Sheep And Beef Production Costs Across New Zealand: Introducing The Spatial Dimension

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Motu is currently developing a dataset of production costs relating to different rural land uses, which we can use to help explain historical land-use trends at a Territorial Authority level. The Meat and Wool Economic Service farm survey provides a rich database containing physical and financial data for New Zealand sheep and beef farms including detailed information on average farm expenditure, from at least 1980. But while this dataset provides extensive information for 8 farm classes and 5 regions, the actual location of the farms within each class is not known. So, we have developed an algorithm that generates a map of potential farm classes utilising supplementary information on farm location from QVNZ and a land productivity map developed by Baisden (2006) at Landcare Research. This map can be used to map any information contained with the farm survey reports.

Key words: spatial allocation, production costs, sheep and beef farming

Introduction

Rural land-use decisions have direct impacts on many environmental issues, including greenhouse gas emissions, erosion, and water quality. At Motu, we are currently studying rural land use to gain a further understanding of what New Zealand's future land-use path is likely to be, and how land use may respond to differing environmental policies. As part of this project, we are collating information for a database that will contain spatial maps of production costs relating to different rural land uses.

The main purpose of creating maps of production costs is to help explain historical land-use trends at a Territorial Authority (TA) level. This will enable us to enhance our integrated economics and natural science simulation model Land Use in Rural New Zealand (LURNZ). LURNZ is a computer model that simulates rural land-use change, producing land use paths and maps (for more detail see Hendy, Kerr and Baisden (2006)). LURNZ is a partial equilibrium model, based on micro-economic theory, and econometrically estimated. The first version of the model (LURNZv1) uses an econometrically estimated relationship between rural land use, commodity prices, and other factors that affect land-use decisions to predict land-use change at the national level (Kerr and Hendy 2004). We are currently developing the second version of LURNZ (LURNZv2), which will use an econometric model estimated at the TA level. This will improve the robustness of LURNZ. To do this, we are compiling the LURNZv2 database, which will contain among other things TA level land use area and production costs for dairy, sheep and beef, and plantation forestry.

This paper describes work in progress. It outlines our first attempt at creating a spatial map of sheep and beef revenues and costs that vary over time, to form part of the LURNZv2 database. To do this we use Meat and Wool New Zealand: Economic Service's (MWES) rich dataset of economic data relating to sheep and beef farms. This data is measured at a farm class scale in five regions. In this paper, we begin by describing the method we use to create a spatial map of MWES farm classes, using supplementary data on rural land type from Quotable Value New Zealand (QVNZ) and pastoral productivity from Baisden (2006). Next, we make visual comparisons between our map and other spatial datasets that are correlated with farm productivity to give us an initial indication of the map quality. We then discuss the next stages in our work.

Data

The main sources of comprehensive sheep and beef statistics in New Zealand include the Agricultural Production Census, Agribase, the Ministry of Agriculture and Forestry (MAF) farm monitoring reports and MWES farm surveys. The Agricultural Production Census collects agricultural information at the TA level but does not include detailed cost and revenue data. Agribase is the most spatially detailed source of land use information, with data geocoded and stored on a Geographic Information Systems (GIS) frame. However, the database is not time-stamped and so does not give us a time-series.

Both MAF farm monitoring reports and MWES farm surveys provide detailed revenue and cost data by region and farm class. However, the regions and underlying models used in the MAF farm monitoring reports are not consistent over time (MAF, 2006). Consequently we use MWES survey data as the basis of our sheep and beef cost and production map.

MWES conducts annual sheep and beef farm surveys, collecting data which links physical production with financial returns and capital structure (Meat and Wool New Zealand, 2002). The farm surveys provide physical and financial data for New Zealand sheep and beef farms including detailed information on average farm expenditure, gross margins and stocking rates. Approximately 550 farms are sampled each year based on a stratified sample. We have this data annually from 1980-2002.

In the farm surveys, New Zealand sheep and beef farms are split into eight different farm classes based on physical farm characteristics, farm practices and location; data is collected for each of these farm classes within the five MWES regions. Table 1 gives general descriptions of each of these farm classes. While this dataset provides extensive information, the actual location of all farms in each class is not known. This means that to use the data to its full potential we need to create a map of the location of farm classes within New Zealand.

Table 1 Farm Class Descriptions

ES Farm Class	Characteristics
North Island Hard Hill Country	Steep hill country or low fertility soils; Most stock sold in store condition
North Island Hill Country	Easier hill country or higher fertility soils; a high proportion of stock sold is in forward store or prime condition
North Island Intensive Finishing Farms	Easy contour land with the potential for high production; high proportion of stock is sent to slaughter house and replacements brought in
South Island High Country	High altitude farms carrying fine wool sheep; main source of revenue is wool
South Island Hill Country	Mainly mid micron sheep; three quarters of wintered stock are sheep and one quarter beef cattle
South Island Finishing-Breeding Farms	Dominant South Island farm class; more extensive finishing farm often combined with cash cropping and irrigation
South Island Intensive Finishing Farms	High producing grassland farms with some cash crop; located mainly in Southland and South and West Otago
South Island Mixed Finishing Farms	High proportion of revenue derived from grain and small seed production as well as stock finishing; mainly on Canterbury plains.

