Water, Water Somewhere:
The Value of Water in a
Drought-Prone Farming Region

Arthur Grimes* & Andrew Aitken**
*Motu Economic & Public Policy Research; & University of Waikato
**Motu Economic & Public Policy Research

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Abstract

Water is critical for agriculture, yet surprisingly few studies internationally have analysed the value placed on water in specific farming contexts. We do so using a rich longitudinal dataset enabling us to extract the value placed by farmers on long-term access to irrigated water. New Zealand has a system of water consents under the Resource Management Act (RMA) that enables farmers with consents to extract specified quantities of water for agricultural purposes. Extraction without a consent is illegal. Some water is extracted through large-scale irrigation infrastructure and other flows by more localised means; the RMA and the water consents themselves are a critical legal infrastructure underpinning farming.

We examine the value that farmers place on water consents using our specially constructed annual dataset covering every rural property in one drought-prone New Zealand local authority (Mackenzie District) over nineteen years. We hypothesise that farmers will pay a premium for land that has a water consent and that the value of the premium will be determined by the present discounted value of the extra income due to the consent. The premium may therefore vary according to the underlying characteristics of the land (e.g. rainfall, slope, drainage) which influence the marginal productivity of the consented water.

Our dataset includes, for every rural property in the region: the land value set by Quotable Value New Zealand (an independent body) for property tax ('rating') purposes, and the sale price of the property (if sold). These variables are used, in separate specifications, as our dependent variable. Longitudinal consents data include a measure of irrigated area and two measures of maximum allowable water flow; these data vary over time for certain properties. Other explanatory variables include: land area; measures of average rainfall, slope and drainage; distance from local towns; and, for the sales price dataset, land use and value of improvements.

Using panel methods, we estimate property values (and sale prices) as a function of all explanatory variables (including water consents), together with the consent terms interacted with other variables to determine how the value of water consents varies according to variations in other local conditions. We also test whether the presence of a water consent affects the propensity for properties to be traded.

While water is not explicitly priced or traded in New Zealand, our methods enable us both to determine a shadow price for water in the region and to isolate key determinants that affect the shadow price. We find that water is valued positively and that the value is higher: (a) where the water right increases in size (flow); (b) where rainfall is lower; and (c) where the land use is oriented towards water-intensive activities. Differing returns across different types of property indicate that the legal restriction that forbids trading of water results in allocative inefficiency for this resource.

The depth of this study is unique internationally. As well as providing valuable information for irrigation and water planning in New Zealand, its methods and results can be used to inform studies of water's value in other settings where water is a scarce commodity.

JEL classifications: Q15, Q25, Q12, D23, D24

Contents

1 Introduction

Water is critical for agriculture, and is becoming increasingly scarce in many places.[1] Water allocation mechanisms are often non-existent or based on first-come first-served principles that do not allocate water to highest end-uses. Irrigation projects may assist in alleviating water scarcities, but they are often bedevilled with inefficiencies related to the lack of efficient allocation of the irrigated water.

The importance of these increasingly vital issues that contribute at the most basic level to humanity's existence suggests that a large body of evidence will be available on the value of water for agricultural and other purposes. Yet surprisingly few studies internationally have analysed the value placed on water in specific farming contexts. We do so using a rich longitudinal dataset that enables us to extract the value placed by farmers on long-term access to irrigated water.

New Zealand has a system of 'water consents' under its Resource Management Act (RMA) that enables farmers with consents to extract specified quantities of water for agricultural purposes. Extraction of water without a consent is illegal. Consents are granted separately for ground and for surface water. Some water is extracted through large-scale irrigation infrastructure and other flows by more localised means.[2] The RMA and the water consents themselves are a critical legal infrastructure underpinning farming. The consents grant farmers the right to extract up to a certain quantity of water (defined by maximum flow rates and by maximum volume flows over time) generally for 30 years. This may enable farmers to change the nature of production on their land (e.g. from sheep grazing to arable or to dairying).[3] However the water rights are not tradeable, nor can the

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[1] In January 2008, the United Nations Secretary-General, Ban Ki-moon addressed the Davos World Economic Forum, Switzerland, stating: "The challenge of securing safe and plentiful water for all is one of the most daunting challenges faced by the world today. Until only recently, we generally assumed that water trends do not pose much risk to our businesses … the notion of water sustainability in a broad sense has not been seriously examined."
Source: www.un.org/News/Press/docs/2008/sgsm11388.doc.htm , sourced 13 May 2008.

[2] From the 1930s to 1984 there was considerable public investment in community irrigation schemes; however since 1985 there has been no direct central government investment in building irrigation schemes. See Le Prou (2007) for a history of New Zealand irrigation administration.

[3] Taylor et al (2003) suggest that land use change comes in waves as irrigation availability is followed by changes in farm ownership and demographic changes. Consistent with this view, there has been a change in the role of irrigation from drought-proofing to being a means of diversifying agricultural production. Ford (2002) notes that land use change can take time, so flow benefits of

water itself be sold. Mostly, consents reflect first-come, first-served (or "first-applied, first-granted") rights to water for local land-owners. If a farm does not use all its entitlement in a certain period, that water is "lost" to the consented properties, and no other property can make use of the lost water (e.g. by diverting the relevant water for its own use).

This system means that we do not observe market prices for agricultural water in New Zealand. Nevertheless, in parts of New Zealand, including the Canterbury Region, water is scarce and a shadow price must therefore exist for this commodity. The shadow price can be observed since resource consents for water remain with the farm when the property is sold. Thus the sale price will reflect, inter alia, the water consents (or lack of them) belonging to the property. Furthermore, if property valuations (for property tax purposes) reflect the full value of the farm (as they are required to by law), they will also indicate the value placed on water consents for each property.

We examine the value that farmers place on water consents using a specially constructed annual (and triennial) dataset. The dataset covers every rural property in one drought-prone New Zealand local authority (Mackenzie District in the Canterbury Region[4]) over a period of nineteen years. We hypothesise that farmers will pay a premium for land that has a water consent and that the value of the premium will be determined by the present discounted value of the extra net farm income due to the consent. The premium may therefore vary according to underlying characteristics of the property (e.g. rainfall, slope, drainage) which influence the marginal productivity of the consented water.

Our dataset includes, for every rural property in the region: the land value set by an independent body (Quotable Value New Zealand) for property tax ('rating') purposes, and the sale price of the property (if sold). These variables are used, in separate specifications, as our dependent variable. Longitudinal consents data include a measure of irrigated area and two measures of maximum allowable water flow; these data vary over time for certain properties. Other explanatory variables include: land area; measures of average rainfall, slope and drainage;

new irrigation may be delayed. Land prices nevertheless should be forward-looking, so the present discounted value of the irrigation should be impounded in the land value.

[4] Canterbury had 287,000 ha (60%) of New Zealand's irrigated land in the 2002/03 season (MAF, 2004).

distance from local towns; and, for the sales price dataset, property land use type and value of improvements (the latter also being set for rating purposes). The variability in the longitudinal consents data enables us to identify the impact of the water consents on property prices, reflecting the implicit market valuation of water rights.

We use panel estimation methods to estimate these values. Specifically, we estimate property values (and sale prices) as a function of a range of explanatory variables including the water consent variables. In some estimates, the consent terms are interacted with other explanatory variables to determine how the value of water consents varies according to variations in other conditions. We also test (using a probit equation) whether the presence of a water consent affects the propensity for properties to be traded. Our methods therefore enable us both to determine a shadow price for water in the region and to isolate key determinants that affect the shadow price. We find that water is valued positively and that the value is higher: (a) where the water right increases in size (flow); (b) where rainfall is lower; and (c) where the land use is oriented towards water-intensive activities. Differing returns across different types of property indicate that the legal restriction that forbids trading of water results in allocative inefficiency for this resource. These results provide valuable information for irrigation and water planning in New Zealand. The paper's methods, especially in bringing together a comprehensive range of farm-specific data covering a whole region over a significant timespan, can also inform studies of the value of water in other settings where water is a scarce commodity.

To provide a background for the analysis, section 2 outlines the (few) other studies that have examined similar issues. Section 3 builds on these to construct a theoretical model that underpins our empirical analysis. In section 4, we describe our data which have been compiled from a number of separate sources, each collated to match at an individual property level. Included in this section are the results of the probit equation determining whether properties with irrigation are more or less prone to be purchased. Our major results are contained in section 5. For each dataset (i.e. valuation dataset and sale price dataset) we have separate samples - 'large' and 'small'. In each case the 'small' dataset excludes lifestyle blocks and some other properties for which land use is uncertain. The large dataset includes some data which appear reliable but where we could not be completely certain of the veracity (e.g. because of missing land use data), but this dataset has the advantages of fewer selection issues and greater degrees of freedom. For the sales dataset, we also conduct our estimates using a restricted dataset that excludes any property that has been subdivided (or aggregated) over the sample period (again with large and small samples).[5] We test the robustness of our results across the six datasets and across different equation specifications. At the close of section 5 we interpret our results, using our estimates to determine the value (in 2006) placed on irrigated water across different farming circumstances. Section 6 concludes, suggesting both research and policy implications of our findings.

2 Prior studies

Methods for valuing irrigation water traditionally include observing water right markets, residual methods, and hedonics. Transactions between buyers and sellers of water rights naturally are a useful source of information for valuing water, although lack of data means this method is rare. Residual methods derive shadow prices from models of decisions made by firms and households. The residual method, as applied to irrigation, often takes the form of farm budget or cost and return analysis (Young, 2005). This method involves pricing inputs and outputs and specifying an appropriate farm production function.

An alternative method, and the method used in this work, uses statistical analyses of farm sales or valuation data to isolate the net economic contribution of irrigation water. This is an example of the hedonic property value approach to water valuation (Palmquist, 1989). In it, a land sales price represents the market's willingness to pay for a bundle of rights to the land and irrigation water. Appropriate data allow the contribution of irrigation water to be statistically isolated from that of the land and other features such as proximity to urban markets, soil quality, and presence of capital items such as farm buildings. Despite

[5] The other datasets include properties that have been subdivided through the period, aggregated to

its attractiveness, relatively few studies have applied the hedonic method to irrigation, and those that do frequently use small samples or suffer from some data deficiency, resulting in statistically insignificant results.

