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The Value of Inherent Soil Characteristics: a hedonic analysis

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Abstract

In an attempt to value soil natural capital, we use the inherent characteristics of soil and land valuation data to examine the relationship between soil characteristics and rural farmland values in the 6000 km^2 Manawatu catchment in New Zealand. The study applies a hedonic pricing method to determine if the value of 'critical' inherent characteristics of soils are reflected in land values. We find empirical evidence that the examined characteristics of soil natural capital stock, e.g., particle size, drainage, potential rooting depth and profile available water, are in fact reflected in rural land values.

Keywords: natural capital, soil characteristics, value of soil, hedonic prices, rural land value

JEL classification Q24, Q51

1. Introduction

The concept of natural capital has evolved in recognition of the increased human influence and reliance on ecosystem goods and services (Corssman and Bryan 2008). Natural capital is commonly defined as any stock of natural resources or environmental assets provided by natural systems, (for instance, forests, oceans, agricultural land, fisheries, minerals, atmosphere and so on) that yields a sustainable flow of useful goods and services over time (Pearce and Turner 1990; Costanza and Daly 1992; Costanza *et al*. 1997; Wackernagel and Rees 1997; Macdonald *et al*. 1999; Olewiler 2004). The goods and services provided by natural capital are essential for sustaining all forms of life. 'Zero natural capital implies zero human welfare because it is not feasible to substitute, in total, purely 'non-natural' capital for natural capital' (Costanza *et al*. 1997). Even though decisions around resource use (which impacts natural capital) are made at the margin, Costanza *et al*. (1997) highlight the lack of substitutability between natural capital and human-made capital. For the scope of this study we look at soil as a critical component of natural capital stocks that provides a range of essential services for human health (Macdonald *et al*. 1999). English Nature (1995) describes critical natural capital as the irreplaceable component of natural assets. Macdonald *et al*. (1999) outlined some criteria that can be used to determine what natural capital stocks could be considered critical. They used the following criteria based on suggestions made by English Nature (1994); the 'critical elements of capital stock should be:

1. Essential to human health, but should also reflect the need for ecosystem health;
2. Essential to the efficient functioning of life support systems;
3. Irreplaceable or unsubstitutable for all practical purposes;

4. In addition, irreversibility of environmental processes or stock changes had implications for intergenerational equity'.

Critical natural capital (CNC) is defined somewhat differently by Ekins (2003) as 'the natural capital which enables environmental functions to be performed, with the additional condition that, for any particular CNC, and resulting environmental function, there is no substitute type of capital, natural or human-made, which would enable the same function to be performed to the same extent'. As explained by Daily *et al.* (1997), soil provides services such as provision of physical support to plants, retention and delivery of nutrients to plants, disposal of wastes, renewal of soil fertility, buffering and moderation of hydrological cycle and regulating major element cycles (of carbon and nitrogen, for example). Thus, we can, without much uncertainty, consider soil a critical natural capital stock that can not be replaced and substituted for all practical purposes given the services it provides.

In this paper we extend the definition of critical natural capital given by Ekins (2003) and the third criterion outlined in Macdonald *et al.* (1999) further, applying it to the characteristics of the soil natural capital stock. Many characteristics of soil can be considered as critical for agricultural landscape as they can not be fully or partially replaced or substituted by human-made capital or other components of natural capital, that enable the services to be performed to the same extent. For instance, soil particle size (the proportions of sand, silt, and clay) can not be easily or cost-effectively modified. However, there are other characteristics of soil stocks that could be partially substituted; for example, deficiencies in soil fertility may be cost-effectively augmented by the application of synthetic fertilizers.

This paper focuses on valuing those 'critical' soil characteristics that can not be replaced or substituted by human-made capital or other components of natural capital, such as particle size and potential rooting depth. We do acknowledge, however, that some of the soil characteristics we consider can be modified to some extent, at a financial cost, with management interventions. For example, low-profile available water in the soil may be compensated for through irrigation and/or increasing the organic matter. Nevertheless, the soil's inability to hold this irrigated water may mean that land must still be irrigated daily, therefore profile available water is a characteristic that can not be replaced and fully substituted for. Moreover, poor drainage may be overcome by draining land. However, subsurface drainage systems remove from the soils not only excess water but also the nutrients, increasing the need for additional nutrients or creating off-site eutrophication problems (Heiler 2008). Thus internal soil drainage can not be fully replaced or fully substituted to enable the same quality of service this attribute provides.

As a capital stock, soil acquires value to the extent people recognise and value the services it provides (Vesely 2006). Agricultural land in the same manner is valued for its productivity-bearing characteristics including soil characteristics, climate conditions and topographical attributes. Soil, climate and water resources are among the most relevant elements of natural capital in the context of agricultural production (Lipper 2002). As suggested in previous studies, farmland buyers and sellers will incorporate the impacts of attributes that affect the productivity of land, given that appropriate information about those attributes are available to them (Ervin and Mill 1985). This study uses the inherent characteristics of soil as a proxy for critical elements of natural soil capital stock to examine the relationship between soil characteristics and rural farmland values. We apply a hedonic pricing method to determine if the value of critical inherent characteristics of soils are reflected in farmland values in the Manawatu catchment, New Zealand.