To help map the likely location of the MWES farm classes we combine information on the biological productivity of pastoral land using an index created by Baisden (2006) with information on land types from QVNZ. Our measure of biological productivity, the Pastoral Productivity Index, is available in a GIS map designed to give results sensible at 1ha resolution. Our land type information comes from the QVNZ valuation database. The collected data includes information on a number of characteristics of the land including land value, capital value, land area and ‘land type’.

The land type variable found within the QVNZ valuation data contains 33 categories defining the best land use in the valuer's opinion including farming, forestry, commercial and residential subcategories. In this paper we only focus on the three pastoral categories (Pastoral Fattening/Stud, Pastoral Grazing and Pastoral Run) to enable the production of the potential farm-class map; we refer to these land types as QVNZ farm-classes.

QVNZ collects valuation data on properties in three yearly cycles. In regions that are not assessed by QVNZ the information is purchased by QVNZ to supplement their dataset providing a comprehensive New Zealand wide dataset. We have data from 1990 to 2002 that is aggregated to the meshblock level. Further information on the QVNZ valuation dataset can be found in Stillman (2005).

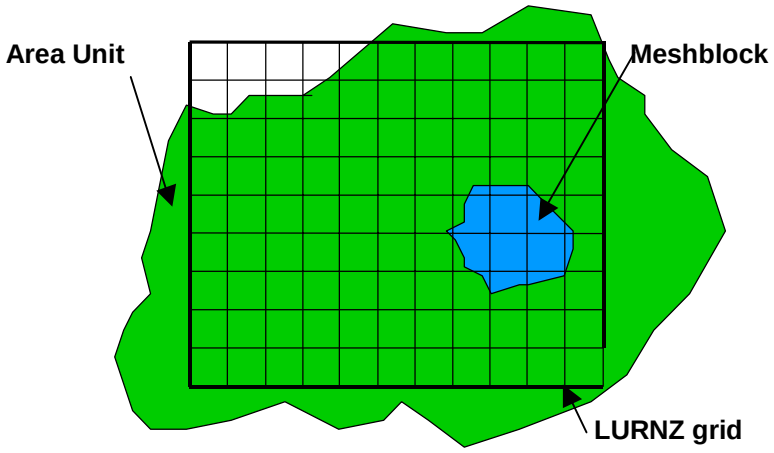
Meshblocks are the smallest geographic area used by Statistics New Zealand and are typically aligned to cadastral boundaries. QVNZ assigns each of the properties in their dataset to the appropriate meshblock area when aggregating their results. In New Zealand there are 38,366 meshblocks defined under the 2001 boundaries. The next smallest geographic unit that is defined by Statistics New Zealand is an area unit. These are aligned with meshblock boundaries and under the 2001 boundaries; there were 1842 area units in New Zealand.

In this paper, we use a subset of the meshblocks. We exclude meshblocks that are defined as being outside the 74 territorial local authorities or over water. In addition, we drop any meshblock that has never had a pastoral land type defined within it, and is also within an area unit that has never had a pastoral land type defined within it.

Scales of analysis

The different data sources use different geographic aggregations. To enable us to combine this information, we need to convert our data to a consistent scale. We use the LURNZ grid as the base scale. The LURNZ grid covers New Zealand in a 25ha square grid. This grid is the basis of the land use maps produced by LURNZ, chosen because it is close to the level at which individuals make land-use decisions and results in a dataset small enough so that computation is not too time-consuming. In Figure 1 we can see the relationship between the different geographic areas.

Figure 1 Different Geographic Scales



We convert QVNZ farm class and pastoral productivity index maps to the LURNZ grid scale. We do this by overlaying the maps onto the grid and assigning each cell the land type and productivity value that corresponds to the cell centroid.

Creating a Farm Class Map

Mapping QVNZ farm classes to the LURNZ grid

Our first step in creating our farm class map is to assign a single QVNZ farm class to each grid cell. Potentially, up to three QVNZ farm classes can exist within a meshblock. The QVNZ data allows us to identify which QVNZ farm classes are within each meshblock, but does not provide us with enough information to identify where within a meshblock each QVNZ farm class resides. Therefore, we use a set of arbitrary rules to uniquely assign a QVNZ farm class to every grid cell within a meshblock.

If the data indicates that there was a single QVNZ farm class in that meshblock in 2002, we assign all pixels within the meshblock to that particular QVNZ farm class. If there were two farm classes within the meshblock in 2002, we identify the relative physical productivity of each grid cell using the pastoral productivity index. We then we assign the most productive half of the grid cells to the 'higher value' farm class and the least productive half of the grid cells to the 'lower value' farm class where the highest value farm class is *stud/fattening*, the next highest is *grazing*, and the lowest value is *run.* Finally, if there were three farm-classes within a meshblock, we assign the most productive third to the 'highest value' farm-class (stud/fattening), the middle third

to the ‘middle value’ farm class (grazing), and the least productive third to the ‘lowest value’ farm class (run).[1]

If no QVNZ farm-class is identified within a meshblock in 2002, then we use the 1999 QVNZ data and follow the same procedure as above. If the 1999 data also does not identify a QVNZ farm class, then we check earlier QVNZ cycles until a farm-class is identified for that meshblock. For some meshblocks, no farm-class has been identified in the QVNZ data that we have. In this case, we move to an area unit level and apply the same rules again.

Converting to MWES farm class definitions

QVNZ and MWES use different definitions of farm classes. Thus, we need to create a concordance between them. Using the detailed descriptions of MWES farm classes (Table 1) in conjunction with recommendations from a QVNZ valuer[2], we match the farm classes according to Table 2.