Recent studies using hedonic valuation methods include Crouter (1987), Torell et al (1990), Xu et al. (1993) and Faux and Perry (1999). Crouter (1987) examined 53 observations of farm sales in Colorado from 1970 but was unable to find a statistically significant effect of irrigation water rights on farm sales price. Torell et al (1990) examined a much larger sample of 7,200 farm sales in a six state region in the Ogallala aquifer in the western United States from 1979-1985. Following Palmquist (1989) they estimate two equations, one for dry land and one for irrigated land, and find that the price differential between the two types of land has declined over time. They estimated values of about $3.90 per acre-foot of water in storage over the entire regions, with values ranging from $1.09/acre-foot in Oklahoma in 1986 to $9.50 per acre-foot in 1983 in New Mexico (an arid state). These estimates suggested that the water value component of irrigated farm sales ranged from 30 to 60 percent of the farm sale price.

Xu et al (1993) study the effects of site characteristics on the valuation of agricultural land between 1980 and 1987 in Washington State. They find a positive and significant effect of irrigation and also find that the type of water distribution system is important, a central pivot system being more valuable than other sprinkler systems.

Faux and Perry (1999) apply the hedonic method to a sample of 225 farm sales in Malheur County, Oregon between 1991 and 1995.[6] They put considerable effort into evaluating the effect of soil quality on farm land prices. Their research assumes a constant 2.5 acre-feet per acre rate of irrigation across all sales to allow them to derive a value per unit of water volume. Their estimates of this value ranged from $9 to $44 for the lowest to highest quality irrigated soils.

Young (2005) reviews a variety of methodological approaches to valuing irrigation water, and notes that estimates of the value of irrigation water from hedonic estimates tend to be much lower than those derived from residual methods. Torell et al. (1990) compared their hedonic valuations with valuations

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a consistent level throughout the sample.

derived from farm budgeting (residual) methods. They found that their hedonic results were much smaller (in $ per acre-foot) than those derived from residual methods. This could be because many residual estimates are short-run and ignore some fixed costs. Another reason for relatively low hedonic estimates might be the choice to exclude non-irrigated land sales (Young, 2005). If all observations represent sales of irrigated land, the range of water supplies across observations is likely to be limited, and relatively little change in output per unit of water input would be expected. Young (2005) also suggests that the hedonic method measures an at-source (or water cost-adjusted) value rather than the at-site measure usually derived by residual methods. Therefore, to make the two approaches comparable, the estimated costs of obtaining water need to be added to the estimated (hedonic) at-source value.

Given Young's analysis, successful use of the hedonic approach requires a location where both irrigated and non-irrigated land parcels of relatively similar climate and market conditions are bought and sold on competitive markets. The observations on the extent of the water right must also vary widely enough for a satisfactory statistical estimate. Our comprehensive data sources enable us to meet these requirements.

In New Zealand, little econometric research has been conducted on the value of irrigation, despite an estimated doubling in irrigated area between 1985 and 1995 (Ministry for the Environment, 2000). At a macroeconomic scale, the Ministry of Agriculture and Forestry (MAF) (2004) calculated that the contribution of irrigation water to GDP was $920 million in 2002/03, or approximately 11% of farmgate GDP. An adjusted gross margin method was used to estimate the change in GDP generated by irrigation.[7]

Two community schemes (Waimakariri and Opuha) have been developed during this period. The Opuha dam was the subject of an *ex post* study by Harris et al (2006). They examined the effect of the Opuha dam, commissioned in 1999, on the local Canterbury economy. The study was conducted over a two-year period (2002/03-2003/04) and used detailed revenue and expenditure data from a

[6] Young (2005) describes Faux and Perry as a quasi-hedonic approach because they lack data on the quantity of the water right for each property.

[7] A gross margin is the total revenue associated with a particular production minus costs, adjusted to take account of differences in overheads between land uses and also for wages and salaries.

final sample of 32 irrigated farms and 20 dry-land properties. The authors estimated total revenue (for the two year period) was $2,073/ha for irrigated farms compared to $862/ha for dry-land farms.

Ford (2002) conducted an *ex post* study of the Lower Waitaki irrigation scheme, assessing a wide range of commercial, economic and social parameters, and comparing the scheme with economic and social changes in the Rangitata area which does not have a community irrigation scheme. (Rangitata was chosen because of its similar soil type, shape and location south of a major river.) Farm output models of income, expenditure, and land use were created using data on typical farm budgets and from a comprehensive agricultural database (Agribase) for both irrigated and dry-land farms. Ford compared the two regions over a period of 20 years and found considerable differences in population, income and employment. The net change in annual cash farm surplus from switching from dry-land to having an irrigation scheme is $29 million per annum, representing a 14.1 percent return on capital at the farm gate. The Waitaki regions had a net population gain of 15.4 percent between 1981 and 2001, compared to a 0.6% loss in Rangitata.

3 Theory

We adopt the hedonic method for valuing farms in relation to their fundamental characteristics [Palmquist (1989); Palmquist & Danielson (1989); Freeman (2003); Taylor (2003)]. Our approach incorporates a semi-log functional form, appropriate for minimising potential heteroskedasticity (Rosen, 1974).

Let Y_{ijt} be real net income (including returns to capital) accruing to the owner of farm i ("the farmer") at time t when the farm is used to produce commodity j (j=1,…,n); for instance, j could represent arable output, sheepmeat, or dairy produce.[8] Nominal net income is given by $P_{jt}*Y_{ijt}$ where P_{jt} is the market price for commodity j at time t. For any j we assume that nominal net income is determined both by land area, L_{ijt}, (subject to scale parameter, α) and by productivity per hectare, A_{ijt} (after adjusting for scale); thus:

[8] This approach implies that the costs of bringing water to the point of use have already been deducted in forming the net income variable.

$P_{jt}*Y_{ijt} = P_{jt}*L_{ijt}^{\alpha}*A_{ijt}$ (1)

Productivity is a function, in part, of land characteristics that cannot easily be changed; these include climate (rainfall), soil structure (drainage), and terrain (slope). It may also be a function of location (distance from towns) and of human modification, notably irrigation. Furthermore, there is likely to be an interaction between irrigation and the innate characteristics of the land. For instance, we hypothesise that irrigation will be more important to farm productivity where a unit has low rainfall than in a situation where a unit already has plentiful rainwater. Similarly, irrigation may be more or less effective in units with different slope and drainage characteristics.

Denoting the vector of farm i's characteristics (which are assumed unchanged across all t) as C_i and letting W_{it} be a measure for farm i's irrigation at time t, we assume that A_{ijt} is determined as in (2):

$\ln A_{ijt} = k + f(C_i) + g(W_{it}) + h(C_i*W_{it}) + \varepsilon_{it}$ (2)

where f(.), g(.) and h(.) are functions to be specified, k is a constant and ε_{it} is a residual term that is uncorrelated with all other explanatory variables. Combining (1) and (2) yields:

$P_{jt}*Y_{ijt} = P_{jt}*L_{ijt}^{\alpha}*\exp\{ k_i + f(C_i) + g(W_{it}) + h(C_i*W_{it}) + \varepsilon_{it} \}$ (3)

For each property i (given its existing characteristics), the farmer chooses an optimal land use, j*, in time t such that $P_{jt}*Y_{ijt}|_{j=j*} = \sup(P_{jt}*Y_{ijt}|_{j=1,\ldots,n})$ to give net income Π_{it}.[9]

The sale price (SP_{it}) of farm i in year t will be given by the present discounted value of net income from the property. If, in period t, net income is henceforth expected to grow at an exponential rate φ_t and the discount rate is expected to be constant at rate r_t, SP_{it} will be given by the standard formula for an infinite series:

$SP_{it} = \Pi_{it}*(1+r_t)/(r_t-\varphi_t)$ (4)

Combining (4) with (3), and taking logarithms, we obtain:

$\ln SP_{it} = k + \alpha \ln L_{it} + f(C_i)+g(W_{it})+h(C_i*W_{it})+\{\ln P+\ln(1+r)/(r-\varphi)\}_t + \varepsilon_{it}$ (5)

In (5), the term in braces is not farm-specific so in a panel application it can be proxied by time fixed effects. In our empirical work, we employ linear functions for each of f(.), g(.) and h(.). As discussed in section 4, we adopt two different measures for SP_{it}, one being actual observed sale price (less improvements) for the sample of properties that are sold each year, the other being the valuation for property tax purposes of virtually the universe of farms in the district. In line with legislative requirements, we assume that the valuation of the property is determined by the same fundamentals as hypothesized in (5).

4 Data

4.1 Valuation data

We use unit record valuation and resource consent data for the Mackenzie District from 1988 to 2006. The valuation data are sourced from Quotable Value New Zealand (QVNZ) a state-owned enterprise that undertakes valuation of properties across New Zealand, principally for property tax (rating) purposes. The valuation dataset contains the valuation date, capital value, land value, improved value, land type, and land area[10] of all rural properties in the Mackenzie District, Canterbury, in the South Island of New Zealand.[11] The dataset also contains an identification number (Land Information New Zealand (LINZ) identification number) that allows us to map the property boundaries using GIS.

In 2006 there were 1,252 currently active rural properties in the Mackenzie District. However 56 properties are without a LINZ number and therefore cannot be mapped or spatially merged with the resource consent data. Valuations are conducted on a three-yearly cycle, and so we have seven waves from 1988 to 2006.

