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# **Natural Amenities and Age Related Population Change in New Zealand.**

A thesis (90 – Point)

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**Abstract:**

Modern day migration literature suggests that natural amenities play a significant role in attracting migrants and thereby influencing population change. Empirical studies however, often find natural amenities of little significance. It can be argued that these conflicting findings are a result of the empirical complexity of representing amenities as well as the way in which causal relationships have been identified.

The effects of population change are not evenly distributed across New Zealand, with growth typically being focused on the main metropolitan areas, while other areas are experiencing population stagnation or decline. Queenstown is experiencing rapid population growth in all ages (with the exception of 20-29). This uncharacteristic migration is argued to partially be due to the regions high level of natural amenity.

This study uses three separate natural amenity indices as well as proxies for the main migration related drivers of population change in order to answer our central question; *Are natural amenities a significant factor in determining age related population change in New Zealand?* Global and exploratory local models have been run for six age groups each representing a demographic group in New Zealand. While there is much room to improve these models in the future the local models have identified several significant areas in New Zealand where there is predominately a positive relationship between natural amenities and population change.

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## **Chapter 1 : Introduction and Motivation**

Population change in New Zealand is seeing the average age of the population rise while the rate of population growth is low compared to the immediate post war period. Current population growth in New Zealand is mainly occurring in main metropolitan areas. Other less populated areas are experiencing population stagnation or decline and out migration of younger adults.

Thames-Coromandel District Council are facing in-migration from the older age groups and out-migration from younger age groups, and Queenstown is experiencing rapid population growth in all ages (with the exception of 20-29) (2006 - 2013 Census). It is assumed that this population growth is occurring for a reason other than the main migration related drivers of population change (employment, access to education and health services (Statistics New Zealand, 2007)). Anecdotal evidence suggests that this uncharacteristic growth in Queenstown is partially due to "the exceptional natural environment and outstanding recreational opportunities [making this] district a favoured destination for tourists and amenity migrants" (Woods, 2009, p. 370) there is a need however to empirically substantiate this claim.

There is little research into the role of natural amenity in New Zealand population growth. Internationally, some studies found that natural amenities are a significant factor of migration and others found them of little significance. Chi and Marcouiller (2009) argue that, "these conflicting findings... are due both to the empirical complexity of amenities and to the partial approach used in isolating causal relationships". These findings indicate a knowledge gap in New Zealand.

This thesis is part of the 'sub-national mechanisms of the ending of population growth: Towards a theory of depopulation' Marsden research

project. This project seeks to integrate demographic and migration transition theories to provide a substantive account of the mechanisms of sub national decline in New Zealand. This thesis broadly focuses on how to measure natural amenity as an aspect of population change in New Zealand. Particular emphasis will be placed on the age related nature of these changes. The central question to be addressed will be; *“Are natural amenities a significant factor in determining age related population change in New Zealand?”*

The second chapter of this thesis focuses on providing the context of this research. Literature on population change and natural amenities is evaluated to find a knowledge gap in New Zealand. The chapter then goes on to explore how best to represent natural amenity as an aspect of population change including available regression techniques.

Chapter three focuses on the methods used in this research. The raw data is outlined in the beginning of the chapter followed by the GIS processing required to convert all the data into one spatial frame. The chapter concludes with explaining how natural amenity is measured and how it is analysed as a determinant of population change.

Chapter four contains the results from the analyses beginning with how natural amenity is represented and ending with a local model showing the significant areas where natural amenity effects population change.

The fifth chapter of this thesis comprises of the considerations for future research and conclusions.

## **Chapter 2 : Literature Review**

### **Context:**

#### **Population Change**

Compared to the immediate post war period population growth in New Zealand is low, and the average age of the population is rising (see Figure 2-1 where there is a greater level of population growth in the older age group 65+ than the younger age group 15-24). Jackson (2014) states; "Driven by structural population ageing that eventually results in more deaths than births, the national trends are typically foreshadowed by the inexorable spread of sub-national depopulation" (p.4). In New Zealand sub-national depopulation is already occurring. Although, the population in New Zealand is still growing strongly at a national level, decline is occurring in 20 of the 72 territorial authorities and 654 of the 1896 census area units (Statistics New Zealand, 2013).

Population growth can occur as a result of internally driven population change rather than migration. Growth and decline in age groups occurs as small cohorts replace large cohorts and vice versa. Following the end of World War II (between 1946 and 1965) there was a period of high fertility rates and high numbers of births. This high fertility period known as the baby boom has resulted in a large cohort of people currently aged between 50 and 69 and a second echo of high fertility where the children of the baby boomers began passing through the ages of reproduction from the late 1980's (Jackson, forthcoming).

During 2006 the baby boomers would have been aged between 41 and 60 moving into the 55-64 and 65+ age groups by 2013. Some of the large increases shown in these age groups can be explained by the movement of baby boomers into these older age groups.

Figure 2-1 shows the usually resident population, percentage population change at the age groups 15-24, 25-39, 40- 54, 55-64, 65+ (representing; young adults, family formation. career, late working and retirement groups) from 2006 - 2013. Each age group represents a different New Zealand demographic classification and as shown in the maps population change does not occur evenly across all age groups.

15-24 year olds represent the young working population. They are the labour market entrants and are the immediate future reproductive age group. At the lower end of this age group teenagers are expected to mainly move with their parents however in the later section of this age group people are likely to move by themselves to pursue higher education, relationships and better job opportunities. In New Zealand while most urban areas (or areas contiguous to them) have seen an increase in 15-24 year olds rural areas appear to be facing decline. It is thought that once there are fewer 15-24 year olds than 55+ year olds you are getting close to the end of growth in the working age population.

The family formation age group is represented by 25-39 year olds. This age group contains the main reproductive ages (30 - 34) (Statistics New Zealand, 2011) and are known to move because of promotion, better housing, better likelihood of finding a partner and better access to schooling. Figure 2-1 shows that there is substantial decline (more than 15%) in this age group across New Zealand with the growth again occurring predominately in and around urban centres. It can also be noted that all depopulating TAs in New Zealand have a lower percentage of 25-39 year olds than the national average (2013 census).

40-54 year olds make up the career age group where migration is often caused by the demand for better housing, work promotion, some partnering and partners job opportunities. Couples in this age group are also likely to have older children and are consequently likely to move for better secondary

and tertiary education. Between 2006 and 2013 there has been some rural decline in this age group (blue areas figure 2-1 40-54) however there is still substantial growth in many CAU particularly those close to urban centres (maroon areas 2-1 40-54).

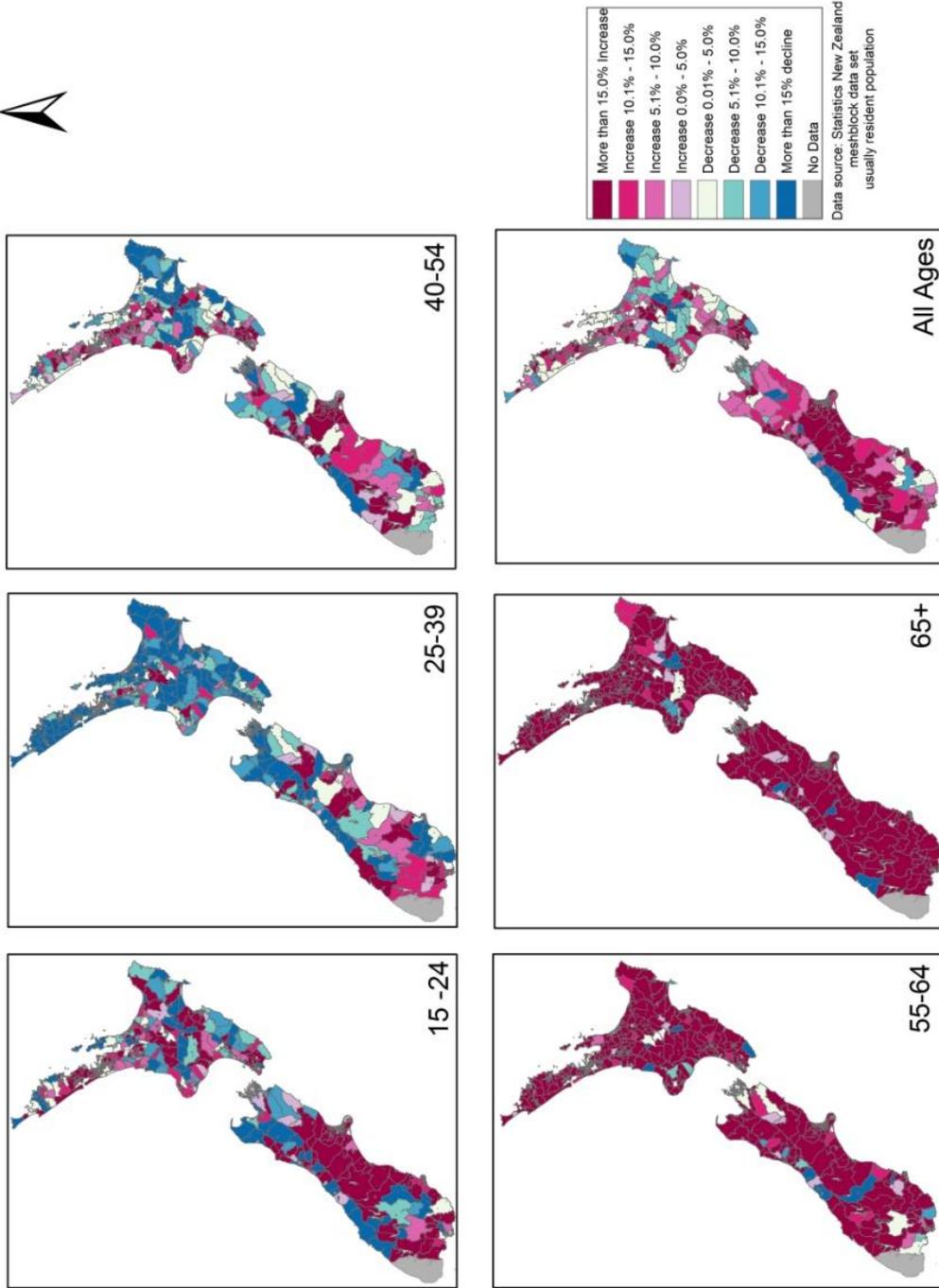
The late working population (55-64) denotes those people entering the retirement 'zone'. 55-64 year olds make up the largest labour market exit group and are currently growing significantly right across New Zealand (see maroon (growth larger than 15%) figure 2-1 55-64).

The final age group is 65+. This age group is best split into 65-74 (early retirement) and 75+ (Retirement) however this data is not readily available at a CAU level and consequently the early retirement and retirement groups have been joined together. These groups mainly move due to retirement and proximity to services however sizeable amounts of growth have occurred in the majority of CAU between 2006 and 2013 (see figure 2 -1).

Some migration literature shows that high amenity areas attract working age adults and retirees(Rickman & Rickman, 2011). "A common finding in the migration literature is that natural amenities are significant factors influencing location decisions of individuals and firms" (Nilsson 2014, p.46).

It is possible that natural amenity will impact on age groups in different ways. Statistics New Zealand states; "The relative importance of the types of reasons for moving from a residence may also vary... with different stages of people's life cycles"(2007).

**Population Change 2006 - 2013:**



*Figure 2-1 Usually Resident Percentage Population Change 2006 - 2013*

## **Population Change and Amenity Preference**

The main drivers of migration-driven population change in New Zealand are employment, access to education and health services (Statistics New Zealand, 2007). A visual representation of this population change can be seen in Figure 2-1 where substantial growth (warmer colours) can be seen in and around major New Zealand cities with patches of decline (represented by the cooler colours) in more rural areas.

While this pattern holds generally true, some areas diverge markedly from this trend. For instance Thames-Coromandel District Council are facing in-migration from the older age groups and out-migration from younger age groups, and Queenstown is experiencing rapid population growth in all ages (with the exception of 20-29). This uncharacteristic migration is partially due to "the exceptional natural environment and outstanding recreational opportunities [making] the district a favoured destination for tourists and amenity migrants" (Woods, 2009, p. 370).

Areas with high amenity experience increased tourism because of greater availability of outdoor activities (Deller et al., 2001; Lewis, Hunt, and Plantinga, 2002; Weiler and Seidl, 2004; Monchuk et al., 2006). "Continued increases in consumption demand for amenities and recreational activities, fuelled by rising income, increased wealth and ageing of the population, could be expected to be the engine of future growth in high-amenity areas" (Rickman & Rickman, 2011, p.864)

Human landscape preference is not an area which has historically been well explored, however over the last 10 years use of public participation GIS (PPGIS) to identify landscape values has increased. The majority of this research has been motivated by environmental planning needs and has focused on a relationship between a single value and a landscape component. Tyrväinen, Mäkinen and Schipperijn (2006) find that "the social values of

urban woodlands are not always sufficiently taken into account in decision-making (on urban land-use and green space planning) ” (p.5). They consequently attempt to quantify the experienced values of urban green areas and integrate them back into the planning process.

Brown and Reed (2009) use PPGIS in a similar fashion for national forest planning in the United States and Raymond and Brown (2011) use PPGIS for climate change planning by collecting information about perceived landscape values and climate change risks. Brown & Brabyn (2012) look to “extend psychophysical analysis of landscapes by examining the relationships between multiple landscape values and physical character” (p. 317).

Research such as that done by Alessa, Kliskey, & Brown (2008) advances the concept of a coupled social–ecological system (SES), where human and biophysical systems are closely linked, to examine and explain variations in landscape values perceived by people in their region.

It is suggested by stated preference studies that New Zealanders place a high value on biodiversity and environmental restoration. The lack of revealed preference methods used in New Zealand makes it difficult to quantify the impact of natural amenities on population change. "As a next best alternative, international studies [can give a] general indication of the impact of proximity to environmental amenities such as forests, wetlands, and the coast" (Moller, 2012).

Moller (2012) reviewed eighteen overseas and five New Zealand case studies to identify instances where properties were preferred. He found that people preferred property that:

1. offers good views, especially overlooking water (sea, lakes, rivers and estuaries)
2. has a diversity rather than uniformity of views
3. is relatively close to cities or towns that supply services, employment and schools
4. provides reliable vehicle access and proximity to an

airport 5. provides or is close to recreational opportunities (swimming, boating, fishing, tramping, skiing) 6. is near the coast 7. has a reliable water supply 8. includes some forest, though is not predominantly forested 9. provides a diverse landscape with fragmented forest patches and more complex natural forest edges 10. is close to wildlife habitat, wilderness and/or protected natural areas 11. is contributing active restoration of biodiversity and ecosystems 12. is close to but not immediately next to rivers and wetlands 13. is not at risk of flooding 14. does not have odours or insects 15. has productive potential (forestry or agriculture) (Moller, 2012).

### **Representing Natural Amenity**

Defining natural amenity is a tricky task and there is a multitude of definitions in the literature. "Definitions of natural amenities vary widely, as different researchers focus on different sets of variables" (Chi & Marcouiller, 2013). Rickman & Rickman (2011) define natural amenities as "the physical and ecological characteristics of an area that make it attractive". Physical and ecological characteristics include; "terrestrial and aquatic landscapes, distinguishing topographical features, climate, air, water and biodiversity quality and quantity" (Moss, 2006, p. 8).

There has been a number of studies in the last decade which attempt to understand the role of natural amenities. Most use similar variables concentrated around representing natural, recreational and climate related amenities. Deller et al (2001) used five broad based indices of amenity and quality of life to capture the role of natural amenities in economic growth. The indices were based on climate, land, water, winter recreation and developed recreational infrastructure each contained a number of variables fitting into that category. Chi and Marcouiller (2013) in their 2012 study about natural amenities and their effects on migration along the urban-rural

continuum used seven directly measured variables; presence of forests, water, wetlands, public lands, golf courses and viewsheds.

In a New Zealand context there are few examples of natural amenity indices. Amenity studies have focused either on recreation opportunity or the impact of amenity on housing prices. The Department of Conservation (DOC) uses a Recreation Opportunity Spectrum (ROS) as a basis of recreation planning. "Planning techniques like the Recreation Opportunity Spectrum (ROS) were developed and applied, to identify the range of settings appropriate for different recreation activities from wilderness to front-country which caters for a wider section of potential visitors" (Department of Conservation, 1996, p.6). "The ROS, although based in public conservation areas, helps to provide a good understanding of the different types of recreational experiences people choose, and the variety of opportunities, facilities, and levels of protection that might be required to enhance people's recreational enjoyment" (Environment Canterbury, 2009).

Measuring amenities has historically been a problem for researchers. Many examples in the literature aim to find the market value of natural amenity (Knetsch, 1962; Kitchen & Hendon, 1967; Darling, 1973; Weicher & Zerbst, 1973; Hammer, Coughlin & Horn, 1974; Correll, Lillydahl & Singell, 1978; Schroeder, 1982). Allen, Steven and More (1985) however, "warn that property value studies may under estimate the value of parks [amenity] because they do not capture benefits enjoyed by distant users"(Bicknell & Gan, 1997, p.11). Deller et al (2001) states "the empirical representation of amenity attributes has tended to be single dimensional, simplistic, and to a large extent ad hoc" p.356. This is mainly because there is no market to derive a dollar value from (Kahsai et al, 2011). Many other approaches to measuring amenities can be found in the literature; including single factor, a summary index approach and principal component analysis.

Single factor analysis such as that used by Duncombe, Robbins and Wolf (2002) provides many positives in measuring amenities. This kind of analysis tries to include all relevant amenity attributes, is straight forward for marginal analysis and provides easy to interpret results. Nevertheless, multicollinearity issues or omitted variable bias may occur as too many or too few variables are included in the analysis.

The summary index approach “defines natural amenities as a single index of different amenity attributes” (Kahsai et al, 2011). Historically the summary index approach was the most commonly used technique in creating natural amenity indices. It has been used by the likes of Duncombe, Robbins and Wolf (2000) and McGranahan (1999) who both generated amenity indices containing climate, water and topographic variables.

The summary index approach is a broader measure than single factor nevertheless; this approach is not free from criticism. Kim et al (2006) has concerns relating to "using a single summary index to represent the heterogeneous nature of natural amenity distributions" (p.277) and about the subjective-ness of deciding which variables to include in the analysis. Kahsai et al (2001) assert that the summary index approach "is criticized for being uni-dimensional in representing the very diverse nature of amenity distributions... and for the subjectivity incorporated in the decisions about which amenity attributes should be included to develop the index".

One method frequently used to construct summary indexes of natural amenity is principle component analysis (PCA) (English et al., 2000; Deller et al., 2005; Marcouiller et al., 2004). This form of factor analysis compresses a block of variables describing a particular attribute into a single measure. Miller (1976) proposed that a group of variables which describe a particular attribute can be reduced to a “single scalar measure that represents the information contained in the original data” (Deller, Tsai, Marcouiller, &

English, 2001). Principal component analysis is a way of achieving Miller's 1976 theory.

Principal component analysis (PCA) can generate results which may be harder to interpret than those provided by other methods; nevertheless PCA "allows researchers to examine the multidimensional aspects of natural amenity attributes" (Kahsai et al, 2011). Deller et al (2001) used PCA to create five sets of amenity variables to substantiate the role of amenities and quality of life in rural economic growth.

### **Regression Analysis**

There are disparities in the natural amenity literature where, some studies find that natural amenities are a significant factor of migration and others find them of little significance. "These conflicting findings, we argue, are due both to the empirical complexity of amenities and to the partial approach used in isolating causal relationships. Most previous studies examine the effect of natural amenities on migration without controlling for other influential factors such as demographic characteristics [and] socioeconomic scenarios" (Chi & Marcouiller, 2009).

Not controlling for other influential factors can lead to problems with omitted variable bias<sup>1</sup> (in ordinary least squares regressions). Elhorst's (2003) paper about regional unemployment differentials has become somewhat of a benchmark for what variables one should include to avoid this. Elhorst outlines a number of explanatory variables of regional unemployment which have often been used in migration and population modelling.

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<sup>1</sup> Omitted variable bias occurs when an independent variable that is correlated with the dependent variable (and another independent variable) is excluded from the model. The model then compensates for the missing variable by over or under estimating the effect of one of the other variables.

One of the most applicable of Elhorst's variables is industry mix. Industry mix comprises of the location of declining and growing industries. Regions with significant declining industries can face generally high levels of unemployment and low levels of in migration; whereas, regions with significant growing industries can conversely face low levels of unemployment and higher levels of migration (Elhorst, 2003).

The second of Elhorst's variables discussed here is that of the educational attainment<sup>2</sup> of the population. Educational attainment "provides a proxy for the quality of human capital in a region which represents an important new (or endogenous) growth indicator(Ehrlich 1990) and a key factor involved in wage inequality" (Kim, Marcouiller, & Deller, 2005).

The level of education a population has, can affect the impacts of unemployment rates. Where "regions with higher-than-average unemployment rates [for the lower educated] provide no motive for outward migration for the lower educated" (Elhorst, 2003, p.738) but do not deter better educated migrants from immigration. It is the lower educated that also face barriers to the housing market which are outlined in the next paragraph.

Economic and social barriers such as those raised by the housing market, government's social security and general tightness of the labour market are also significant factors in migration. Barriers raised by the housing market centre around ownership and pricing of houses where; the proportion of households in publicly owned housing and the proportion of households in the owner operator sector both have a positive relationship with unemployment. This can be understood as both these groups face greater mobility restrictions than those in privately rented accommodation. "The rate of mobility of public tenants, owner-occupiers and private renters is approximately 0.3 to 1 to 1.7" (Elhorst, 2003, p.736). Elhorst (2003) also

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<sup>2</sup> . Educational attainment refers to the highest level of education an individual has completed.

mentions the negative relationship between house price and unemployment (caused by the considerable variation in consumer spending when fluctuations in the housing wealth occur). Evans and McCormick (1994), and Molho (1995a, 1995b) found empirical evidence that this relationship is negative. Elhorst (2003) states "If these barriers severely restrict mobility, then weak labour demand in a region will raise the unemployment rate there above that in regions with stronger labour demand" (p.736).

Another example of economic and social barriers are those created by the government's social security policy. Although, there is little variation in social policy across regions in New Zealand and Europe social security can vary substantially across regions in the US States and the Canadian Provinces. Those regions with good social security options have a decreased cost of being unemployed and consequently face reduced migration (as the population deters job searches). Eight out of nine studies "that have investigated the effect of the availability and generosity of the social security system... found empirical evidence in favour of the assumed positive relationship" (Elhorst, 2003, p.737).

The final example of economic and social barriers is those caused by the tightness of the labour market. "In a slack labour market, job opportunities dry up, partly because employers would find it less necessary to advertise vacancies outside their local region, and migration drops as a consequence" (Elhorst, 2003, p.737).

Chi and Marcouiller (2012) use a number of explanatory controls in their paper about natural amenities and their effects on the urban-rural continuum. The "explanatory controls include two demographics indices (age structure and race), three liveability indices (wealth and education, modernization, and luxury), two accessibility indices (proximity and infrastructure, and public transportation), and one land develop-ability index that are generated from 32 variables" (Chi & Marcouiller, 2012).

In their (2000) paper about natural amenities and population growth Hansen and Rasker use eight explanatory controls to represent the relationship between population growth and economic and social variables. These independent variables are; the percentage of population over 18 years old with a college degree, the number of colleges and universities in the county, serious crimes known to police per 100,000 people, counties where over 15 percent of personal income is earned in producer service, percent of total employment in business services, community hospital beds per 100,000 people, percent of total employment in hotels and lodging, percent of total employment in real estate and percent of total employment in health services.

Another influential factor when measuring the effect of natural amenity on population change is spatial autocorrelation. In his 1970 paper Tobler stated "I invoke the first law of geography: everything is related to everything else, but near things are more related than distant things". In an essence the issue Tobler was referring to is now recognised as spatial autocorrelation. According to Anselin and Bera (1998),

Spatial autocorrelation can be loosely defined as the coincidence of value similarity with locational similarity. In other words, high or low values for a random variable tend to cluster in space (positive spatial autocorrelation) or locations tend to be surrounded by neighbours with very dissimilar values (negative spatial autocorrelation). (p.241)

When spatial-autocorrelation is present non-spatial regression specifications that exclude spatial effects from a model specification can lead to estimates that suffer from omitted variable bias (LeSage, 2014). "When errors are spatially correlated [one of] the problem[s] with using ordinary least squares (OLS) is that the usual standard estimator tends to underestimate the true standard error. The inefficient variance estimators

affect levels of statistical significance and lead to incorrect policy implications" (Kim et al., 2005).

In order to decide on a spatial regression model one must first work out whether the spatial spillovers are global or local. A global spatial spillover occurs when endogenous interaction<sup>3</sup> and feedback effects are present. For example, a "resource shared by numerous regions such as a highway (or river) can be one cause of global spillovers. Congestion (or pollution) on a highway/river segment passing through one region can produce impacts on all other regions through which the highway/river passes". (LeSage, 2014, p.15) A local spatial spillover occurs when this endogenous interaction and associated feedback effects are not present and is the most common form of spatial spillover. LeSage (2014) states "an oft-quoted statement is that "all politics is local", which is meant to imply that national congressional representatives react most strongly to issues of concern to local constituents. A similar statement could be applied to spatial regression models, taking the form: "most spatial spillovers are local"" (p.14).

There is an overwhelming number of alternative model specifications discussed in the literature. Prior to 2007 spatial econometricians were mainly interested in models containing one type of spatial interaction effect: the spatial error model[SEM]<sup>4</sup> and the spatial lag model [SLX]<sup>5</sup> Anselin's influential 1988 book *Spatial Econometrics: Methods and Models* and his 1996 paper *Simple diagnostic tests for spatial dependence* have often been described as the leading literature for this way of thinking (Elhorst, 2010).

After 2007 the interest in models containing more than one spatial interaction effect increased. In his keynote speech at the first World

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<sup>3</sup> "Endogenous interaction leads to a scenario where changes in one region/agent/entity set in motion a sequence of adjustments in (potentially) all regions in the sample such that a new long-run steady state equilibrium arises" (LeSage, 2014, p.15).

<sup>4</sup> The SEM is a model specification which incorporates a spatial autoregressive process in the error term.

<sup>5</sup> The SLX is a model specification which contains a spatially lagged dependent variable.

Conference of the Spatial Econometrics Association in 2007, Harry Kelejian advocated models that include both a spatially lagged dependent variable and a spatially autocorrelated error term (based on Kelejian & Prucha, 1998 and related work), while James LeSage, in his presidential address at the 54th North American Meeting of the Regional Science Association International in 2007, advocated models that include both a spatially lagged dependent variable and spatially lagged explanatory variables. In analogy to Durbin (1960) for the time series case, Anselin (1988) labelled the latter model the spatial Durbin model [SDM]. (Elhorst, 2010)

LeSage (2014) argues that there are only two model specifications worth considering when using spatial regression models in applied work. He recommends the use of a spatial Durbin model (SDM) for global spillover specifications and a spatial Durbin error model (SDEM) for local spillover specifications.

The SDM is a global spillover specification [introduced by Anselin in 1988] taking the form:  $y = \rho W y + \alpha n + X\beta_1 + W X \beta_2 + \varepsilon$ . This model includes a spatial lag vector  $Wy$  representing a linear combination of values of the dependent variable vector from neighbouring observations, as well as a matrix of own region characteristics  $X$ , and a matrix of characteristics of neighbouring regions ( $WX$ ) as additional explanatory variables." (LeSage, 2014, p.17) In simple terms the SDM has a spatially lagged dependent variable ( $Wy$ ) and spatially lagged independent variables ( $Wx$ ).

"One strength of the spatial Durbin model is that it produces unbiased coefficient estimates also if the true data-generation process is a spatial lag or a spatial error model. Another strength is that it does not impose prior restrictions on the magnitude of potential spatial spillover effects. In contrast to other spatial regression specifications,

these spillover effects can be global or local and be different for different explanatory variables" (Elhorst, 2010)

The SDEM is a local specification which allows for local spillovers to neighbouring observations through spatial lag term. This spillover specification has spatially lagged independent variables (WX) and a spatially autocorrelated error term. The SDEM takes the form:

$$y = X\beta_1 + W X\beta_2 + u$$

$$u = \lambda W u + \varepsilon$$

$$\varepsilon \sim N(0, \sigma^2 \varepsilon I_N)$$

This model is very adaptable and effectively represents a number of local specifications. When there is no spatial dependence in the disturbances it subsumes the spatial lag of x model specification (SLX) and when there are no local spatial spillovers it subsumes the spatial error specifications (SEM). When there is no spatial dependence and no local spatial spillovers the SDEM model is the same as an ordinary non-spatial regression model.