Table 2 QV-ES Farm class concordance

QVNZ farm classes	MWES farm classes
NI Stud	NI Intensive Finishing
NI Grazing	NI Hill Country NI Hard Hill Country
NI Run	NI Hard Hill
SI Stud	SI Intensive Finishing SI Finishing Breeding SI Mixed Finishing
SI Grazing	SI Hill Country
SI Run	SI High Country

Unfortunately there is not a one-to-one correspondence for all the farm classes. Grid cells assigned as QVNZ farm class NI Grazing could either be MWES farm class NI Hill country or NI Hard Hill Country and those assigned as QVNZ farm class SI Stud could be MWES farm class SI Intensive, SI Finishing or SI Mixed.

To split QVNZ NI Grazing pixels between MWES NI Hill Country and MWES NI Hard Hill Country, we first calculate the total area of each MWES farm class in the 2000-01 MWES farm survey report (Meat and Wool New Zealand 2002) by

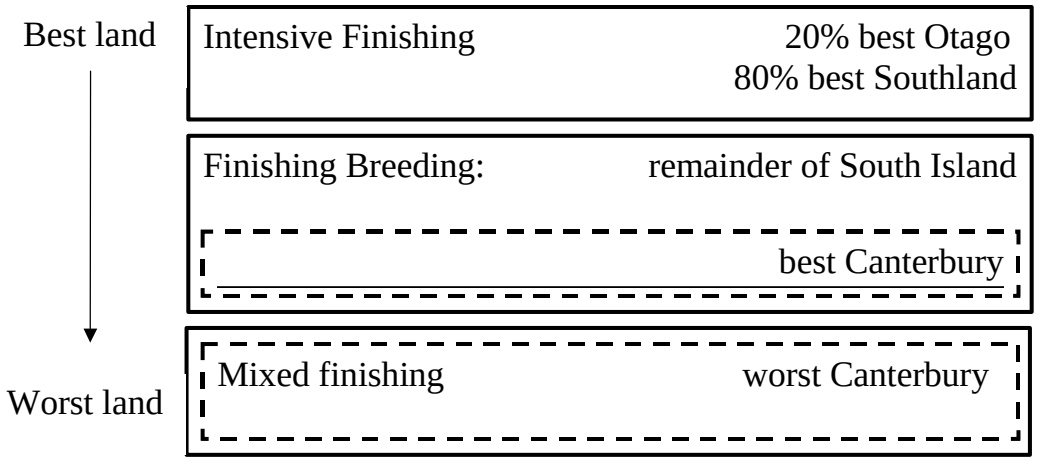
[1] When these proportions imply a non-integer number of grid-cells for each use, we round up the number of pixels allocated to the highest value use and we round down the number of pixels allocated to the lowest value use.
[2] Personal Communication with Simon Willocks, QVNZ valuer.

multiplying average farm area by number of farms in each class. We then calculate the ratio of the areas in those MWES farm classes, and used this ratio to split the QVNZ NI Grazing pixels into the two MWES classes. We assign the highest quality pixels to MWES NI Hill Country, and the lowest quality pixels to MWES NI Hard Hill Country.

Splitting the QVNZ Stud pixels between MWES SI Intensive Finishing, SI Finishing Breeding, and SI Mixed Finishing is more complicated because we want to take into account regional information included in the farm class descriptions. According to the farm class descriptions, MWES Mixed Finishing is mainly located in Canterbury and MWES SI Intensive Finishing is mainly located in Southland and Otago. Consequently, we make the simplifying assumption that all MWES Mixed Finishing resides within Canterbury, and all the Intensive Finishing resides within Southland and Otago.[3]

We also make an assumption about which of these three QVNZ farm classes resides on the highest quality land and which resides on the lowest quality land. In 2000-01, MWES SI Intensive Finishing had an average stocking rate of 12.2 stock units per hectare, MWES SI Finishing Breeding had on average 8.6 stock units per hectare, and MWES SI Mixed Finishing had on average 6.1 stock units per hectare. Accordingly, we assume that MWES SI Intensive Finishing resides on the highest quality land, MWES SI Finishing Breeding resides on the next highest quality land, and MWES SI Mixed Finishing resides on the worst quality land.

Figure 2 Allocation of MWES farm classes within South Island Stud



We calculate the area of MWES SI Mixed Finishing, MWES SI Intensive Finishing, and MWES Finishing Breeding by multiplying average farm size by number of farms from the 2000-01 farm survey report (Meat and Wool New Zealand 2002). We then use the proportions to split the QVNZ Stud pixels between the three MWES classes. Within Canterbury, we assign the lowest quality QVNZ Stud pixels to MWES SI Mixed Finishing and the remaining highest quality pixels to MWES SI Finishing Breeding. Then based on the distribution of the actual survey farms in the 2000-01 farm survey, we assume 20% of MWES SI Intensive Finishing land is within Otago and the

[3] Regions were defined using Statistic New Zealand regional council boundaries.

