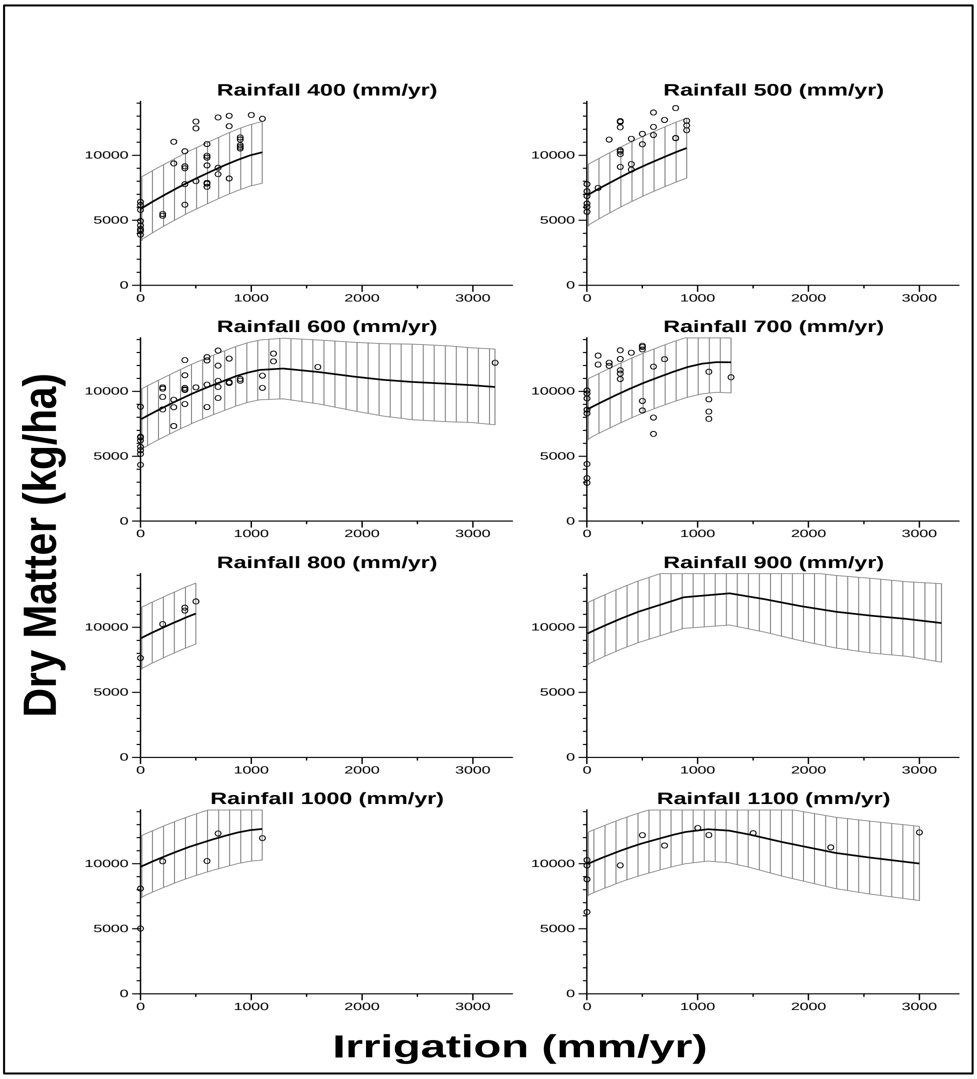
(Figures in parentheses are standard errors)

Figure 1: Contour plot of Dry matter as a function of Rainfall and Irrigation
(Circles are the data positions)



We need only the coefficient of the Irrigation term when employing equation (2) to describe pasture production on farms in mid-Canterbury. The different fertility levels found on different farms will be managed with different constants. This coefficient is the change in production = 5.6 (±0.6) × the change in irrigation water (i.e. the change in supply reliability of water). We use this relationship to estimate the additional pasture production associated with irrigation in the Hinds catchment. The estimates were similar to the results from a study on the pasture growth response to irrigation water availability in the Manawatu region by Sumanasesa (2003). The coefficient of determination between irrigation water availability and pasture production measured here is 0.6, whereas in the Sumanasena study the estimated value is 0.54. However, our estimation is only approximate given a number of apparent limitations. First, the dry matter production and irrigation were applied all through the irrigation season in the Wunchmore trial. In reality, farmers in mid-Canterbury will irrigate only when it is dry. Second, the timing of the irrigation restriction in relation to rainfall times has been ignored. Last, the data was derived from a border-dyke irrigation trial, while the more efficient centre-pivot method of irrigation is now used.

Figure 2: Relationship between dry matter and irrigation at different rainfall levels



Estimating farm and catchment level impact of the increased water supply reliability

For the areas that are being supplied with irrigation from surface water only, and where there is no ground water backup, ECan has assumed different supply reliability as follows (Baseline Summary Report, ECan, 2013).