When considering a model for spillover specifications the spatial autoregressive combination (SAC)<sup>6</sup> model is often one of the first considered. The SAC model can provide increased efficiency when the model disturbances exhibit spatial dependence. However, the SAC specification has been criticised due to its severe restriction on partial derivatives<sup>7</sup>. "Needless to say, this is an extremely restrictive aspect of the simultaneously autoregressive model (SAR)<sup>8</sup> as well as the SAC specifications, which should

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<sup>6</sup> The SAC model has a spatially lagged dependent variable (WY) and a spatially autocorrelated error term (Wo).

<sup>7</sup> "That is, if explanatory variable X1 has a direct effect of 1 and indirect effect of 0.5, then explanatory variable X2 must also have a direct effect that is twice that of the indirect effect, as do all other explanatory variables (see Elhorst, 2010)." (LeSage, 2014, p.20)

<sup>8</sup> The SAR model specification or spatial lag model contains only one interaction effect (endogenous interaction effects).

make them relatively unattractive compared to the SDM and SDEM specifications for use in applied situations"(LeSage, 2014, p.20).

Chi & Marcouiller (2012) use an OLS regression model as a starting point for examining effects of natural amenities. Due to the fact "Ignoring spatial autocorrelation and estimating using OLS leads to inefficient standard errors which in turn affects the significance levels of the variables" (Kahsai et al., 2011, p.80 ) their model was checked for the existence of spatial dependence. It was found that a spatial lag model was more appropriate for examining the effects of natural amenities on migration and a spatial regime model<sup>9</sup> was used to deal with issues of spatial heterogeneity (see section on spatial non-stationarity).

A spatial lag of the dependent variables was used by Nzaku and Bukenya (2005) to capture spatial dependence. "Recent works of Kim et al. (2005, 2007), Monchuk and Miranowski (2007) [and others] also used a spatial model to control for the unobserved spatial distribution of amenities in the region"(Kahsai et al., 2011, p.80). Other than Monchuk and Miranowski (2007) these authors did not try to estimate the spatial impacts of surrounding county amenities. "Thus, their studies reflect only the direct effects of local amenities on the regional growth indicators ignoring the spillover effects coming from surrounding counties"(Kahsai et al., 2011, p.80). Kahsai et al., (2011) extends past these studies by capturing both the direct and indirect effects of amenities through the use of a SDM.

The importance of natural amenities in population change has been shown in a large body of literature (c.f., Brown et al. 1997; Deller et al. 2001; Clark and Hunter 1992). However, some of the literature has concluded that natural amenities have little influence on population change (c.f., Kim et al. 2005; Lewis et al. 2002). Chi and Marcouiller argue that these conflicting findings

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<sup>9</sup> spatial regime model is a model which contains different intercepts and/or slopes in the regression equation for spatial subsets or clusters of the data.

are a result of not only the empirical complexity of measuring amenities and the partial approach used in isolating causal relationships but also due to spatial heterogeneity in the effects of natural amenities. (Chi & Marcouiller, 2012).

"The conflicting findings are further argued to be due to the existence of spatial heterogeneity in the migration effects of natural amenities, that is, the migration effects of natural amenities vary spatially (Partridge et al. 2008a). The effects vary spatially because local areas are likely to exhibit spatial variation in their growth mechanisms, areal characteristics, resource endowments, and temporal contexts." (Chi & Marcouiller, 2012)

This spatial variation is often referred to as non-stationarity. "In essence, the process we are trying to investigate might not be constant over space" (Fotheringham, Brunson, & Charlton, 2002, p.9). Fotheringham, Brunson, & Charlton (2002) affirm that social processes often appear to be non-stationary: "the measurement of a relationship depends in part on where the measurement is taken" (p.9). They go further to compare stationary processes to more physical applications such as the famous relationship relating to energy and mass in physics. That is " $E = mc^2$ , is held to be the same no matter where the measurement takes place: there is not a separate relationship depending on which country or city you are in" (p.9).

Any relationship that varies over space will not be particularly well represented by a global statistic, in fact, this global statistic may be very misleading locally (Fotheringham et al., 2002). Brudson et al (1996) state "spatial non-stationarity is a condition in which a simple 'global' model cannot explain the relationships between some sets of variables" (p.280). Fotheringham et al (2002) identifies several possible causes of relationships varying over space. Firstly a simple sampling variation issue where if spatial

subsets were taken for a dataset and then the model was calibrated separately for each of the subsets. There would be some variation in the parameter estimates due to the different samples used (see Fotheringham 2002, p.9). Secondly some relationships are intrinsically different across space. "Perhaps, for example, there are spatial variations in people's attitudes or preferences or there are different administrative, political or other contextual issues that produce different responses to the same stimuli over space" (Fotheringham et.al, 2002, p.9). A third possible cause "is that the model from which the relationships are estimated is a gross misspecification of reality and that one or more relevant variables are either omitted from the model or are represented by an incorrect functional form"(Fotheringham et.al, 2002, p.10).

Interest in local regression modelling has been growing since the recognition that global models are of very limited use in situations where behaviour varies over space. This kind of thinking has been around since at least Linneman's calibration of the origin-specific models of international trade flows (Linneman, 1996). The school of thought focuses on the fact that the calibration of global models represents an 'average' type of behaviour and therefore cannot represent relationships which vary over space (Fotheringham et al, 2002).

Fotheringham (1997) remarks that the emergence of an array of techniques for local modelling is notable for several reasons. "Among these are that it refutes the criticism that those adopting a quantitative approach to investigate spatial processes are only concerned with the search for broad generalisations and have little interest in identifying local exceptions" (Fotheringham et al., 2002). Secondly, techniques for local modelling also provide a link between the visual capabilities of GIS and the outputs of spatial techniques allowing for a new level of visual representation. Lastly they aid us to a better understanding of spatial processes and model development by providing us with more information on spatial relationships.

Local statistics and local models provide us with the equivalent of a microscope or telescope; they are tools with which we can see so much more detail. Without them, the picture presented by global statistics is one of uniformity and lack of variation over space: with them, we are able to see the spatial patterns of relationships that are masked by the global statistics. (Fotheringham et al., 2002).

One approach to regression modelling which allows spatially varying relationships is Casetti's expansion method (Casetti 1972; Casetti and Jones 1992). "In this framework, parameters in a global model can be made functions of geographic space so that *trends* in parameter variation over space can be measured (inter alia, Fotheringham and Pitts 1995; Eldridge and Jones 1991) " (Brunsdon et al 1996, p.282). Though this method has been important in promoting awareness of spatial non-stationarity and is a good guideline for which models can be developed it does have several limitations (see Fotheringham et al, 2002, p.17). Brudson et al, (1996) claims "it is a trend-fitting exercise which is of limited use in situations where parameters exhibit complex variation over the space being studied" (p.282).

Spatially adaptive filtering (SAF) is a second approach to regression modelling which allows coefficients to vary locally (Widrow and Hoff, 1960; Trigg and Leach, 1968). Foster and Gorr (1986) and Gorr and Olligschlaeger (1994) suggest that adaptive filtering ideas can be applied to spatial data in order to investigate the 'drift' of regression parameters (see Fotheringham et al, 2002, p.17). This approach is considered to be of limited applicability as it has been known to "incorporate spatial relationships in a rather ad hoc manner and produce parameter estimates that cannot be tested statistically." (p.282)

Another local modelling technique is Geographically Weighted Regression (GWR). GWR is an exploratory technique which "allows the actual

parameters for each location in space to be estimated and mapped as opposed to having a trend surface fitted to them” (Brunsdon et al 1996, p.282). "For the purpose of exploring spatial variability and local nature of amenity valuations...the GWR approach has been increasingly used in the literature (Brunsdon, Fotheringham, & Charlton, 1996; Fotheringham, Brunsdon, Charlton, & Fotheringham, 2002)."(Nilsson, 2014. p.47).

Partridge, Rickman, Ali & Olfert (2008) explain that in contrast to global approaches for each observation (area) GWR can estimate separate coefficients. In estimating each individual region's own regression, "characteristics of the individual areas included in the sub-sample are weighted by their spatial proximity. Spatial weighting smoothes variation in parameter estimates, revealing broad regional differences in the local marginal responses."(Partridge, Rickman, Ali, & Olfert, 2008)

Nilsson (2013) used GWR techniques to calculate the value of amenities in urban space. The paper particularly focused on examining spatial heterogeneity in the benefits of proximity to open space amenities. The GWR model can account "for spatial heterogeneity in responses to variables by estimating separate regressions for each sample observation including the location of interest and other spatially weighted observations (Fotheringham, Brunsdon, and Charlton 2002). The weights represent the adjacency effects for neighboring locations within a specified distance (or bandwidth) " (Partridge et al., 2008).

## **Summary**

While the relationship between population growth and natural amenities has been a topic of great discussion overseas there are few local examples. Overseas literature has typically represented natural amenity with sets of variables focused around natural, recreational and climate based amenities.

Regression techniques have produced mixed results with modern day literature showing concern about some previous results. Some past regression techniques fail to control for additional influential factors of population change and others fail to account for the spatial variations of amenity. GWR techniques can account for these spatial variations by estimating separate equations for each region.

## Chapter 3 : Methodology

This research did not involve the collection of any primary data. The New Zealand Landscape Classification Version II (the basis of the natural amenity index) and the Landcare Research climate data was generously provided by Lars Brabyn and the rest of the data required was readily available through the Statistics New Zealand and Land Information New Zealand (LINZ).

In this study geographic units of analysis are developed at the census area unit level (CAU) for the whole of New Zealand. CAUs generally coincide with suburbs or parts thereof and contain a population between 3,000 and 5,000. This can vary in sparsely populated areas within urban area boundaries.

### Data

This section outlines the raw data used in the analysis of this project.

#### Natural Amenity Data

The data used for the natural section of the analysis was based on New Zealand Landscape Classification Version II (Brabyn, 2009a). The generalised layers were used in the analysis and were based on a variety of sources.

The New Zealand Landscape Classification Landform classification is a morphological classification and is consequently based on the shape of the landform. Slope, relative relief, elevation and neighbourhood analysis radius have been used to differentiate between the different potential landforms.

Generalised Layers:	Original Layers:	Layer Criteria:
Land form:		
High Mountain	High Mountains, Very High Mountains	Slope > 4, Relative relief > 900, maximum elevation > 1800 and neighbourhood analysis radius (m) = 5000

**Landcover:**

The New Zealand Landscape Classification Landcover classification is based on the Ministry for the Environment's (MfE) Landcover 2 dataset. Original definitions of the MfE Landcover 2 data set classes can be seen in appendix A.

<b>Landcover:</b>	<b>Original Layers:</b>	<b>Mfe Landcover 2 data set Class:</b>
Agriculture	Low Producing Grassland, High Producing Grassland	Short-rotation Cropland, High Producing Exotic Grassland, Low Producing Grassland and Depleted Grassland.
Exotic Forest and Scrub	Exotic Forest, Exotic Scrub	Gorse and Broom, Mixed Exotic Shrubland, Afforestation, Afforestation (imaged, post LCDB 1), Forest - Harvested, Pine Forest - Open Canopy, Pine Forest - Closed Canopy, Other Exotic Forest and Deciduous Hardwoods
Indigenous Forest and Scrub	Indigenous Forest, Indigenous Scrub	Fernland, Manuka and or Kanuka, Matagouri, Broadleaved Indigenous Hardwoods, Grey Scrub and Indigenous Forest
Alpine	Alpine Rock, Tussock, Sub Alpine Scrub.	Alpine Gravel and Rock, Sub Alpine Shrubland and Tall Tussock Grassland.
Wetland	Saltwater Wetland, Freshwater Wetland	Herbaceous Freshwater Vegetation, Herbaceous Saline Vegetation, Flaxland and Mangrove

**Water:**

The water component of the New Zealand Landscape Classification “was derived separately using various data sets and then combined into one water component layer” (Brabyn, 2009).

<b>Generalised Layers:</b>	<b>Original Layers:</b>	<b>Layer Criteria:</b>
Water:		
Enclosed Sea	Estuarine, Enclosed Sea	Enclosed sea is mostly deep water and estuarine

		is tidal. (Estuarine was based off the Landcover 2 dataset)
Open Ocean	Open Ocean	Expand and shrink technique was used to distinguish between enclosed sea and open ocean (Brabyn, 1996b)
Lake	Small Lakes, Medium Lakes, Large Lakes	Lakes > 1ha (Identified using GIS and the 1:50;000 topographic data set.
Rivers	Rivers	River layer from the Landcover 2 dataset. (See Appendix A).

**Water View:**

The water view component of the New Zealand Landscape Classification was calculated with GIS. Elevation data and points (representing water components) were used to calculate the number of points which can be seen for each cell of the elevation layer

If a cell had a value of more than one then it had a view of the water. If a cell had a high value then it had an extensive view of water. The visibility of each water component (small lakes, medium size lakes, large lakes, estuarine, enclosed sea, and open ocean) was calculated separately. Where an area had more than one type of water view, such as a lake and sea view, then the view with the most water points dominated....Only contiguous areas greater than 10 ha were used. If an area was within 500m of the coast it was also classified as coastal view. This is because people this close to the sea are likely to hear or smell the sea and are thus experiencing a coastal environment (Brabyn, 2009)

<b>Generalised Layers:</b>	<b>Original Layers:</b>
Water View:	
View of Sea	View of; Open Ocean, Enclosed Sea, Estuarine
View of Lake	View of; Small Lake, Medium Lake, Large Lake

***Climate:***

The climate data used in this analysis was based on the 2002 Landcare Climate Surfaces for New Zealand. Mean monthly estimates of; daily average temperature, total rainfall and daily solar radiation were available; however January and July averages have been used for each variable. January and July averages were used to represent summer and winter climates. As previously discussed in Chapter Two, Deller et al (2001) used similar measures to create an index for climate.

Layer Name:	Source:	Description:
Daily Average Temperature	Landcare - Climate surfaces for New Zealand	Mean monthly estimates of daily average temperature for January and July
Solar Radiation	Landcare - Climate surfaces for New Zealand	Mean monthly estimates of solar radiation for January and July
Rainfall	Landcare - Climate surfaces for New Zealand	Mean monthly estimates of rainfall for January and July

***Recreation:***

The recreation data used in this analysis comes from the Department of Conservation and Land Information New Zealand.

Layer Name:	Source:	Description:
DOC Public Conservation Areas 2009. <ul style="list-style-type: none"><li>• National Parks</li><li>• Reserves</li><li>• Conservation Areas</li></ul>	Department of Conservation	“Spatial representation of DOC’s management units defined by various acts of parliament and legislation. The attributes in this dataset are derived from the (NaPALIS) National Property and Land Information System, which is a centralised database for all Land Information New

		Zealand (LINZ) and Department of Conservation (DOC) administered land” (Koordinates 2014).
New Zealand Boat Ramp Centre Lines	Land Information New Zealand (LINZ)	Boat ramp centrelines layer from the LINZ digital topographic data. Boat ramp defined by LINZ as: “A place for launching or retrieving boats from the water”.
New Zealand Golf Courses	Land Information New Zealand (LINZ)	Golf courses layer from the LINZ topographic data. Golf courses defined by LINZ as: “An area set aside for playing golf”.
New Zealand Ski Lifts	Land Information New Zealand (LINZ)	Ski lifts layer from the LINZ 1:50,000 NZTopo database. Ski lifts defined by LINZ as: “a conveyor system in which carrier units run on wire cables strung between supports for transporting skiers (who sit in a chair or similar construction; ie. not in contact with the ground) up the slope”.
New Zealand Ski Tows	Land Information New Zealand (LINZ)	Ski tows layer from the LINZ 1:50,000 NZTopo database. Ski tows defined by LINZ as: “a conveyor system in which carrier units run on wire or rope cables strung between supports for transporting skiers up the slope - the skier remains in contact with the ground whilst being towed up the slope.”

## Population Data

The population data used in this analysis is the mesh block dataset Usually Resident Population Count at CAU level for 2006 and 2013, by broad age group.. Migration data would be a better dependent variable as it would allow the natural increase component of population change (births minus deaths) to be excluded, however; data for net migration is not available CAU units and would be very difficult to create. Justification for the choice of these age groups was discussed in the regression analysis section of Chapter 2. Methodologically it is also acknowledged that change by broad age group conceals underlying changes in cohort size, with small cohorts replacing larger ones (e.g., currently at 15-19 years) and vice-versa (e.g. at 55+ years). However, because these shifts are more or less similar nationally, their sub-national variations are taken here to reflect different mobility motivations.

Layer Name:	Source:	Description:
Percentage change 15-24	Statistics New Zealand	Percentage change in population 15-24 years between 2006 & 2013 (NZ Census)
Percentage change 25-39	Statistics New Zealand	Percentage change in population 25-39 years between 2006 & 2013 (NZ Census)
Percentage change 40-54	Statistics New Zealand	Percentage change in population 40-54 years between 2006 & 2013 (NZ Census)
Percentage change 55-64	Statistics New Zealand	Percentage change in population 55-64 years between 2006 & 2013 (NZ Census)
Percentage change 65 plus	Statistics New Zealand	Percentage change in population 65 years and over between 2006 & 2013 (NZ Census)

Percentage change total	Statistics New Zealand	Percentage change in total population between 2006 & 2013 (NZ Census)
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### **Social and Economic Data**

The social and economic control variables were sourced from Statistics New Zealand. The following variables attempt to proxy three of Elhorst's explanatory variables outlined in the social and economic data section of chapter two.

Layer Name:	Source:	Description:
Population Density (2001 - 2006)	Statistics New Zealand	Usually resident population per hectare
NZDep2006 (See Appendix B for a full list of NZDep Components).	Statistics New Zealand	New Zealand deprivation score.
Bartik Index (2001 - 2006)	Bartik index calculated from Statistics New Zealand data.	The project growth in employment if the national level industry growth rate is applied to the regional industry structure
Higher Education (2001 - 2006)	Statistics New Zealand	The percentage of the population with a bachelors degree or higher qualification (NZ Census)

The Bartik instrument can be represented by the equation;

$$\hat{L}_{jt} = \sum_k \left[ \left( \frac{\text{National Employment in Industry } k \text{ at time } t}{\text{National Employment in Industry } k \text{ at time } t-1} \right) \times (\text{Area } j \text{ Employment in Industry } k \text{ at time } t-1) \right]$$

Where  $j$  indexes geographic area (CAU) and  $t$  indexes time. Predicted employment in the next period relies only on initial industry composition and national growth rates. An area's own growth is not used in this formula. The Bartik Instrument, then is simply the predicted employment growth rate:

$$\text{Bartik Instrument}_{jt} = \frac{\hat{L}_{jt} - L_{j,t-1}}{L_{j,t-1}} \text{ or } \text{Bartik Instrument}_{jt} = \frac{\sum_k \left[ L_{jk,t-1} \left( \frac{L_{kt}}{L_{k,t-1}} - 1 \right) \right]}{\sum_k L_{jk,t-1}}$$

Maestas, Mullen, Powell, & Labor (2013) "employ the Bartik instrument to act as [their] exogenous change in local labor demand. The Bartik instrument is constructed by using national changes in employment by industry interacted with a geographic area's initial baseline industry composition." (p.7)

### **Measuring Natural Amenity**

Creating a natural amenity index requires the data be all at the same spatial level. The population data was available at Census Area Units (CAU) so this seemed like a reasonable starting point. It is assumed that viewing amenity at a regional or territorial level would lose much of the spatial variance and meaning of the data.

In order to convert the natural data layers to CAU form a Python computer script was used in conjunction with ArcGIS software. The script calculated the proportion of each NZLC layer (outlined in the data section of this chapter) within each CAU in New Zealand. This data was then used in the factor analysis.

The climate data was originally in a surface / in raster format<sup>10</sup>. In order to calculate a single number representing each variable for each CAU the focal statistics tool in ArcGIS was used. The Focal Statistics Tool Calculates for each input cell location a statistic of the values within a specified neighbourhood (CAU) around it.

The recreation data involved the most complex process. 15minute, 1 hour, 2 hour and 3 hour travel times (to represent weekday, and weekend day trips and overnight stays) were calculated from the centroid of each CAU using ArcGIS Network Analysis tools. The proportion of conservation land, national parks and reserves were then calculated (within each of the travel times for every CAU) with a Python script in conjunction with ArcGIS software. The LINZ data was mostly in centre line form and consequently required conversion to point form. The number of points for each recreational variable was then found for each CAU within each travel time. This data was then used in the factor analysis explained in the following section.

### **Creating the Natural Amenity Indices**

The factor analysis for this study was performed in SPSS. SPSS offers five methods of rotation; two methods of oblique rotation (direct oblimin and promax) and three methods of orthogonal rotation (varimax, quartimax and equamax). Choosing a method of rotation can be a very complex task with the choice being based on whether there are theoretical grounds to assume that the factors are independent (Field 2009).

It is recommended that if your factors are likely to correlate (the factors are dependent) then one of the oblique methods should be selected where as if your factors are unlikely to correlate a method of orthogonal rotation is preferred. Unfortunately some level of correlation can be argued for almost

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<sup>10</sup> " In its simplest form, a raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps" (Esri, 2015) .

all factors so the method of rotation depends largely on what suits the data set the best.

The different methods of rotation differ in how they rotate the factors. In terms of orthogonal rotation varimax maximises the dispersion of loadings within factors, whereas quartimax rotation is almost the opposite and tries to maximise the spread of factor loadings for a variable across all factors. Quartimax can be easier to interpret but can result in many variables loading on a single factor. Tabachnick and Fidell (2007) report that equamax (the hybrid approach) behaves unpredictably, consequently for those factor analyses which require orthogonal rotation varimax rotation has been selected.

Oblique rotation can be more complex due to the fact that correlation between variables is allowed. Promax is designed for very large sets of data and direct oblimin determines the degree in which factors can relate with the value delta. For the analyses which there is theoretical grounds to assume that the factors are dependent, direct oblimin with a delta of 0 (high correlation is not allowed) has been chosen.

Individual methods of rotation were picked for each of the principal component analysis and are outlined in the results chapter of this thesis.

Tabachnick and Fidell (2001) cite Comrey and Lee's (1992) advice regarding sample size. 1000 or more cases is excellent, 500 is very good, 300 is good, 200 is fair and 100 is poor (p.588).

Kaiser-Meyer-Olkin (KMO) measure for verifying sampling adequacy "represents the ratio of the squared correlation between variables to the squared partial correlation between variables" (Fields 2009 p647). The KMO varies between 0 and 1. Kaiser (1974) suggests below 0.5 is unacceptable, 0.5 – 0.6 is miserable, 0.6 – 0.7 is mediocre, in the 0.7s is middling, in the 0.8s is meritorious and in the 0.9s is marvellous p.35.

Bartlett's test of sphericity is based on the correlation matrix. Bartlett's test looks at whether this matrix is proportional to an identity matrix. If the correlation matrix resembles an identity matrix then the variables correlate poorly with each other and because with factor analysis we are looking for clusters of variables having zero correlation makes the analysis very poor. If Bartlett's test is statistically significant then the correlations between variables are generally significantly different from zero. (Fields 2009 607)

"The Bartlett Test of Sphericity compares the correlation matrix with a matrix of zero correlations (technically called the identity matrix, which consists of all zeros except the 1's along the diagonal). From this test we are looking for a small p value indicating that it is highly unlikely for us to have obtained the observed correlation matrix from a population with zero correlation. However there are many problems with the test – a small p value indicates that you should not continue but a large p value does not guarantee that all is well (Norman & Streiner p 198) " (Beaumont 2012).

When using oblique rotation there are two different sets of factor loadings due to the difference in the resulting correlations between variables and factors and the corresponding regression coefficients. The first, the structure matrix represents the correlation coefficients for each variable and factor and the second, the pattern matrix represents the regression coefficients for each variable on each factor.

A dependent variable can be constructed from the principal component results by using the first principal component as a weight (Vyas & Kumaranayake, 2006). This independent variable will be regarded as a regions (CAU) natural, recreational or climate score and combined into the final GWR.

## The Regression

"The standard approach in most empirical work is to start with a non-spatial linear regression model and then to test whether or not the model needs to be extended with spatial interaction effects" Elhorst (2010). This thesis has followed this approach by first estimating an ordinary least squares (OLS) regression then estimating an exploratory GWR model.

OLS is one of the best known of all regression techniques. It creates a single linear regression equation to represent the process you are trying to understand. OLS can be represented by the equation;

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon$$

Where  $y$  is the dependent variable,  $\beta$  the regression coefficients,  $X$  represents the independent and explanatory variables and  $\varepsilon$  is the error term/ residuals.

Six OLS models were run one for each of the five age groups and one for the total population. Any CAU with a very small or no population such as lakes and inlets were removed from the data set before running the regression. Following low measures of fit from the OLS models (see results chapter). The amenity variables were tested for spatial autocorrelation using the classic univariate Moran's  $I^{11}$  statistic.

Before calculating the Moran's  $I$  statistic one must first create a spatial weights matrix. There are many different options of spatial weights matrices falling under either contiguity based spatial weights or distance band spatial weights. Contiguity based spatial weights can be created from polygon data and include rook contiguity or queen contiguity based spatial weights. Queen contiguity uses both common boundaries and vertices to define neighbours

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<sup>11</sup> Measure of spatial autocorrelation.

whereas, rook contiguity uses only boundaries. Consequently, spatial weights based on queen contiguity always generates more neighbours.

Distance band spatial weights are the second category of weights matrices and can be created from point data. Distance band spatial weights are based on the distance between points. The spatial data used in this analysis is CAU polygons and distance band spatial weights cannot be computed for this data without polygon to point manipulation.

The univariate Moran statistic was calculated in Geoda for each of the natural amenity variables using a queen's first order contiguity weights file. "Inference for Moran's I is based on a permutation approach, in which a reference distribution is calculated for spatially random layouts with the same data (values) as observed. The randomization uses an algorithm to generate spatially random simulated data sets outlined in Anselin (1986) " (Anselin, 2003, p.91). It is possible to specify the number of random permutations used in constructing the reference distribution. For this analysis 9999 random permutations were used for providing the pseudo significance level. Using 9999 random permutations allows the minimum p-value to show significance at the 99.9% level.

The Moran's I statistics indicated some spatial autocorrelation in the amenity data (see results chapter). As a result of the spatial autocorrelation the OLS model may produce biased standard errors. Lacombe et al (2014) comments:

Reliance on traditional non-spatial estimation techniques for data with known spatial effects is problematic. The presence of spatial error dependence can lead to biased standard errors much like other forms of autocorrelation.... The benefit of utilizing spatial econometric techniques is that they can take into account these econometric issues that may unknowingly bias standard normal linear model results (p.299).

Many options for spatial models were outlined in the literature review in the previous chapter. Of those listed geographically weighted regression (GWR) has been selected due to its ability to account for spatial heterogeneity. GWR generates a separate regression equation for each observation rather than calibrating a single regression equation (Mennis, 2006). "GWR accounts for spatial heterogeneity in responses to variables by estimating separate regressions for each sample (Fotheringham, Brunson, and Charlton 2002). The weights represent the adjacency effects for neighboring locations within a specified distance (or bandwidth) " (Partridge et al., 2008).

Six GWR were run in GWR4 a specialist free GWR program developed and programmed by Professor Tomoki Nakaya of the Department of Geography, Ritsumeikan University, Kyoto, Japan. GWR4 has a number of options for the regression. The first option available is the model type. The options available for selection in the GWR4 software are Gaussian, Poisson or logistic. The most conventional of the three, the Gaussian model was selected for this thesis and can be described as;

$$y_i = \sum_k \beta_k(u_i, v_i) x_{k,i} + \varepsilon_i \quad (1)$$

"where  $y_i$ ,  $x_{k,i}$  and  $\varepsilon_i$  are, respectively, dependent variable,  $k$ th independent variable, and the Gaussian error at the location  $i$ ;  $(u_i, v_i)$  is the x-y coordinate of the  $i$ th location; and coefficients  $\beta_k(u_i, v_i)$  are varying conditionals on the location" (Nakaya et al., 2012, p. 11).

Poisson and logistic GWR provide a natural extension to the conventional model and are commonly used when modelling count or binary data (see Nakaya et al., 2012 for more information).

The next option available is the selection of the kernel function for geographical weighting, its bandwidth size, and model selection criteria. Kernel functions are either fixed or adaptive and GWR4 offers both Gaussian

and bi-square fixed and adaptive options. When a fixed kernel is selected the "geographic extent for local model fitting to estimate geographically local coefficients is constant over space" (Nakaya et al., 2012, p.23) or in other words these kernels use a fixed distance to solve each local regression. Alternatively, an adaptive kernel "changes such a local extent by controlling the  $k$ -th nearest neighbour distance for each regression location" (Nakaya et al., 2012, p.23). When the feature distribution is dense an adaptive kernel will use a smaller spatial context than when the feature distribution is sparse.