Hedonic methods have widely been used in the literature to determine the relationship between soil characteristics and farmland values. However, most of the early studies (Miranowski and Hammes 1984; Ervin and Mill 1985; King and Sinden 1988; Palmquist and Danielson 1989) have focused on examining the effect of potential soil erosivity measures (average slope of each farm, RKLS factor in the universal soil loss equation, for instance) on farmland values. Miranowski and Hammes (1984) utilised farmland prices during 1974-79, and RKLS factor from the universal soil loss equation, in order to estimate the value that land purchasers place on the reduction of potential erosion hazards in Iowa, U.S. They found on average, that buyers value farmland with lower erosion potential, illustrating that differences in soil characteristics are indeed reflected in farmland prices in Iowa. Ervin and Mill (1985) applied the same technique to estimate the impact of soil erosion on farmland prices in Iowa, using transactions occurring between 1976-78. They used average parcel slope to measure the effect of future potential erosion damage, and percentage of a parcel that is eroded to measure the effect of past erosion. However, their study failed to exhibit reliable evidence that farmland prices reflect the effects of past and potential erosion damage. In a similar hedonic study, Palmquist and Danielson (1989) measured the effect of soil's erosion potential on farmland prices and found that farmland prices in North Carolina, U.S., significantly reflect the effect of susceptibility to erosion. King and Sinden (1988) used the hedonic pricing method to determine the relationship between on-farm soil conservation work and farmland value in the Australian farmland market of Manilla Shire in Northern NSW. They included soil conservation work, average slope per property and potential quantity of soil movement as measures of land condition and found that the market recognises the value of land condition. While the above studies have examined the impact of soil characteristics on farmland values, they did not include climate variables. The following studies incorporate both climatic variables and soil characteristics in their hedonic models. Mendelsohn *et al*. (1994) and more recently, Mendelsohn and Dinar (2003) examined the impact of climate conditions on average farmland values of counties, by applying the hedonic pricing method and have shown that values of both climate and soil attributes (e.g. water capacity, sand/ clay) are reflected in the value of land, in counties across U.S.[1] Maddison (2000) has used hedonic techniques to measure the productivity of farmland characteristics including land quality[2] and climate variables in England and Wales, and found the implicit values for land quality and climate were embedded in farmland prices.

This paper focuses more broadly on assessing whether rural farmland values can be used to assign a value to the critical inherent characteristics of natural soil capital stocks. In addition to incorporating soil characteristics we use the size, climatic, topographical, geographical and locational attributes of each individual farm. We find significant relationships between inherent soils characteristics and farmland values. This paper differs from previous studies as we use a comprehensive set of soil characteristics along with climatic, locational, geographical and topographical attributes of each individual farm in a large study area. Moreover, this study to our knowledge is the first to use hedonic methods to look at the value of inherent soil characteristics in the context of soil being a critical natural capital stock. The four remaining sections of this paper: describe our econometric model; discuss our study

[1] Farmland value is defined in these studies as the estimate of the current market value of farmland including buildings, provided by farmers. However, they did not control for the buildings in their regression analysis.
[2] Land quality is measured by land grades given by the official land classification of England and Wales in which the land is graded in to 7 classes according to the extent to which its physical characteristics impose long term limitations on agricultural use.

area and the data; present the empirical results of our hedonic analysis; and close the discussion.

2. Econometric Model

This study uses hedonic price analysis to estimate the value of inherent characteristics of soils. Hedonic price is defined as the implicit prices of attributes and as explained by Rosen (1974), hedonic methods are based on the hypothesis that differentiated products in a competitive market are valued for their utility bearing attributes. The value of each individual farm (V_i) is functionally dependent on its characteristics, for example, the size (A_i), soil (S_i), climate conditions (C_i), topography (T_i), geography (G_i), and location (L_i). We specify the following hedonic price model:

$$Log\ V_i = \beta_1 + \beta_2 A_i + \beta_3 S_i + \beta_4 C_i + \beta_5 T_i + \beta_6 G_i + \beta_7 L_i + \varepsilon \qquad (1)$$

where A_i, S_i, C_i, T_i, G_i, L_i are nxk matrices, β_1, β_2, β_3, β_4, β_5, β_6, β_7 are the parameters to be estimated, and ε is the random error term, which is assumed to be independently and identically distributed. Given the hedonic method, the partial derivative of farmland value with respect to a characteristic gives the marginal willingness to pay to increase one unit of that characteristic, all else constant. We apply a semi-log functional form as opposed to a simple linear functional form to help reduce possible heteroscedasticity among land values (Basu and Thibodeau 1998). Given this functional form, the marginal effect of a unit change in any untransformed continuous explanatory variable (or a change in one category of a dummy variable) on land value can be measured by 100* [$exp\ (\beta_i)-1$] as a percentage.

3. Study Area and Data

3.1 Study Area

This study uses individual farmland values from rural farms in the Manawatu catchment, New Zealand. Located in the lower North Island, the Manawatu catchment has approximately 6000 km^2 of land ranging between sea level to 1630 m in altitude (Schierlitz 2008). The Manawatu Gorge, which runs between the Tararua and Ruahine Ranges, bisects the catchment, and the Manawatu River flows through the Ranges. Figure 1 illustrates the location of the study area on a map. Annual rainfall ranges from 900 mm to more than 1200 mm and the climate is temperate with the main city of Palmerston North having a maximum daytime temperature ranging from 22 °C in summer to 12 °C in winter. Soil distribution in the Manawatu catchment is highly variable as it depends on the climate, topography and parent rock material (Schierlitz 2008). Dairying and sheep and beef farming are the predominant land uses in the catchment at present, while some forestry, cropping and arable farming take place at a smaller scale (see Figure 2).