The Barrhill Chertsey scheme has an area of approximately 4,500 ha. Water is sourced from the RDR and is dependent on the supply reliability from the Rakaia, which has an average reliability of supply of 50%.

Valetta groundwater supplies an area of approximately 3,200 ha. The recent Valetta hearings placed conditions on the groundwater consents that will restrict their reliability of supply to below 95%. The actual reliability is difficult to determine but has been assumed to be 80%.

The Hinds River surface water supplies an area of approximately 300 ha. The abstractions from the Hinds River have a reliability of supply estimated at approximately 40%.

Lowland drains surface water supplies an area of approximately 3,300 ha. The lowland drains all have different minimum flows and flow regimes and the majority are not measured. Analysis of the drains that are measured suggests an average reliability of supply of 80%.

Using these supply reliability data and the irrigation and pasture growth relationship (equation, 2) we have estimated the loss pasture yield of the above irrigation schemes compared to the ideal 95% reliability. We also use the data provided by MacFerlance Rural Business Ltd on current pasture yield for different farming systems (dairy = 13,917Kg/DM/ha/Yr: dairy support = 11833 Kg/DM/ha/Yr) for this assessment. We also assumed that lost pasture yield due to the lack of water would have to be provided through supplementary feeding. The price of supplementary pasture is assumed as $0.21/kgDM (Harris et al., 2012). Then we estimated the potential range of yield loss across the catchment, considering the average dairy system 4 and 5 farms as having the highest DM production and dairy support farms as having the lowest DM production. We derived the range of catchment level income gain using this relationship.

Estimating regional level impact of the increased water supply reliability

In the regional level assessment we used a Social Accounting Matrix (SAM)-based Input-Output (SAMI-O) model that we developed for this study. We used the model to capture and understand the Canterbury Regional economic structure in terms of how industries are linked and interdependent on each other. We also used the model to estimate the economic impact multipliers before applying it to assess the impact of changes in industry production based on the catchment level value added due to increase in water supply reliability. This modelling approach captured the impacts of changes in an economy and what is being produced on the wealth of that economy (West 1992). Generally, the direct value of a sector is measured in Gross Domestic Product (GDP) contribution to the economy. The impact of catchment level production value changes was captured in terms of linkages and interdependency between the industries as represented in the SAM database. For example, an increase in income in the livestock and cropping industry results in increased demand for inputs within the industry as well as from other industries, such as fertiliser, services and tourism. Therefore, farm-level activities that result in production value changes lead to both direct and indirect industry production income, value added income, and employment. These measurable economic parameters give an indication of market values of the impact of farming on non-farming activities.

The data behind the model

The model used the Canterbury Region SAM obtained from Market Economics Ltd, the company that generates SAMs from the Statistics New Zealand 2006-07 Supply Tables, using the ANZSIC96 industry definitions[1]. The SAM database is a comprehensive, economy-wide dataset showing payments and expenditures between

[1]Statistics New Zealand has only recently released 2006-07 Supply Use Tables (and an Input-Output Table) based on ANZSIC06 industry definitions.

industries. The “social” aspects of the SAM captured how households earn and spend their incomes. The SAM included the industries that are of interest in this study, namely horticulture and fruit growing, livestock and cropping farming, dairy cattle farming, and other farming, but they were not disaggregated to the level of farm types being considered in this study. Another database used in the model is the employment number (as of March 2004) by industries in the region (Department of Labour, 2004). This was the most recent available employment data by the industries. This employment data by industry served as baseline employment numbers by industry. The industry structure, however, as represented in SAM, has not changed dramatically since 2004 and thus this will not have significant impact on the assessment.

RESULTS AND DISCUSSION

The potential gain in pasture production (Table 1), and thus the income gain at assumed 95% supply reliability, varies between the schemes because they have different reliability levels (Table 2). For example, the area covered by the Hinds River surface water is estimated to have the highest gain in pasture production, and thus the greatest income gain per ha of farm at the 95% reliability, because it has the lowest estimated current reliability of 40%. This analysis shows that the catchment level total gain due to the increase in reliability will range from \$16m (assuming the whole area is under dairy support) to \$17m (assuming that the whole area is under dairy farming).