The classic geographic kernel types for GWR are "adaptive bi-square kernel" and "Gaussian fixed kernel". Bi-square kernel is suitable when you want to clarify local extents for model finding and has a clear-cut range where kernel weighting is non-zero. "In the case of adaptive kernel, the number of areas included in the kernel is kept constant so that using bi-square kernel is secure" (Nakaya et al., 2012, p.23). Gaussian kernel "weight continuously and gradually decreases from the centre of the kernel but never reaches zero. Gaussian kernel is suitable for fixed kernels since it can avert or mitigate the risk of there being no data within a kernel" (Nakaya et al., 2012, p.23).

Different combinations of kernel types and functions can also be used with adaptive Gaussian being selected for this analysis. Adaptive Gaussian can provide a greater level of accuracy seeing as adaptive bi-square kernels are not secure when the outcome distribution is unbalanced (Nakaya et al., 2012, p.23).

Once a kernel type has been chosen you must also select the kernel bandwidth size. Selection searches are available to automatically search for the optimal bandwidth size and GWR4 opts for either a golden selection search or an interval search. In most cases a golden-section search will identify the optimal bandwidth and consequently a golden-selection search has been used in this analysis.

The selection searches offered finds the optimal bandwidth "by means of comparison of model selection indicators with different bandwidth sizes" (Nakaya et al., 2012, p.26) selection search consequently also requires a selection criteria. The default selection criteria is AICc. AICc uses the Akaike Information Criterion as a bandwidth parameter and is the most suitable " in terms of statistical prediction for local Gaussian regression modelling where the local degree of freedom is likely to be small"(Nakaya et al., 2012, p.26). Another selection criteria offered is cross validation (CV). CV is only applicable to Gaussian models. The GWR models have been run with AICc as it provides a good balance between optimality and parsimony.

"Spatial non-stationarity (i.e. whether the locally specific regression coefficients vary significantly across space) was evaluated using the Monte Carlo test specified by Fotheringham *et al*" (Cameron, Cochrane, Gordon, & Livingston, 2015, p.3). From the results of this test it is possible to fit a fixed GWR model which holds the spatially non-varying parameters to a global estimate and allows the spatially varying parameters to a global estimate. The data used in this analysis was tested for non-stationarity with the dependent variable all ages. The test for geographic variability showed there was one stationary variable. A fixed GWR model was run with this stationary variable set to global. The results from the fixed GWR displayed significantly worse statistical properties than the standard GWR model and consequently only the standard GWR results have been reported.

There can be some complications in displaying the results of GWR with each analysis having the potential to produce voluminous amounts of results. Mapping these results can be problematic when the wrong classifications and colour schemes are used. The Parameter estimates and corresponding t-values have been mapped according to Mennis (2006) specification. The parameter estimate classifications have been based on standard deviations and a diverging colour scheme allows the viewer to differentiate between

positive and negative values. The t-values have been classified to display areas of significance with a no hue colour scheme to allow the viewer to determine which parameter estimates are significant. As an attempt to contain the number of maps in this thesis only the stationary natural amenity indices maps have been included.

Performance of the OLS and GWR models are evaluated on basis of measures of fit which include, the adjusted  $R_2$  and Akaike Information Criterion and can be seen in the following chapter.

## **Chapter 4 : Results and Discussion**

Please note: Images produced for thesis are at a large scale to keep the number of maps and size of the document manageable. GWR results maps have been included in appendix C but please contact the author for any other high resolution images or inserts of particular areas of interest.

### **Principal Component Analysis**

#### **Natural - Factor Analysis**

The variables used in the natural variable factor analysis were all extracted from the New Zealand Landscape Classification version 2. A total of fifteen generalised layers were examined resulting in seven variables being suitable for use in a factor analysis. These layers were water, agriculture, exotic vegetation, indigenous vegetation, alpine, high mountains and water view. The river and wetland variables were found to have insufficient variance for a factor analysis and the other variables already had some representation within another variable. These variables were consequently excluded from the analysis. Further information with regard to the variables can be seen in chapter three.

In factor analysis choosing a method of rotation relies largely on whether there is a theoretical reason to assume that the factors are dependent and which method suits the data set the best (refer to chapter 3). The natural data contains some correlation, nevertheless some level of correlation can be argued for almost every factor analysis. This analysis was performed with an un-rotated solution, an oblique rotation and an orthogonal rotation, the best fit for the data was an orthogonal rotation and as a result of this a varimax rotation has been chosen.

According to those criteria discussed in the methodology chapter of this thesis there should be no trouble with the sample size for this analysis;

according to Comrey and Lee the number of observations (nearly 2000) is excellent. The KMO = 0.524 is only just above the acceptable limit of 0.5 (Kaiser 1974) Bartlett's test of sphericity with an associated p value of 0.000 indicates that we can proceed.

The naturalness PCA by varimax rotation produces an index of naturalness with the first factor explaining 27.16% of variance, mainly explained by the proportion of mountains, indigenous vegetation and alpine (see Table 1-1).

### **Recreation - Factor Analysis**

The initial variables used for the recreation factor analysis came from a variety of sources. A total of twenty eight variables were examined for the analysis; conservation areas, reserves, national parks, boats ramps, golf courses, ski lifts and tows at 15minute, 1hour, 2hour and 3hour travel times (see chapter 3). The 15 minute travel time variables were found to have insufficient variance for a factor analysis and were therefore excluded from the analysis.

Due to the same variables being used for each of the travel times there is most likely some correlation between variables, consequently, a direct oblimin rotation with a delta of 0 (high correlation is not allowed) has been chosen. It should be noted that this rotation was compared to both orthogonal rotation methods and the un-rotated solution. The direct oblimin approach provided the most statistically significant and interpretable answer.

The KMO indicates that there are no problems with the sample size for this analysis and Bartlett's test of sphericity indicated that correlations were sufficiently large for a factor analysis.

Table 4-1 shows the recreation PCA results. The PCA was run using a direct oblimin rotation and produced an index which explains 31.93% of variance.

The first factor variance was mainly explains national parks, conservation areas, reserves, boat ramps and golf courses at the 2 and 3 hour drive times.

### Climate Factor Analysis

The climate factor analysis variables were based on the Landcare 2004 Climate Layer Data. A total of six variables were used; Mean temperature, mean rainfall and mean solar radiation during both January and July.

The correlation of the climate variables also satisfied Bartlett’s test of sphericity and had a high enough KMO to conclude that there were no problems with the sample size. Following these tests a factor analysis with direct oblmin rotation was run. The factor analysis (Table 4-1) shows that the climate index explains 56.92% of variance, mainly explained by January and July solar radiation and rainfall.

**Table 4-1 Principal Component Analysis Results**

<b>Variable:</b>	<b>Factor Loadings:</b>
<b>Climate Variables</b>	
<i>Variance explained</i>	56.91%
January average temperature	-0.203
July average temperature	0.461
January average solar radiation	0.915
July average solar radiation	0.894
January average rainfall	0.791
July average rainfall	0.948
<b>Recreation Variables:</b>	
<i>Variance explained</i>	31.93%
1 hour drive time - National parks	0.159
1 hour drive time - Reserves	0.081
1 hour drive time - Conservation areas	-0.073
1 hour drive time - Boat ramps	-0.746
1 hour drive time - Golf courses	-0.688
1 hour drive time - Ski lifts	0.227
1 hour drive time - Ski tows	0.273
2 hour drive time - National parks	0.736
2 hour drive time - Reserves	0.546
2 hour drive time - Conservation areas	0.708
2 hour drive time - Boat ramps	-0.825
2 hour drive time - Golf courses	-0.823
2 hour drive time - Ski lifts	0.349
2 hour drive time - Ski tows	0.386
3 hour drive time - National parks	0.611
3 hour drive time - Reserves	0.396

3 hour drive time - Conservation areas	0.539
3 hour drive time - Boat ramps	-0.819
3 hour drive time - Golf courses	-0.828
3 hour drive time - Ski lifts	0.400
3 hour drive time - Ski tows	0.454
<b>Natural Variables:</b>	
<i>Variance explained</i>	27.16%
Water	-0.079
Agriculture	-0.069
Exotic vegetation	0.149
Indigenous vegetation	0.554
Alpine	0.844
Mountains	0.910
Water view	-0.142

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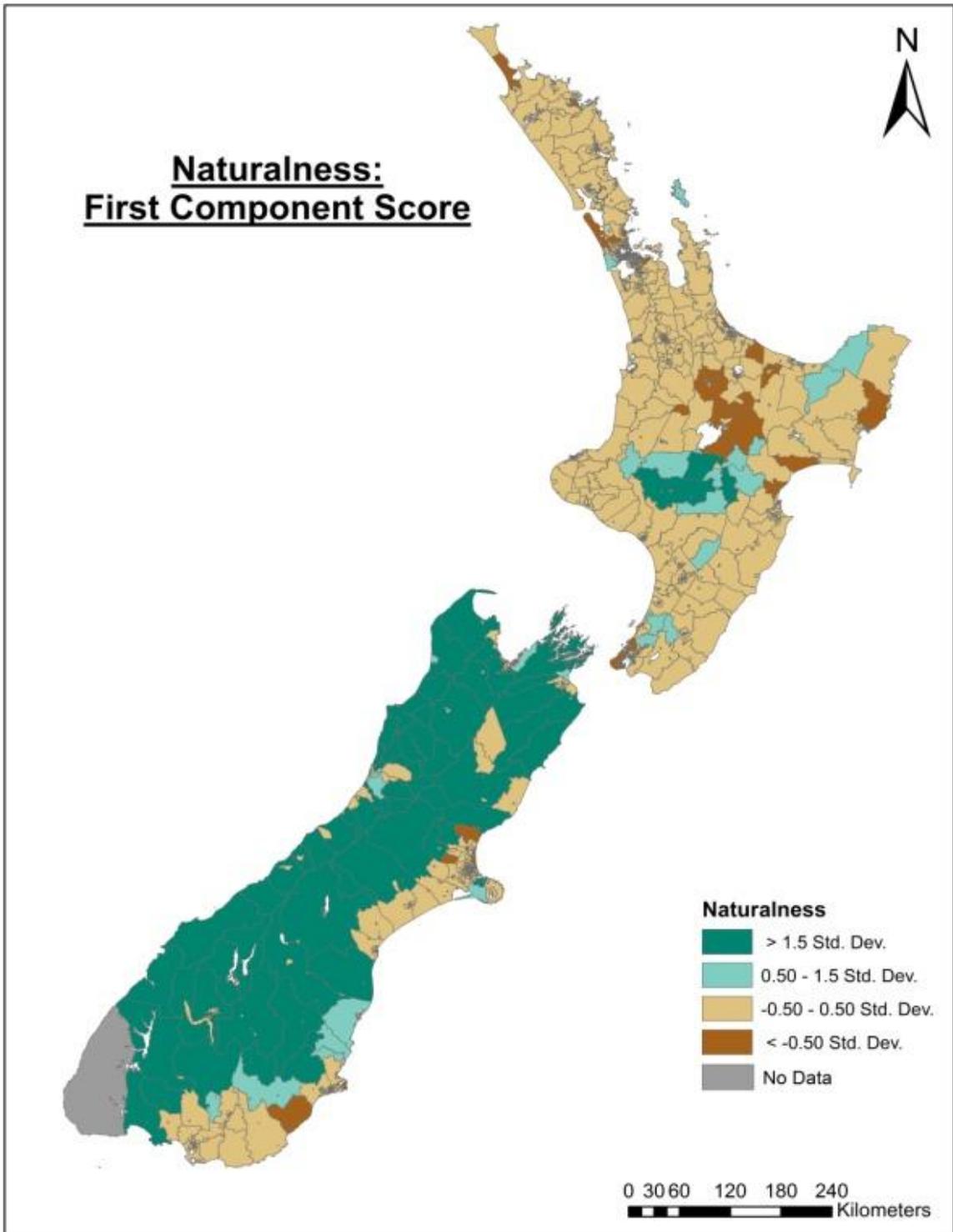
## **Regression Results**

The effects of natural amenities on population change were examined across six age groups. As outlined in the methodology chapter of this thesis an OLS 'global' model and a 'local' GWR model were used in this analysis.

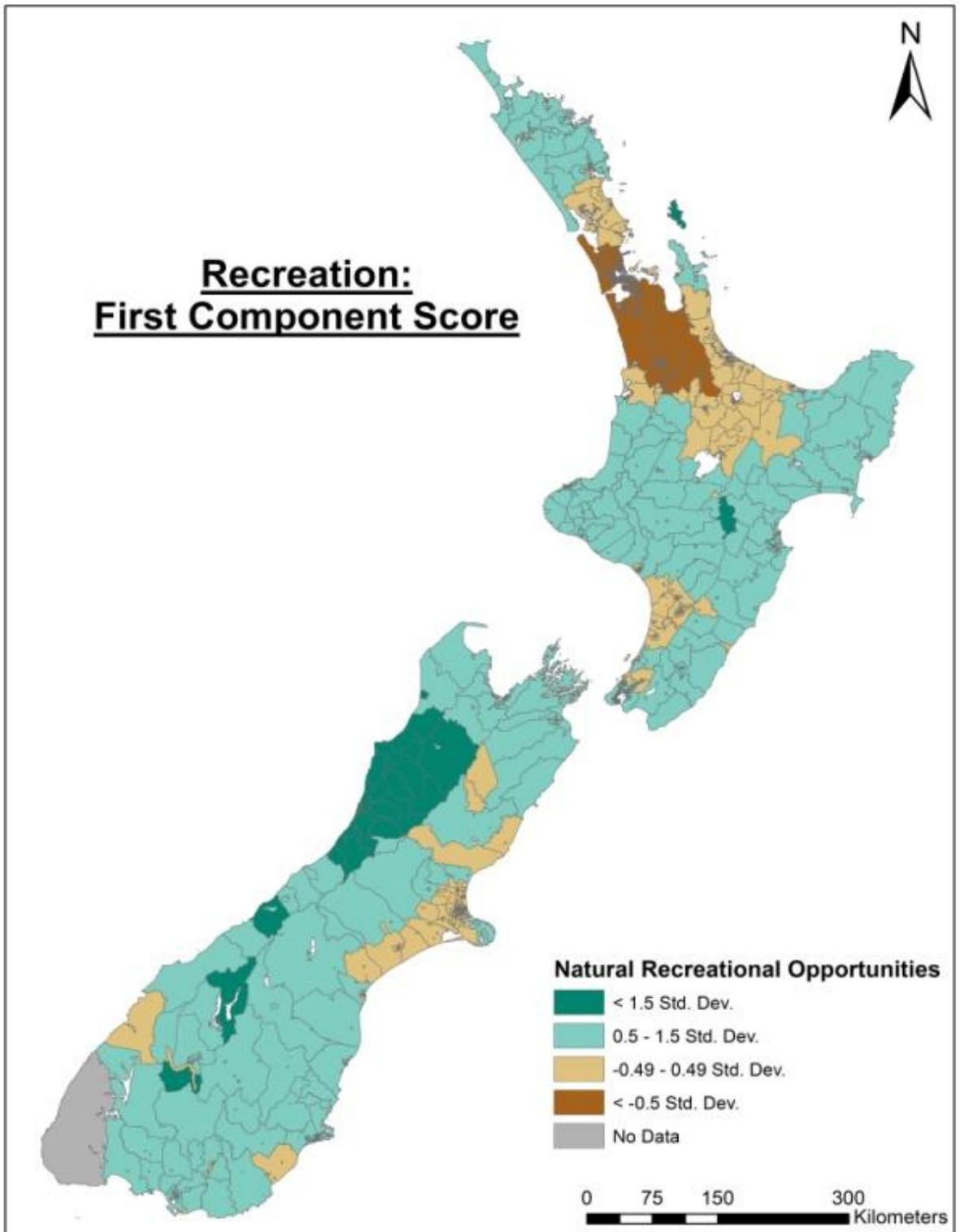
Prior to completing these analyses the principal component scores were mapped (see figures 4-1, 4-2, 4-3). This allowed spatial interpretation and verification of the of natural amenity variables. Overall, the maps of the three natural amenity principal component analyses showed that the natural amenities spatial distributions were clustered in some areas. The naturalness map (Figure 4-1) shows that the west of the South Island and the centre of the North Island have reasonably high principal component scores (above 1.5 standard deviations) with lower scores (below -0.5 standard deviations) occurring around and in more urban areas such as Auckland, Wellington, Christchurch and Dunedin.

The recreation map (Figure 4 -2) (representing only natural recreation) shows some similar patterns with high scores (standard deviation above 1.5) favouring the west of the South Island. More moderate scores appear around the central, southern and very northern areas of the North Island and east coast of the South Island (standard deviation 0.5 - 1.5).

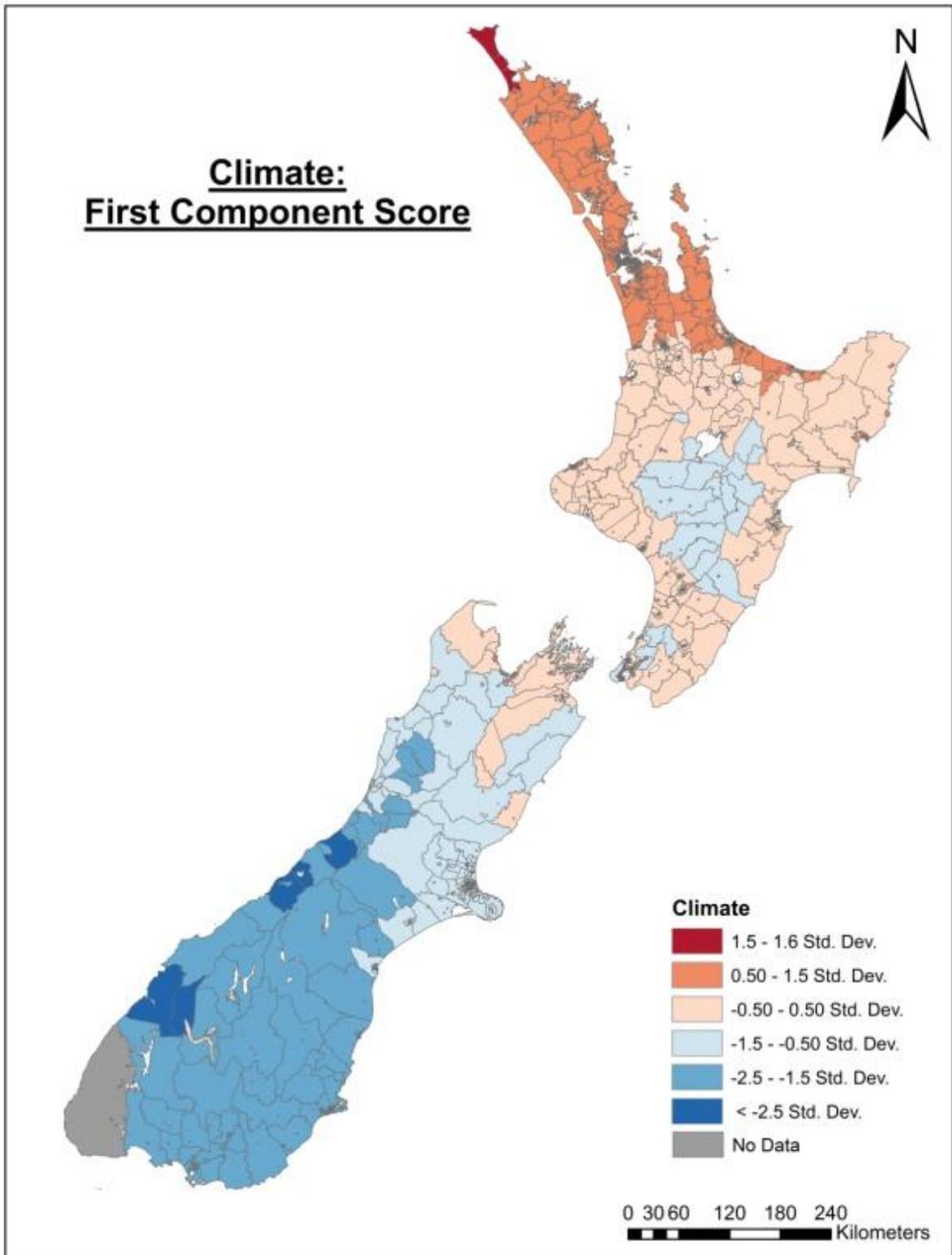
The climate first component map Figure 4-3 varies significantly from the other two first component maps with the highest scores (standard deviation above 1.5) in the north of the North Island and moderate scores (-0.5 - 1.5) for most of the North Island as well as the north of the South Island. Low scores (-0.5 - -1.5) occur more toward the bottom half of the North Island with frequency increasing the further south you go.



*Figure 4-1 Spatial Distribution of Nature Based Amenities*

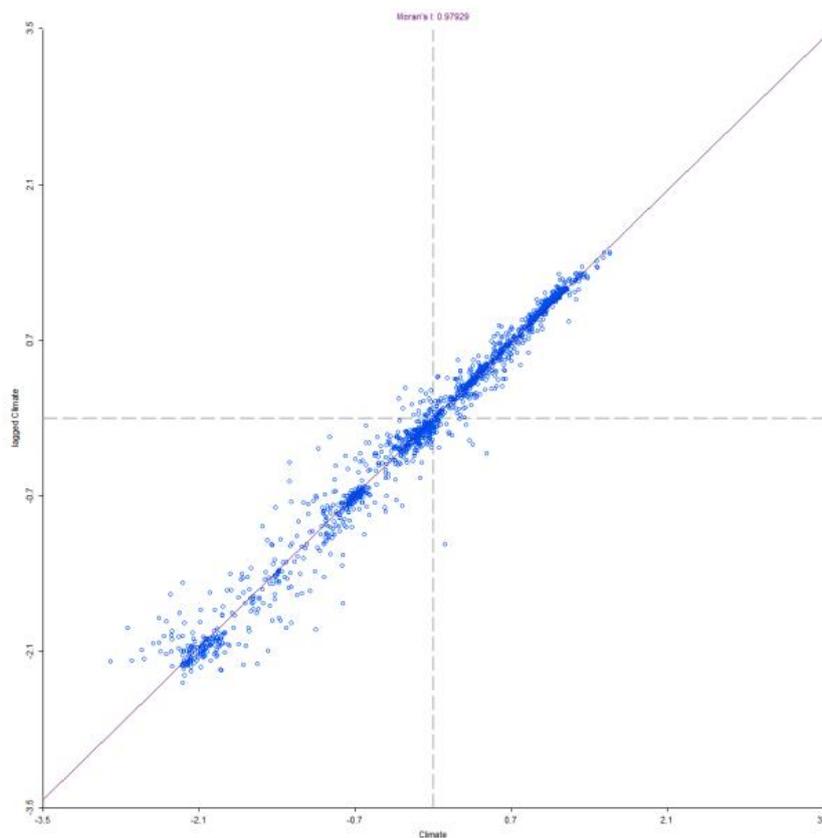


*Figure 4-2 Spatial Distribution of Recreation Based Amenities*

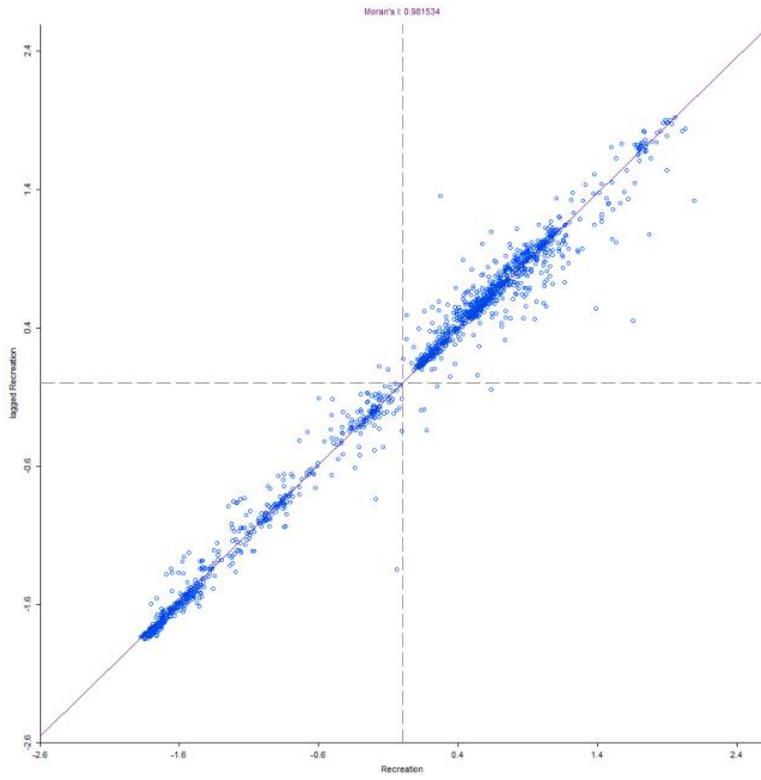


*Figure 4-3 Spatial Distribution of Climate Based Amenities*

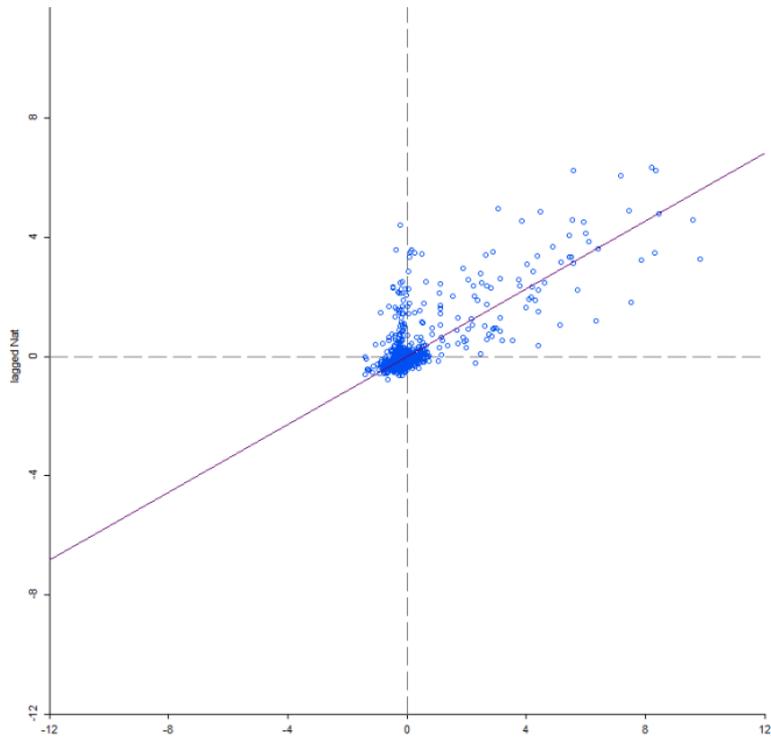
Mapping the scores, however, is only visually descriptive. Quantitatively, the most frequently used statistic for identifying if there is spatial clustering is Moran's I. The Moran's I statistic has been calculated for the natural amenity index with all three variables showing positive spatial autocorrelation significant at the 99.9% level (see Table 4-2). The pseudo  $p$ -value "is computed as the ratio of the number of statistics for the randomly generated data sets that are equal to or exceed the observed statistic" (Anselin, 2003, p.91). Hence, the pseudo  $p$ -values for all three amenity variables indicate that none of the simulated values were larger than their observed Moran's I statistics. It is possible to display these statistics on scatter plots. Figures 4-4 to 4-6 display the scatter plots of the natural amenity Moran's I statistics. The scatter plots also indicate positive spatial correlations with the majority of points for all three variables occurring in the bottom left and top right quadrants.



**Figure 4-4 Climate Moran's I Scatter Plot.**



**Figure 4-5 Recreation Moran's I Scatter Plot**



**Figure 4-6 Natural Moran's I Scatter Plot**

**Table 4-2 Descriptive Statistics and Moran's I**

Variable	Minimum	Maximum	Mean	Standard Deviation	Moran's I	Moran's I Pseudo-P-value
Natural	-1.42	9.60	0.00	1.00	0.57	0.0001
Recreational	-1.89	2.07	0.00	1.00	0.98	0.0001
Climate	-2.87	1.55	0.00	1.00	0.98	0.0001
Age 15-24	-100.00	5850.00	11.37	149.79		
25-39	-100.00	20400.00	10.64	500.36		
40-54	-100.00	6066.00	12.44	161.59		
55-64	-100.00	3600.00	28.98	114.54		
65+	-100.00	4400.00	41.70	143.66		
All ages	-100.00	5175.00	12.96	151.62		
Population Density	0.00	77.33	10.84	11.94		
NZDep 2006	0.00	1452.00	981.68	132.66		
Bartik	-12.61	35.51	13.45	4.95		
Higher Education	0.00	53.91	12.41	8.85		

Both OLS regressions and GWR were run with each of the six age groups as the dependent variable (see Table 4-3). Local  $R^2$  values were displayed in figure 4-7 with one map for each of the six age groups and parameter estimates and corresponding t-values being displayed for the two amenities which vary spatially. It was found that that the GWR better represented the relationship between population change and natural amenity at every age group with both higher adjusted  $R^2$  and lower AICc values. The results are reviewed further in the following paragraphs.