3.2 Data

The data used in this study come from different sources. The variables used in the analysis are defined in Appendix A and the descriptive statistics appear in Table 1. The current farmland valuation data are acquired from a property valuation database created by Quotable Value New Zealand (QVNZ).[3] The land value of individual farms extracted from the valuation database does not include the value of any physical

[3] QVNZ currently conducts legally required property valuation for rating purposes for most of the local governments in New Zealand. Councils revalue their land on a 3-year cycle that differs across regions and the current valuation data used in this study were carried out in 2005, 2006 or 2007. QVNZ 'uses advanced mass-appraisal techniques with a combination of technology, local valuation experts, and full inspection techniques, to assess the value of each property' (QVNZ 2008).

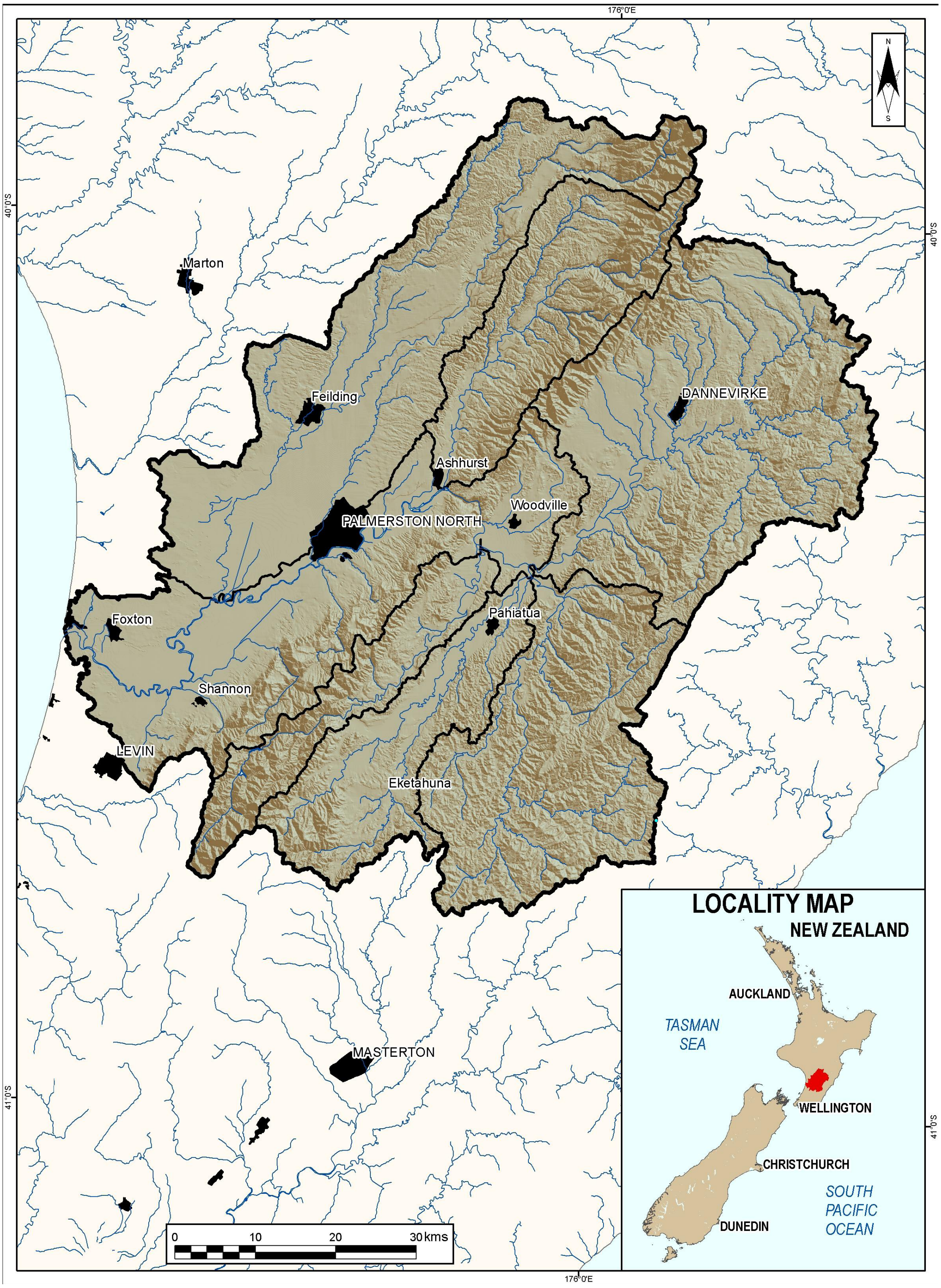

Figure 1: Location of the Manawatu catchment.