Table 1: Impact of Reliability of Water on Dry Matter Production (tDM/ha/yr)

Under current reliability	Dairy	Dairy Support
Farm-level pasture production at baseline reliability		
Valleta Hearing Consent (80% reliability)	8.5	6.8
Barhill-Chertsey (50% reliability)	4.3	3.3
Hinds River (40% reliability)	2.9	2.1
Lowland Drains surface (80% reliability)	8.5	6.8
Pasture Production at 95% reliability	13.9	11.8

Table 2: Economic Impact of Reliability of Water Supply

Under environment scenario	Dairy	Dairy Support
Income gain at farm level at 95% reliability ($/ha)		
Valleta Hearing Consent	1,136	1,054
Barhill-Chertsey	2,013	1,799
Hinds River	2,305	2,048
Lowland Drains surface	1,136	1,054
Potential gain at catchment level ($m)		
Valleta Hearing Consent (3200ha)	3.6	3.4
BCIL (4500ha)	9.1	8.1
Hinds River water surface (300ha)	0.8	0.7
Lowland drains (3300ha)	3.8	3.5
Total across the catchment ($m)	17.3	15.7

Multipliers estimated by SAMI-O simulations are indicated in Table 3. The potential economic impacts (direct and indirect) at the regional level of this catchment level estimated by using the SAMI-O model simulations results indicate that total industry production income will increase by around $64m. The value-added income was estimated to vary from around $20m (if the land was all used for dairy support) to $23million (if the land was all used for dairy farming). Therefore, the total income gain at the regional level due to catchment level increase in reliability will range from around $84m (assuming all areas under dairy support) to $87 million (assuming all land area was under arable production). This change in the income gain was estimated to result in an increase in the total employment ranging from 137 full-time equivalents (FTE) (assuming all farms are dairy support) to 207 FTE (assuming all area is under dairy farming) (Table, 4)

Table 3: Estimated Multipliers for different farm types

Impact	Multiplier		
	Dairy Support & Sheep & Beef	Dairy Cattle	Other Farming
Total Industrial Output ($)	4.11	3.71	4.44
Value Added ($)	8.22	17.97	5.12
Jobs	4.28	1.95	10.61

Source: Own estimation by SAMI-O simulation

Table 4: Economic impact of increased reliability at regional level

Potential gain at catchment level	Dairy	Dairy Support
Total gain at the catchment - from Table 1 ($m)	17.3	15.7
Potential gain at regional level		
Industry production income ($m)	64.0	64.4
Direct impact ($m)	17.3	15.7
Flow-on impact ($m)	46.7	48.7
Value added income ($m)	22.6	20.3
Direct impact ($m)	1.3	2.5
Flow-on impact ($m)	21.3	17.9
Total regional income gain (GDP)	86.6	84.7
Total employment (number of job FTE)	207	137
Direct impact (number of job FTE)	106	32
Flow-on impact (number of job FTE)	101	105

* Numbers may not add up exactly due to rounding errors

Source: own computation based on SAMI-O simulation

In summary our assessment shows that the potential income loss of failing to reach 95% of supply reliability ranges from $15 to 17 million/ year in the catchment area. The economic impact of this loss is considerable as this lost income will have flow on impacts in the economy. In this assessment we have not considered the cost of an attempt to increase the supply reliability to 95% from the current reliability level. We would expect that considerable costs will be involved in providing infrastructure to provide additional water from sources such as ground water. Furthermore, we understand that both surface and groundwater resources are over-allocated (ECan, 2013- Personal communication). Therefore, an attempt to further promote reliability could cause further pressure on already depleted water sources and thus negative impacts on the other industries that depend on this resource, unless considerable water use efficiency improvements could be achieved through efficient irrigation systems. This is already a trend that is being observed in the catchment, as farmers have been progressively changing from border-dyke to centre-pivot irrigation to increase water and nutrient-use efficiency. However, this change reportedly has had some negative environmental impacts in the lowland areas because of less seepage water in downstream areas. Therefore, in-depth analyses of potential direct and indirect costs that result from increased reliability are important factors that should be considered in addressing the issue of low reliability. In fact, in a detailed economic analysis, one should consider the time factor in the analysis and thus a discounted measure on net gains of the capital investment over time. In addition, marginal cost benefit analysis of the capital investment will show the optimum level of investment that will give the maximum benefits at the catchment level. We have not considered these analyses in this study as we have focused on cost and benefit of the reliability change in a given point of time.

CONCLUSION

In this study we have assessed the catchment and regional level economic impacts of potential increase in supply reliability of water considering the Hinds catchment in the Ashburton District of Canterbury Region in New Zealand as a case study. The catchment and regional level economic gain of potential increase in supply reliability of water is considerable in this case. However, most of the catchments in New Zealand, especially in the Canterbury Region, water is reportedly over allocated. In addition, in most of the catchments' the nutrient outputs of farming is greater than the capacity of the environment to withstand them. Thus, promoting the supply reliability of water is difficult for regional councils, who are also responsible for reducing nutrient outflows from agriculture. Moreover, potential direct and indirect costs to supply the infrastructure needed would be considerable. We have not considered these costs in the current assessment, but future research in this area should ensure that all costs and benefits have been adequately considered.

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