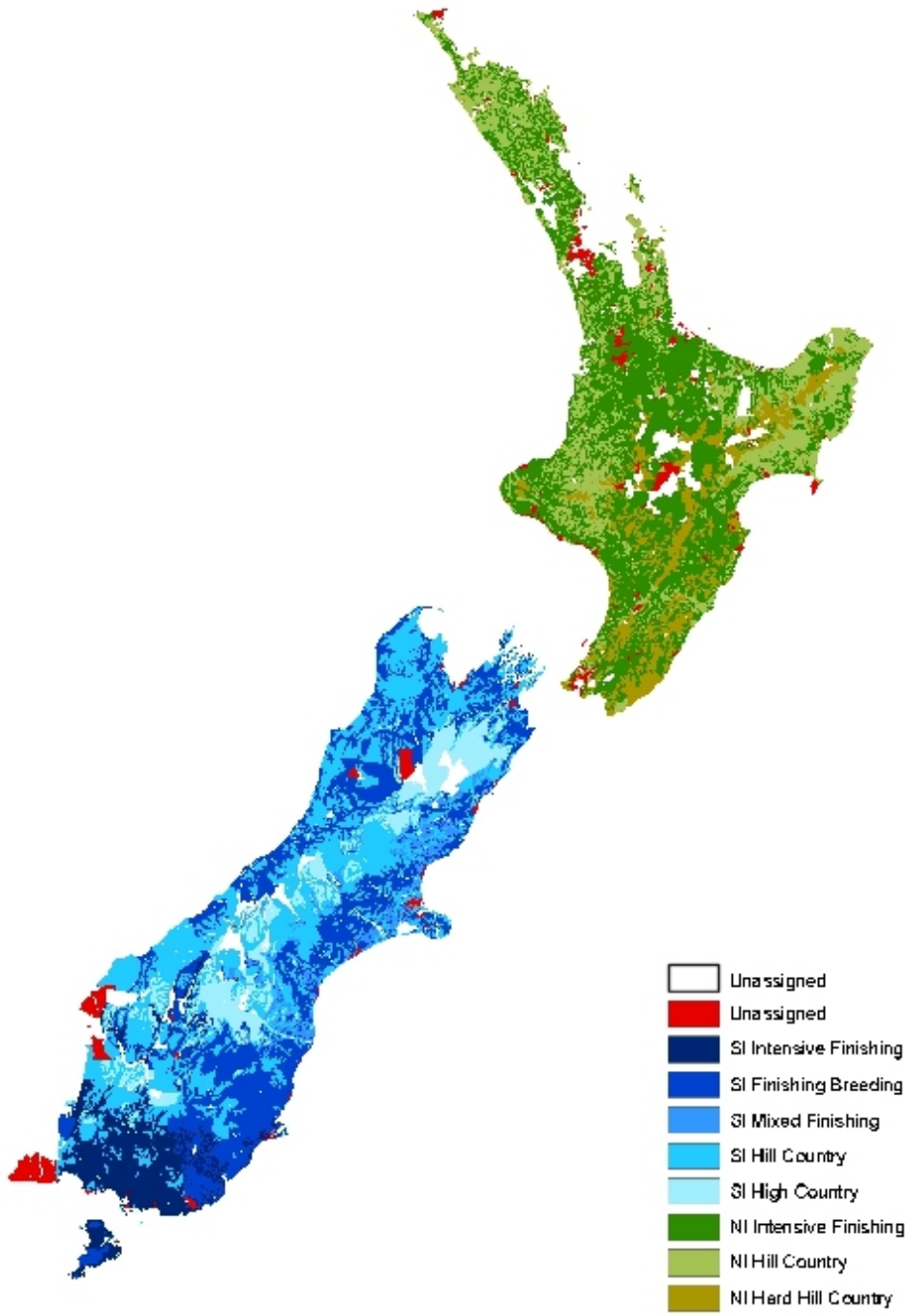
remaining 80% is within Southland. Using these proportions to apportion the farm class area across the two regions, we assign the highest quality QVNZ Stud pixels to MWES SI Intensive Finishing, and the lowest quality pixels to MWES SI Finishing Breeding. In the remaining regions, we assign all QVNZ stud pixels to MWES SI Finishing Breeding. This gives us our final map of MWES farm classes.

Results

Figure 3 below shows our final map of farm classes. This map is designed to represent potential farm class not actual farm class. That is, if a cell in the LURNZ grid were part of a sheep/beef farm, our farm class map should indicate which farm class it would mostly likely be. The map that was created appears to be reasonably representative of the actual locations of MWES farm classes across New Zealand, especially once the conservation land was taken into consideration (Rob Davison, pers. comm. 2006). But it is likely that there may have been more North Island Hard Hill country in Northland previously than the map indicates. However, much of the land that was classified as North Island Hard Hill country is now being used for forestry.

At a finer scale however, some areas are unlikely to accurately reflect the farm class that would be used on that site. For example, according to the potential farm class map there is a lot of North Island Hard Hill country in the area surrounding Napier and Hastings despite this area being high productivity land. This land is currently used for horticulture and is unlikely to have had sheep and beef farms on it in the range of the QVNZ data. Thus, when the allocation rules were applied it would have been difficult to allocate a farm class from within the meshblock. Instead, the area unit rule is likely to have been used for assigning farm classes, potentially picking up the North Island Hard Hill country that is now being used for wine cultivation. Areas such as this, where there has been limited sheep and beef farming over range of the data, will be less accurately represented in the data. The quality of the inference depends on homogeneity of land within the meshblocks and area units. Because Area Units are large, they are likely to be heterogeneous so inference is poor.