Significant cleaning of the data was undertaken as a result of having multiple observations for the same property in the same year. The two main situations when this occurs are as follows. First, when a change to the property occurs between regular valuations, for example because of major renovation work, the property is revalued. Precisely when the revaluation takes place is not

[9] Henceforth we drop the j subscript, assuming that all land is devoted to the optimal land use.
[10] In our empirical work, land area of each farm is denoted LAND.

known and in these cases the first record (based on the date stamp by which the data was exported by QVNZ) is kept. Any changes to the property are therefore picked up in the next regular valuation. The second case occurs when a property is subdivided. In this case it is possible to aggregate properties that have been subdivided to form the previous property, thereby allowing us to form a continuous series for each (aggregated) property. Of the 1,169 properties in 2006, 645 are the result of subdivision. After aggregating these subdivisions we are left with 761 properties covering 1988-2006.

Due to a lack of adequate land use data, we form two valuation samples for our estimation. The first (larger sample) is formed on the basis of land use in 1988 and includes all agricultural categories in addition to properties with a missing land use code in 1988. Table 1 presents a summary of the main variables in this sample of 3,951 observations. The second sample excludes all properties that had a missing land use code in 1988, reducing the sample to 2,702 observations.

Both the valuation and consent data (see below) are aggregated to economic units, as this is the basis on which valuations are conducted. For example a farm may be divided into several parcels with different legal ownership, but may be operated as a single farm, thus 'property' refers to the economic unit not the legal land parcel as defined by LINZ.

4.2 Sales data

For market sales, we use QVNZ annual sales data for the Mackenzie District from 1988-2006. The dataset includes the sales date, sales price, and land type, of all rural properties sold in the Mackenzie District. Two main samples are formed based on the land use data, which is substantially complete in comparison to the valuation data (only 75 sales have no land use code out of 1,366 sales). The first sample includes all agricultural properties, plus properties coded as lifestyle properties, and properties with no land use code. The second sample excludes sales of lifestyle properties and those with a missing land use code. Three land use variables are also formed, the first includes dairy, arable, specialist agriculture and properties with no land use code, the second is pastoral (which is hypothesized to

[11] However the land type data is substantially incomplete.

be less water-intensive than the first category), the third is lifestyle. These variables, when included, are interacted with an irrigation variable to test whether the value attributed to irrigation varies according to the nature of land use (over and above the underlying characteristics of the land).

The sales price of a property includes the value of improvements as well as the value of land (i.e. capital value equals improvement value plus land value). For each property, we have the QVNZ valuation of improvements as at the most recent triennial valuation cycle. We interpolate the improvement value between any two valuation cycles by applying a constant growth rate to improvements during that three year period to obtain an estimate of improvement value annually for each property. We subtract the improvement value from the sales price to derive a sales price-based land value (since land value is the variable that we require in order to assess the value attributed to the hedonic variables, including irrigation).[12]

Table 2 presents summary statistics for the larger sales price sample. The mean of each of the variables in the sales price dataset (Table 2) is within one standard deviation of the respective mean for the valuation dataset (using the standard deviations from the valuation dataset, which can be considered the 'universe' in this application). Thus there is no evidence from this comparison that the sales dataset suffers from material selection bias.

Another way of testing for selection bias in the sales price dataset is to estimate a probit equation explaining the probability of sale for any property (within the valuation dataset) in any year. To estimate this equation, we include only properties that have not been subdivided (or aggregated) during the period 1988-2006 to ensure a sample with consistent characteristics over time. Within this restricted set of properties, we again have two samples: the first includes lifestyle blocks and properties with missing land use codes, and the second

[12] Of the 1,304 sales, we can only form the interpolated improvement values for 761 properties, since it is not always possible to match every sale with the appropriate improvements data when a sale of a subdivided property has occurred and where we have aggregated that subdivided property back to its pre-subdivision status. In addition we drop some sales (primarily lifestyle blocks) where the ratio of improvement value to sales price is greater than 0.9 (leaving virtually zero, or negative, implied land value). This leaves us with a sample of 678 sales (in the larger sales sample).

excludes them. Results of the probit equation are reported at the end of this section.

We estimate the sales price regressions on the two sub-samples used to estimate the probit regression as well as on the larger samples. The sub-samples used for the probit equation exclude all properties that have been subdivided, so we can be confident that the sales price results based on these sub-samples are not affected in any way by our method of linking subdivided properties over time. (However they have a relatively small sample size and may suffer from some selection issues.) The use of the restricted sample forms another robustness check on our results.

4.3 Resource consent data

The second source of data is the Canterbury regional council, Environment Canterbury, which has provided us with details of all irrigation resource consents issued in the Mackenzie District. There are four types of irrigation consents: surface water, surface divert, ground water and consents for dams. All four were provided in the form of point data in ArcGIS shapefiles. Surface water consents refer to situations where water is drawn directly from a river or lake, surface divert consents refers to situations where a watercourse has been altered. Ground water consents are required for extracting water from underground aquifers. Dam consents are for generally small private dams that have been built to store water.

The available data include the start and end date of the consent, the maximum legal rate of water extraction in litres per second and cubic metres per day, the irrigated area and property area.[13] These data also required some cleaning. First, consents were sometimes geocoded outside of a property boundary and therefore the consent cannot be linked with the valuation data. Generally these cases relate to consents that are for local council water supply or similar.

Second, some consents lacked any date information rendering these consents unusable. The majority of these are consents for which, after an initial investigation, no consent was actually sought or the application was withdrawn.

For a few active or expired consents without date information it was possible to get this information from the Environment Canterbury online consent search tool. For properties with more than one consent the water right variables are aggregated; irrigated area is summed, and the rate of extraction and volume is averaged (weighted by the irrigated area).

The spatial distribution of consents over the period 1988-2006 is shown in Figure 1. There is significant variation in the extent of the water right across different properties. On average, properties that are irrigated are allowed a maximum extraction rate of 100 litres per second (l/s), ranging from 0.4 l/s to 4,000 l/s (with a standard deviation of 101 l/s). Similarly the average maximum volume is 22,335 cubic metres per day, ranging from 65 m^3/day to 345,600 m^3/day (with a standard deviation of 22,561 m^3/day).

We form several interaction variables for use in the regression analysis. The variables rainfall, slope, drainage, distance to the nearest town, and distance to Timaru are each interacted with the rate of water extraction expressed as a ratio of the total area of each property (RATE). We also interact RATE with land use characteristics for certain estimates.

4.4 Location and land characteristics variables

GIS was used to compute the distance between the centroids of every property and four towns: Fairlie, Geraldine, Temuka, and Timaru. Two variables were created, one for the distance from each property centroid to the nearest town (DIST1) and another for the distance from each property centroid to Timaru, a port and rail city with a population of 27,000 in 2001 (DIST2). All distances are straight line distances measured in metres.

We use additional data, sourced from LENZ (Land Environments of New Zealand)[14] that characterizes natural features of each farm unit, such as average rainfall (RAIN), average slope (SLOPE) and soil drainage (DRAIN). The data is in raster form in GIS layers and is averaged and merged onto the property

[13] In our empirical work we form three variables from these irrigation data: irrigated area/property area (IRRIG), maximum legal rate of water extraction in litres per second/property area (RATE) and maximum legal rate of water extraction in cubic metres per day/property area (VOL).

boundary layer. Figure 2 shows the distribution of average rainfall (mm) across the Mackenzie District. Figure 3 shows the average slope (degrees) across the district for each property. Figure 4 shows the average soil drainage measure across each property in the Mackenzie District.[15]

4.5 Sales propensity

We test the representativeness of the sales dataset relative to the (considerably more comprehensive) valuation dataset by estimating a probit regression in which the dependent variable is the probability of sale for any property in any year. The explanatory variables are the same as those that we choose for our structural estimates in the following section, i.e. log of land area (lnLAND), three irrigation variables (IRRIG, RATE, VOL), three land characteristics variables (RAIN, SLOPE, DRAIN), two distance variables, respectively to the nearest town and nearest city (DIST1, DIST2), plus year fixed effects and a constant. Each of these variables is described further in the next section. For now, our focus is on whether sales propensity is affected materially by these variables and, particularly, by the three irrigation variables.

We estimate the probit regression only on properties that have not undergone any subdivision (or aggregation) over the 19 year period (1988-2006) to ensure that we match sale properties to a suitable universe of titles. In doing so, we form two samples, respectively including and excluding lifestyle blocks. Lifestyle blocks are small-holdings that may or may not be used for genuine farming activities; the two samples are used to test robustness of our estimates. If sales are drawn randomly from the universe of properties, the explanatory variables will have no statistical significance and the overall explanatory power of the equation (pseudo-R^2) will be low.

Table 3 presents the probit results based on the two samples. Properties are more likely to be sold if they are larger; although the effect is minor for the more complete sample (implying that the exclusions of lifestyle blocks in the 'small'

[14] This database is produced by Landcare Research

[15] This ranges from very poor, where the soil has pale colours due to water-logging in the horizon immediately below the top layer; to good, where there is a lack of any significant mottling or pale

sample are biasing the size result in that sample). In addition, location, slope and drainage characteristics affect sale propensity. In each case, consistent with the size estimate, the coefficients imply that properties will have a higher probability of sale if they are on high country land (high slope, poor drainage and distant from city and towns).

Importantly for our purposes, however, none of the irrigation variables is linked to sales propensity. This finding is consistent with the maintained hypothesis of the study that irrigation characteristics are fully impounded into the sale price of the property; thus the presence and nature of irrigation should not affect sale propensity over and above any other property characteristic. Another feature of the probit results is that the pseudo-R^2 for both samples is very low, and especially so for the larger sample (0.0274). Thus, the estimated higher probability of sale for "high country" properties has very little overall predictive power for sale propensity. This finding is in keeping with comparison of the data summary statistics in tables 1 and 2 showing little difference in sample means between the valuation and sales samples. Given these results, in our subsequent estimates we treat the sales samples as constituting random samples from the larger valuation universe.