Source: Schierlitz (2008)

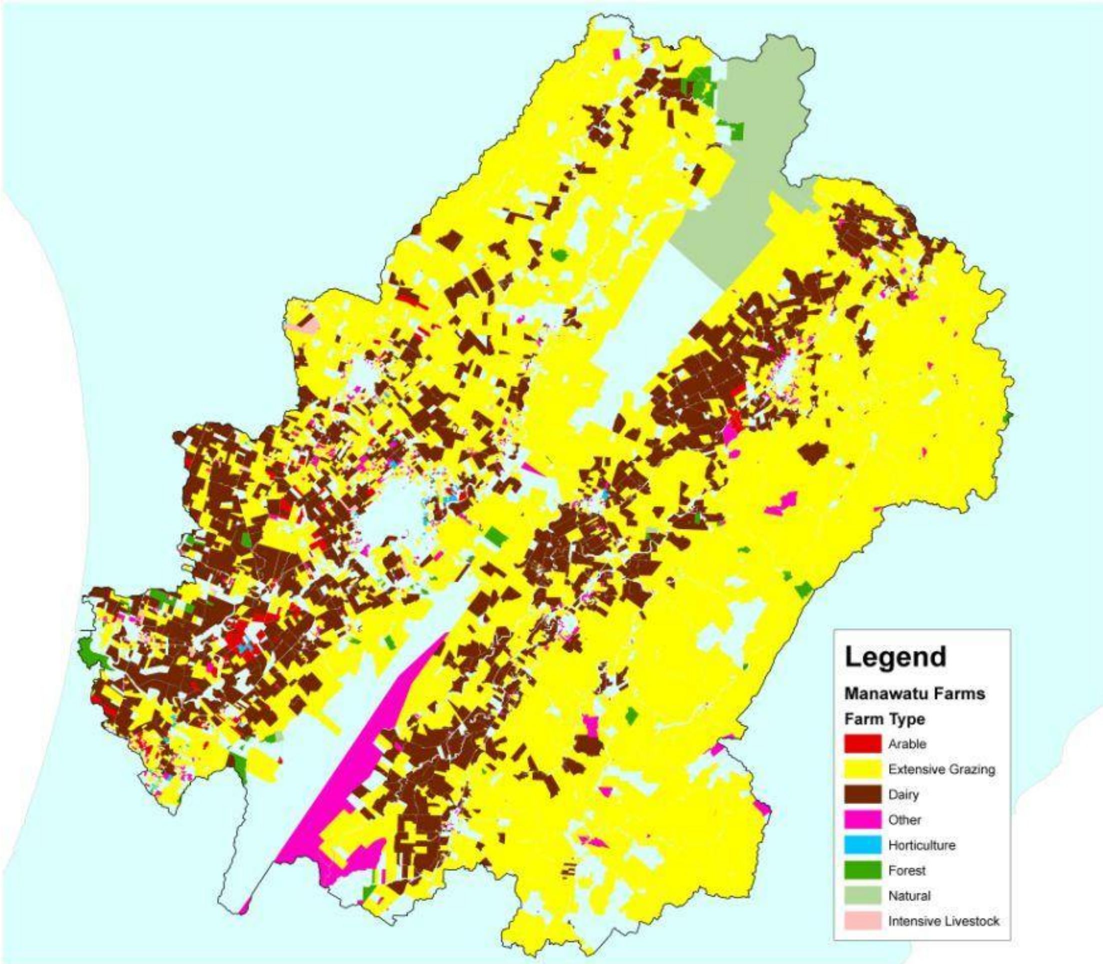

Figure 2: Present land use cover of the Manawatu catchment

improvements (buildings, fences and landscaping for example). QVNZ database also provided the land area and territorial authority[4] (TA) of each farm. Soil characteristics are obtained by intersecting the cadastral layers with the fundamental soil layers (Landcare Research 2009), while the climate variables are obtained by intersecting cadastral layers with the climate layers provided by the National Institute of Water and Atmospheric Research (NIWA). Locational variables, for instance, distance to the

[4] Territorial Authority (TA) is defined as 'a City Council or District Council named in the Local Government Act 2002' (Statistics New Zealand 2008).

nearest major town, cadastral roads[5] and rivers are added with the aid of Geographical Information Systems (GIS).[6]

Various soil types exist within individual farms, thus soil characteristic variables for each farm are created either by calculating the weighted average[7] if the variable is continuous or by taking the value of the dominant[8] soil type if the variable is categorical. Soil characteristics included in this study are particle size class (PARTICLE), soil drainage class (DRAINAGE), potential rooting depth (PRD) and profile total available water (PAW). A top soil gravel content variable was available but not included in the analysis due to correlation between gravel class and the particle size class. These soil characteristics are identified as the most important soil characteristics in determining the farmland values, by soil scientists in Landcare Research (Hugh Wilde, 2008, pers.comm.; Roger Parfitt, 2008, pers.comm.). Weighted averages are taken on PRD and PAW, while the value of the dominant soil type is used for PARTICLE and DRAINAGE.