The 15 - 24 (young adult) OLS regression identified only two significant variables. With recreation being significant at the 0.001 level and higher education significant at the 0.05 level. It is possible that these were the only significant factors for this age group however with the very low adjusted  $R^2$  value of 0.01 and the obvious spatial autocorrelation in the amenity variables it is necessary to investigate the relationship further. The exploratory GWR

showed a greater overall level of accuracy with a higher adjusted R<sup>2</sup> of 0.13 and an AICc 150 lower than the OLS AICc of 24140. The local R<sup>2</sup> values revealed in figure 4-7 (15 -24) show substantially higher local R<sup>2</sup> values (between 0.3 - 0.5) in and around the cities of Hamilton, Palmerston North, Wellington, Nelson, Blenheim, Christchurch and Dunedin and slightly better scores (0.2 - 0.3) for much of the lower and central North Island and upper South Island.

**Table 4-3 OLS Regression and GWR Models and Diagnostics**

Variable	OLS Coeff. (Std Err)	GWR		
		25th Percentile	50th Percentile	75th Percentile
<b>Dependent Variable:</b>				
Population change 2006 - 2013				
<b>All Ages</b>				
<b>Independent Variables:</b>				
Natural	-2.74 (3.82)	-21.24	-7.01	1.95
Recreational	-15.08 (4.78)**	-94.94	-18.83	-6.77
Climate	-1.74 (4.53)	-9.34	4.54	24.10
Population Density	-1.50 (0.37)***	-1.54	-0.84	-0.32
NZDep 2006	0.02 (0.03)	-0.08	-0.06	0.03
Bartik	-1.37 (0.85)	-7.23	-0.18	1.60
Higher Education	1.69 (0.48)***	0.11	0.63	1.63
Intercept	7.62			
R <sup>2</sup>	0.01	0.21		
Adjusted R <sup>2</sup>	0.01	0.14		
AICC	24187.59	24022.15		
<b>Dependent Variable:</b>				
Population change 2006 - 2013				
<b>Ages 15 -24</b>				
<b>Independent Variables:</b>				
Natural	0.03 (3.76)	-25.59	-8.14	1.44
Recreational	-17.76 (4.72)***	-61.39	-18.26	-9.51
Climate	-2.279 (4.47)	-41.50	-4.06	3.76
Population Density	-1.62 (0.36)	-1.77	-0.82	-0.19
NZDep 2006	0.01 (0.02)	-0.09	-0.05	0.03
Bartik	-0.74 (0.84)	-4.78	-0.34	1.55
Higher Education	1.36 (0.47)*	-0.18	0.44	1.39
Intercept	8.47			
R <sup>2</sup>	0.02	0.20		
Adjusted R <sup>2</sup>	0.01	0.13		
AICC	24140.36	23990.28		

**Dependent Variable:**

Population change 2006 - 2013

**Ages 25 -39****Independent Variables:**

Natural	-3.22(12.64)	-20.77	-7.74	8.90
Recreational	-39.71(15.85)*	-122.82	-32.23	-9.67
Climate	-3.98(15.01)	-6.13	7.44	35.54
Population Density	-2.96(1.21)*	-3.18	-0.94	0.00
NZDep 2006	0.04(0.09)	-0.06	0.00	0.07
Bartik	-3.60(2.83)	-10.55	-3.86	0.82
Higher Education	3.43(1.58)*	0.46	1.67	3.77
Intercept	5.85			

R <sup>2</sup>	0.01	0.16		
Adjusted R <sup>2</sup>	0.00	0.09		
AICC	28691.84	28581.09		

**Dependent Variable:**

Population change 2006 - 2013

**Ages 40 - 54****Independent Variables:**

Natural	-2.1185 (4.07)	-25.19	-8.61	1.87
Recreational	-16.9098 (5.09)***	-88.50	-21.80	-9.71
Climate	-1.18514 (4.83)	-20.50	2.94	18.13
Population Density	-1.42114 (0.39)***	-1.57	-0.79	-0.25
NZDep 2006	0.011871 (0.03)	-0.09	-0.06	0.02
Bartik	-1.3281 (0.91)	-5.45	-0.60	1.66
Higher Education	1.739991 (0.51)***	-0.05	0.46	1.72
Intercept	12.18707			

R <sup>2</sup>	0.02	0.22		
Adjusted R <sup>2</sup>	0.01	0.14		
AICC	24427.90	24243.80		

**Dependent Variable:**

Population change 2006 - 2013

**Ages 55 - 64****Independent Variables:**

Natural	3.71 (2.87)	-12.82	0.70	19.15
Recreational	-14.36 (3.59)***	-20.45	-2.73	12.50
Climate	-1.08 (3.40)	-99.59	-21.87	-2.98
Population Density	-1.63 (0.27)***	-2.11	-1.08	-0.60
NZDep 2006	0.03 (0.02)	-0.04	0.01	0.08
Bartik	0.41 (0.64)	-1.70	0.26	3.50
Higher Education	1.43 (0.36)***	0.02	0.68	1.72
Intercept	-5.92			

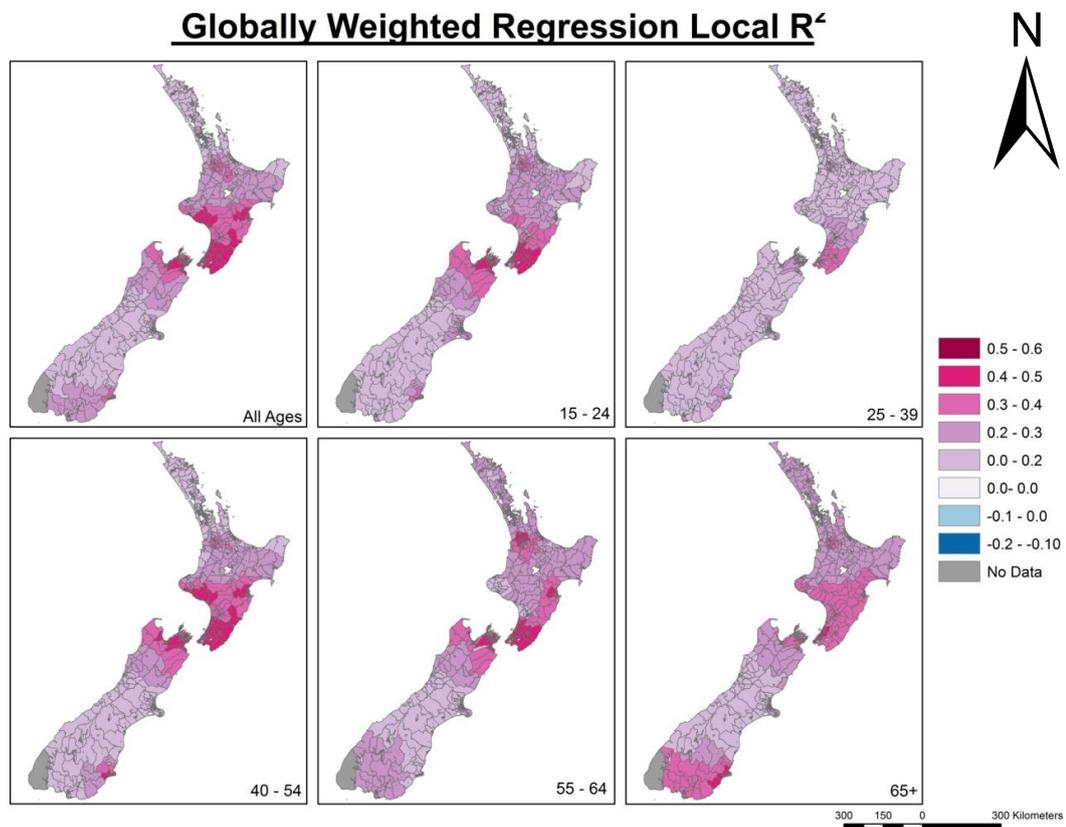
R <sup>2</sup>	0.03	0.27		
Adjusted R <sup>2</sup>	0.02	0.18		
AICC	23112.37	22880.66		

**Dependent Variable:**  
Population change 2006 - 2013

**Ages 65+**

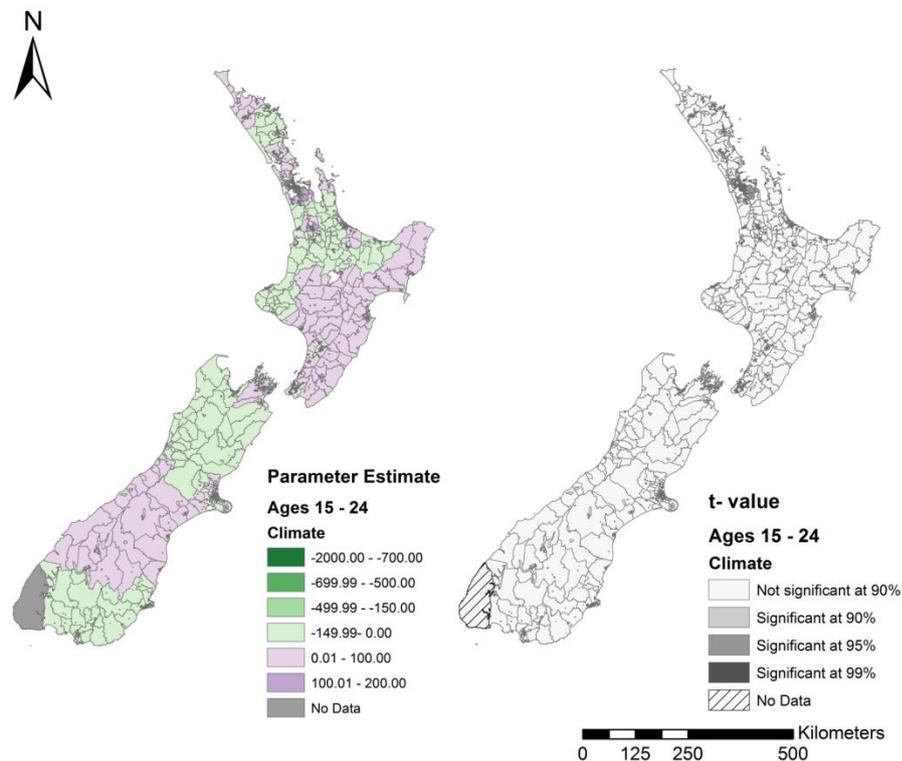
**Independent Variables:**

Natural	-2.37 (3.58)	-27.16	-7.90	18.14
Recreational	-11.64 (4.49)**	-129.60	-16.78	0.31
Climate	1.42 (4.25)	-16.12	0.12	27.20
Population Density	-2.26 (0.34)***	-2.32	-1.82	-1.29
NZDep 2006	0.02 (0.03)	-0.21	-0.13	-0.01
Bartik	-2.04 (0.80)*	-7.92	-0.28	3.99
Higher Education	2.09 (0.45)***	0.25	0.92	1.74
Intercept	51.37	55.99	160.21	394.06
R <sup>2</sup>	0.03	0.24		
Adjusted R <sup>2</sup>	0.03	0.17		
AICC	23952.99	23720.88		



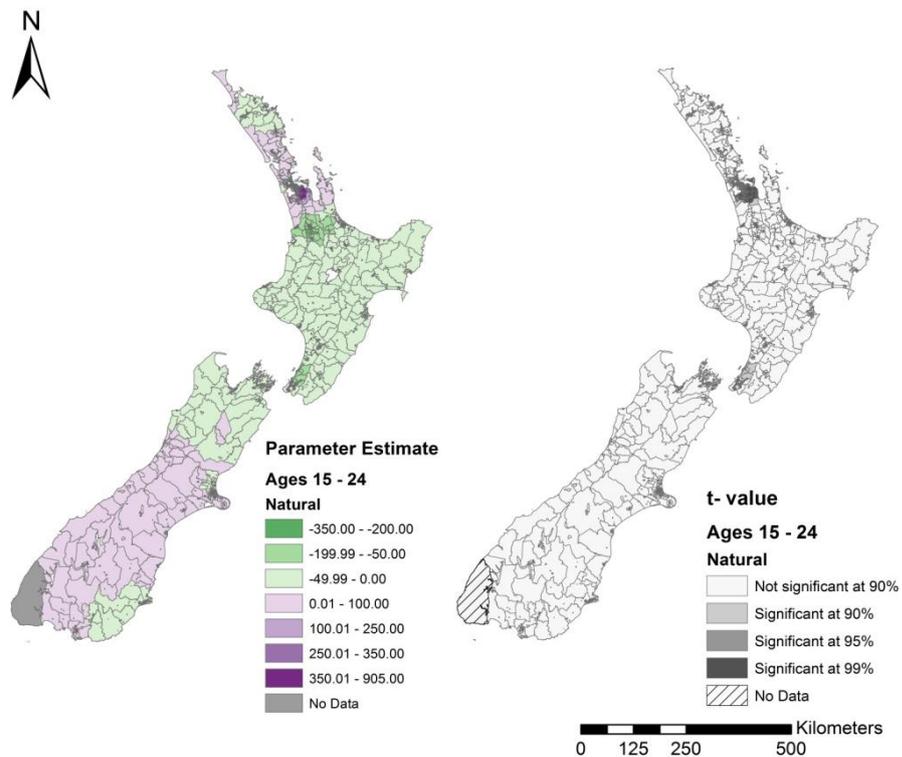
**Figure 4-7 Globally Weighted Regression Local R<sup>2</sup> Values**

The parameter estimate and the t-value maps must be read together in order to determine which parameter estimates are likely to have occurred randomly and which are significant. Full page results maps are included in Appendix C. Figure 4-8 shows both the parameter estimates and the t-values for the climate index and it appears that the majority of values across New Zealand are insignificant at the 90% level. Auckland provides an exception to this with most of central Auckland showing significance at the 99% level and the south east of these areas being significant at the 95% level. Parameter estimates in the central city show very high negative coefficients and estimates in the western suburbs show moderately high positive coefficients compared to the rest of the country. This indicates that climate has a positive effect on population change in this age group in the western suburbs and a negative effect in the central city.



**Figure 4-8 Parameter Estimates and Associated t-values for Climate Ages 15-24** Page

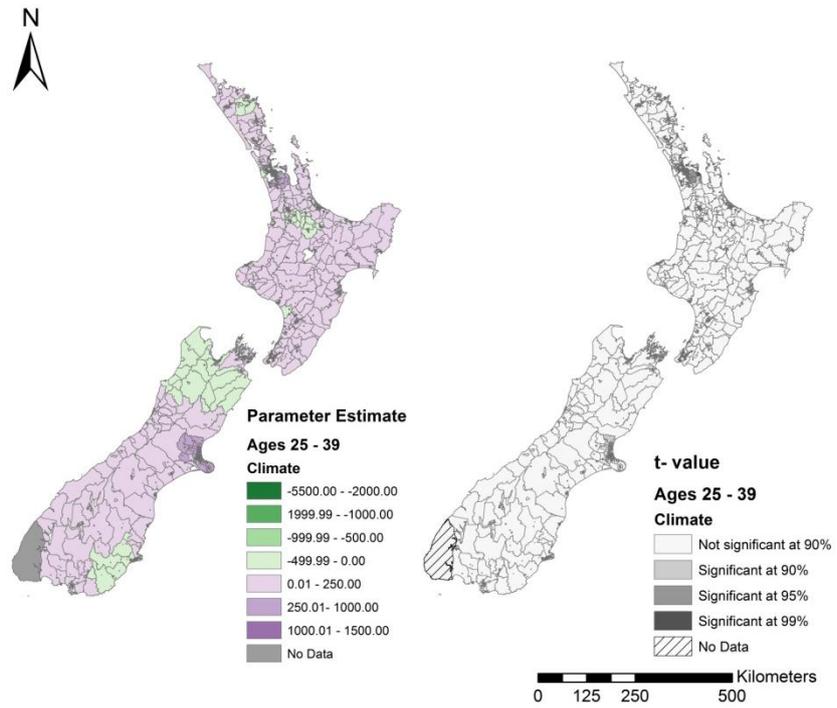
The natural index also shows significant parameter estimates in the Auckland region with significance in the central and south western suburbs varying between 95 - 99%. Parameter estimates in these areas are strongly positive showing that the relationship between population change in this age group and naturalness is positive. The area just north of Wellington (see figure 4-9) shows significance at the 90% level and parameter estimates appear to be moderately negative in that region indicating a negative relationship between naturalness and population change for 15 - 24 year olds in that area.



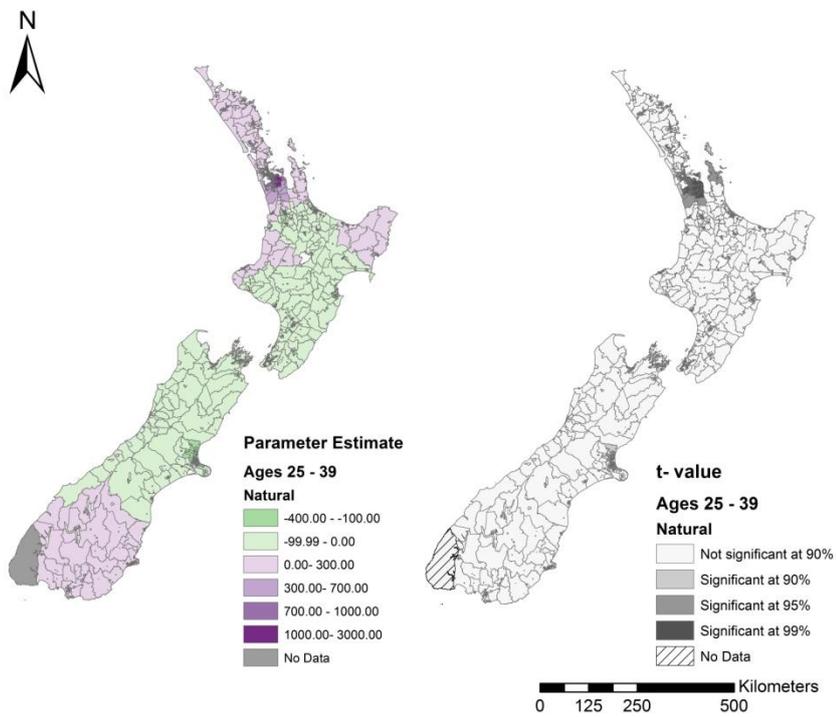
**Figure 4-9 Parameter Estimates and Associated t-values for Naturalness Ages 15-24**

The OLS for the family formation age group (25 - 39) produced a very low adjusted  $R^2$  value of 0.004. The OLS revealed three significant variables all significant at the 95% level (seen in table 4-3) nevertheless the model is such a poor fit to the data that interpretation of these variables is unlikely to be accurate. Considering the GWR results, the AICc and adjusted  $R_2$  demonstrates that the GWR model is a better fit to the data than the global OLS model. The local  $R_2$  values from the GWR are displayed in figure 4-7. The local  $R_2$  map indicates some spatial variation in value with much higher values around Wellington (0.3-0.4) and slightly higher values around some of the major urban centres.

Although the GWR showed the highest  $R_2$  values in Wellington both the naturalness and climate indices showed significance only in and around the Auckland and Christchurch areas. North of the Christchurch CBD shows moderately low parameter estimates for naturalness and moderately high parameter estimates for climate (see figures 4-10, 4-11) indicating a negative relationship between naturalness and population change and a positive relationship between climate and population change for 25-39 year olds in this area. Auckland also showed areas of significance with climate and naturalness having a positive effect on population change toward the eastern suburbs, a strongly positive effect on population change in the central suburbs and a moderately positive effect toward the south. The Coromandel Peninsular showed some significance at the 95% level for the naturalness index with a positive parameter estimate. This shows that naturalness has a positive effect on population change for 25-39 year olds in this region.



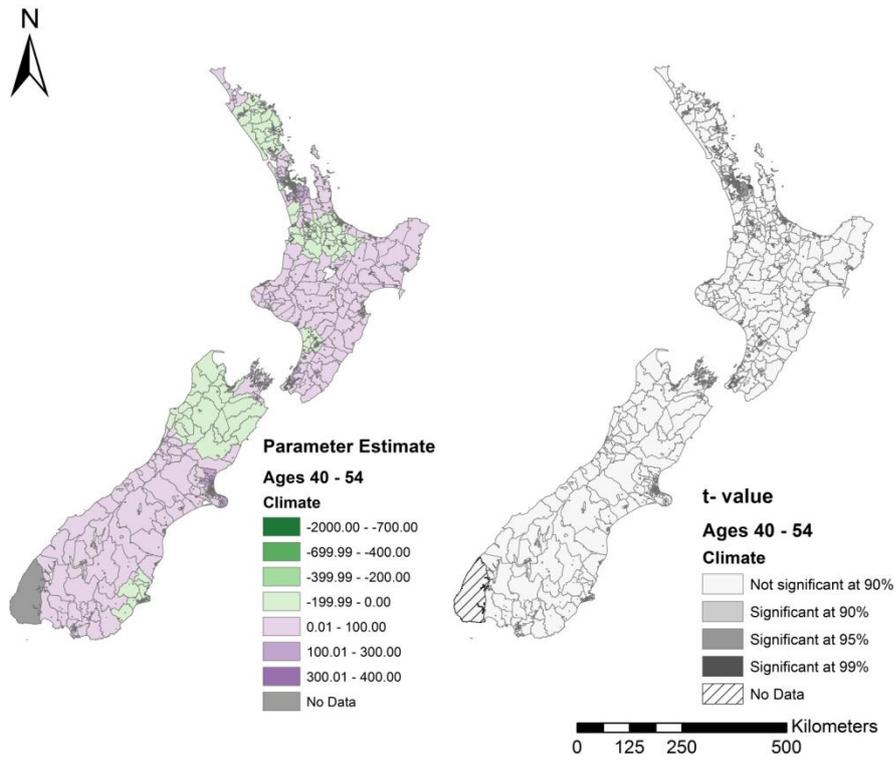
**Figure 4-10 Parameter Estimates and Associated t-values for Climates Ages 25-39**



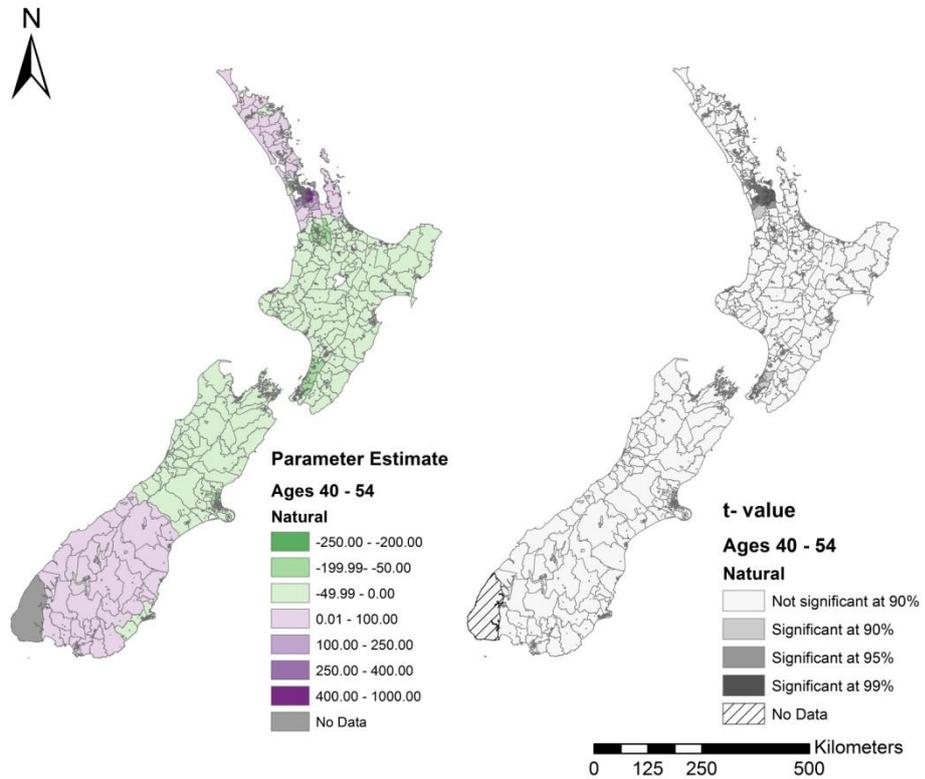
**Figure 4-11 Parameter Estimates and Associated t-values for Naturalness Ages 25 - 39**

The OLS for the population between 40 and 54 years old also identified recreation, population density and higher education as significant variables at the 99.9% level. The GWR model still outperformed the OLS with a higher adjusted  $R_2$  of 0.14 and a slightly lower AICc. The (40 - 54) local  $R_2$  map shows that the model generally accounts for the data better in and around urban areas with Dunedin, Nelson, Wellington, Whanganui, Napier, Hastings with moderate local  $R_2$  values between 0.4 - 0.5. The upper South Island and central to lower North Island also display reasonable local  $R_2$  values between 0.2 and 0.3 (see figure 4-7).

The parameter estimates and associated t-values for the naturalness and climate indices at the 40 -54 age group showed similar relationships to those from the previous age group. Parameter estimates indicate a positive relationship between climate and population change and a negative relationship between naturalness and population change for 40-54 year olds in the area just north of the Christchurch CBD (see figures 4-12 and 4-13). Climate and naturalness showed a positive effect on population change toward the eastern suburbs of Auckland. The naturalness maps also show an area of significance at the 90% level just north of Wellington which shows that naturalness has a moderately negative relationship with population change for 40-54 year olds in this area.



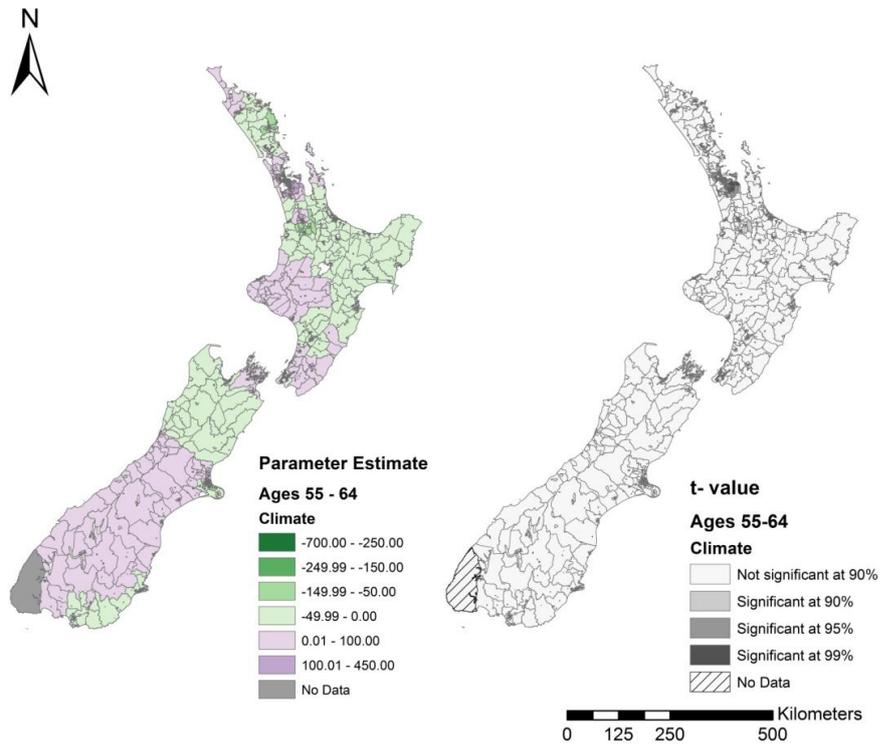
**Figure 4-12 Parameter Estimates and Associated t-values for Climate Ages 40 - 54**



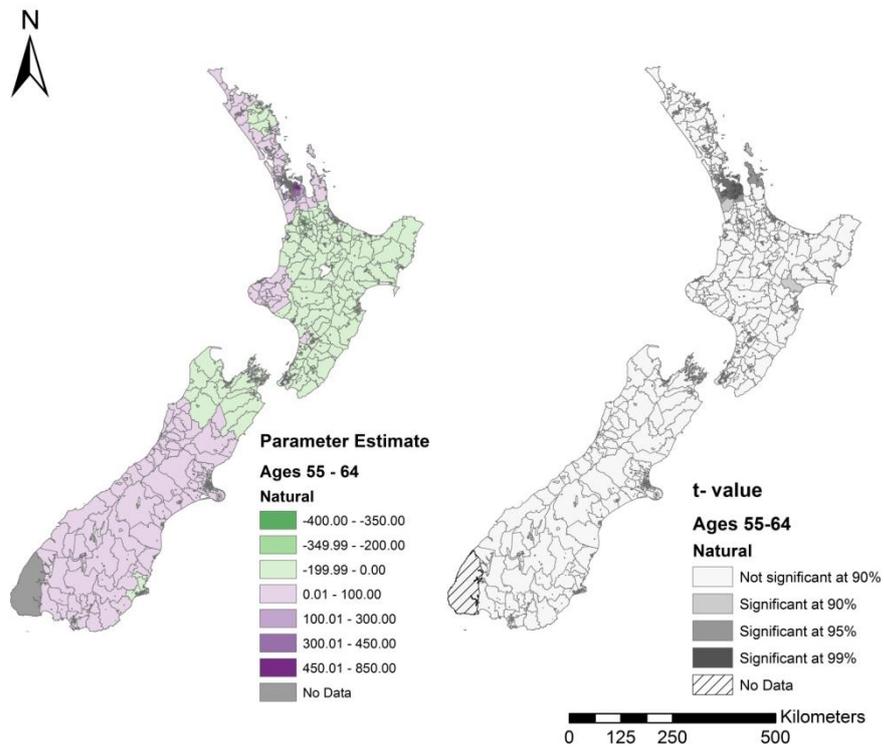
**Figure 4-13 Parameter Estimates and Associated t-values for Naturalness Ages 40-54**

The early retirement age group's (55 - 64) OLS regression had a slightly better fit than the younger age groups with the model accounting for three percent of variance in the data. This age group also showed recreation, population density and higher education as significant variables at the 99.9% level however with such a low  $R_2$  there little reason to believe these results are accurate. When comparing the GWR model for early retirement to its OLS counterpart the GWR showed the highest adjusted  $R_2$  of 0.18 and a slightly lower AICc. Local  $R_2$  values shown in figure 4-7 indicate similar spatial patterns of accuracy to the previous age group with higher scores appearing in and close to major urban centres. Hamilton, Napier and Hastings, Wellington and Nelson displayed the best fit with their local  $R_2$  values varying between 0.4 - 0.5.