5 Results

5.1 Valuation results

As described previously, we use two different samples ('large' and 'small') when estimating our equations using the valuation data. Each set of panel estimates is conducted at three yearly intervals from 1988 – 2006 (i.e. seven waves), coinciding with the years in which the valuations are conducted. The sample comprises virtually the universe of eligible farms and so selection issues are not of concern. Furthermore, the land characteristics, farm size and presence or nature of irrigation are each predetermined variables in each time period; thus

colours. Moderately drained soil has some pale mottled colours due to water-logging at lower depths in the subsoil.

pooled-OLS is an appropriate estimator (we use robust standard errors throughout to correct for any remaining heteroskedasticity).

Equation (5) forms the basis of our estimates. For each sample, we initially estimate a simple form of (5) that includes: the logarithm of the land parcel area (lnLAND), the three land characteristics variables (RAIN, SLOPE, DRAIN), the two distance variables (DIST1, DIST2) from the nearest town and from Timaru respectively, plus the time fixed effects and constant;[16] irrigation variables (and interaction terms) are not included. This equation provides a baseline against which we examine the effects of incorporating the irrigation terms. This baseline equation is shown in columns 1 and 6 of Table 4 for the 'large' and 'small' samples respectively.

The scale variable is highly significant in each case, with a scale parameter of approximately 0.69 and 0.88 in the large and small samples respectively. These are intuitively sensible coefficients; the finding that they are less than unity probably reflects the feature that large properties normally involve less intensive land uses (e.g. sheep and beef grazing) than do smaller holdings (used for dairying, arable and specialist agricultural uses). In the large sample, the three land characteristics variables are each significant. The coefficient on RAIN is negative, consistent with high rainfall in the more mountainous (less productive) parts of the region. The SLOPE coefficient is negative (i.e. flatter land is valued more highly), while the positive coefficient on DRAIN indicates that well drained land is valued more highly (ceteris paribus); the sign of these coefficients is in accordance with our priors. For the small sample, only the SLOPE coefficient is significant amongst these three variables. The distance variables indicate that land value decreases as distance from the nearest town and city increases. This finding is consistent with expectations if farms rely on access to processing facilities and/or consumer markets situated in local towns and/or rely on port or rail facilities (provided by Timaru).

Columns 2, 3 and 4 (for the large sample) and 7, 8 and 9 (for the small sample) add each of the three irrigation variables (IRRIG, RATE, VOL) separately to the baseline equation. In both samples, the RATE variable (i.e. the maximum permissible flow rate of water expressed relative to the size of the property) has considerably more explanatory power than either of the other two variables. (This finding is consistent with results for the sales price sample discussed below.) The RATE variable is significant at the 1% level for the large sample and at the 10% level for the small sample.

As discussed in the theory section, the existence of irrigation (through a legal water right) is unlikely to impact on land prices in an identical fashion across rural properties owing to potential interactions of irrigation with the land characteristics variables. Columns 5 and 10 each add interaction terms between the RATE variable and the land characteristics and distance variables. The overall significance and size of the RATE variable increases very substantially in both cases, and a majority of the interactions are statistically significant. The results indicate that irrigated water is more highly valued in drought-prone areas, i.e. areas with low rainfall (negative coefficient on RATE*RAIN) and in areas with poor drainage (negative coefficient on RATE*DRAIN). The latter may be because the irrigated water is retained on the property for longer (and hence is more useful to the farm with the specific water right) where soils are less freely draining.[17] Water is also more highly valued where the property is situated close to a town. This finding is consistent with more water-intensive activities that rely on proximity to processing facilities (e.g. dairying) or consumer markets (e.g. arable/market gardens) locating close to populated areas.

In section 5.3, we interpret what the estimated coefficients imply about the magnitude of the effect of irrigation on farm values. Here we note that while the RATE variable indicates a significant positive impact of irrigation on land values (especially for farms with certain characteristics), the additional explanatory power given by the RATE variable is small (see the R^2 and RMSE statistics). It is possible that valuers do not accurately assess the effect of irrigation on farm value, especially if they do not have access to all details of the resource consent for water rights held by the individual farm. In order to test whether this may be a

[16] For sake of clarity, we do not report the time fixed effects or constant in our tables, but they are included in all equations. The time fixed effects (which are jointly significant at the 1% level) trend upwards through the sample as expected if commodity prices are rising over time.

[17] Interactions of RATE with SLOPE are not consistent across the two samples.

source of inaccuracy, we estimate the same relationships as above (plus some extended relationships) using the four different sale price samples.

5.2 Sales price results

Table 5 presents the equivalent results, as in Table 4, for the two major sales price samples (i.e. the 'large' sample that includes lifestyle properties and properties with no land use code, and the 'small' sample that excludes lifestyle blocks and properties with no land use code; both samples including subdivided and aggregated properties).

In most respects, the results from the sales data are similar to those obtained from valuation data. The irrigation variable with the highest explanatory power is again RATE (i.e. the maximum permissible flow rate of water expressed relative to the size of the property) which in three cases out of four is significant at the 10% level. In the equations without interaction terms, the coefficient on RATE in the sales price samples is between the two point estimates obtained from the corresponding valuation regressions. When the interaction terms are added (columns 5 and 10), the interaction of RATE with DRAIN is (significantly) negative, as in the valuation samples. Interactions with other land characteristics variables are not significant. Properties located close to town are again found to value water more highly (the coefficient on RATE*DIST1 is negative in both samples, significant in one). Generally, the smaller sample size results in a number of the terms being statistically insignificant in these sales price samples. An exception is the distance from Timaru (DIST2) which indicates that proximity to a city increases land values. Again this relationship is consistent with the results using the valuation data.

The estimated scale coefficient (at 0.44 to 0.47) is considerably smaller for both sale price samples than is found with the valuation samples. One possible reason for this result is that the probit regression showed some tendency for larger than average properties to be sold; this may affect the estimate of the scale coefficient. Another possibility is that our method of deducting improvement value from the sale price may incorporate some systematic inaccuracy, potentially reflecting some inadequacy in the official method for valuing improvements. When we estimate the same equations as Table 5 using sale prices with no adjustment for improvements, the scale variable falls further, to approximately 0.33 to 0.38 (for the two samples). In this latter case, improvement value is clearly under-stated (being set to zero). The corollary of this observation is that if the QVNZ-based improvement data are systematically under-stated, our estimate of the scale coefficient may be biased downwards. However there is no evidence from other studies to suggest that the method used to value improvements (based on market replacement values) is problematic in New Zealand applications; nevertheless this is a potential area for further investigation.

Table 6 reports comparable sales price equations to Table 5, but where the samples solely use a much more restricted range of properties that have not been subdivided or aggregated over the entire sample period. (The 'large' sample includes lifestyle and unallocated properties, the 'small' sample excludes them.) The benefit of these samples is the use of a consistent definition of rural unit over the entire sample period. This contrasts with the prior valuation and sales price datasets that include some observations aggregating units which were subdivided through the sample period. The downside of the restricted samples in Table 6 is the much reduced degrees of freedom (already severely depleted for the full sales price sample relative to the valuation universe) and the potential for greater selection bias.

The estimates obtained from these samples are similar to those in Table 5, but with reduced significance. RATE is consistently positive (but not significant at the 10% level) and interacts negatively with distance from Timaru (significant at the 5% level). It again interacts negatively with DRAIN (but not significant at 10%). The scale parameter is a little larger than found for the broader sales samples, but still considerably below that for the valuation data. The general consistency of these results with the broader sales sample (albeit with reduced significance) implies that we can be confident that our methods of aggregating subdivided properties (for the valuation dataset) have not materially affected our estimates, while at the same time enabling consideration of a much wider range of properties over the period.

To this point, we have made no use of the land use categories available for (most) properties that are sold. In part, this is because land use and irrigation are co-determined; i.e. a property without irrigation that is currently used for sheep grazing may be converted into a dairying unit by introducing irrigation once a water right has been obtained. Our previous estimates account for the underlying characteristics of the land which are strictly exogenous and so do not face this issue of co-determination. However, it is still useful to examine whether the presence of irrigation is valued more highly for properties with certain land uses than for others, after accounting for all other factors included in our analysis.

Table 7 presents the results from an extended equation for each of our four sales price samples (the columns are labelled in the order in which these samples appear in Tables 5 and 6).[18] In this case, the RATE variable is replaced by separate interaction terms in which RATE is interacted with each of the land use codes applicable to the sample. The land use variables correspond respectively to: dairy, arable, specialist agriculture and no land use code (LU1); pastoral (LU2); and lifestyle (LU3). Of these, LU1 includes the most water-intensive activities. All three categories are included in the first and third samples; LU3 is omitted in the second and fourth samples since lifestyle blocks are excluded from those samples.

Results across all four samples indicate that water is most highly valued in properties with water-intensive land use applications, even after controlling for underlying land and distance characteristics and for the interactions of irrigation with these characteristics. The interaction between RATE and LU1 is significant at the 1% and 5% levels respectively in the two restricted samples (columns 3 and 4); estimates in the samples that include subdivided properties are similar, albeit with less significance. Together, these results are supportive of the hypothesis that water is more important (and hence is valued more highly) for these activities than for other land uses.

5.3 Magnitudes of Irrigation Effects

Our econometric results indicate that the right to extract irrigated water has a significant effect on farm values within the study area. We now turn attention to the magnitude of these effects, i.e. to examine whether the effects are material in an economic sense as well as being statistically significant. In interpreting the

[18] We do not have sufficiently comprehensive land use data to make this estimation possible using the valuation dataset.

results, we stress that the effects we are measuring reflect the *net* benefit of water rights to the farmer (i.e. to the farm's present discounted returns after subtracting any costs associated with accessing the water, capital payments on irrigation infrastructure, etc). Gross returns to irrigation may be higher, but net return is the relevant economic measure since the value of resources used to extract the water must be taken into account. The ability of the hedonic method to capture the impact of irrigation on net (rather than gross) returns is one advantage of this methodology.