Particle size class (PARTICLE) in broad terms describes the proportion of sand, silt and clay in the fine earth fraction of the soil. The skeletal particle size category is where the coarse fraction is more than 35% of the whole soil (Landcare Research 2009). Soil particle size is important for moisture storage capacity and permeability. As Webb and Wilson (1995) explained, the capacity of internal soil drainage is characterised by DRAINAGE and is important for the supply of oxygen to the root zone and water drainage. Potential rooting depth (PRD) describes the depth to a layer that may physically hinder root extension which is important for plant growth, whereas

[5] Cadastral roads consist of all the roads included in the cadastral database (sealed roads, metalled and unmetalled roads and highways).
[6] Distances are as the crow flows.
[7] Weighted averages are calculated using the percentage of each soil type in a farm and the soil characteristics values.
[8] Soil type that covers the largest percentage of a farmland

Table 1: Descriptive statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
VALUE	19077.4586	12457.7453	316.0000	66709.0000
AREA	100.6866	140.6859	15.0497	2388.3559
PARTICLE_SAND	0.1140	-	0.0000	1.0000
PARTICLE_SKELETAL	0.0020	-	0.0000	1.0000
PARTICLE_CLAY	0.0004	-	0.0000	1.0000
PARTICLE_SILT	0.5086	-	0.0000	1.0000
PARTICLE_TL	0.0093	-	0.0000	1.0000
PARTICLE_TP	0.0016	-	0.0000	1.0000
PARTICLE_LOAM	0.3640	-	0.0000	1.0000
DRAINAGE1	0.0064	-	0.0000	1.0000
DRAINAGE2	0.2888	-	0.0000	1.0000
DRAINAGE3	0.1625	-	0.0000	1.0000
DRAINAGE4	0.1404	-	0.0000	1.0000
DRAINAGE5	0.4019	-	0.0000	1.0000
PAW	111.5376	29.7635	35.0000	200.0000
PRD	0.6840	0.1618	0.3400	1.3500
FLOOD_1	0.1769	-	0.0000	1.0000
FLOOD_2	0.0722	-	0.0000	1.0000
FLOOD_3	0.0213	-	0.0000	1.0000
FLOOD_4	0.7296	-	0.0000	1.0000
RAIN_T	684.9661	174.3700	479.1790	1902.5800
SOLAR_RAD	17.1399	0.2566	16.4920	17.9920
TEMP_MIN	9.5132	0.6563	6.6690	10.6020
TOWN	7411.8662	4302.4594	176.7910	24 791.4820
C_ROAD	440.1494	259.4825	5.5170	2927.7250
RIVER	833.9243	654.1422	20.0000	5483.3560
TA_HOROWHENUA	0.1275	-	0.0000	1.0000
TA_ MANAWATU	0.3769	-	0.0000	1.0000
TA_PALMERSTON	0.0498	-	0.0000	1.0000
TA_TARARUA	0.4404	-	0.0000	1.0000
TA_HAWKESBAY	0.0053	-	0.0000	1.0000
SLOPE1	0.0620	-	0.0000	1.0000
SLOPE2	0.0286	-	0.0000	1.0000
SLOPE3	0.0864	-	0.0000	1.0000
SLOPE4	0.2352	-	0.0000	1.0000
SLOPE5	0.0631	-	0.0000	1.0000
SLOPE6	0.0049	-	0.0000	1.0000
SLOPE7	0.5199	-	0.0000	1.0000

Note: table is based on estimation sample of 4516 farms in the Manawatu catchment. Summary statistics are given for variables prior to any transformation. See Appendix A for variable descriptions. The mean value for a dummy variable indicates the proportion of farms with the particular attribute.

PAW measures the soil's capacity to hold water and the soil's ability to provide water for plant growth (Webb and Wilson 1995).We use these soil characteristics to describe and to capture the value of services provided by natural soil capital stocks. Particle size (PARTICLE) influences the provision of buffering and moderation of hydrological cycle service. The profile available water (PAW) affects the nutrient retention and delivery services supplied by soil, while the provision of physical support services to plants by the soil is influenced by the potential rooting depth (PRD). Soil drainage (DRAINAGE) affects both the physical support services and the hydrological cycle services. Moreover, slope classes (SLOPE) are utilised as a proxy for current and potential erosion damage (Ervin and Mill 1985; King and Sinden 1988). In the Manawatu catchment, lands on slope of over 28^0 are considered highly erosive (John Dymond, Landcare Research, 2009, pers. comm.).

Climate attributes used in the study consists of total rainfall (RAIN_T), daily mean solar radiation (SOLAR_RAD) and minimum daily mean temperature (TEMP_MIN). These variables are derived from long- term (1971-2000) median values for the growing season months (September-April) (Andrew Tait, NIWA, 2008, pers. comm.). Mean values of maximum daily temperature, growing degree days and potential evaporation total are also available but not included in the analysis due to high multicollinearity between climatic variables. The above-mentioned climatic attributes are identified as the most important determinants of plant growth in pasture and for forestry (Val Snow, AgResearch, 2008, pers. comm.; Thomas Paul, Scion Research, 2008, pers. comm.). Distance to the nearest major town (TOWN), cadastral roads (C_ROAD), rivers (RIVER) and territorial authority location (TA) are incorporated as locational attributes while potential flood hazard level (FLOOD) dummy variables are included to assess the impact of geographical characteristics on farmland values.

4. Empirical Results

Empirical analysis is based on the hedonic model specified in equation 1 with value per hectare (VALUE) as the dependent variable. All the variables described in Appendix A are considered in the analysis. Farmland area (AREA) is transformed by computing the natural log prior to estimation, in order to capture the expected non linear relationship between farmland area and farmland value. Hence, the coefficient on AREA measures the elasticity of per hectare farmland value with respect to land area (Gujarati 1988). Test for heteroscedasticity was significant thus we estimate heteroscedasticity corrected White estimators. The model explains 84% of variation in per hectare farmland values. Regression results are given in Table 2.