Figure 3 Potential Farm Class Map



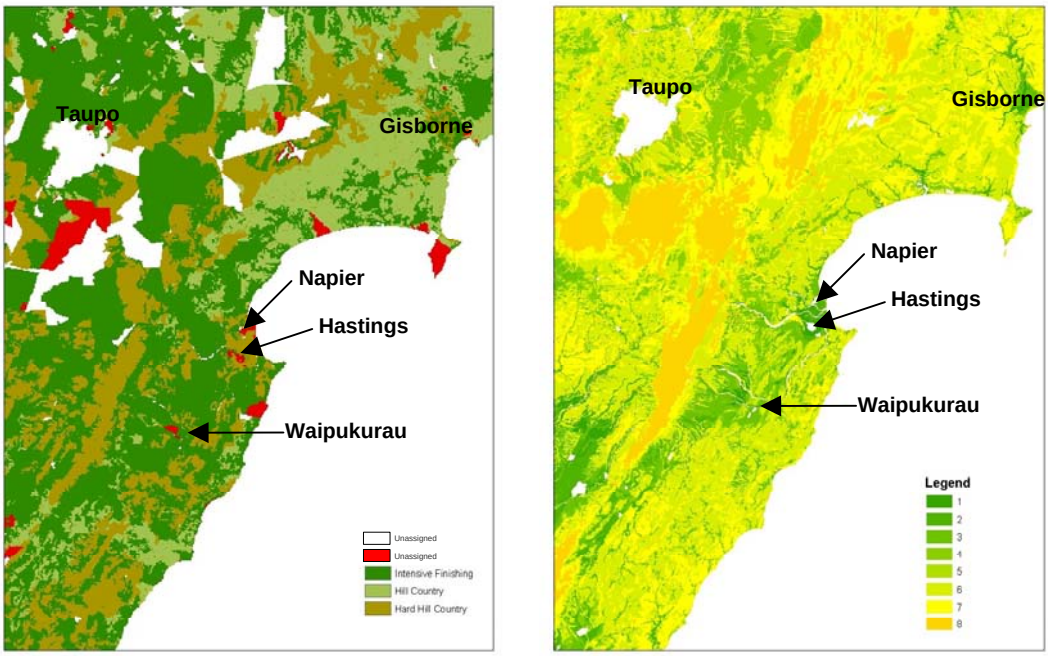
To be able to assess the quality of the map, we wanted to undertake some comparisons with other related maps. We compare our potential farm class map to other well-tested maps of factors related to land productivity. These include the land use capability index, the stock carrying capacity and rural land values. We expect these maps to exhibit similar, but not identical, spatial patterns to our potential farm class map.

The Land Use Capability layer comes from the New Zealand Land Resource Inventory (NZLRI) database, and classifies land based on its limitations for productive use. This classification gives an indication of what uses the land is capable of supporting long-term by describing the limitations on land use. Areas of land that are essentially homogeneous in rock type, soil unit, and slope form the polygons within this layer. Each polygon is classified on a discrete scale from 1 to 8, with class 1 land being the best for sustained agricultural production and class 8 being land with severely limited uses (Froude, 1999). Looking at our map of farm classes, we expect the land with the highest value farm class to correspond with the least limited classes and the land with lower valued farm classes to correspond with the more limiting LUC classes.

Comparing the maps of potential farm class (Figure 3) and land use capability at the national scale (see Appendix for the national land use capability map), we see similar patterns. Areas that have severe limitations on their land use such as the mountain ranges also correspond to areas with lower quality farm classes. Conversely areas with few limitations on their land use such as the Canterbury plains are associated with higher quality farm classes in the potential farm class map.

To illustrate the quality of our maps on a finer scale we will focus on the Hawke's Bay region, which has a large proportion of sheep and beef farms. Figure 4 shows the potential farm class map on the left and map of land use capability on the right for Hawke's Bay region. Comparing these two maps we can see clear areas of concordance. For example, the areas with high land use capability values (reflecting severe limitations on land use) along the ranges are reflected in our farm class map as areas with large amounts of NI Hard Hill Country (the lowest quality MWES farm class). Also areas that have low land use capability values are also areas that have a large amount of NI Intensive Finishing allocated. However, some areas such as those surrounding Napier, Hastings and Gisborne have few limitations on land use according to the land use capability index but are allocated to the MWES farm class NI Hard Hill Country. These areas are unlikely to have had much sheep and beef farming throughout the range of the QVNZ data meaning that the allocation rules could potentially be allocating a farm class across an entire area unit based on a single valuation.

Figure 4 Maps of Potential Farm Class (left) and Land Use Capability Index (right) in Hawkes Bay.