Our calculations of net benefit are each based on an estimated equation in which RATE is used as the irrigation measure. In each case, we first set RATE=0 to calculate a baseline land price, holding all other variables at their sample means.[19] Thus the baseline provides an estimate of what the land is worth (or will sell for) given a typical property in the district where it has no associated water right. We use both the valuation dataset and the sales price datasets, in each case restricting our attention to the largest available sample for that dataset.

Once we calculate the baseline, we include the effect of the RATE variable (as discussed in each example) and estimate the resulting land price. We express the difference between the two prices as a ratio of the baseline calculation to give an estimate of the irrigation premium (i.e. the premium attributed to the water right). We do so for a number of cases.

The first case uses the valuation database and calculates the irrigation premium by setting RATE equal its mean value for those properties for which RATE>0 (i.e. we only use properties with an actual water right in calculating the mean water flow). In this case, since we are not varying other characteristics of the property, we use the basic equation that includes RATE without interaction terms (Table 4, equation 3). As shown in Figure 5 case 1, the resulting premium is measured at 3.65%.[20] When we calculate the irrigation premium using the same method based on the sales price sample (Table 5, equation 3) we obtain an estimated premium of 2.00% (Figure 5, case 2).

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[19] For the time fixed effects, we use the 2006 effect, meaning that our measures are in 2006 dollars.

[20] The baseline land value in this case is estimated at $317,023 and the irrigated land value is estimated at $328,598.

These calculations imply only a small (net) premium for properties with access to irrigated water. Recall, however, that water rights have been granted largely on the basis of "first-applied first-granted"; thus one might expect considerable differences in the value of water rights in different circumstances.

One difference in circumstances across properties is the size of the water right. Given that there is no resource rent associated with the water right (although there may be extraction costs) we expect that the monetary value of the right will increase as the value of RATE rises. To test this conjecture, we calculate the equivalent irrigation premia as before for the valuation and sales price samples, but using a value for RATE equal to the mean plus one standard deviation for the respective samples. The estimated premium from the valuation sample is now 17.54%, while that for the sales price sample is 9.02% (Figure 5, cases 3 and 4).

Another circumstance where the value of the water right may differ relates to the underlying characteristics of the property. In particular, we expect the water right to have higher value in places where rainfall is low than in higher rainfall areas. To estimate this effect, we use equation 5 in Tables 4 and 5 (respectively for the valuation and sales price datasets), in each case valuing the irrigation premium at the means of each of the variables. The valuation dataset indicates virtually no premium in this case (0.43%) while the sales price dataset indicates a 9.46% irrigation premium (Figure 5, cases 5 and 6).

As before, however, the size of the premium is likely to vary for properties with different rainfall characteristics (but with the same value of RATE). When we evaluate the irrigation premium for the case of a property that has half the mean rainfall (and half the mean for the interaction term, RATE*RAIN) we obtain a 26.79% irrigation premium using the valuation dataset and a 23.04% premium when using sales prices (Figure 5, cases 7 and 8).

Finally, the nature of the premium is likely to vary according to the property's land use; we expect that a property used for water-intensive activities will benefit much more than does a property that is used for pastoral use. To estimate this difference, we use the largest of the samples in Table 7 (equation 1) again setting all variables to their means. The estimated irrigation premium for pastoral land use (i.e. where LU2=1) is 18.72%, which is broadly in keeping with prior estimates. By contrast, the irrigation premium for water-intensive land uses (LU1=1) is calculated as 110.59% (Figure 5, cases 9 and 10).[21] The calculated premium for farms with LU1=1 is broadly consistent with the finding by Harris et al (2006) that farms irrigated by the Opuha Dam (situated in the Mackenzie District) had estimated total revenue per hectare that was 140% above that for non-irrigated farms.

One must be a little careful when using our estimated figure for these farms, however. It is possible that the land value of properties involved in water-intensive activities also reflect the value of other characteristics that have been impounded into the price (e.g. fences, etc). Strictly, our data should be immune to contamination from any such effects since these types of characteristics are classified as improvements, and we have deducted the estimated value of improvements in forming our land use values. However in our discussion in section 5.2, we noted the possibility that the improvements data at our disposal may understate the true value of improvements. If this were so, then the calculated irrigation premium would likely be overstated.

Nevertheless, the gap between the estimated irrigation premium for water-intensive and pastoral land uses is in a direction that is consistent with the hypothesis that irrigated water is more highly valued for certain activities, and the result is consistent with findings of a prior study that used a completely different methodology. Coupled with the legal inability to trade water between land uses, the irrigation premium may well be much higher for properties able to undertake water-intensive land uses than those (possibly because of terrain or location) that are not able to do so.

Overall, our calculations show a positive premium for properties with irrigated water relative to properties without. Furthermore, the water right is more valuable: (a) the larger the right relative to the size of the property; (b) the lower the rainfall of the property; and (c) where the property is engaged in water-intensive agricultural activities. All of these findings accord with our underlying hypotheses.

[21] The baseline land value is estimated at $349,751 (noting that the sample is slightly different from that of the valuation sample) and the irrigated land value is estimated at $736,529.

6 Conclusions

Water is a crucial input into agricultural production. In areas where the demand for (free) water exceeds the available supply, some form of allocation mechanism is required. This may be through a "first-come first-served" approach, but such an approach by itself is likely to be highly inefficient, with upstream users benefiting relative to those downstream. New Zealand's Resource Management Act (RMA) requires potential users (including farmers) to obtain a resource consent to draw both surface and ground water for agricultural, industrial and other purposes. However this system is, to a large extent, a "first-applied first-granted" system. Not only is there no formal price mechanism to allocate the water, the existence of such a mechanism is contrary to current law.

Water rights, under the RMA, are attached to enterprises; thus when a farm is sold its water right is sold along with it. This feature, together with the scarcity of water in certain regions, means that not only does a shadow price for water exist but also that it can be observed at the time of farm sale through the sale price. Furthermore, all properties are valued triennially by an independent body (for property tax purposes) and those values are required by law to reflect the current market value of the property. These capital valuations further split the value of each property into value of land and value of improvements. Thus we have two sources of data that we can use to extract the value of water rights after controlling for other features of each farm.

In our study, we ascertain the value of irrigation by estimating the price implicitly placed on water (through farm sale prices and valuations) in the Mackenzie District, a drought-prone region of Canterbury, New Zealand. Our hedonic approach contrasts with previous studies in New Zealand which have used other methods (especially the adjusted gross margin method) to determine the value of irrigation for certain areas.

Our approach also contrasts with prior hedonic studies internationally in several respects. First unlike most previous studies, we have observations on all rural properties in the region – both with and without water rights and (for the valuation database) those that are sold and not sold. This means that we avoid many of the selection issues and issues of low variation in the irrigation variable that have bedevilled earlier studies. Second, we have much more comprehensive data than in most other studies, not only covering a wide range of properties, but also covering a nineteen year timespan. GIS techniques have enabled us to determine comprehensive farm-specific measures of land characteristics such as average slope, drainage and rainfall, as well as farm-specific measures of distance to towns and the nearest city which we use as controls in our equations. Third, we have exact measures of the water rights – and how those water rights change over time – for each farm over the nineteen years. The cross-sectional and time variation in water rights, coupled with controls for other farm characteristics and for macroeconomic variables (the latter through time fixed effects), allows us to identify the impacts of water rights on farm values. Contrary to most previous hedonic studies that have worked with less adequate data, we find significant impacts of irrigation on farm prices. This points to the need for other studies internationally to obtain comprehensive data across a large and representative range of farms, across a significant time period, and across a range of irrigation and control variables, in order to extract the value placed on water when using hedonic valuation methods.

Our approach enables us to differentiate the effects that irrigation has on farms with different characteristics. In particular, in accordance with our priors, we find that the benefit from irrigation falls as rainfall rises. Furthermore, areas with poorly draining soils benefit most from irrigation, possibly because the water is retained for longer on those soils. Farms that are situated close to cities and towns benefit more from irrigation than more distant properties since these properties are most likely to have potential water-intensive land uses such as dairying and market gardens or other cropping. Based on our estimated equations, reasonable variations in the size of water right and of rainfall give a positive irrigation premium of up to 27% prior to taking land use into account.

In assessing the value of irrigated water, it is also important to take account of the use to which the water is put. In cases where water cannot be traded, it may be quite possible to have different returns to irrigation depending on existing land use (which may be determined by other characteristics of the farm such as terrain and location). We find that the mean irrigation premium for land in pastoral use is close to 20%, in accordance with our prior estimates. However the premium for land engaged in water-intensive activities (e.g. dairying and arable) is much higher, possibly reaching 110%.

The positive net returns to irrigation found here indicate that water, and an associated water right through a resource consent, is a valuable commodity in this drought-prone region. Perhaps even more importantly, we find that the shadow price placed on that water varies materially according to other characteristics. Farmers benefit more as their water right increases (i.e. as they have access to a greater water flow) and value the water right more highly in areas with low rainfall and where the land is suitable for water-intensive land uses.

For most commodities, agents who value that commodity highly will be purchasers, and those with lower valuations (but who have initial ownership of the commodity) will be sellers. However there is no explicit market for irrigated water in New Zealand owing to legal restrictions. Thus the value of the water is restricted to its on-site benefit. The present discounted value of this on-site benefit appears to be reflected in sales prices and valuations of farms in the district. Nevertheless, it remains the case that the full value of water is not being realised since returns differ significantly according to farm characteristics. Thus, while irrigation is of net benefit to farms in the region, our findings indicate that full value from irrigation is not being achieved owing to the current restrictions on water trading that are legally in force.