The value of land per hectare declines with the size of the farm, indicating economies of scale. Estimated results suggest, on average, a 0.13% decrease in per hectare farmland values with a 1% increase in land area, keeping other things constant. All the soil characteristic variables appear statistically significant, suggesting that inherent soil characteristics are important determinants of the farmland values. Two of the PARTICLE dummy variables are statistically significant and have the expected signs. Keeping everything else constant, farmland with loamy soil particle size is valued on average 8% and 29% more than farmland with sandy and skeletal soil particle size classes, respectively. Loamy soils buffer and moderate the hydrological cycle better than sandy and skeletal soils that have higher permeability and lower water-holding capacity, which is indeed reflected in the estimated coefficients. Estimated signs on DRAINAGE dummy variables appear counter-intuitive; however, a closer look at the data unravels the story. Results from the empirical model suggest farmland with very poor (DRAINAGE1) and moderately well (DRAINAGE4) internal soil drainage are valued higher than those with well-

Table 2: Estimation results

Variable	Coefficient	Standard Error	t- value	Significance
(INTERCEPT)	2.02620	0.65248	3.10530	**
LOG(AREA)	-0.13415	0.00846	-15.86150	**
PARTICLE_SAND	-0.08760	0.01903	-4.60270	**
PARTICLE_SKELETAL	-0.34479	0.09962	-3.46110	**
PARTICLE_CLAY	-0.08287	0.25155	-0.32940	
PARTICLE_SILT	0.00086	0.01153	0.07430	
PARTICLE_TL	-0.13316	0.12236	-1.08830	
PARTICLE_TP	-0.03199	0.12868	-0.24860	
DRAINAGE1	0.51731	0.12515	4.13360	**
DRAINAGE2	0.01327	0.01933	0.68640	
DRAINAGE3	-0.10391	0.01969	-5.27860	**
DRAINAGE4	0.05581	0.02299	2.42710	*
PRD	0.19324	0.03766	5.13100	**
PAW	0.00135	0.00022	6.24060	**
FLOOD_1	0.06286	0.01613	3.89760	**
FLOOD_2	0.20430	0.02247	9.09110	**
FLOOD_3	0.01409	0.04176	0.33750	
RAIN_T	-0.00014	0.00006	-2.24900	*
SOLAR_RAD	0.27717	0.03884	7.13710	**
TEMP_MIN	0.35365	0.01816	19.47420	**
TOWN	-0.00002	0.00000	-10.42190	**
C_ROAD	-0.00008	0.00003	-2.52610	*
RIVER	-0.00001	0.00001	-1.43220	
TA_HOROWHENUA	0.06414	0.07522	0.85270	
TA_ MANAWATU	0.42878	0.06870	6.24150	**
TA_PALMERSTON	0.29416	0.07385	3.98350	**
TA_TARARUA	0.01910	0.06759	0.28260	
SLOPE1	0.03371	0.02054	1.64130	
SLOPE2	-0.12610	0.02941	-4.28800	**
SLOPE3	-0.31700	0.02107	-15.04530	**
SLOPE4	-0.57662	0.01816	-31.74620	**
SLOPE5	-0.89808	0.03528	-25.45940	**
SLOPE6	-1.13970	0.16309	-6.98850	**

Note: table is based on estimation sample of 4,516 farms in the Manawatu catchment. Dependent variable is the natural log of per hectare farmland value. Standard errors are based on heteroscedasticity corrected white covariance matrices. See Appendix A and Tables 1 for variable definitions and descriptive statistics, respectively. * Significant at the 95% confidence level, ** significant at the 99% confidence level.

drained soils. On the other hand, imperfectly drained soils (DRAINAGE3) appear to have a lower value compared with the well drained soils, as one would expect. On closer examination, only small number (29) of farms are very poorly drained; these have loamy peat soils and all are located on flat land area with no flood risk. This land is predominantly used for dairying and arable uses where the relevant plant growth is likely not being inhibited by the poor drainage, with flooding not likely to exacerbate drainage issues. Most of the farms with moderately well-drained soils are used for pastoral farming. Moderately well drained soils are likely to be valued higher for their relatively favorable productivity for pasture under dryland conditions (Webb and Wilson 1995), and our results support this. PRD and PAW are found to impact the farmland values significantly. As expected, farmlands with higher potential rooting depth and higher profile total available water are valued higher, on average. Given the average per hectare value of farmland, estimated coefficients suggest that a farmer is willing to pay a premium of approximately NZ$ 1,017 per hectare (5% of the average per hectare farmland value) to avoid reducing potential rooting depth by 25 centimeters. These findings provide evidence that farmers value the critical soil characteristics that affect the services provided by soils.

Coefficients on five of the six SLOPE dummy variables are highly significant and have expected signs, suggesting that farms on rolling to steeply sloped land are discounted relative to farms in flatter areas. Moreover, the coefficients reveal that on average, land on steep (SLOPE5) and very steep (SLOPE6) slopes are valued approximately 59% and 68% lower than otherwise similar farmland in flatter areas, respectively. These results elucidate that current and potential erosion damage, and thereby potential land use limitations, significantly affect the farmland values. Coefficients on FLOOD dummy variables imply that farmland with slight and moderate flood hazards have a significantly higher value than farmlands with no flood hazards. As one would expect, farmland with no flood risks are on steeper slopes and are likely to be less productive, thus valued lower than land with slight and moderate flood risks, located on flatter slopes. All three variables measuring the climatic attributes (total rainfall, daily minimum temperature and daily solar radiation) appear to be significant determinants of farmland value. Higher annual rainfall is estimated to lower farmland values. This confirms anecdotal evidence that farms with more than 1400 mm rain per year have lower values (Hugh Wilde, Landcare Research, 2008, pers. comm.). Higher temperature and higher solar radiation are estimated to add to the farmland values. As this catchment is not located in an area of extreme temperature and solar radiation this finding is expected.