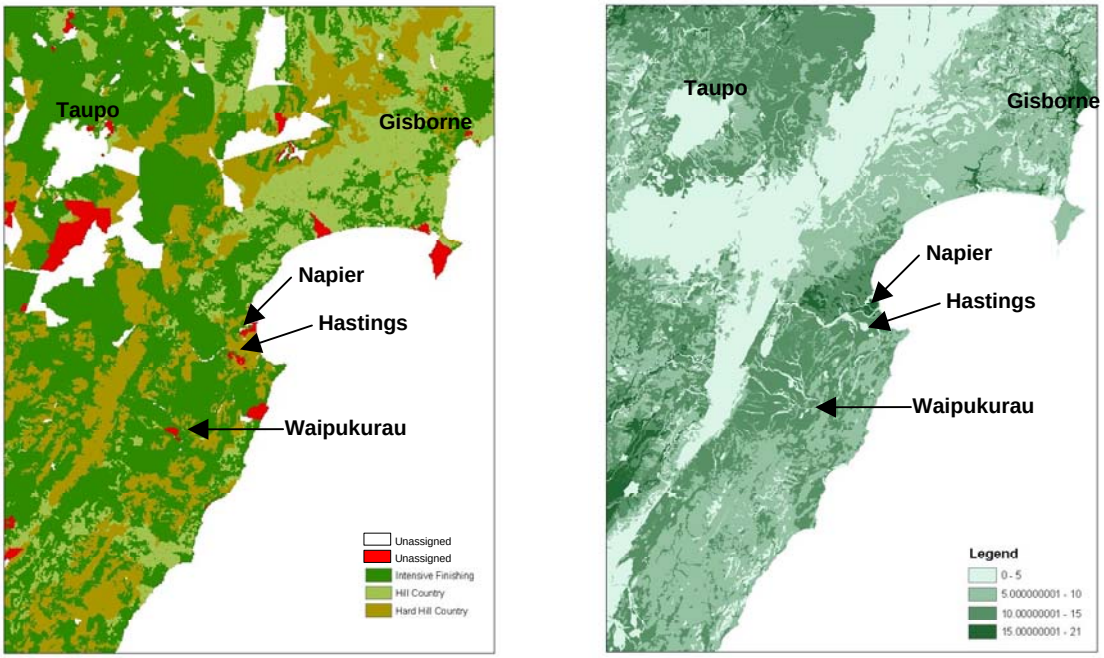


The Carrying Capacity (CCAV), also from the NZLRI database, describes both "best" farmer stocking rates, and "average" farmer stocking rates. For this analysis we will use the "average" farmer stocking rates map. We expect our farm class map to correspond reasonably closely to the CCAV with areas with high stocking rates having better quality farm classes allocated. Conversely, we would expect areas with low stocking rates to correspond to areas with lower quality farm classes.

A comparison of our potential farm class map (Figure 3) and the CCAV map (Appendix) shows that the expected concordance does seem to hold. Areas that are associated with high carrying capacity such as Southland and Waikato also have better quality farm classes. Also mountainous areas such as the Southern Alps not only have lower quality farm classes but also low carrying capacity, as we would expect.

When we compare the maps on a smaller scale by examining the Hawke's Bay area (Figure 5) we see a similar pattern. Areas with low CCAV values representing areas that have low average carrying capacity are associated with lower quality farm classes. Conversely, areas such as those around Taupo have high stocking rates associated with them and correspond to areas that have high quality farm classes assigned. Thus, the comparison of the potential farm class map adds to the support provided by the other map comparisons and gives us confidence in the map that we have created.

Figure 5 Maps of Potential Farm Class (left) and Carrying Capacity (CCAV) (right) in Hawkes Bay.



Land values reflect expectations of future utility from use of the land, which to some extent, we expect to be related to the current productive value of the land (Stillman, 2005). Because of this, we expect some correspondence between our potential farm class map and the spatial distribution of rural land values. However we would not expect an exact correspondence because rural land values will also reflect other factors such as proximity to towns or to the coast.

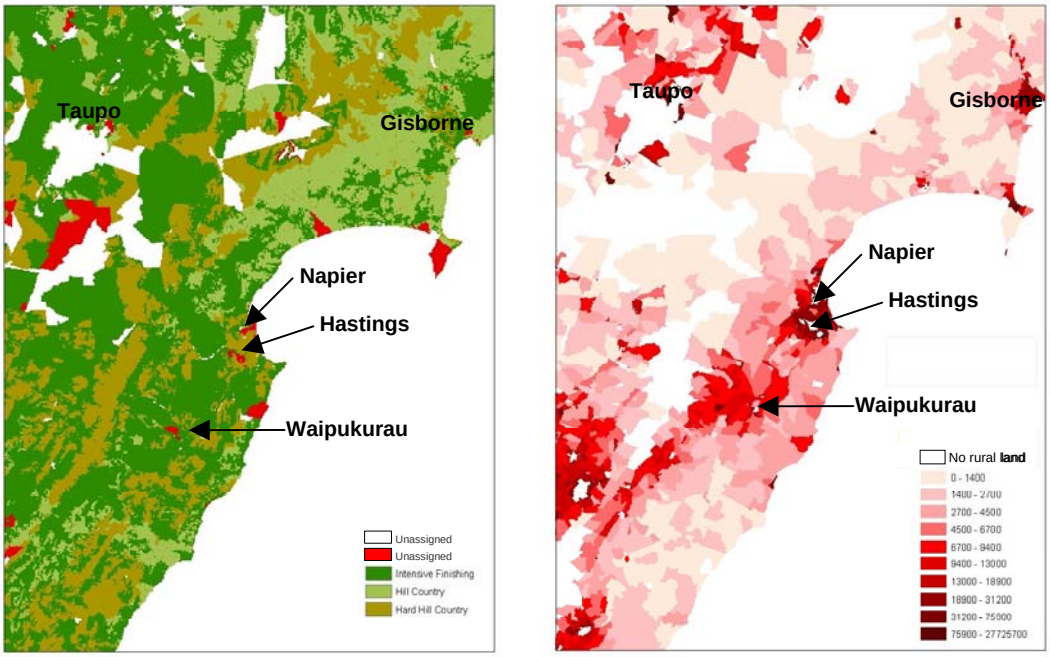
To compare our farm class map to the distribution of rural land values we use a map from Stillman (2005), where values are calculated using the QVNZ valuation data (see Appendix for the full map). The rural land values map excludes any meshblocks that are in cities, towns, offshore islands, water, or conservation land. The map represents the spatial variation in average land values in rural meshblocks with rural meshblocks ranked by average value divided into deciles. The more valuable land are mapped in progressively darker shades of red.