The GWR results for the early retirement age group again show that climate has a positive effect on population change toward the eastern suburbs of Auckland with significance in this area ranging from 95 - 99 %. The parameter estimates show a small area of negative coefficients for climate just south of Hamilton. t-statistics in this area prove it to be significant at the 90% level showing that climate has a negative effect on population change for those in the early retirement age group in this area. The naturalness maps show significance predominately in the Auckland and Coromandel regions with relationships between naturalness and population change positive for 55-64 year olds in these areas (See figures 4-14 and 4-15).



**Figure 4-15 Parameter Estimates and Associated t-values for Climate Ages 55-64**



**Figure 4-14 Parameter Estimates and Associated t-values for Naturalness Ages 55-64**

The OLS regression for the (retirement) 65+ age group had an  $R^2$  of 0.03 indicating that the model explained 3 percent of variance in the data and the corresponding p-values(not reported) identified four of the seven variables as significant. The GWR model had substantially better measures of fit with an adjusted  $R^2$  of 0.17 and a lower AICc score with much of the populated parts of the country having local  $R^2$  values greater than 0.2 (table 4-3 and figure 4-7).

The parameter estimates and associated t-values for the retirement age group indicate areas of significance for naturalness in the central and western suburbs of Auckland, those CAU north of Wellington city and in the South Island significance mainly occurs in the northern suburbs of Christchurch and CAU north of Christchurch city (see figures 4-16 and 4-17). Christchurch and those CAU north of Christchurch have negative parameter estimates for naturalness indicating that population change and naturalness have a negative relationship in this area for those aged 65+. Conversely the climate parameter estimates around Christchurch and those areas identified as being significant in and around Auckland have positive parameter estimates showing that naturalness and climate both have a positive effect on population change for 65+ year olds in this area.

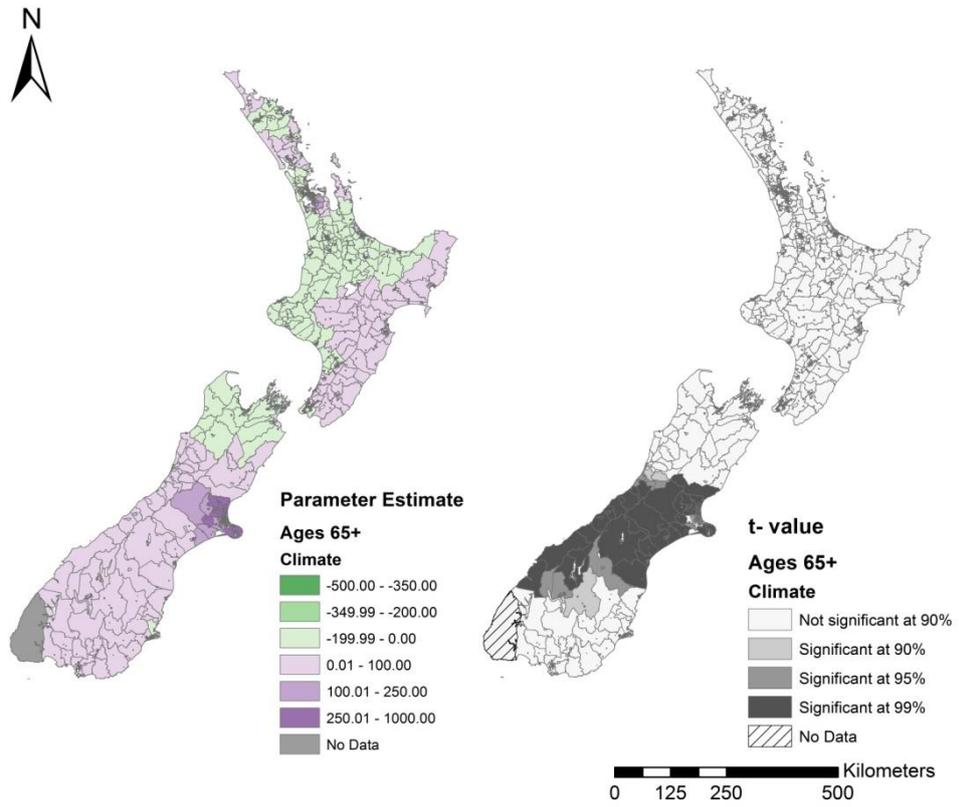


Figure 4-16 Parameter Estimates and Associated t-values for Climate Ages 65+

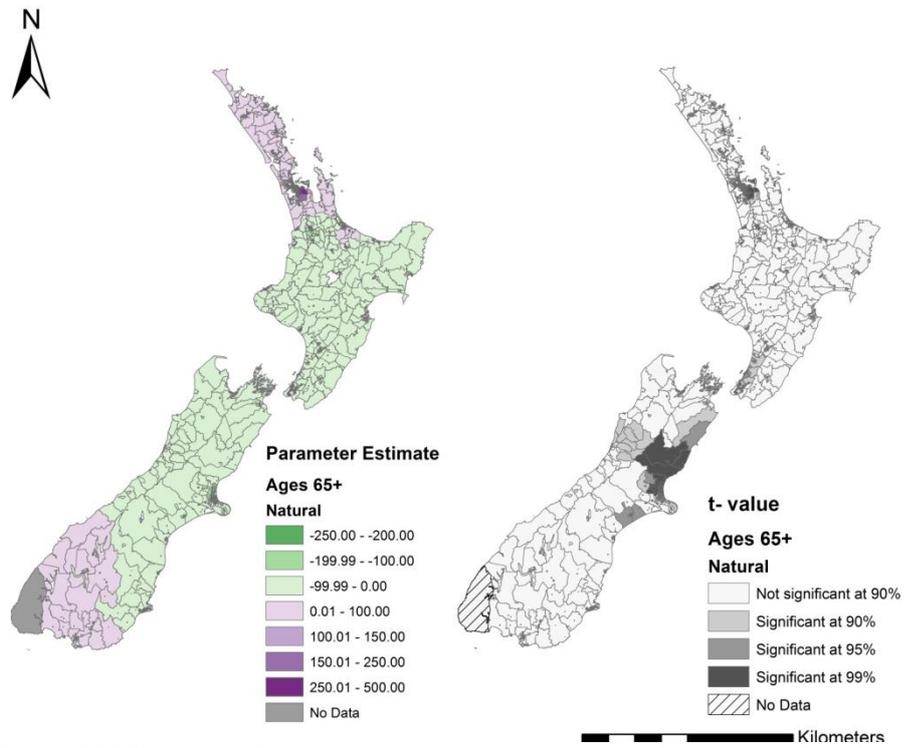
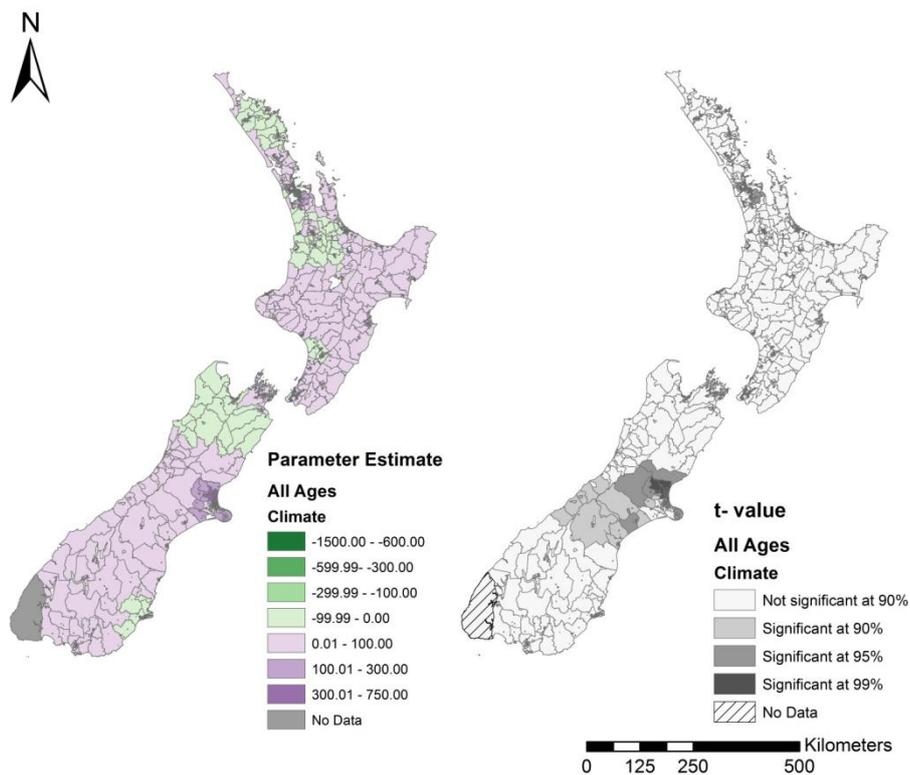


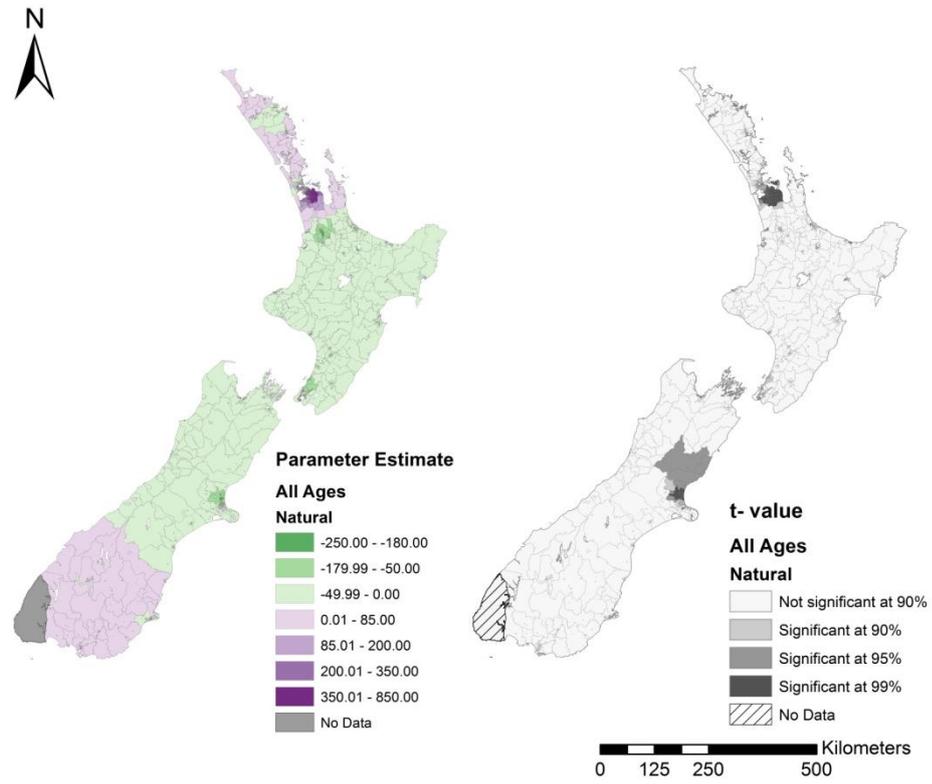
Figure 4-17 Parameter Estimates and Associated t-values for Naturalness Ages 65+

Both an OLS and a GWR model were also run with dependent data for all ages. The resulting measures of fit again favoured the GWR model with its adjusted  $R_2$  being 0.14 and having a slightly lower AICc score. The highest local  $R_2$  values occur in Whanganui, Napier, Hastings and Nelson with values between 0.4 - 0.5. Scores between 0.3 - 0.4 also appear in several other urban centres and around those areas with the highest local  $R_2$  values.

The GWR parameter estimates for the climate and natural variables are shown in figures 4-18 and 4-19. The climate maps indicate that climate has a positive relationship with population change around both the Christchurch and Auckland areas. The naturalness maps show similar trends in both Auckland and Christchurch where naturalness has a positive impact on population change for all ages in both areas.



**Figure 4-18 Parameter Estimates and Associated t-values for Climate All Ages**



**Figure 4-19 Parameter Estimates and Associated t-values for Naturalness All Ages**

## **Discussion**

GWR is an exploratory technique and has identified several areas of interest across New Zealand. GWR results do not provide the same kind of interpretable results as explanatory methods but do show areas which would benefit from future analysis. Interestingly those areas of high natural amenity initially mentioned in the introduction and motivation chapter of this thesis have not shown very much significance in this analysis. The GWR models show areas of interest predominately in and around Auckland and Christchurch.

In 2011 Christchurch City was the victim of a large earthquake with widespread damage across the city. The census following this earthquake showed a 2% decrease in Christchurch's population between 2006 and 2013 with the surrounding regions of Selwyn and Waimakariri seeing increases of 32.6 percent and 16.7 percent respectively (Statistics New Zealand, 2014). Data from previous censuses showed that similar movements had already been occurring in years prior to the earthquakes, due to some unknown factor.

Auckland alone was responsible for over half of New Zealand's population growth between 2006 and 2013 (Statistics New Zealand, 2013). The magnitude of growth in Auckland and areas surrounding Christchurch city are undoubtedly larger than that of other urban areas potentially reducing the significance of the effects of natural amenities on population change in these smaller areas.

Another potential reason for the models inability to identify the areas which we would have expected to show natural amenity having an effect on population change is the factor loadings of the natural amenity indices. When looking at the factor loadings in Table 4-1 it is possible to understand how these areas have been missed with the variation of the natural index mainly

being explained by mountains, alpine and indigenous vegetation and the recreation index loadings showing little spatial variation potentially due to both high positive and high negative factor loadings.

Moving forward from here it may be necessary to split the recreation index into two or three new indices representing different types of recreation to avoid the cancelling out effect of positive and negative factor loadings. The natural index would also benefit from being split into water based and land based amenity. These distinctions would allow areas with recreation based and water based amenities such as Tauranga and Queenstown to be more easily identified.

The areas which were identified as having significant amenity effects were predominately in or around Auckland and Christchurch. The south eastern suburbs of Auckland appeared to be significant at every age group with parameter estimates showing very high to highly positive relationships between both climate and population change and naturalness and population change. This area has a moderate climate and coastal access with some landscape variation with the Hunua Ranges toward the east so while it is not known as intuitively for its high amenity values as Queenstown or Tauranga it does have some natural amenity to offer.

The suburbs north of Christchurch in the Waimakariri Region showed that the parameter estimates for naturalness and climate were significant for all age groups except 15-24. In the family formation to early retirement age groups naturalness had a negative effect on population change and climate had a positive effect where as the older age group of 65+ and the all ages group showed a positive relationship for both variables. In this area the older age group (65+) has a greater value for naturalness than the younger age groups and that the moderate climate of Christchurch (compared to the rest of the South Island) has a positive effect on population change.

As previously mentioned in 2011 Christchurch had a large earthquake resulting in population loss in the city and population gain in the surrounding regions (Selwyn and Waimakariri). While Waimakariri had some population growth potentially as a result of the earthquake it had a smaller percentage increase than the region to the south east Selwyn. It is possible that the significance shown in the region is a result of the earthquake migration and further investigation would be needed to exclude this.

Arguably the most interesting areas that showed significant natural amenity parameter estimates at the 90% level were Coromandel and the Kapiti Coast. The Coromandel Peninsular has significant naturalness parameter estimates for both the 25 - 39 age group and the 55 -54 age group. The parameter estimates for both age groups showed that there was a positive relationship between naturalness and population change in this areas showing that people between 25 - 39 and 55 - 54 in this area value high natural amenity.

The Kapiti coast north of Wellington also had some significant naturalness parameter estimates with 15-24 and 40 - 54 both showing significance at the 90% level. These parameter estimates however were surprisingly negative indicating a negative relationship between natural amenity and population change in this area. The Kapiti coast may of course have a population which does not value natural amenity however due to the undoubted high amenity in the area (coast, Tararua Range, Tararua Forest Park and rivers) its natural amenity also may not be recognised as a result of the factor loading issues outlined earlier in this section.

Overall, the exploratory GWR and has identified several areas of interest across New Zealand. Moving forward from here it is necessary to develop an explanatory model in order to investigate the true effect of natural amenities on population change in New Zealand. This model should have a particular focus on those areas identified both by unusual population growth trends

(Tauranga and Queenstown) and those identified in the GWR (the Kapiti Coast and the Coromandel).

## **Chapter 5 : Conclusions and Recommendations**

### **Considerations for Future Research**

The results suggest that there is much more work to be done in order to find out how natural amenities truly effects population change in New Zealand.

This analysis has not identified significance in many of New Zealand's initiatively high amenity areas such as Queenstown. This could be a result of the recreation index being found to be stationary. That is it did not vary over space. As discussed in the results chapter it may be necessary to split the recreation index into two or three new indices representing different types of recreation to avoid the cancelling out effect of positive and negative factor loadings. The natural index would also benefit from being split into water based and land based amenity. These distinctions would allow areas with recreation based and water based amenities such as Tauranga and Queenstown to be more easily identified.

Many of the results maps showed significance in and around Auckland and Christchurch. As discussed in the context section of the literature review much of New Zealand's growth is occurring in urban areas. It is possible that the large magnitude of growth in these areas is lessoning the significance of natural amenity migration in other regions. Christchurch also suffered from a substantial earthquake in 2011 which may account for some of its significance in the models. Local  $R^2$  values indicate that the GWR models have clusters of areas of good fit. In the future it could be possible to run separate analyses for different areas (such as urban/rural split) or include them in a spatial regime model of some kind.

The overall model could also benefit with a number of additional variables. First and foremost a better dependent variable for this study would be migration. It is not available at the CAU level however population change includes births and deaths which are not very relevant to amenities. At the

very least some region/area specific control for births and deaths could be added to population change and ideally a control for the effects of changing age cohorts would be added to the model. This would attempt to control for the effects of both growth and decline occurring as a result of births and deaths and growth and decline occurring as a result of changing cohort sizes.

Secondly, natural amenities may be valued differently according to accessibility. Adding distance to the nearest airport could help to establish which areas have natural amenities with easy accessibility. Thirdly, this analysis does not include any urban amenities. Urban amenities play a big factor in migration where different age groups move toward education, healthcare and employment opportunities. This study would benefit from the inclusion of the access to healthcare as well as some kind of control for economic growth. These additions would help to provide a more accurate prediction of the effects of natural amenities on population growth.

## **Conclusions**

During the last decade the importance of natural amenities in migration internationally has been discussed frequently. Natural amenities are thought to provide an essential component of recreation, tourism, and retirement development (Kim et al., 2005). "As a quality-of-life factor, [Natural amenities] are believed to play a critical role in human migration and firm location decisions (Kim et al., 2005). Goetz & Rupasingha (2004) state "Natural amenities such as open spaces, scenic lakes, rivers, beaches, mountain vistas, and mild temperatures are widely believed to be important factors considered by migrants" (p.245). In America the likes of Deller et.al (2001), Howe, McMachon and Propst conclude that "Americans are moving to rural areas in search of amenity attributes to improve their quality of life" (Deller et al., 2001).

During the literature review of this thesis we developed a critical review of the existing literature that has focused on the role of natural amenities in explaining population change in New Zealand. Our discussion centred on the age related effect of amenities and the lack of New Zealand based literature on this subject. In response, to this issue and in line with international works such as Deller et, al (2001) a set of natural amenity indices have been developed to represent an overview of natural amenity in New Zealand. These variables combined with other control variables have been used in both global and local regressions after exploring problems with spatial autocorrelation and spatial heterogeneity.

In this study ordinary least squares and geographically weighted regressions were used to explore the relationship between natural amenities and population change in New Zealand at the CAU level. Measuring the age related effects of natural amenities on population change has proven to be a complex topic with the results suggesting that there is much more work to be done in this area. As discussed in the considerations for future research section there are many ways to improve this analysis. This thesis has been a learning experience and future works will focus on developing an explanatory model with a comprehensive range of variables and better controls for other factors of migration. Future work would also explore spatial regimes to help to understand what effect natural amenities have on areas outside of Auckland and Christchurch.

Where the GWR models have generated significant results the effects of natural amenities have generally been positive with few areas having unexplained negative relationships. Future work will have a particular focus on those areas identified both by unusual population growth trends (Tauranga and Queenstown) and those identified in the GWR (the Kapiti Coast and the Coromandel).

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## Appendix A- MfE Landcover 2 Data Set Class Definitions

### NZLC Agriculture:

**Short-rotation Cropland:** Land generally found within the developed farm landscape on plains, terraces and down-land having a spectral signature indicating that soil has been exposed by cultivation or indicating land uses that typically involve regular, at least annual cultivation. The class includes land used for growing cereal crops, root crops, annual seed crops, annual vegetable crops, strawberry fields, annual flower crops, and open ground nurseries. Land lying fallow at the time of imageing will also be included. Multitemporal imagery will be used to exclude land cultivated for pasture renewal. A sample of land classified as short rotation cropland will be inspected to determine ratios of deep, shallow and chemical tillage.

**High Producing Exotic Grassland:** This class comprises areas of exotic grassland characterised by a spectral signature indicating good vigour of the vegetation cover. Typically, these areas are intensively managed exotic grasslands, rotationally grazed for wool, lamb, beef, dairy, and deer production. These pastures are usually found on land that can be cultivated and are subject to a 'long-rotational' cycle with pasture renewal every 5-10 years. Productivity is enhanced through fertiliser application and in some areas, irrigation. Dominant species are usually clovers (*Trifolium* spp.) and highly productive pasture grasses, such as ryegrass (*Lolium perenne*) and cocksfoot (*Dactylis glomerata*). However, the class also includes areas of extensively managed exotic grasslands that show lush growth due to inherently high soil fertility or high annual rainfall. In these grasslands low productive grasses, such as browntop (*Agrostis capillaris*) and sweet vernal (*Anthoxanthum odoratum*), can be dominant.

**Low Producing Grassland:** This class comprises areas of exotic and indigenous grasslands characterised by a spectral signature indicating lower plant vigour and biomass compared to Class 40 – High Producing Exotic Grassland. The reduced vigour reflects lower levels of inherent soil fertility, lower fertiliser application, seasonal drought, or a shorter growing season, especially in the South Island. Typically the class comprises extensively managed grasslands grazed for wool, sheep-meat and beef production. It is usually found on steep hill and high country throughout New Zealand, often intermixed with areas of High Producing Exotic Grassland on more accessible and fertile sites. Dominant species are less productive exotic grasses, such as browntop (*Agrostis capillaris*) and sweet vernal (*Anthoxanthum odoratum*), usually mixed with indigenous short tussock species. Areas of Low Producing Grassland show a tendency to "brown off" during summer months. Paddock size is generally larger than in areas of Class 40. In wetter areas, scrub

reversion is evident on sites less accessible to stock. This class also includes areas of short tussock grassland such as hard tussock (*Festuca novaezelandiae*), blue tussock (*Poa colensoi*), and / or silver tussock (*Poa cita*). Exotic grasses are usually present, however as a minor component. Short tussock grasslands can be extensively managed for fine wool, sheepmeat, beef and deer production, ungrazed areas exist as part of the conservation estate. The class is typically found in low rainfall valleys and montane basins eastward of the Southern Alps and in the North Island volcanic plateaux.

**Depleted Grassland:** Areas of very low herbaceous vegetation with grassland/herbfield character. Short tussock grassland species are usually present, but show less than 10% cover. Hieracium species and/or exotic grasses are conspicuous, as is the bare ground component. Plant vigour and biomass are significantly lower than in Low Producing Grassland due to soil nutrient loss through repeated burning and overgrazing. The class is found in areas with a known history of livestock grazing. Areas of Depleted Tussock Grassland are particularly prominent in the dryer parts of the South Island high country, such as the Mackenzie Basin and Central Otago. The signature of Depleted Grassland in the satellite imagery is very variable. Characteristic is a blue hue reflecting the high bare ground component.

#### **NZLC Exotic Forest and Scrub:**

**Gorse and Broom:** Commonly associated with Low Producing Exotic Grassland on hill country throughout New Zealand, where low site fertility, extensive grazing and fire facilitate the plants' spread and establishment. Gorse and/or broom will reach heights of 1 - 2m, and are typical of land subject to frequent physical disturbance such as aggrading river beds, road cuttings, and firebreaks. Either of these species can be dominant, but they also occur in mixtures. Left undisturbed, the class is transitional towards indigenous broadleaved shrubland and eventually tall forest. The period this occurs over is strongly related to rainfall. Gorse and broom scrub have been grouped together in one land cover class.

**Mixed Exotic Shrubland:** Single-species or mixed communities of introduced shrubs and climbers, such as boxthorn, hawthorn (*Crataegus* spp.), elderberry (*Sambucus* spp.), brier (*Rosa rubiginosa*), buddleja (*Buddleja davidii*), blackberry (*Rubus* spp.), and old man's beard (*Clematis vitalba*). The class also includes areas of amenity planting where the shrubland component reaches the 1 ha MMU.

**Afforestation:** Areas of *pinus radiata* forest not visible in the satellite imagery, but identified during the field-checking phase, or because of contextual patterns associated with forest establishment, e.g. roading and firebreaks. Because this class is identified in a random fashion, it contains a

larger error than classes identified on the images, i.e. the true area of new afforestation is likely to be larger than assessed.

**Afforestation (imaged, post LCDB 1):** Areas of *Pinus radiata* forest visible in the imagery and located on sites recorded as nonforested in LCDB 1. These areas represent young forests that were not visible in the 1996 /97 imagery used for LCDB 1 or have been planted since. Young plantations are identifiable in satellite imagery 4-5 years after planting, depending on initial stocking.

**Forest - Harvested:** Areas showing evidence of harvesting since LCDB1, e.g. forest canopy openings, skidder tracking, new roading or log landings. For plantations and woodlots, the classification assumes these sites to be replanted, and this will be checked in the next iteration of the database. By this time, if the areas were replanted in plantation forest species, the trees will be at least 5 years old and identifiable. If the area was indigenous forest in LCDB1 the cleared area is mapped as class 64. The next iteration of the database will be record the actual land cover on these sites. Forest loss due to localised erosion is mapped as class 12, Landslide.

The purpose class 64 is to confirm the extent of harvested pine forest that is replanted and indigenous or exotic forest that is converted to another land cover / land use.

**Pine Forest - Open Canopy:** Plantations of *Pinus radiata* showing significant reflectance of understorey land cover. The reflectance values for stand biomass and pine canopy indicate that trees are in an age class of approximately 6 - 15 years.

**Pine Forest - Closed Canopy:** Plantations of *Pinus radiata* where reflectance is dominated by the pine canopy. Reflectance values for stand biomass and shadow from canopy texture indicate that trees are likely to be older than 15 years. The purpose of this class is to highlight stands likely to be harvested within 10 - 15 years of the image date.

**Other Exotic Forest:** Exotic forest consisting of conifers other than *Pinus radiata*, such as Douglas fir, macrocarpa, and larch, or evergreen broad-leaved species, such as Acacia and Eucalyptus. This class also includes stands of wilding pines (i.e. usually Corsican, Contorta and Ponderosa Pine), as far as they are identifiable in the satellite imagery, i.e. stands are dense/tall enough to show a distinct signature.