Estimated results imply that the locational attributes also have significant impacts on the farmland values. Proximity to a major town and cadastral roads have positive impacts on land values. Estimated coefficients reveal that on average, a one kilometre increase in the distance to a major town decreases the per hectare land value by 1.7%, while a kilometre increase in the distance to cadastral roads lowers the per hectare value of farmland by 7.6%, all else constant. Proximity to rivers does not appear to be a significant determinant of farmland values. Farms in the Manawatu District and Palmerston North City appear to be valued higher than similar farms in the Central Hawke's Bay District. This finding is expected as the two largest towns in the catchment (Palmerston North and Fielding) are located in the Manawatu District and Palmerston North City.

5. Conclusion

This study applies hedonic pricing method to assess whether rural farmland values can be used to assign a value to the inherent soil characteristics of soil natural capital stocks. Estimated results suggest farmland values indeed reflect the value of the inherent characteristics of soils. Moreover, results imply that climatic, topographical, geographical, locational and size attributes also contribute to determining the value of rural farmland values.

We identified soils as a critical natural capital stock because soil and many of its characteristics cannot, for all practical purposes, be replaced or substituted for. Even though it has been assumed by many people that the soil natural capital stock may not be encapsulated by farmland values, we find evidence to support that this is not the case. Our study provides empirical evidence that the critical characteristics of the soil natural capital stocks, e.g., particle size, drainage, potential rooting depth, and profile available water, are in fact valued by land valuers, and used by regional councils to determine property rates for rural land. Moreover, results from this study indicate the usefulness of hedonic technique in identifying the value of various soil characteristics of the soil natural capital stock, and the potential usefulness of these regression equations in determining the value of specific land areas within the Manawatu catchment. This information could be used in selecting which soil natural capital stocks should be targeted for urban development, or conversely to identify those natural soil capital stocks to protect.

While this is a first exploration of these relationships there are many additional research opportunities, such as including a greater number of soil characteristics where man-made capital can compensate for relevant soil deficiencies (e.g., soil fertility) to determine if the unsubstitutable or irreplaceable components are valued more in an agricultural context, than those that can be compensated for. Furthermore, this may also indicate if the externalities created by these compensation measures (e.g., addition of synthetic N fertilisers which results in N leaching and the eutrophication of waterways) are accounted for in farmland values.

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Reference

Basu, S. and Thibodeau, T.G. (1998). Analysis of spatial autocorrelation in house prices, Journal of Real Estate Finance and Economics17, 61-85.

Costanza, R. and Daly, H. E. (1992). Natural capital and sustainable development, Conservation Biology 6(1), 37-46.

Costanza, R., d'Arge, R., de Groot, R. S., Farber, S., Grasso, M., and Hannon, B. (1997). The value of the world's ecosystem services and natural capital, Nature 387, 253–260.

Corssman, N.D. and Bryan, B.A. (2009). Identifying cost-effective hotspots for restoring natural capital and enhancing landscape multifunctionality, Ecological Economics 68 (3), 654-668.

Daily, G.C., Matson, P.A. and Vitousek, P.M. (1997). Ecosystem services supplied by soil. In: Daily, G.C. (Ed.). Nature Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC, pp. 113–132.

Ekins, P. (2003). Identifying critical natural capital conclusions about critical natural capital, Ecological Economics 44, 277-292.

English Nature. (1995). Establishing Criteria for Identifying Critical Natural Capital in the Terrestrial Environment, Discussion Paper No. 141. English Nature, Peterborough, UK.

Ervin, D.E. and Mill, J.W. (1985). Agricultural land markets and soil erosion: policy relevance and conceptual issues, American Journal of Agricultural Economics 67, 938-942.

Gujarati. D.N. (1988). Basic Econometrics (2nd ed.). McGraw-Hill Book Co, Singapore.

Helier, T. (2008). 'Irrigation and drainage', Te Ara: the Encyclopedia of New Zealand, URL: http://www.TeAra.govt.nz/TheSettledLandscape/ChangingTheLandscape/IrrigationAndDrainage/en [accessed 14 Jan 2009].

King, D.A and Sinden, J.A. (1988). Influence of soil conservation on farm land values, Land Economics 64(3), 242-255.

Landcare Research. New Zealand Soils, URL: http://soils.landcareresearch.co.nz/contents/SoilData_FSL_Maps.aspx?currentPage=SoilData_FSL_Maps&menuItem=SoilData [accessed 12 Jan 2009].

Lipper, L. (2002). Dirt poor: Poverty, farmers and soil resource investment. Pages 1–43 in 2 essays on socio-economic aspects of soil degradation FAO Economic and Social Development Paper No. 149. FAO, Rome.

Macdonald, D. V., Hanley, N. and Moffatt, I. (1999). Applying the concept of natural capital criticality to regional resource management, Ecological Economics 29, 73-87.

Maddison, D. (2000). A hedonic analysis of agricultural land prices in England and Wales, European Review of Agricultural Economics 27(4), 519-532.