A comparison of our farm class map and the map of rural land values shows that a correspondence, while not exact, does exist. For example, areas such as the Waikato, Taranaki and South Canterbury have high rural land values, which correspond to areas of better quality farm classes in our farm class map. However, this comparison is difficult since there are large areas especially in the South Island, which we do not have valuation data where the Department of Conservation owns the land.

Figure 6 shows the potential farm class map on the left and rural land values on the right for Hawke's Bay region. We can see that there are a number of areas where high land values correspond to areas with the better quality farm classes such as the area to the southwest of Napier/Hastings. In contrast, the area surrounding Gisborne corresponds to both poor quality farm classes and low rural land values. While we would

not expect to see an exact correlation between the two maps, being able to see similar patterns in both of these maps provides some confidence in the accuracy of the maps created.

Figure 6 Maps of Potential Farm Class (left) and Rural Land Values (right) in Hawkes Bay



Next Steps

From the simple comparisons in this paper, our first attempt at creating a farm class map seems to match other representations of productivity reasonably well in most regions. To further these comparisons we could also apply the stocking rate information located in the MWES farm surveys to the farm class map to create a map of potential stocking rates. This map can then be used for comparison with the CCAV which maps stocking rates across the country visually as above. Our next step will be to assess the quality of our map in more quantitative ways. By overlaying actual sheep and beef area in 2002 onto our stocking rate map, we can calculate the stock numbers at a TA level implied by our map, and compare this with the TA stock numbers from the Agricultural Production Census. Also, by overlaying actual sheep and beef area in 2002 onto our farm class map, we can calculate the implied actual farm-class area for each MWES region, and compare this to the MWES data.

To address the problem of poor inference in meshblocks where no sheep/beef agriculture has recently been observed we will explore the possibility of limiting our initial mapping effort to meshblocks which have recently had sheep/beef. Then we will regress these results using a multinomial on underlying geophysical characteristics to

predict what the likely farm class would be in meshblocks where sheep/beef is not observed.

In the longer term, MWES is developing a set of rules that will allow allocation of farm classes within regions based on stocking rates. Using these rules in conjunction with the stock carrying capacity map (CCAV) would give us an alternative method to creating a farm class map. This may ultimately give us a superior farm class map.

Creating a map of MWES farm classes enables us to map any of the economic variables measured in the MWES farm surveys. These variables can then be aggregated to many different geographical scales. Thus by creating a map of MWES farm classes we now have the ability to create a panel of data that describes regional differences in sheep and beef production costs and economic productivity over the last 20 years.

This paper describes work in progress. When finalised, we will make our map of farm classes publicly available. Please visit http://www.motu.org.nz/land_use_nz.htm for more details.