Figure 1: Map showing the location of irrigation consents in the Mackenzie District

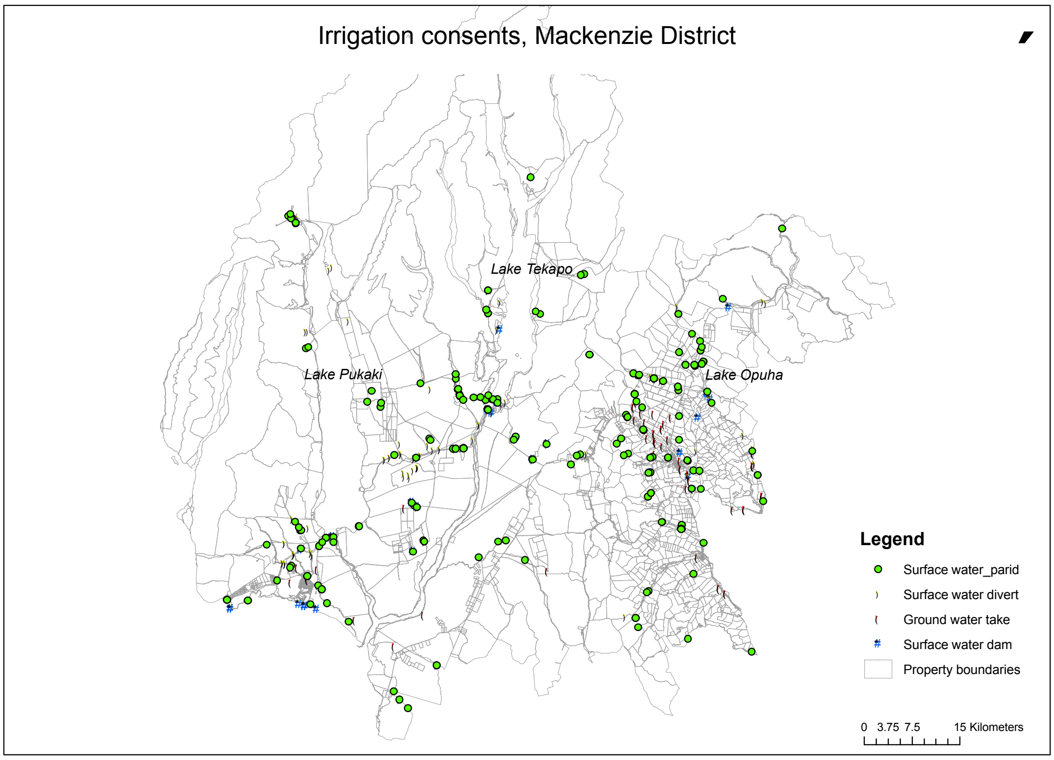


Figure 2: Map showing the distribution of average annual rainfall (mm) in Mackenzie District

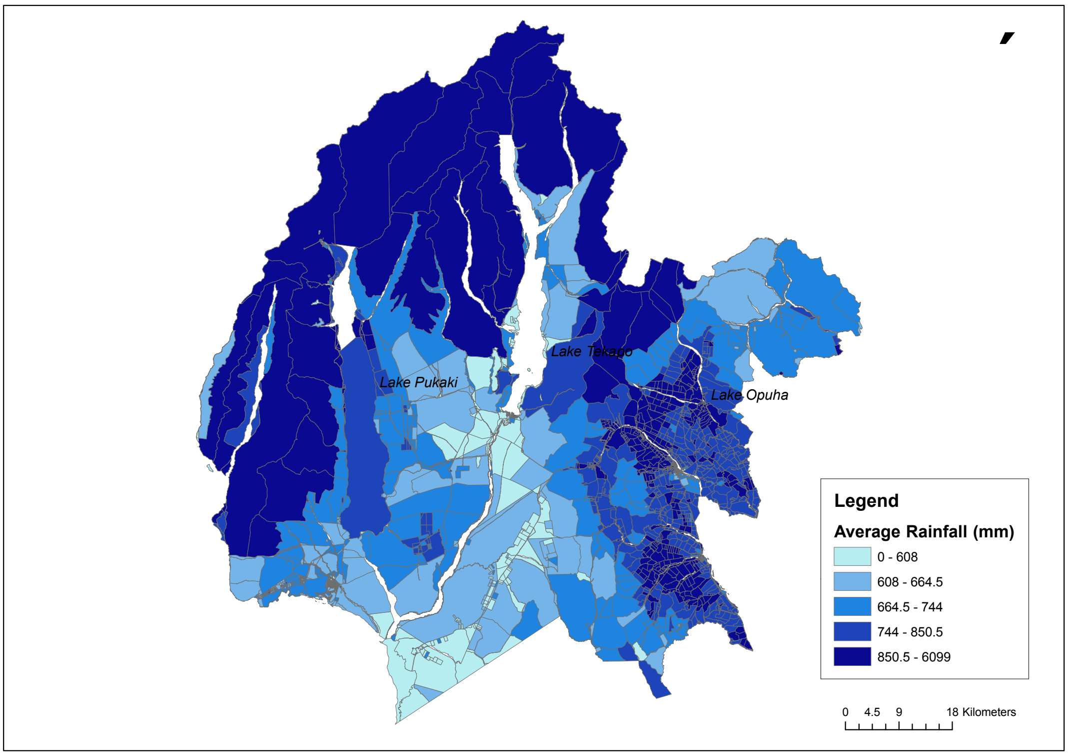


Figure 3: Map showing the average slope of the land (degrees) in Mackenzie District