Mendelsohn, R. and Dinar, A. (2003). Climate, water, and agriculture, Land Economics 79(3), 328-341.

Mendelsohn, R., Nordhaus, W.D. and Shaw, D. (1994). The impact of global warming on agriculture: a ricardian analysis, The American Economic Review 84(4), 753-771.

Miranowski, J.A. and Hammes, B.D. (1984). Implicit Prices of Soil Characteristics for Farmland in Iowa, American Journal of Agricultural Economics 66, 745-749.

Olewiler, N. (2004). The Value of Natural Capital in Settled Areas of Canada. Ducks Unlimited Canada, the Nature Conservancy Canada. Available from URL: http://www.ducks.ca/aboutduc/news/archives/pdf/ncapital.pdf [accessed 12 Jan 2009].

Palmquist, R.B. and Danielson, L.E. (1989). A hedonic study of the effects of erosion control and drainage on farmland values, American Journal of Agricultural Economics 71(1), 55-62.

Pearce, D. W. and Turner, R. K. (1990). Economics of Natural Resources and the Environment. John Hopkins University Press, Baltimore.

QVNZ. (2009). URL: https://www.qv.co.nz/valuations/ [accessed 12 Jan 2009].

Rosen, S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition, Journal of Political Economy 82, 34-55.

Schierlitz, C. (2008). New Zealand Empirical Erosion Model(NZeem®): analysis, evaluation and application in climate change scenarios, Masters Thesis, Department of Geography, University of Bonn, Bonn.

Statistics New Zealand. (2008). URL:http://www.stats.govt.nz/statistical-methods/classifications-and-related-statistical-standards/territorial-authority/definition.htm [accessed 16 Jan 2009].

Vesely, E.T. (2006). Economic value of soil quality, Landcare Research contract report LC0607/006, Prepared for Sustainable Land use Initiative (SLURI).

Wackernagel, M. and Rees, W. E. (1997). Perceptual and structural barriers to investing in natural capital: Economics from an ecological footprint perspective, Ecological Economics 20, 3-24.

Webb, T. H. and Wilson, A.D. (1995). A Manual of Land Characteristics for Evaluation of Rural Land. Manaaki Whenua Press, Lincoln.

Appendix A: Descriptions and definitions of variables

Variable	**Description**
VALUE	per hectare value of farmland as at current valuation period, excluding the value of any physical improvements (NZ$)
	values are adjusted for inflation to 2006 June prices using the consumer price index (CPI)
AREA	land area of the farm (ha)
	we have used farms with more than 15 hectares of land in this analysis
PARTICLE	particle size class dummy variable with 7 categories
	PARTICLE_SKELETAL =1 if skeletal; 0 otherwise
	PARTICLE_CLAY =1 if clayey; 0 otherwise
	PARTICLE_SILT =1 if silty; 0 otherwise
	PARTICLE_TL=1 if loamy peat or loamy litter, organic matter>50%, sand in mineral fraction<50%; 0 otherwise
	PARTICLE_TP =1 if peat or litter, organic matter>50%; 0 otherwise
	PARTICLE_SAND =1 if sandy; 0 otherwise
	omitted class is loamy particle size class
DRAINAGE	soil drainage class dummy variable with 5 categories
	DRAINAGE1 =1 if very poor; 0 otherwise
	DRAINAGE2 =1 if poor; 0 otherwise
	DRAINAGE3 =1 if imperfect; 0 otherwise
	DRAINAGE4 =1 if moderately well; 0 otherwise
	omitted class is well drained soil
PRD	potential rooting depth (m)
PAW	profile total available water (mm)

FLOOD	flood hazard indicator dummy variable with 4 categories
	FLOOD_1 =1 if slight; 0 otherwise
	FLOOD_2 =1 if moderate; 0 otherwise
	FLOOD_3 =1 if severe; 0 otherwise
	Omitted flood class is nil
RAIN_T	total rainfall for the growing season months September–April (mm) calculated from long-term (1971–2000) median values
SOLAR_RAD	daily mean solar radiation for the growing season months September–April (MJ/m2/day) calculated from long-term (1971–2000) median values
TEMP_MIN	daily mean minimum temperature for the growing season months September–April (°C) calculated from long-term (1971–2000) median values
TOWN	distance to the nearest major town (m)
	10 major towns (population > 1500) within and just outside the catchment are considered
C_ROAD	distance to the nearest cadastral road (m)
RIVER	distance to the nearest rivers – Manawatu River or its main tributaries (m)
	rivers outside the catchment are not considered due to potential difficulties of accessing water
TA	dummy variable for territorial authority in which the farm is located
	TA_HOROWHENUA =1 if Horowhenua District; 0 otherwise
	TA_MANAWATU =1 if Manawatu District; 0 otherwise
	TA_PALMERSTON =1 if Palmerston North City; 0 otherwise

TA_TARARUA =1 if Tararua District; 0 otherwise

omitted territorial authority is Central Hawke's Bay District

SLOPE slope class dummy variable with 7 categories

SLOPE1 =1 if undulating; 0 otherwise

SLOPE2 =1 if rolling; 0 otherwise

SLOPE3 =1 if strongly rolling; 0 otherwise

SLOPE4 =1 if moderately steep; 0 otherwise

SLOPE5 =1 if steep; 0 otherwise

SLOPE6 =1 if very steep; 0 otherwise

omitted slope class is flat to gently undulating