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Appendix

Figure 7 Map of Rural Land Values

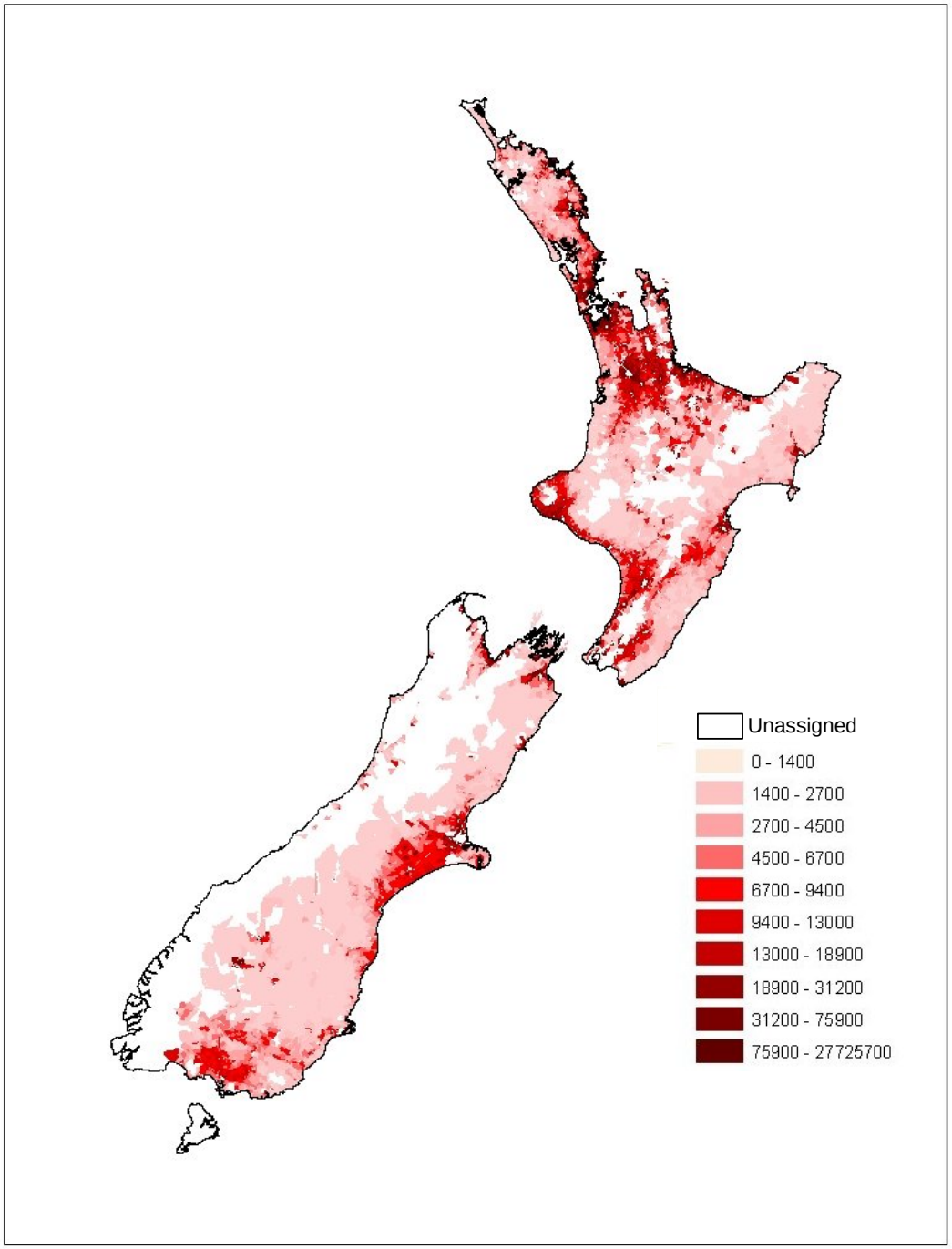

Figure 8 Map of Land Use Capability

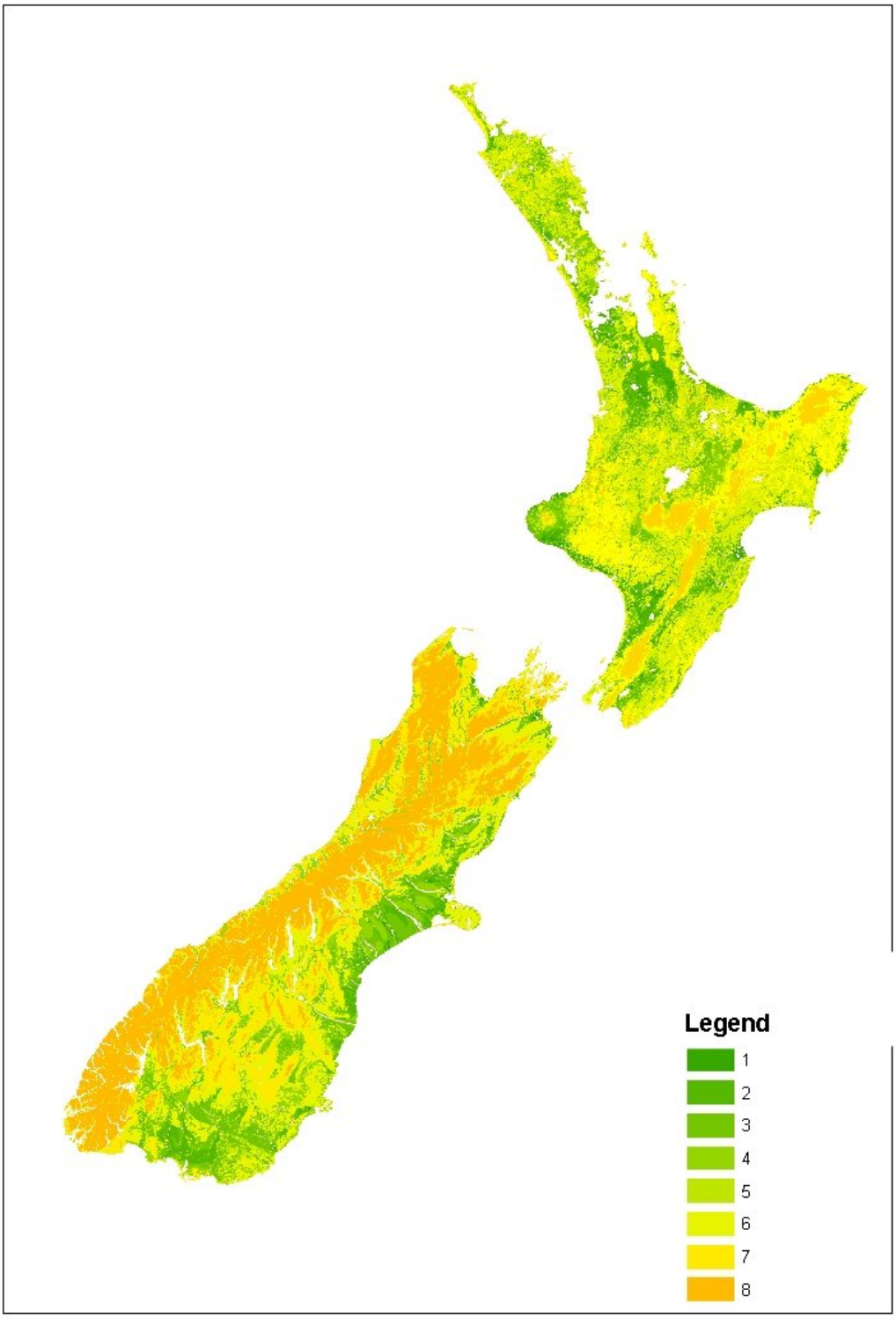

Figure 9 Map of CCAV indicating Stock Carrying Capacity.