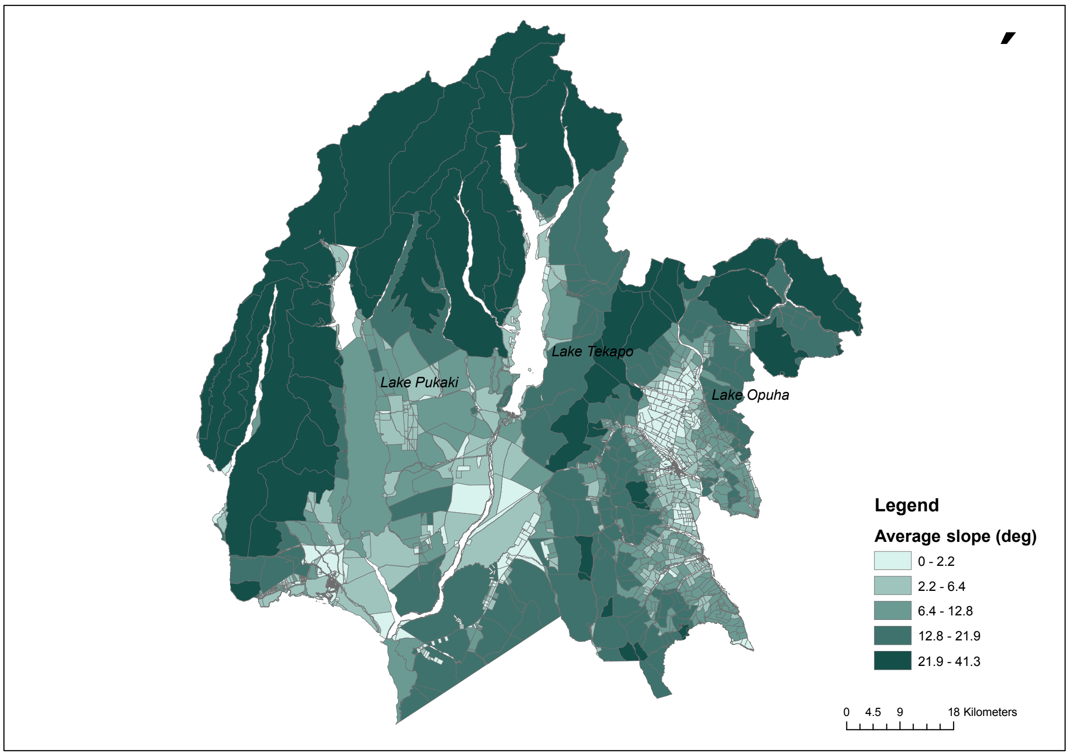


Figure 4: Map showing soil drainage quality in the Mackenzie District

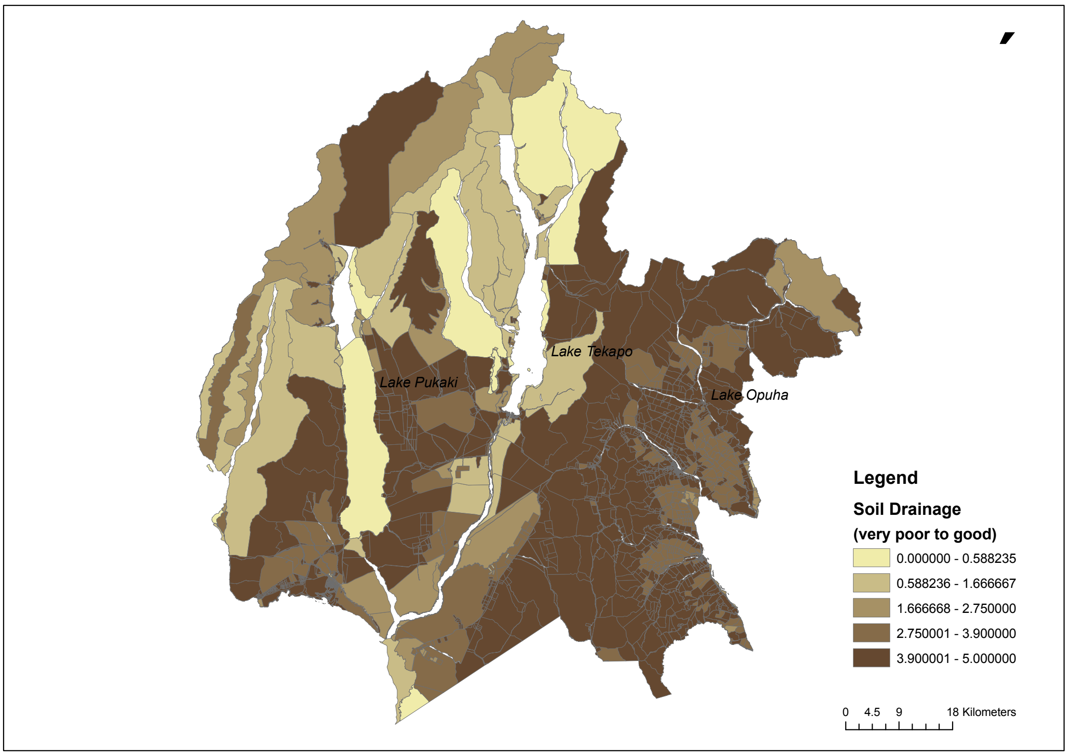
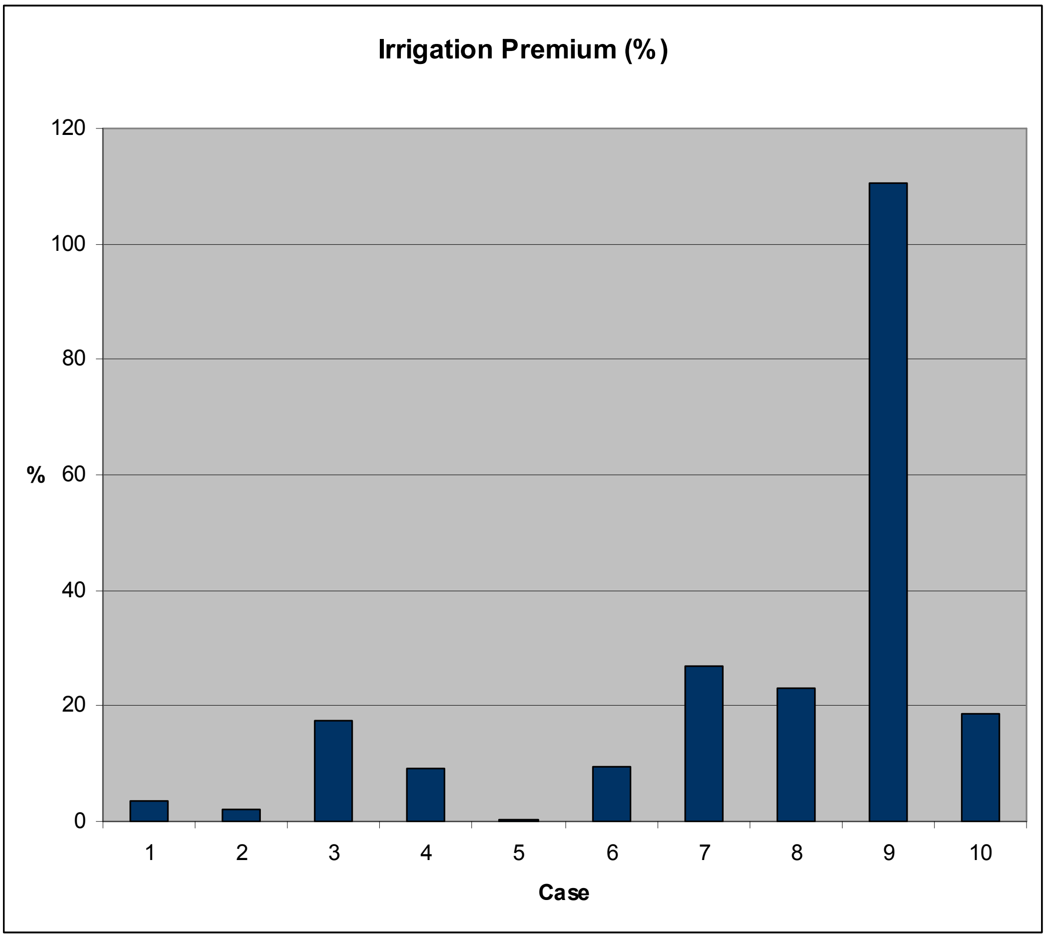


Figure 5: Irrigation Premia for 10 Different Cases*



* Irrigation premium defined as value of land with water right expressed as a premium relative to baseline of equivalent land with no water right. All variables set at means unless otherwise stated.

Case 1: Valuation dataset; mean of RATE (Table 4, eqn 3)
Case 2: Sales price dataset; mean of RATE (Table 5, eqn 3)
Case 3: Valuation dataset; mean +1 sd of RATE (Table 4, eqn 3)
Case 4: Sales price dataset; mean +1 sd of RATE (Table 5, eqn 3)
Case 5: Valuation dataset; mean of RATE and RAIN*RATE (Table 4, eqn 5)
Case 6: Sales price dataset; mean of RATE and RAIN*RATE (Table 5, eqn 5)
Case 7: Valuation dataset; RAIN and RAIN*RATE at 50% of means (Table 4, eqn 5)
Case 8: Sales price dataset; RAIN and RAIN*RATE at 50% of means (Table 5, eqn 5)
Case 9: Sales price dataset; water-intensive land uses (LU1=1) (Table 7, eqn 1)
Case 10: Sales price dataset; pastoral land use (LU2=1) (Table 7, eqn 1)

Table 1: Summary Statistics of all variables in main valuation sample

Variable	Mean	Std. Dev.	Variable description
lnVAL	11.55827	2.114182	Logged land value (NZ$)
1988	*10.75575*	*2.131853*	
2006	*12.68608*	*1.870366*	
lnLAND	3.59611	2.652807	Logged area of property (m^2)
RATE	.0362	.5570275	Maximum rate of irrigation water (l/s) over property area
VOL	.0059041	.0684627	Maximum volume of irrigation water (m^3/day) over property area
IRRIG	.0209966	.2384297	Irrigation area over property area
RAIN	805.1816	150.0832	Average rainfall of each property (mm p.a.)
SLOPE	4.407813	4.732518	Average slope of each property (degrees)
DRAIN	3.997944	.9158189	Average drainage score of each property
DIST1	22467.81	20443.09	Distance to nearest town (Fairlie, Geraldine, Temuka, or Timaru) (m)
DIST2	57826.53	21350.23	Distance to Timaru (m)

Table 2: Summary statistics of all variables in main sales sample

Variable	Mean	Std. Dev.	Variable description
lnSALE	11.88952	1.502068	Logged sale price less improved value (NZ$)
1988	*10.87289*	*1.122177*	
2006	*12.45656*	*1.293207*	
lnLAND	3.160063	2.544957	Logged area of property (m^2)
RATE	.0493385	.5484844	Maximum rate of irrigation water (l/s) over property area
VOL	.0141204	.0859315	Maximum volume of irrigation water (m^3/day) over property area
IRRIG	.0745375	.403664	Irrigation area over property area
RAIN	800.4022	137.957	Average rainfall of each property (mm p.a.)
SLOPE	3.830603	4.45555	Average slope of each property (degrees)
DRAIN	4.131274	.9102215	Average drainage score of each property
DIST1	26276.71	23786.24	Distance to nearest town (Fairlie, Geraldine, Temuka, or Timaru) (m)
DIST2	61678.58	23550.11	Distance to Timaru (m)

Table 3: Probit regression results

Dependent Variable is $DSALE_{it}$ = 1 if property i is sold in year t; = 0 otherwise
Equation 1 includes lifestyle block sales.
Equation 2 excludes lifestyle block sales.

Expl Var:	1	2
ln(LAND)	0.0300	0.1347
	[3.217]***	[10.005]***
IRRIG	0.0285	0.0395
	[0.232]	[0.312]
RATE	-0.1088	-0.0737
	[0.900]	[0.645]
VOL	-1.1248	-1.0813
	[1.219]	[1.114]
RAIN	0.000016	-0.000004
	[0.106]	[0.022]
SLOPE	0.095	0.015
	[3.850]***	[0.510]
DRAIN	-0.014	-0.012
	[2.408]**	[1.806]*
DIST1	0.000002	-0.000006
	[0.798]	[2.689]***
DIST2	-0.000008	-0.000011
	[4.217]***	[5.146]***
Obs.	13205	13205
Pseudo-R^2	0.0274	0.0809

Robust z-statistics in brackets;
*significant at 10%, **significant at 5%, ***significant at 1%.
Time fixed effects and constant included (but not reported).

Table 4: Valuation Data Results

Dep Var: lnVAL	'Large' Sample					'Small' Sample				
Expl Var:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ln(LAND)	0.6899	0.6902	0.6898	0.6896	0.6907	0.8780	0.8782	0.8779	0.8780	0.8779
	[57.539]***	[57.461]***	[57.552]***	[57.504]***	[57.487]***	[89.486]***	[89.491]***	[89.440]***	[89.431]***	[89.326]***
IRRIG		-0.0408					-0.0272			
		[1.285]					[1.071]			
RATE			0.0552		0.5893			0.0320		2.6957
			[3.374]***		[1.994]**			[1.917]*		[4.823]***
VOL				0.2176					0.0033	
				[1.543]					[0.016]	
RAIN	-0.0004	-0.0004	-0.0004	-0.0004	-0.0004	0.0001	0.0001	0.0001	0.0001	0.0001
	[2.807]***	[2.777]***	[2.830]***	[2.823]***	[2.651]***	[0.312]	[0.335]	[0.280]	[0.311]	[0.362]
SLOPE	-0.0786	-0.0788	-0.0785	-0.0785	-0.0791	-0.0724	-0.0725	-0.0724	-0.0724	-0.0726
	[16.442]***	[16.417]***	[16.426]***	[16.377]***	[16.424]***	[18.648]***	[18.608]***	[18.640]***	[18.602]***	[18.440]***
DRAIN	0.0863	0.0865	0.0880	0.0869	0.0917	-0.0173	-0.0169	-0.0175	-0.0173	-0.0144
	[3.175]***	[3.183]***	[3.234]***	[3.197]***	[3.332]***	[0.590]	[0.576]	[0.596]	[0.590]	[0.483]
DIST1	0.000002	0.000002	0.000002	0.000002	0.000002	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
	[0.930]	[0.918]	[0.924]	[0.939]	[0.925]	[6.336]***	[6.344]***	[6.319]***	[6.332]***	[6.161]***
DIST2	-0.000003	-0.000003	-0.000003	-0.000003	-0.000003	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
	[1.967]**	[1.962]**	[2.014]**	[1.994]**	[2.023]**	[8.390]***	[8.379]***	[8.408]***	[8.382]***	[8.456]***
RATE*RAIN					-0.00097					-0.00375
					[4.189]***					[2.768]***
RATE*SLOPE					0.01752					-0.07719
					[3.534]***					[3.055]***
RATE*DRAIN					-0.05289					-0.39319
					[4.736]***					[2.850]***
RATE*DIST1					-0.00001					-0.00003
					[1.504]					[1.801]*
RATE*DIST2					0.00001					0.00006
					[1.067]					[3.623]***
Obs.	3951	3951	3951	3951	3951	2702	2702	2702	2702	2702
R^2	0.6721	0.6721	0.6723	0.6722	0.6726	0.8445	0.8445	0.8445	0.8445	0.8447
RMSE	1.2125	1.2126	1.2123	1.2125	1.2124	0.9473	0.9475	0.9474	0.9475	0.9476

Robust t-statistics in brackets; *significant at 10%, **significant at 5%, ***significant at 1%. Time fixed effects and constant included (but not reported) in all equations.