**Deciduous Hardwoods:** Typically willow and poplar species growing adjacent to inland water and rivers, this class also includes stands of planted

exotic deciduous hardwoods, such as oak (*Quercus* spp.), ash (*Fraxinus excelsior*) and elm (*Ulmus* spp.).

### **NZLC Indigenous Vegetation and Scrub:**

**Fernland:** This class includes areas of dominant bracken fern (*Pteridium esculentum*), umbrella fern (*Gleichenia* species), and ring fern (*Paesia scaberula*). The ferns are often associated with shrubs, such as manuka or kanuka, as the community represents a successional vegetation type on previously forested land. Sites have low fertility and often a history of recent burning. The ferns reach heights of 0.5 - 3m.

**Manuka and or Kanuka:** Indigenous shrubland found throughout New Zealand often associated with lightly grazed hill country. Typically found as early successional scrub type on previously forested land with a history of burning to control scrub reversion. Presence of mature stands signifies an advanced stage of reversion, also indicated by the presence of broadleaved forest species. Manuka (*Leptospermum scoparium*) or kanuka (*Kunzea ericoides*) can be dominant, but they also occur in mixtures. Both species have been grouped together in one land cover class. Kanuka is more common in the North Island with a maximum height of 8-10m on moist sites. Manuka dominates South Island communities with a maximum height of 2-6m.

**Matagouri:** A divaricating, thorny shrub reaching a height of 1 - 2m found in open shrubland or thickets. Matagouri (*Discaria toumatou*) is restricted to montane areas of the South Island and is often associated with Low Producing Grassland. Matagouri is commonly found on freely drained recent soils, especially on river terraces and outwash fans. Matagouri benefits from certain farm management practices, in particular phosphate fertiliser application, and therefore, occurs often in extensively managed grazing country. Its open growth habit and low plant biomass relative to height mean that areas are difficult to reliably detect in the satellite imagery. Therefore, areas mapped are generally thickets or older stands where the canopy is dense, while more open or young stands can often not be separated from the surrounding grassland.

**Broadleaved Indigenous Hardwoods:** Typically found in high rainfall areas associated with Low Producing Exotic Grassland in hill country throughout New Zealand. However, the class also includes low-growing, coastal broadleaved forest. Characteristic is the presence of a mix of broad-leaved, generally seral hardwood species, such as wineberry (*Aristotelia serrata*), mahoe (*Melicytus ramiflorus*), *Pseudopanax* spp., *Pittosporum* spp., *Fuchsia*

spp., ngaio (*Myoporum laetum*), and titoki (*Alectryon excelsus*), together with tutu (*Coriaria* spp.) and tree ferns. The presence of this class usually indicates an advanced successional stage back to indigenous forest. Canopy height ranges from 3 - 10m.

**Grey Scrub:** Areas of small-leaved indigenous shrubs with mainly divaricate growth form, i.e. the shrubs form dense masses of entangled, fine branches by branching at almost right angles. Smallleaved *Coprosma* are usually dominant. Characteristic is also the presence of native climbers such as *Muehlenbeckia* and *Parsonsia*. From a distance these areas have a grey appearance (hence 'grey scrub'), as the woody component is the dominant feature, while leaves are small and inconspicuous. Areas of dominantly manuka / kanuka and matagouri are mapped separately (see classes 52 and 53).

**Indigenous Forest:** Classification of indigenous forest classes using satellite imagery has not been attempted for LCDB2. A national programme establishing permanent plots throughout all indigenous forest and scrub mapped in LCDB1, began in 2002. Ground data from this programme and other survey records may be used to update indigenous forest classes at a later date. Indigenous forest is defined as vegetation dominated by indigenous tall forest canopy species.

**NZLC Alpine:**

**Alpine Gravel and Rock:** A class mainly represented in the Southern Alps above an altitude of approximately 1300m, but includes scree slopes and glacial debris, as well as rock tor areas, throughout the hill and high country of New Zealand. Dominant cover is solid or fractured rock, mostly greywacke and argillite. Surfaces are recent and vegetation, if present, is of very low biomass and not apparent in the imagery.

**Sub Alpine Shrubland:** This class includes a diverse range of shrubland communities usually occurring within an altitudinal range of 900 - 1200m,

but also at lower altitudes where they represent secondary vegetation after forest clearance. The class is transitional between Indigenous Forest at lower altitudes and Tall Tussock Grassland, Alpine Grass-/Herbfields, and Alpine Gravel and Rock above 1200 - 1300m. Communities are more stable than lowland scrub types with composition and height strongly influenced by rainfall and exposure. Typical species present include Hebe, Olearia, Dracophyllum and Cassinia with canopy height ranging from 0.3 - 4m. The class also includes frostflat areas at lower altitudes, where comparable scrub types have established due to microclimatic conditions. Such areas are widespread in the central North Island.

**Tall Tussock Grassland:** This class is typically found at higher altitudes in the South Island high country with limited presence in the North Island main ranges. Tall Tussock Grassland occurs in areas that have not been subject to intensive farm management. The class is characterised by the presence of *Chionochloa* species, usually accompanied by short tussock grassland species, and a number of herbs, in particular, *Celmisia* species. The structure of this vegetation type varies considerably. In some areas the *Chionochloa* tussocks are very low growing, e.g. where carpet grass (*Chionochloa australis*) is dominant, in other areas they reach up to 150cm in height. Exotic grasses are usually present, especially on pastoral runs that support summer grazing. Paddock size is large reflecting the extensive nature of pastoral activity.

This class also includes areas of red tussock (*Chionochloa rubra*) growing in damp hollows and on boggy ground on terraces and valley floors as part of freshwater wetland systems.

**NZLC Wetland:**

**Herbaceous Freshwater Vegetation:** Areas dominated by herbaceous aquatic vegetation as a component of freshwater wetlands, i.e. the plants emerge over freshwater or grow in freshwater saturated soils. The vegetation is dominated by sedges (*Cyperaceae*), rushes (*Juncaceae*), or tall

erect herbs from other families (Poaceae, Restionaceae, Typhaceae ). The class also includes areas of low-growing dicotyledon herbs and areas of sphagnum moss. Areas of red tussock are excluded, as they are mapped under Tall Tussock Grassland (Class 43). Areas of Herbaceous Freshwater Vegetation can be permanently or periodically wet (ephemeral wetlands). The mapped area reflects the extent evident in the 2001 / 2002 satellite imagery

**Herbaceous Saline Vegetation:** Areas dominated by herbaceous aquatic vegetation as a component of estuarine or coastal wetlands, i.e. the plants emerge over saline or brackish water or grow in saltwater saturated soils. Most areas of Herbaceous Saline Vegetation are subject to tidal changes in water level. The vegetation is dominated by salt-tolerant plants, such as *Schoenoplectus* spp., *Apodasmia similis*, or glasswort (*Sarcocornia quinqueflora*).

**Flaxland:** Areas dominated by lowland flax (*Phormium tenax*). Sites are usually moist and often represent parts of wetland systems. (Note: In LCDB 1, stands of flax outside wetland systems were mapped in the scrub class. Where flax mapped in LCDB 2 corresponds with scrub in LCDB 1, it will be removed from the LCDB 1 scrub class and reassigned to the most appropriate LCDB 1 wetland class, to ensure compatibility between LCDB 1 and 2.)

**Mangrove:** Mangrove (*Avicenna officinalis*) communities found on estuarine mudflats and tidal creeks. Distribution is restricted to upper North Island northward of latitude 38°. Canopy height can reach 7m reducing to 1m in the southern range of the distribution.

**NZLC Water:**

**Rivers:** Areas of flowing open freshwater without emerging vegetation (riverine systems). The class includes natural and modified rivers, creeks, canals, and channels. The area of flowing open freshwater reflects the water levels at time of image acquisition, and is limited to water bodies exceeding a width of 30 m (2 pixels). Rivers are bounded downstream by Estuarine Open Water, which has a saline influence.

**Estuarine:** Areas of standing or flowing open water without emerging vegetation, where occasionally or periodically saline waters are diluted by freshwater or freshwater is made saline. The class includes the estuaries of rivers, lagoons, and dune swales. The area of estuarine open water reflects the maximum extent documented in either the satellite imagery or NZ 260 Topodata.

## Appendix B - NZDep Components

<i>Dimension of deprivation</i>	<i>Variable description (in order of decreasing weight)</i>
Income	People aged 18-64 receiving a means tested benefit
Income	People living in equivalised* households with income below an income threshold
Owned home	People not living in own home
Support	People aged <65 living in a single parent family
Employment	People aged 18-64 unemployed
Qualifications	People aged 18-64 without any qualifications
Living space	People living in equivalised* households below a bedroom occupancy threshold
Communication	People with no access to a telephone
Transport	People with no access to a car

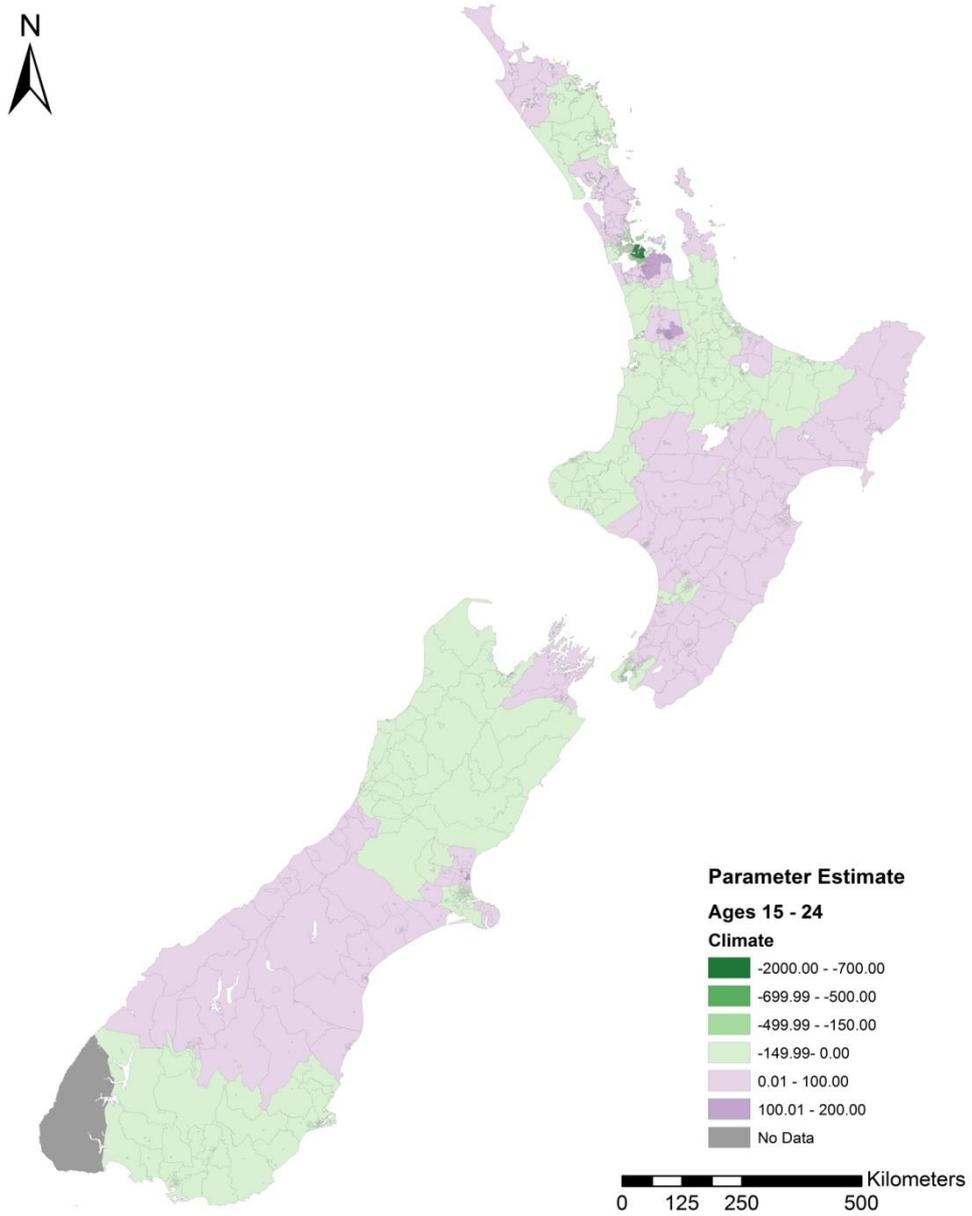
\*Equivalisation: methods used to control for household composition.

(Salmond & Crampton, 2012)

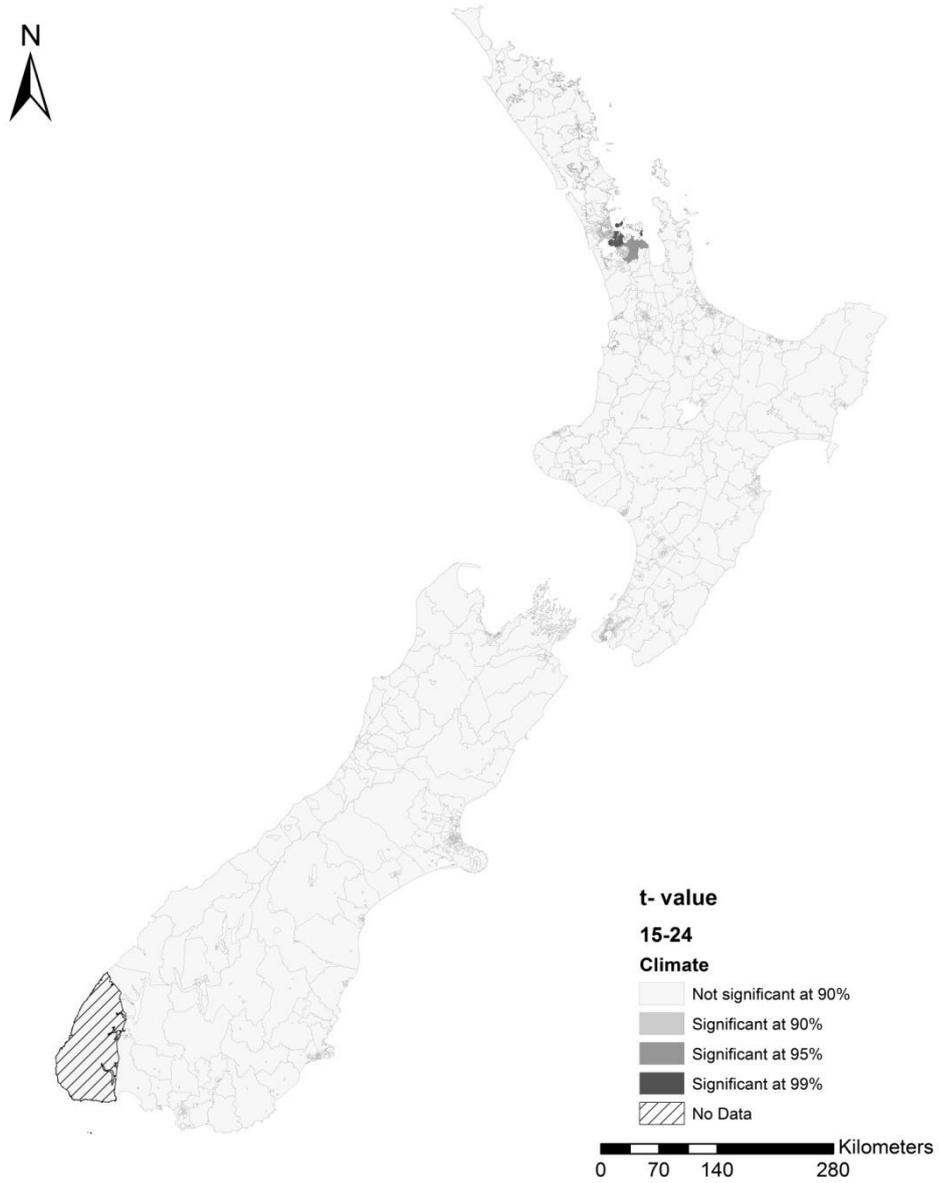
## Appendix C - Geographically Weighted Regression Full Page Maps

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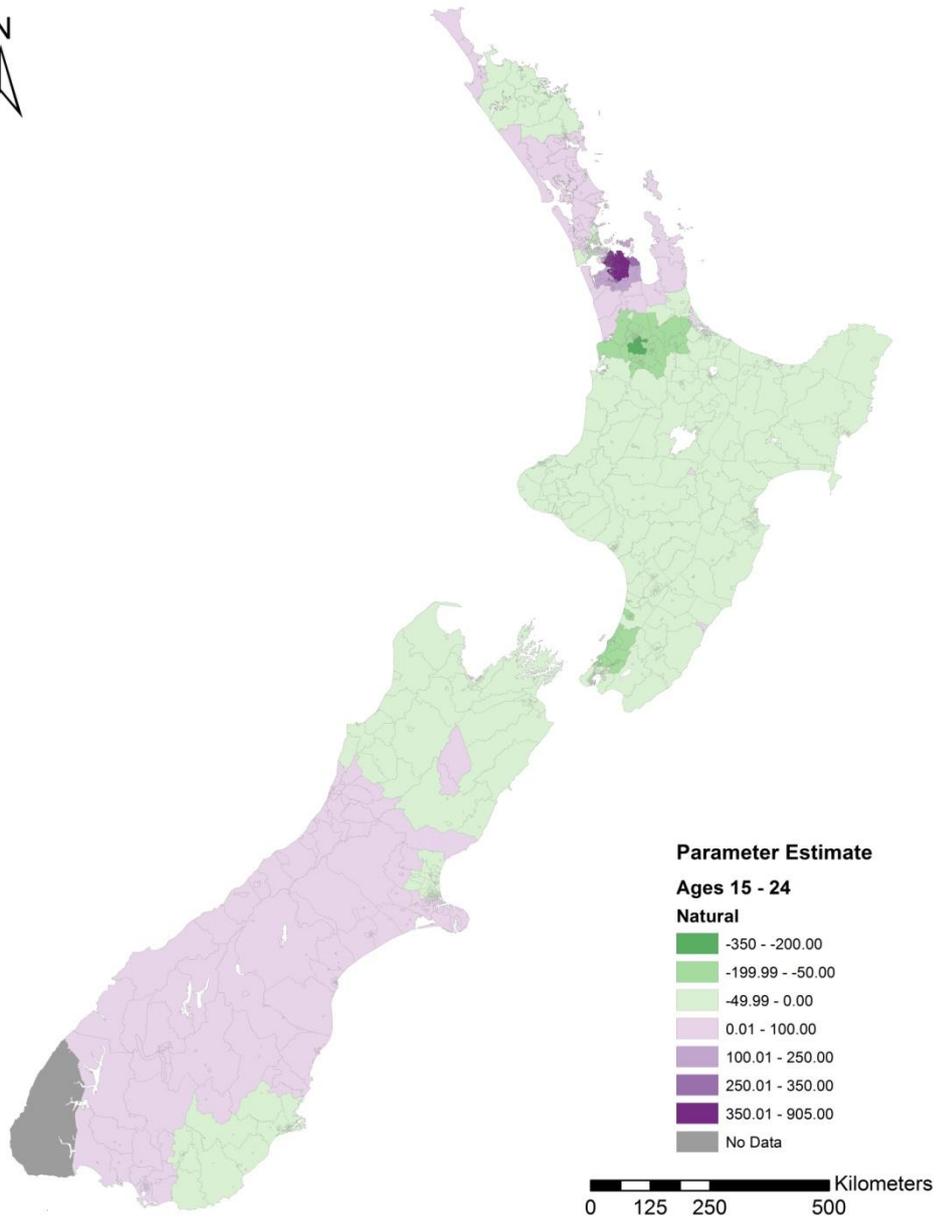
### Globally Weighted Regression Results



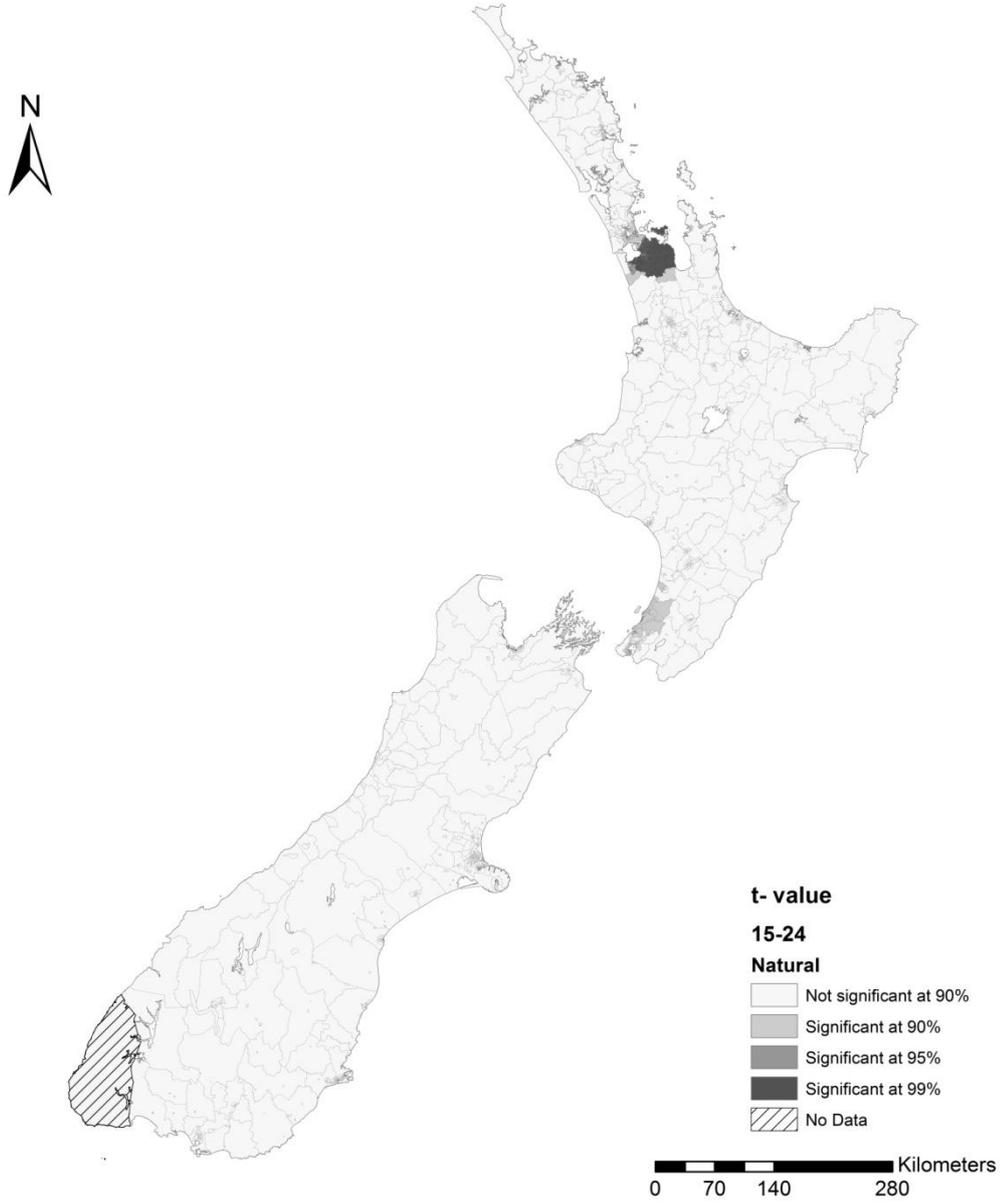
## Globally Weighted Regression Results



## Globally Weighted Regression Results

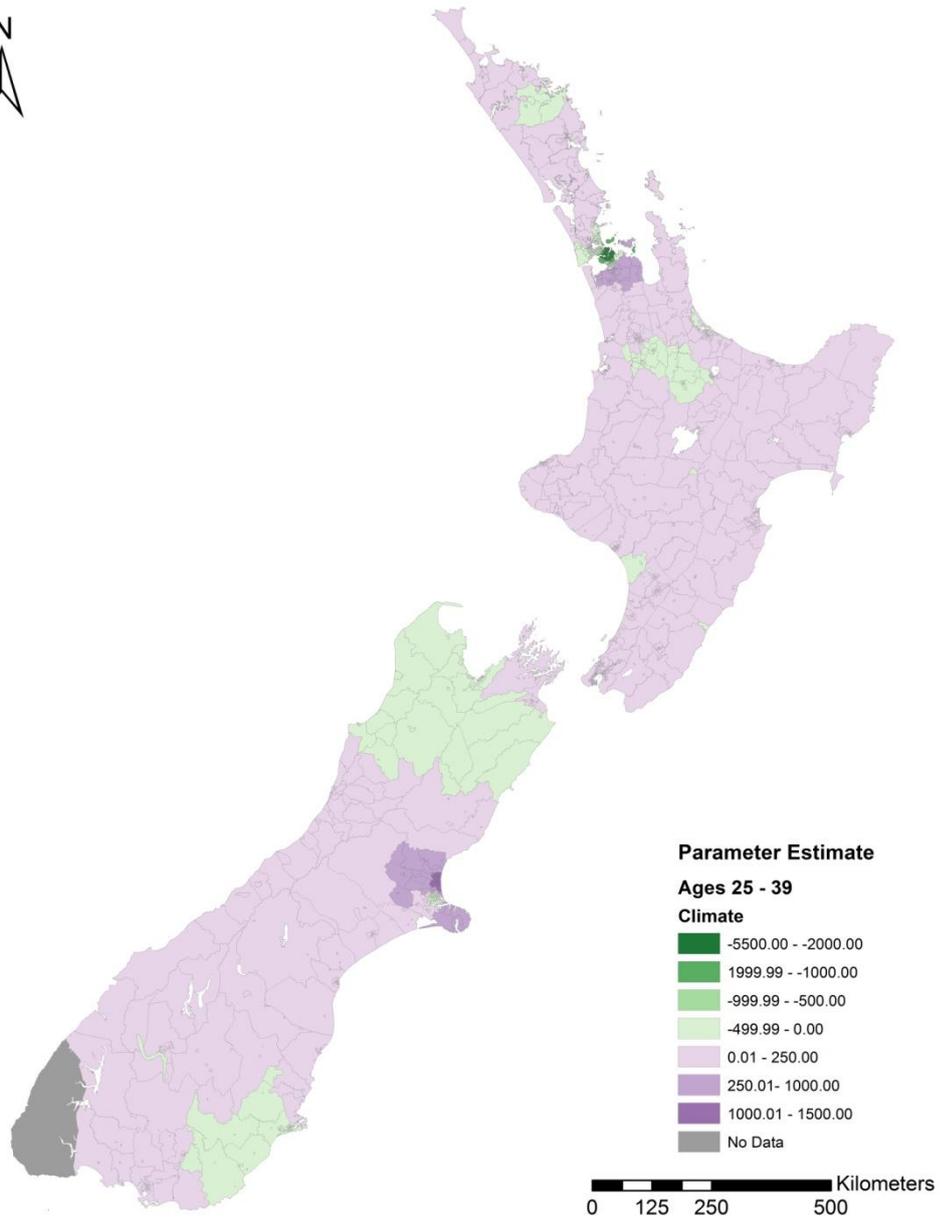


# Globally Weighted Regression Results

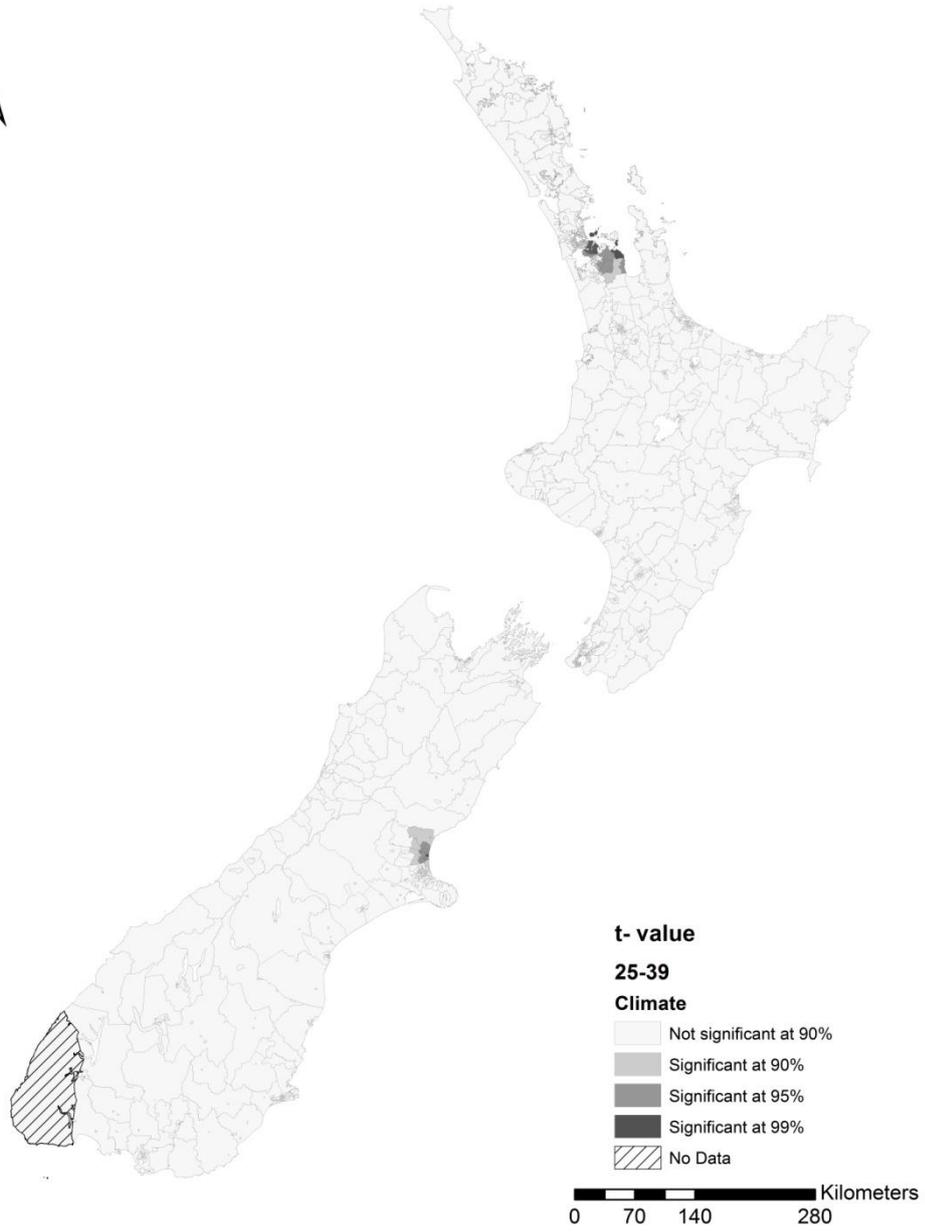


Ages 25-39:

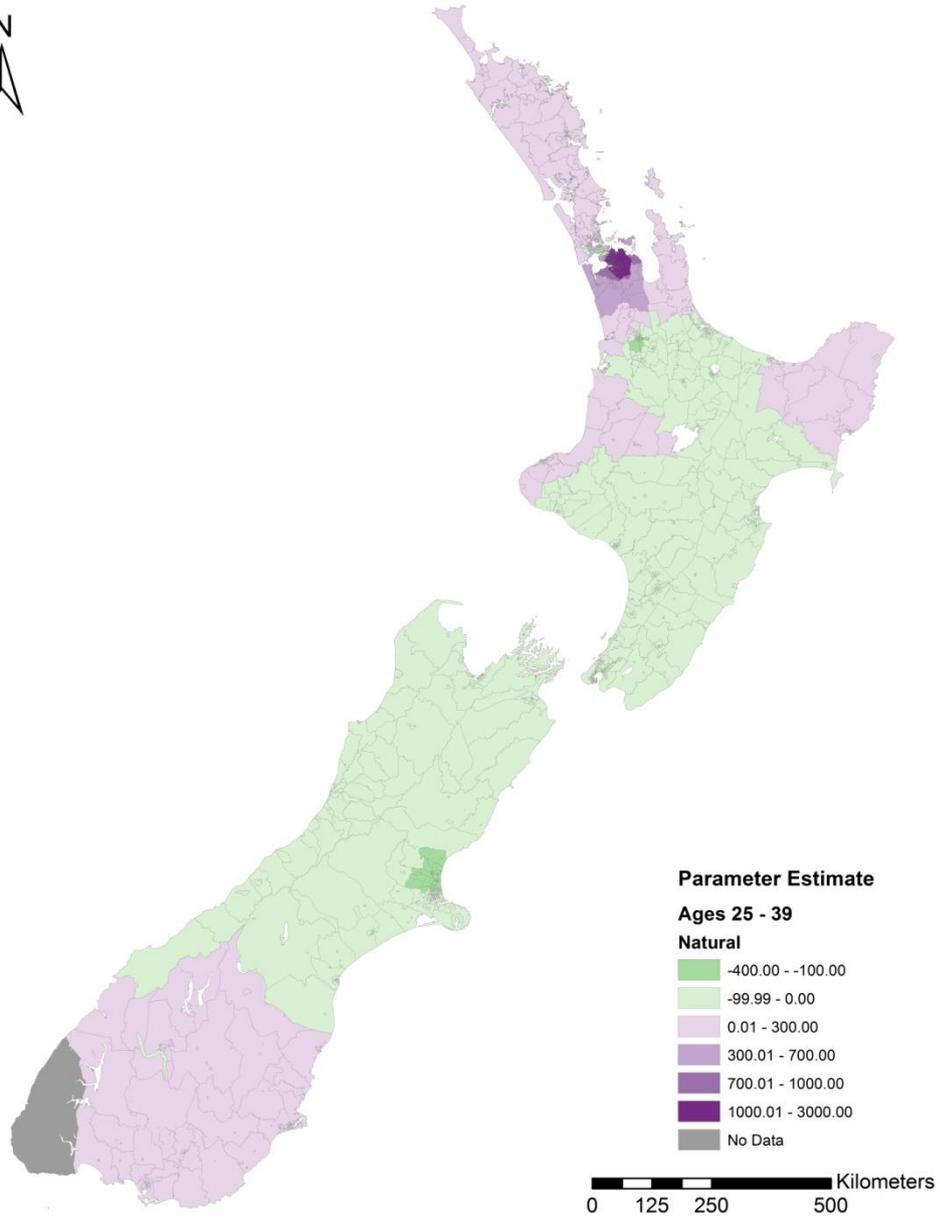
## Globally Weighted Regression Results



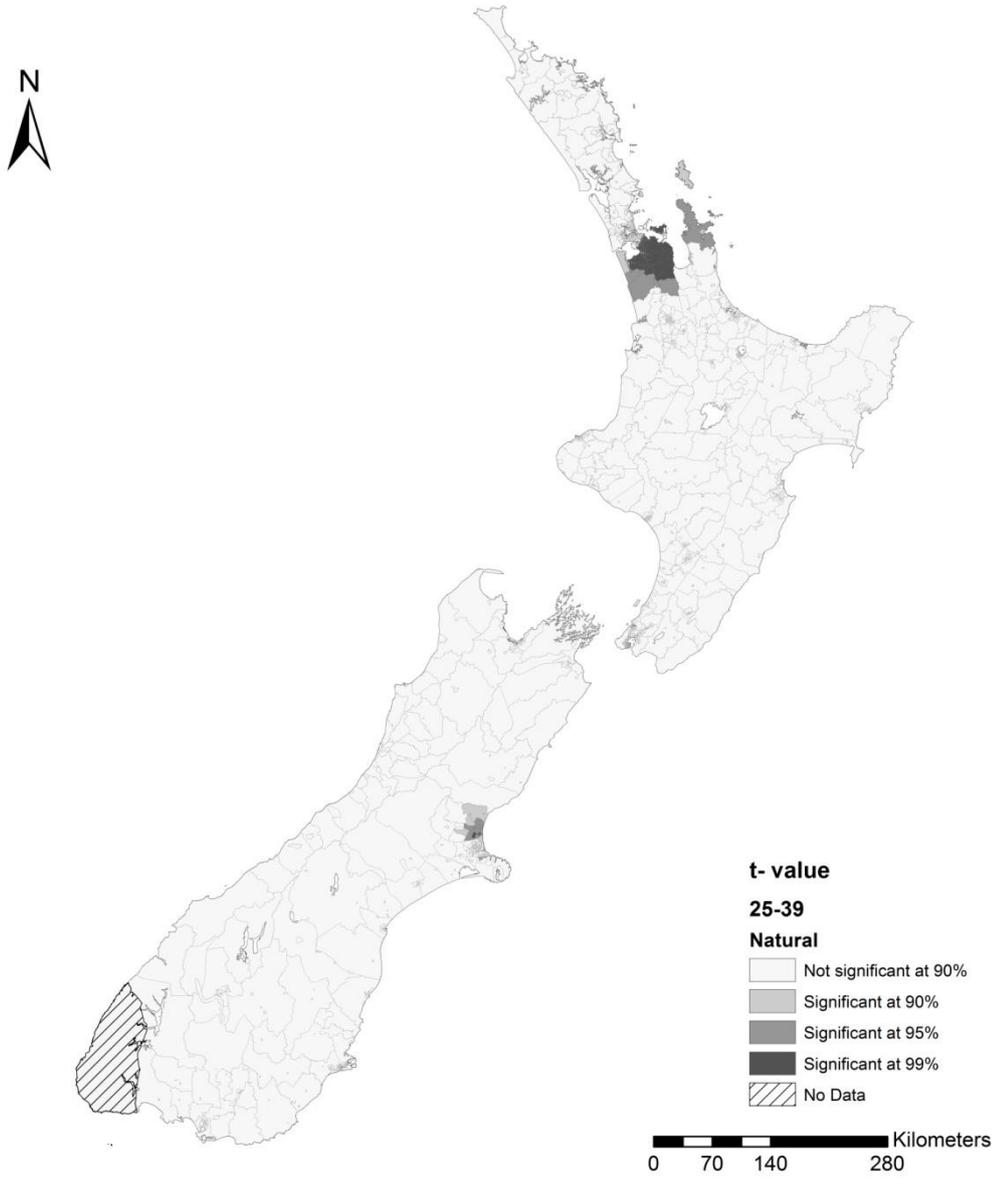
## Globally Weighted Regression Results



# Globally Weighted Regression Results

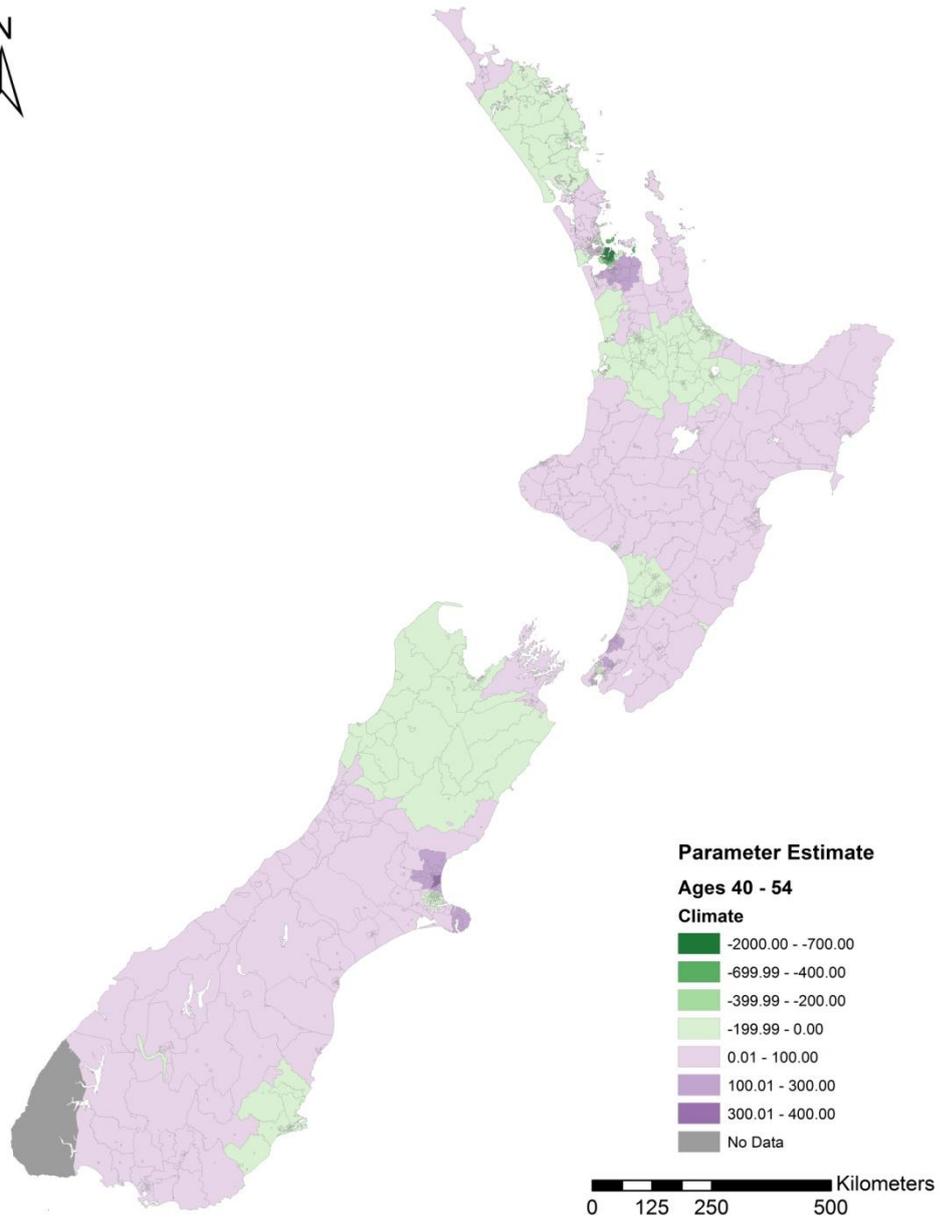


## Globally Weighted Regression Results

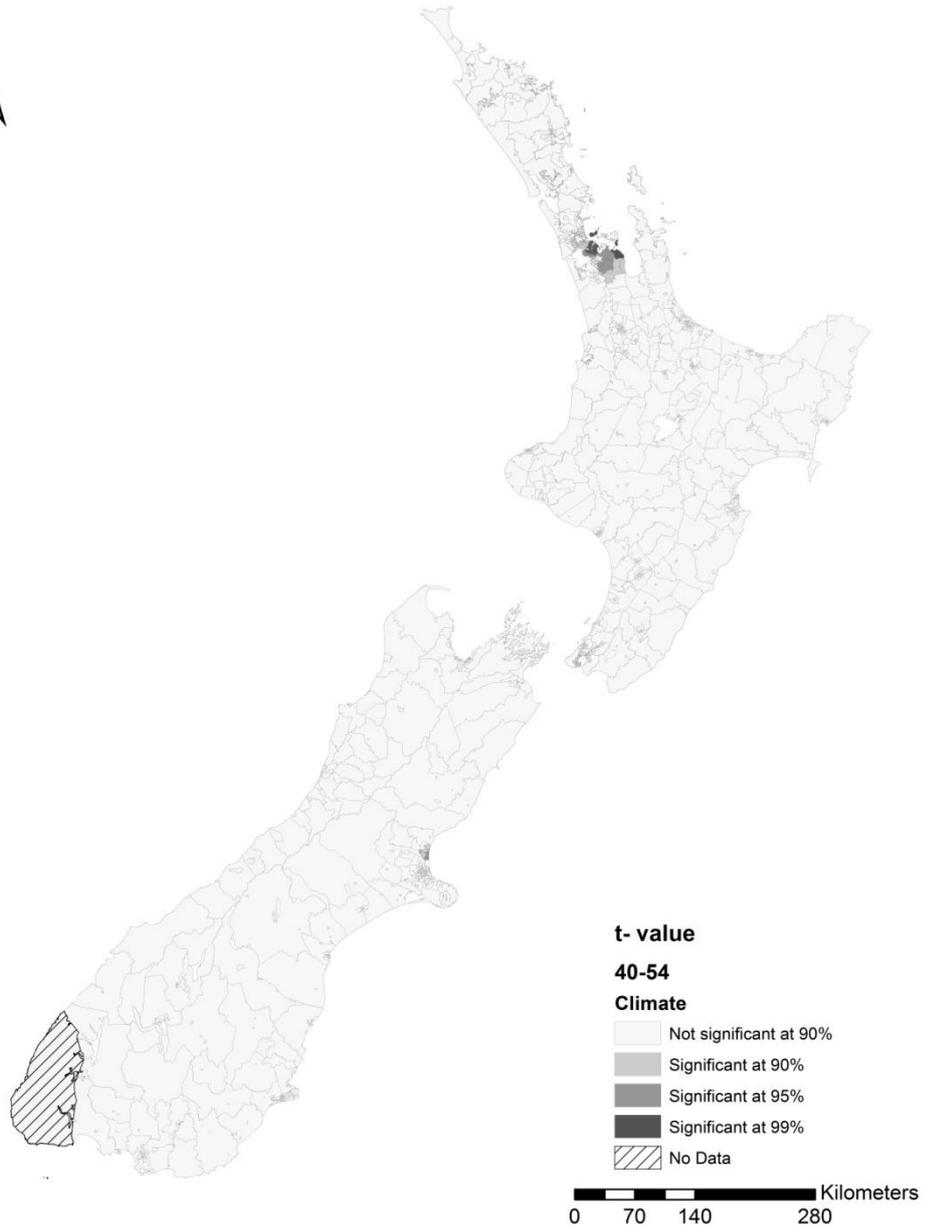


Ages 40-54:

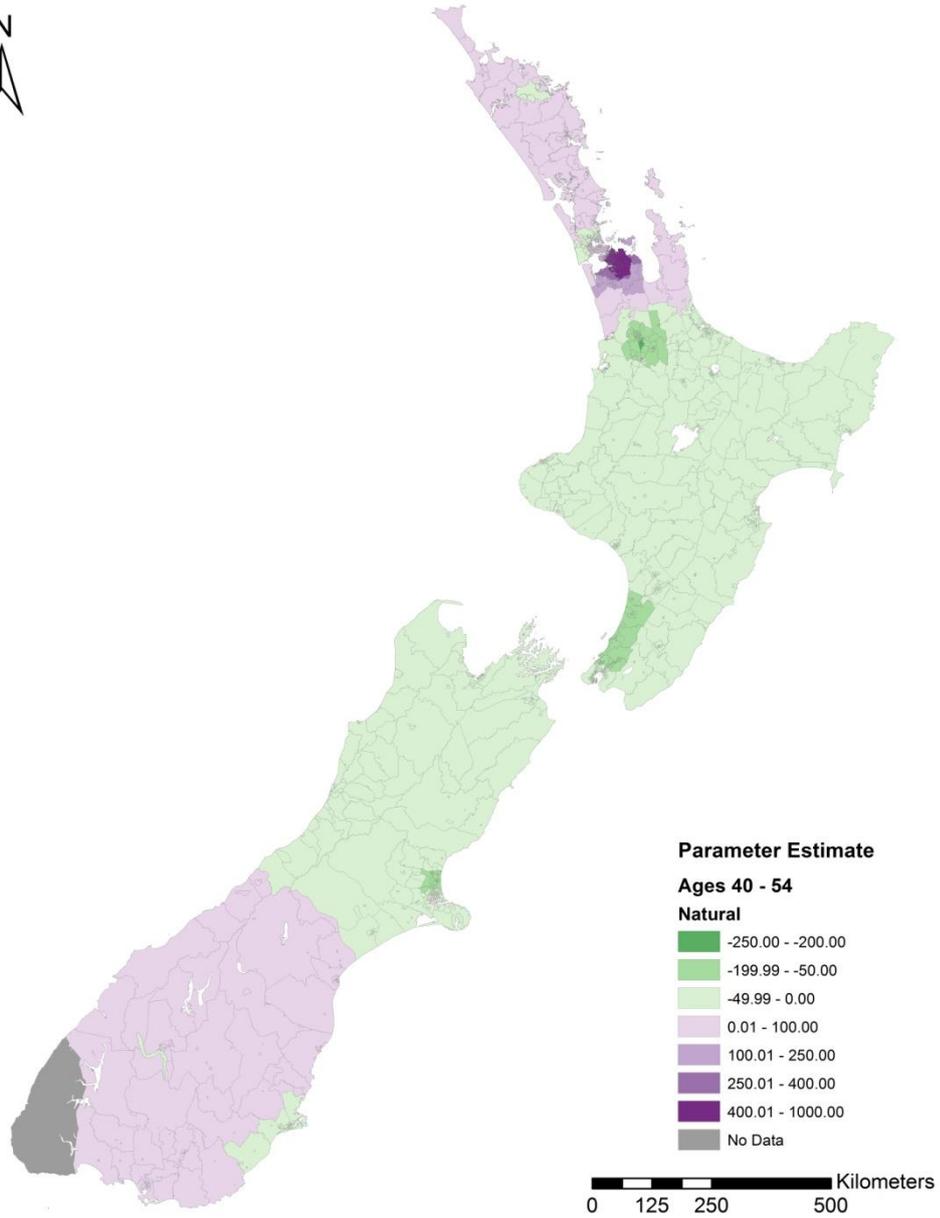
## Globally Weighted Regression Results



## Globally Weighted Regression Results



# Globally Weighted Regression Results

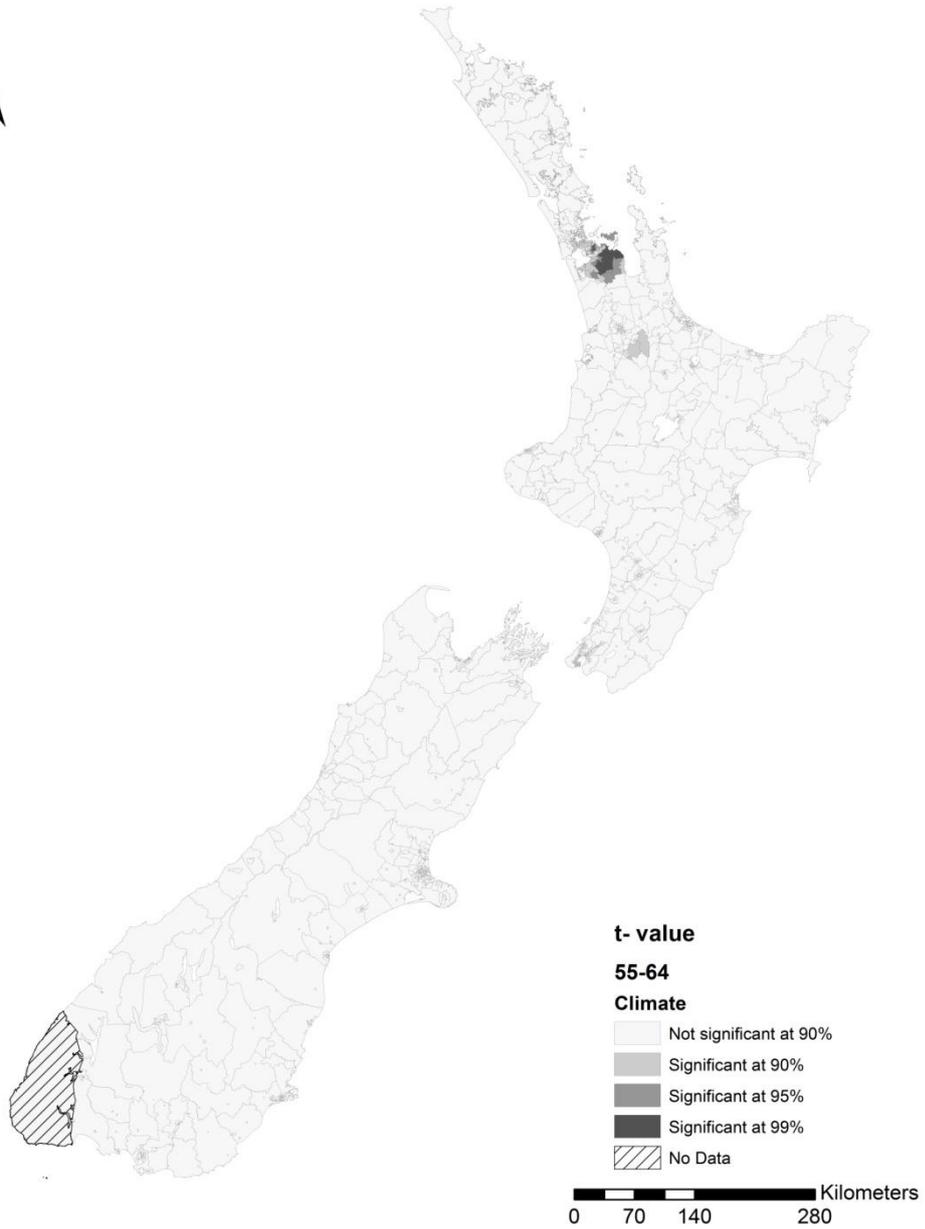


# Globally Weighted Regression Results

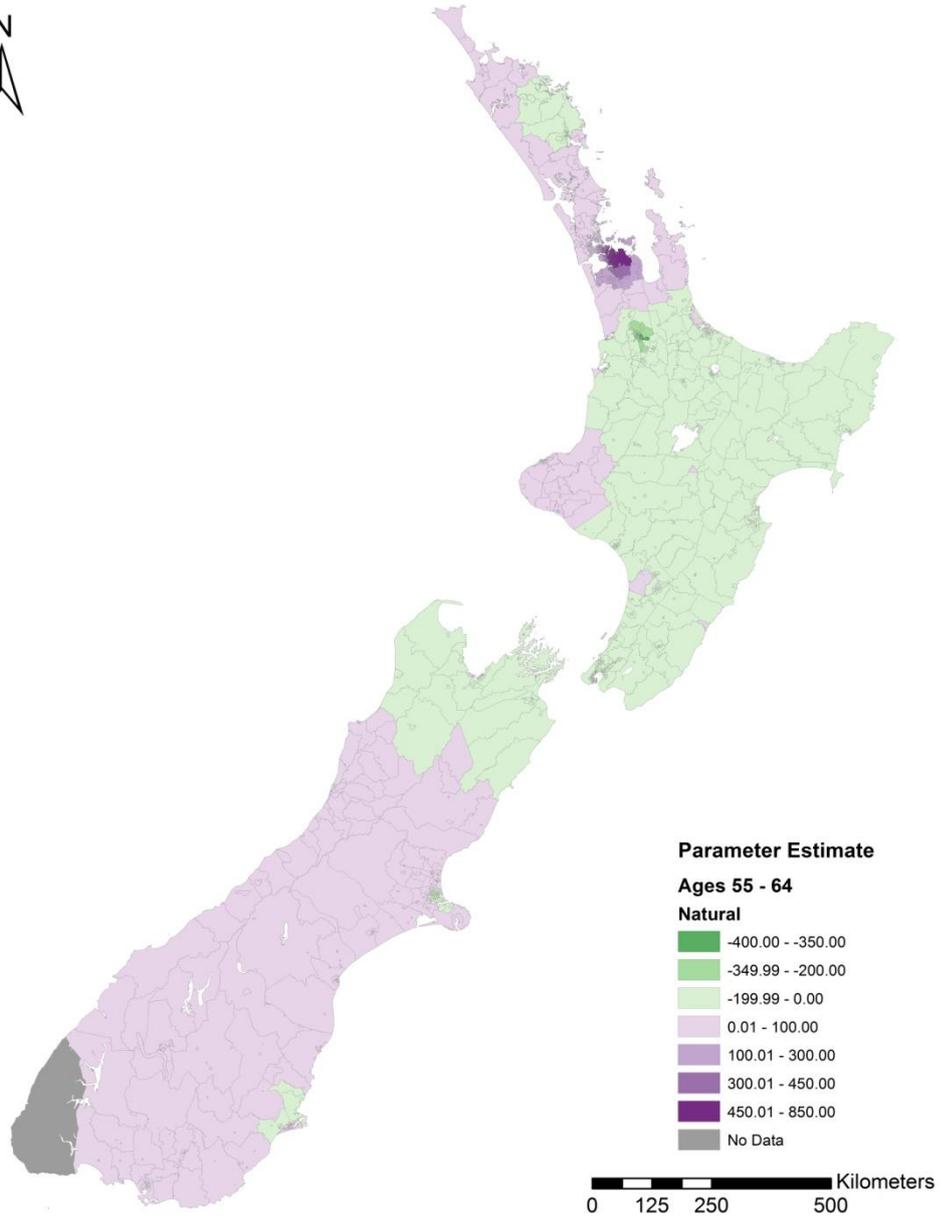


Ages 55 - 64:

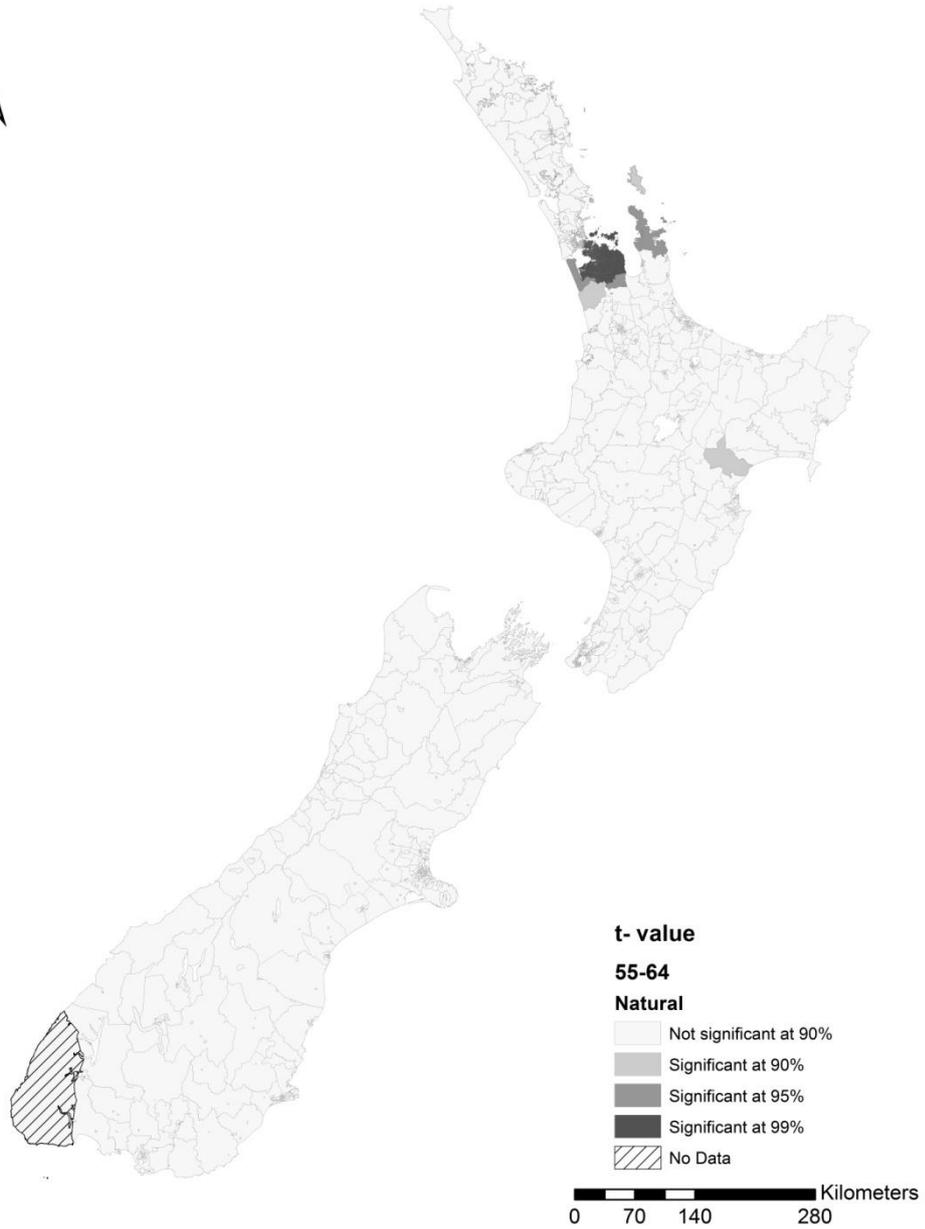
## Globally Weighted Regression Results



# Globally Weighted Regression Results

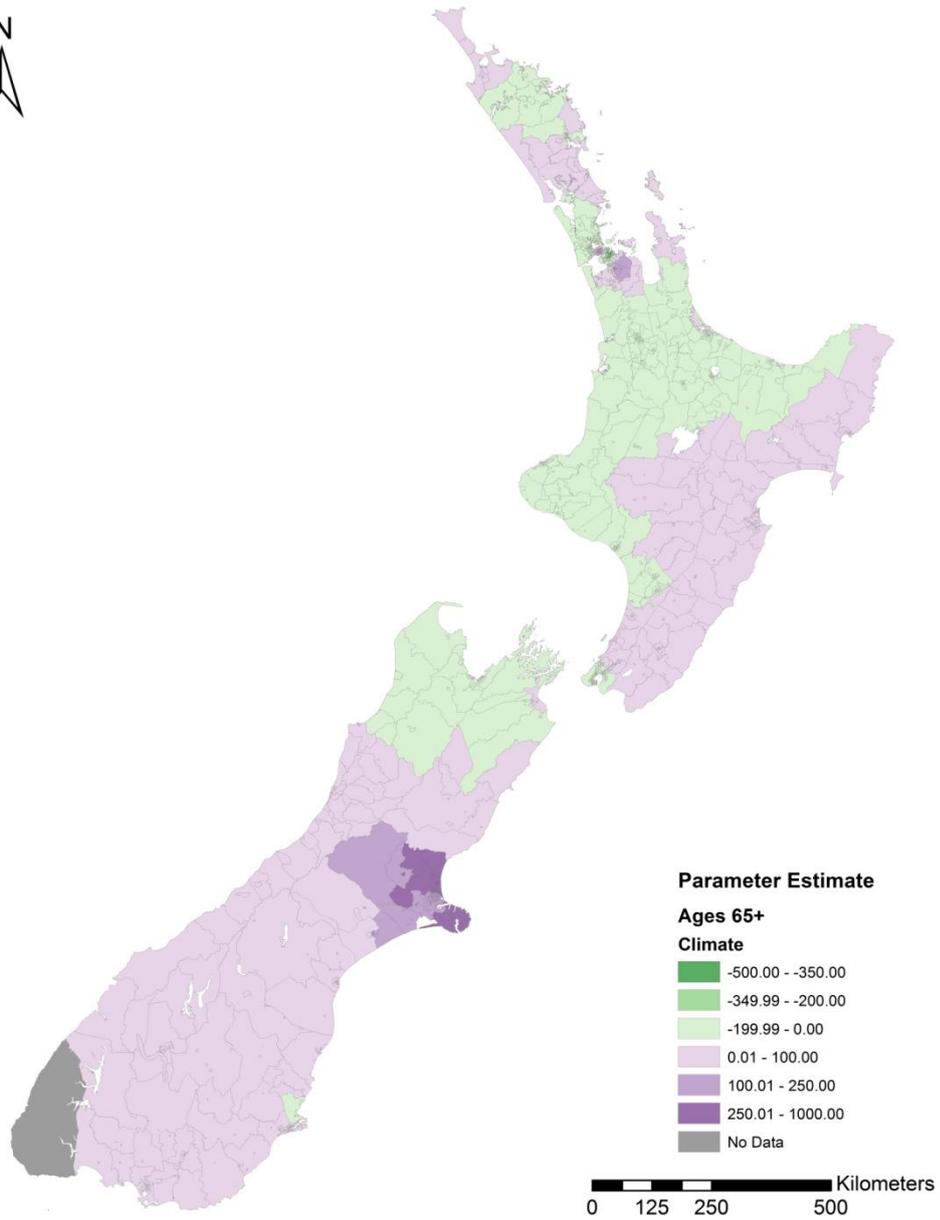


## Globally Weighted Regression Results

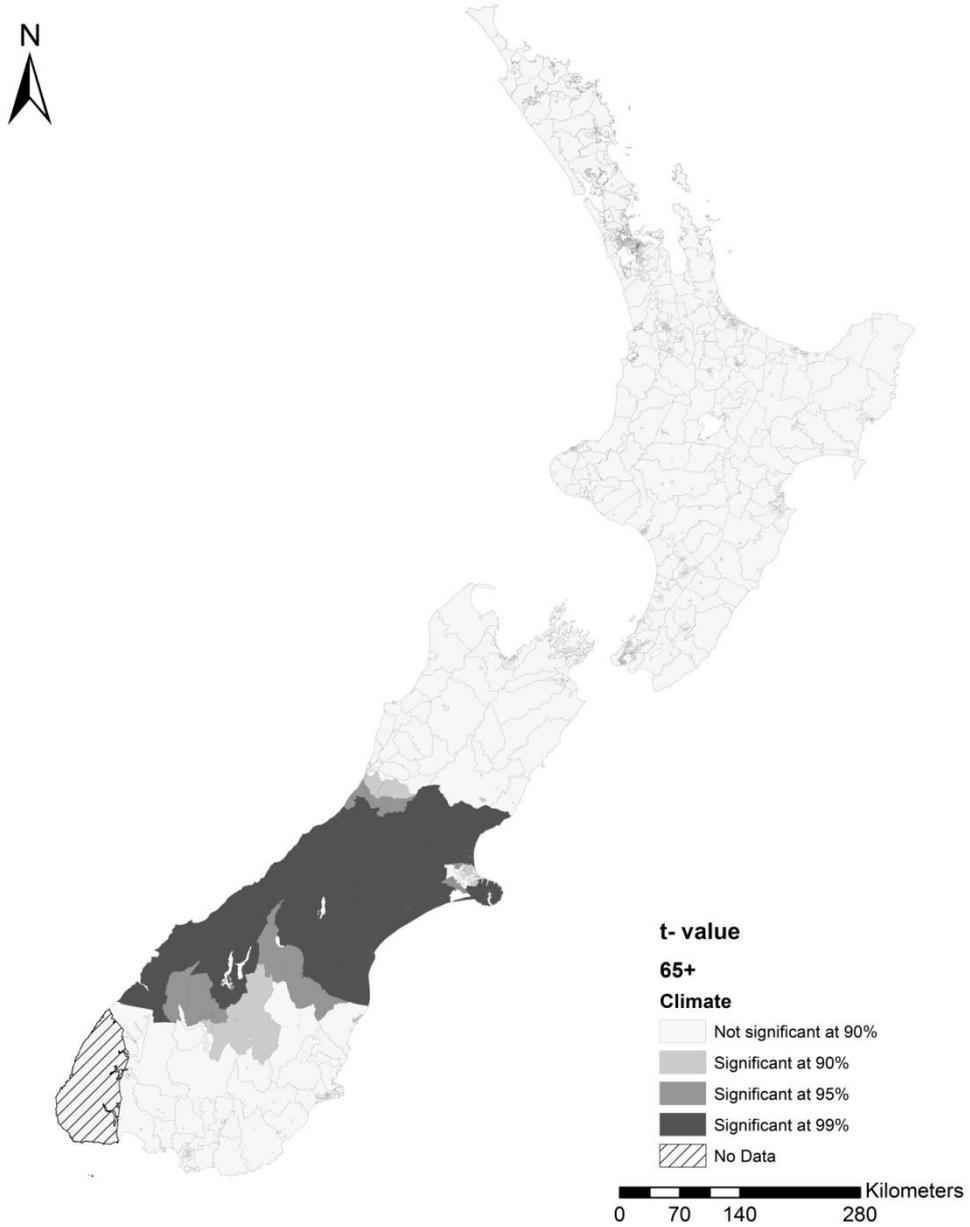


**Ages 65+:**

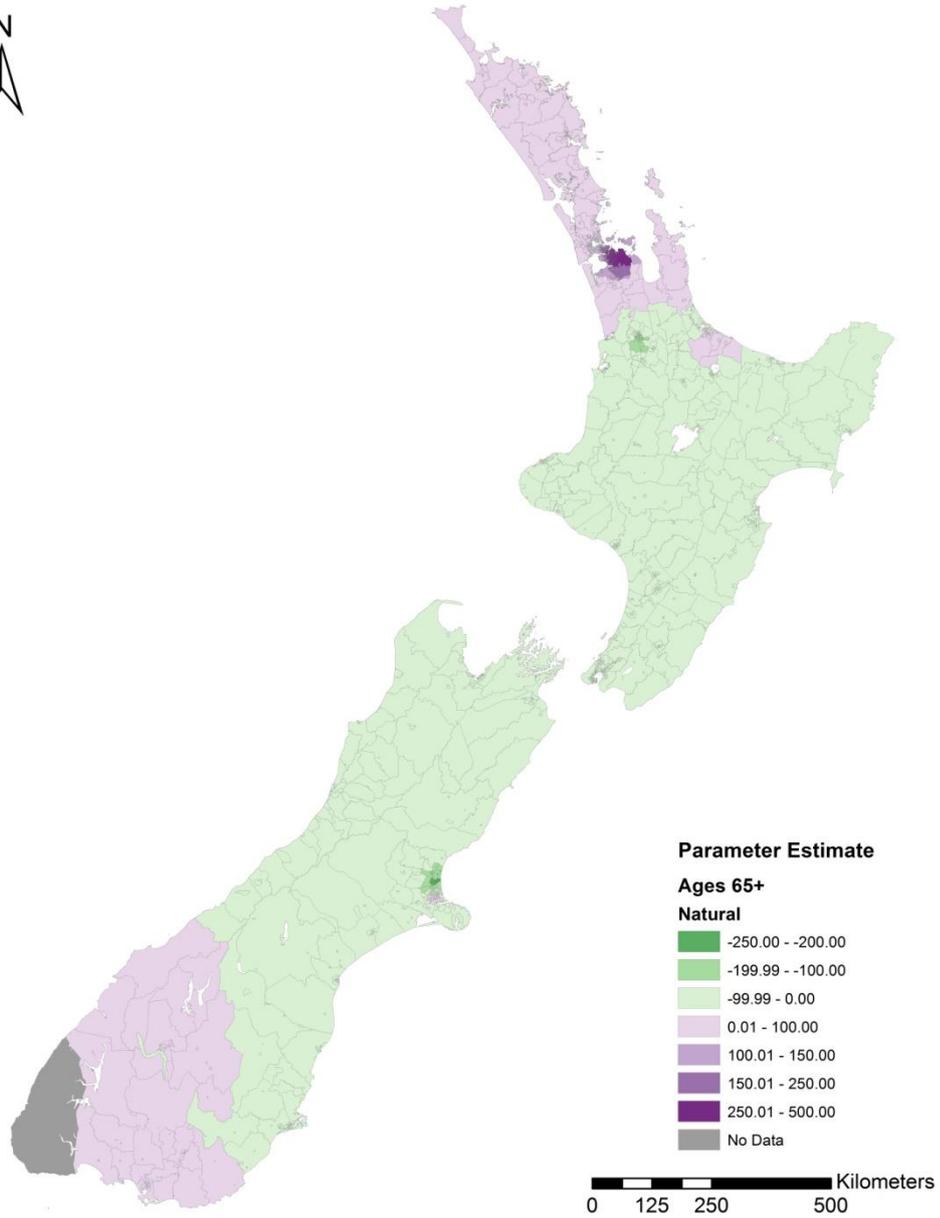
## **Globally Weighted Regression Results**



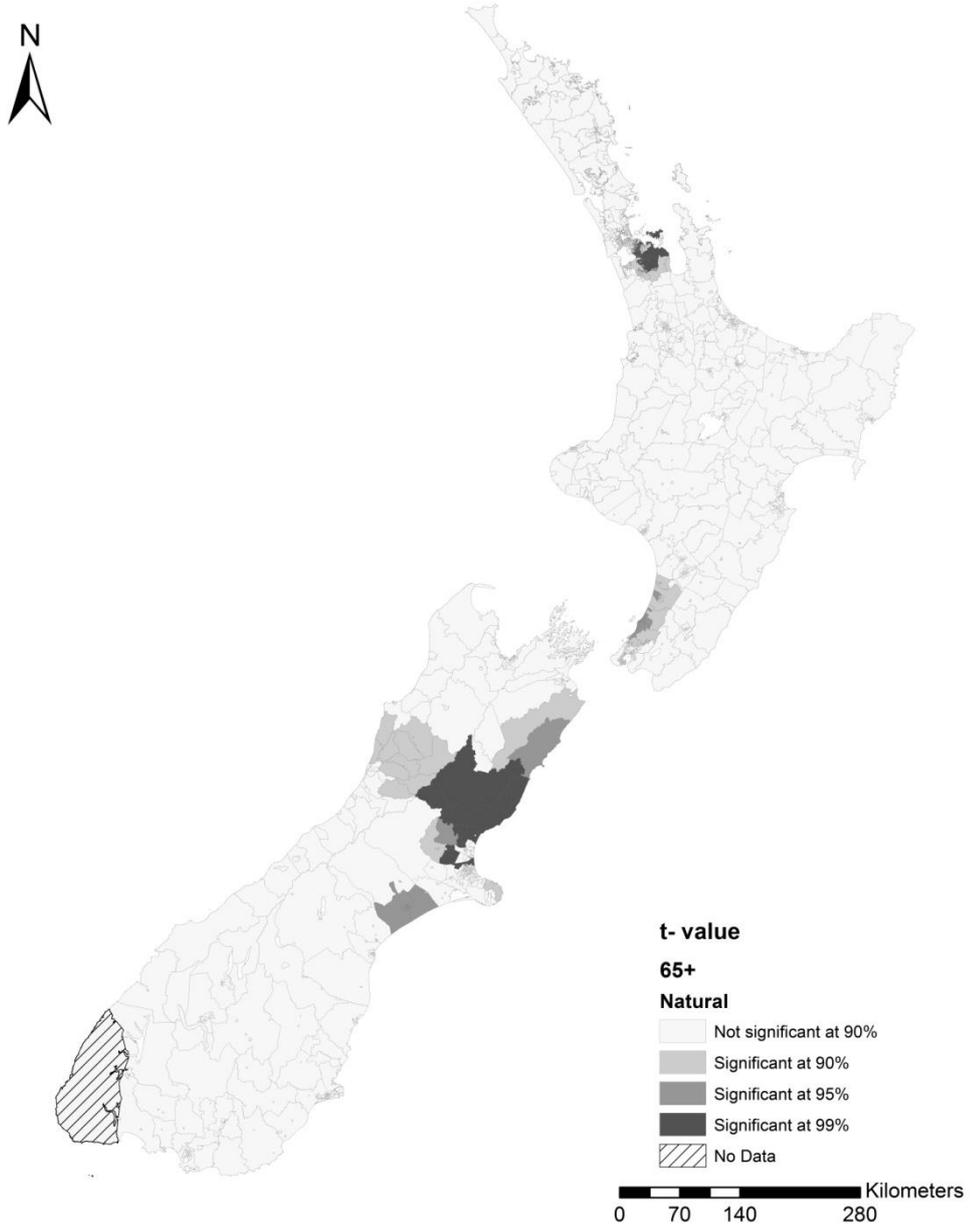
## Globally Weighted Regression Results



# Globally Weighted Regression Results

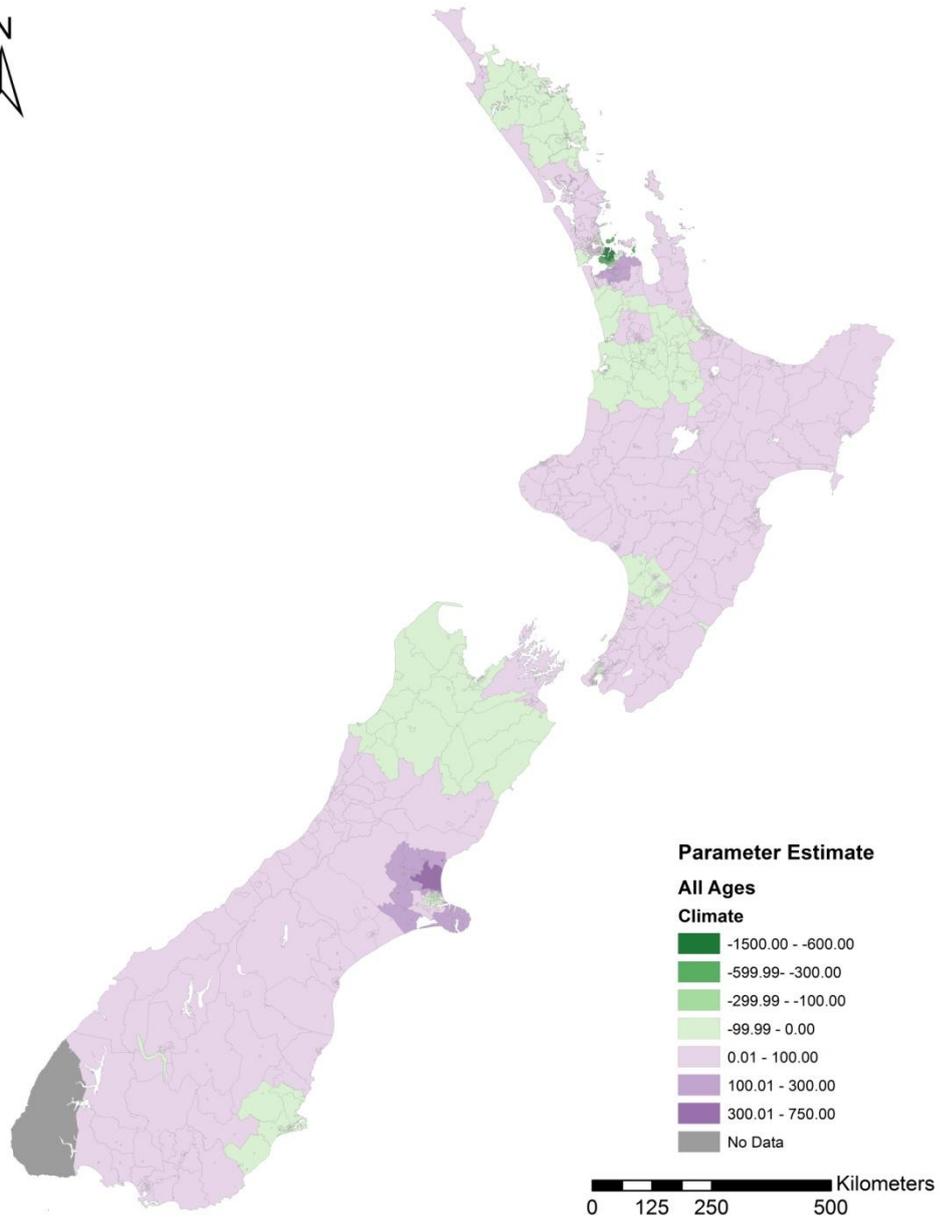


## Globally Weighted Regression Results

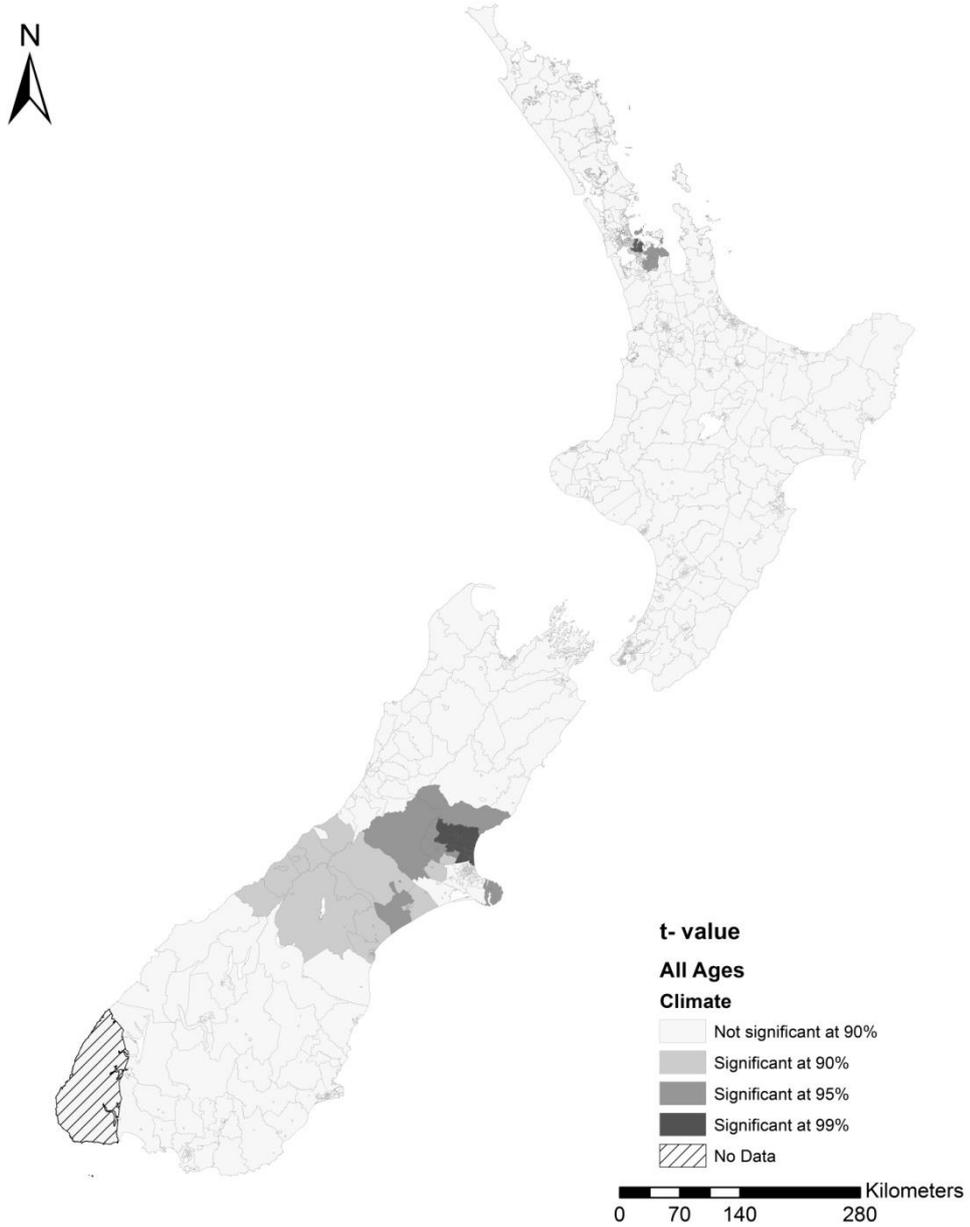


All Ages:

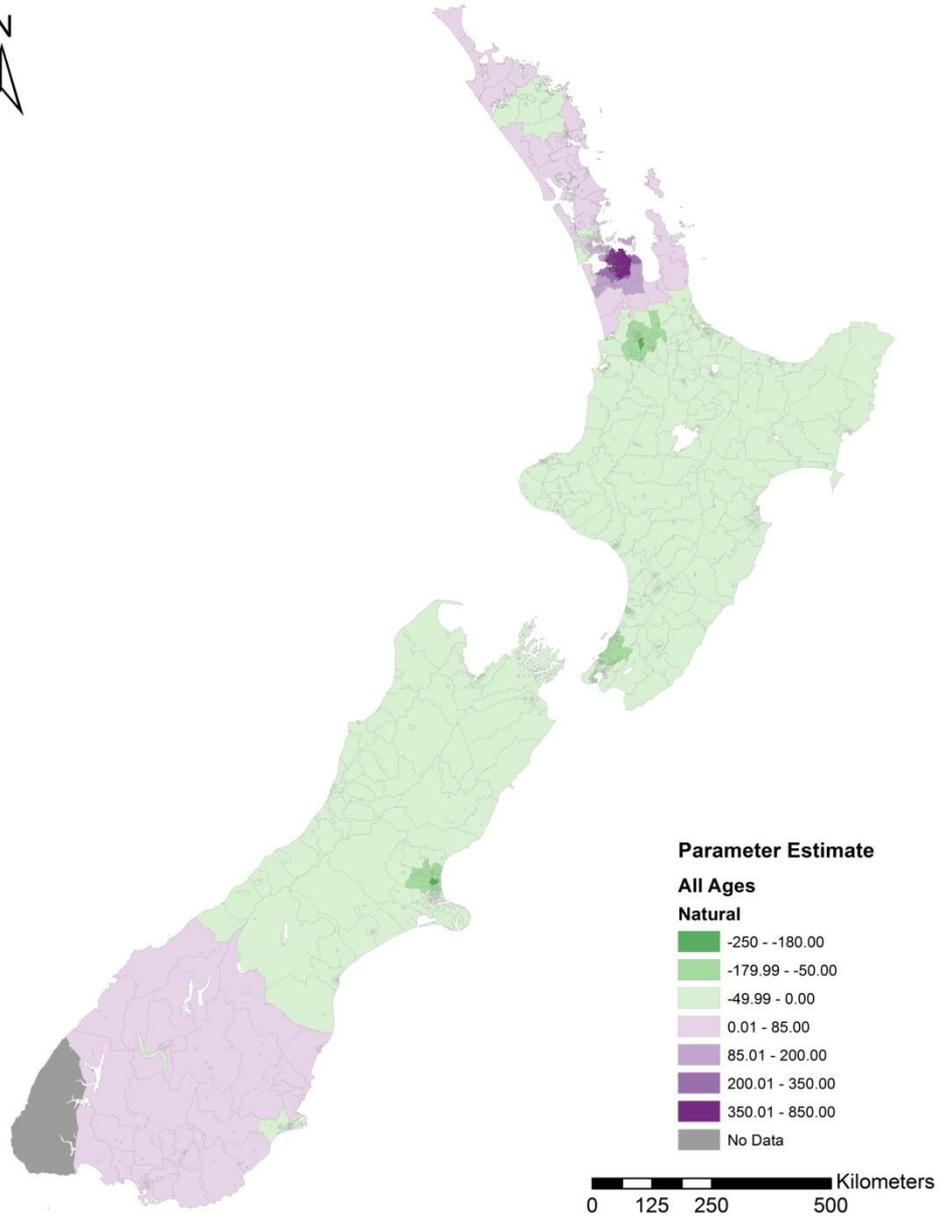
## Globally Weighted Regression Results



## Globally Weighted Regression Results



# Globally Weighted Regression Results



# Globally Weighted Regression Results