Table 5: Sale Price Data Results (Including Subdivided Properties)

Dep Var: lnSALE	‘Large’ Sample					‘Small’ Sample				
Expl Var:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ln(LAND)	0.4743	0.4702	0.4736	0.4719	0.4722	0.4459	0.4434	0.4459	0.4447	0.4436
	[19.596]***	[19.198]***	[19.536]***	[19.499]***	[19.287]***	[9.524]***	[9.404]***	[9.515]***	[9.510]***	[9.358]***
IRRIG		0.0968					0.0570			
		[0.741]					[0.444]			
RATE			0.0477		6.6336			0.0393		6.7466
			[1.917]*		[1.812]*			[1.316]		[1.894]*
VOL				0.4138					0.2803	
				[0.877]					[0.561]	
RAIN	-0.00028	-0.00029	-0.00029	-0.00029	-0.00024	-0.00022	-0.00023	-0.00023	-0.00023	-0.00012
	[0.836]	[0.876]	[0.850]	[0.862]	[0.678]	[0.494]	[0.517]	[0.511]	[0.517]	[0.260]
SLOPE	-0.01155	-0.00964	-0.01152	-0.01064	-0.01041	-0.01605	-0.01478	-0.01626	-0.01547	-0.01476
	[1.071]	[0.893]	[1.069]	[0.994]	[0.954]	[1.190]	[1.097]	[1.202]	[1.158]	[1.073]
DRAIN	0.00261	0.00323	0.00353	0.00502	0.02258	-0.01134	-0.01140	-0.01067	-0.00862	0.04655
	[0.071]	[0.089]	[0.096]	[0.138]	[0.618]	[0.163]	[0.165]	[0.153]	[0.125]	[0.660]
DIST1	0.00001	0.00001	0.00001	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
	[1.501]	[1.542]	[1.536]	[1.527]	[1.438]	[0.785]	[0.807]	[0.813]	[0.802]	[0.759]
DIST2	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
	[1.896]*	[1.931]*	[1.936]*	[1.928]*	[1.743]*	[1.657]*	[1.674]*	[1.684]*	[1.675]*	[1.583]
RATE*RAIN					-0.00066					0.00154
					[0.382]					[0.600]
RATE*SLOPE					-0.10202					-0.07350
					[1.049]					[0.739]
RATE*DRAIN					-1.20145					-1.36681
					[1.869]*					[2.141]**
RATE*DIST1					-0.00004					-0.00012
					[1.096]					[1.847]*
RATE*DIST2					0.00000					-0.00002
					[0.025]					[0.438]
Obs.	678	678	678	678	678	416	416	416	416	416
R^2	0.6051	0.6056	0.6054	0.6055	0.6087	0.5003	0.5006	0.5006	0.5006	0.5075
RMSE	0.9265	0.9266	0.9269	0.9267	0.9266	1.0284	1.0294	1.0294	1.0294	1.0289

Robust t-statistics in brackets; *significant at 10%, **significant at 5%, ***significant at 1%. Time fixed effects and constant included (but not reported) in all equations.

Table 6: Sale Price Data Results (Excluding Subdivided Properties)

Dep Var: lnSALE	'Large' Sample					'Small' Sample				
Expl Var:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
ln(LAND)	0.5691	0.5695	0.5690	0.5684	0.5678	0.5340	0.5350	0.5343	0.5339	0.5291
	[15.257]***	[15.302]***	[15.238]***	[15.279]***	[15.067]***	[8.031]***	[8.034]***	[8.017]***	[8.030]***	[7.692]***
IRRIG		-0.0060					-0.0160			
		[0.053]					[0.144]			
RATE			0.0250		4.7919			0.0218		5.3578
			[0.841]		[1.289]			[0.674]		[1.440]
VOL				0.1305					0.0436	
				[0.312]					[0.105]	
RAIN	0.000093	0.000095	0.000083	0.000087	0.000263	0.000145	0.00015	0.000135	0.000143	0.00034
	[0.181]	[0.185]	[0.162]	[0.169]	[0.491]	[0.245]	[0.254]	[0.228]	[0.241]	[0.545]
SLOPE	-0.02343	-0.02359	-0.023589	-0.023146	-0.024901	-0.021051	-0.021512	-0.021302	-0.020959	-0.022381
	[1.824]*	[1.854]*	[1.831]*	[1.814]*	[1.905]*	[1.405]	[1.445]	[1.411]	[1.407]	[1.454]
DRAIN	-0.075313	-0.075307	-0.073933	-0.073569	-0.009234	-0.08963	-0.089564	-0.088386	-0.08897	-0.010286
	[0.917]	[0.914]	[0.898]	[0.901]	[0.109]	[0.992]	[0.986]	[0.976]	[0.989]	[0.109]
DIST1	-0.000011	-0.000011	-0.00001	-0.00001	-0.000012	0.0000	0.0000	0.0000	0.0000	0.0000
	[1.590]	[1.581]	[1.567]	[1.571]	[1.738]*	[2.242]**	[2.234]**	[2.211]**	[2.225]**	[2.263]**
DIST2	-0.000002	-0.000002	-0.000002	-0.000002	-0.000001	0.0000	0.0000	0.0000	0.0000	0.0000
	[0.453]	[0.447]	[0.478]	[0.466]	[0.151]	[0.626]	[0.616]	[0.643]	[0.626]	[0.411]
RATE*RAIN					0.0034					0.0022
					[1.088]					[0.682]
RATE*SLOPE					0.0950					0.0576
					[0.997]					[0.569]
RATE*DRAIN					-0.6894					-0.8215
					[1.033]					[1.155]
RATE*DIST1					0.0000					0.0000
					[0.132]					[0.385]
RATE*DIST2					-0.0001					-0.0001
					[2.551]**					[2.107]**
Obs.	313	313	313	313	313	274	274	274	274	274
R^2	0.6516	0.6516	0.6518	0.6517	0.6589	0.5602	0.5602	0.5604	0.5602	0.5692
RMSE	0.9172	0.9188	0.9186	0.9187	0.9172	0.9441	0.946	0.9458	0.946	0.9459

Robust t-statistics in brackets; *significant at 10%, **significant at 5%, ***significant at 1%. Time fixed effects and constant included (but not reported) in all equations.

Table 7: Extended Sale Price Data Results (Four Samples)

Expl Var:	1	2	3	4
ln(LAND)	0.4659	0.4388	0.5613	0.5260
	[18.739]***	[9.090]***	[14.774]***	[7.625]***
RATE*LU1	5.7967	5.2910	7.1608	6.8944
	[1.716]*	[1.583]	[2.595]***	[2.464]**
RATE*LU2	4.4151	4.0543	0.6042	0.5796
	[1.214]	[1.136]	[0.172]	[0.165]
RATE*LU3	2.0207		-0.8812	
	[0.606]		[0.273]	
RAIN	-0.00026	-0.00016	0.000296	0.00038
	[0.754]	[0.322]	[0.552]	[0.612]
SLOPE	-0.00842	-0.01331	-0.023577	-0.021223
	[0.763]	[0.956]	[1.798]*	[1.374]
DRAIN	0.02315	0.04552	-0.008946	-0.012452
	[0.633]	[0.646]	[0.105]	[0.132]
DIST1	0.00001	0.00000	-0.000011	0.0000
	[1.344]	[0.684]	[1.676]*	[2.211]**
DIST2	-0.00001	-0.00001	-0.000001	0.0000
	[1.677]*	[1.492]	[0.217]	[0.442]
RATE*RAIN	0.00131	0.00459	0.0021	0.0013
	[0.449]	[1.568]	[0.731]	[0.447]
RATE*SLOPE	-0.12577	-0.02341	0.1749	0.1798
	[1.463]	[0.280]	[2.184]**	[2.162]**
RATE*DRAIN	-1.19837	-1.13764	0.1334	0.1832
	[2.219]**	[2.034]**	[0.241]	[0.320]
RATE*DIST1	0.00003	-0.00006	0.0000	0.0000
	[0.564]	[0.835]	[0.087]	[0.199]
RATE*DIST2	-0.00001	-0.00006	-0.0001	-0.0001
	[0.149]	[1.364]	[2.582]**	[2.210]**
Obs.	678	416	313	274
R^2	0.6111	0.5091	0.6666	0.5773
RMSE	0.9252	1.0286	0.91	0.9389

Columns 1-4 correspond respectively to: Table 5 'large' sample; Table 5 'small' sample; Table 6 'large' sample; Table 6 'small' sample.
The land use variables correspond respectively to: dairy, arable, specialist agriculture and no land use code (LU1); pastoral (LU2); and lifestyle (LU3).
LU3 is omitted in columns 2 and 4 since lifestyle blocks are excluded from those samples.

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