EAI Endorsed Transactions
on Pervasive Health and Technology
Research Article EAI.EU

The associations between mental health and environmental factors in New Zealand: A region-based analytical study

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Abstract

INTRODUCTION: Connections between environmental factors and mental health issues have been postulated in many different countries around the world. Previously undertaken research has shown many possible connections between these fields, especially in relation to air quality and extreme weather events. However, research on this subject is lacking in New Zealand, which is difficult to analyse as an overall nation due to its many micro-climates and regional differences.
OBJECTIVES: The aim of this study and subsequent analysis is to explore the associations between environmental factors and poor mental health outcomes in New Zealand by region and predict the number of people with mental health-related illnesses corresponding to the environmental influence.
METHODS: Data are collected from various public-available sources, e.g., Stats NZ and Coronial services of New Zealand, which comprised four environmental factors of our interest and two mental health indicators data ranging from 2016 up until 2020. The four environmental factors are air pollution, earthquakes, rainfall and temperature. Two mental health indicators include the number of people seen by District Health Boards (DHBs) for mental health reasons and the statistics on suicide deaths. The initial analysis is carried out on which regions were most affected by the chosen environmental factors. Further analysis using Auto-Regressive Integrated Moving Average(ARIMA) creates a model based on time series of environmental data to generate estimation for the next two years and mental health projected from the ridge regression.
RESULTS: In our initial analysis, the environmental data was graphed along with mental health outcomes in regional charts to identify possible associations. Different regions of New Zealand demonstrate quite different relationships between the environmental data and mental health outcomes. The result of later analysis predicts that the suicide rate and DHB mental health visits may increase in Wellington, drop-in Hawke's Bay and slightly increase in Canterbury for the year 2021 and 2022 with different environmental factors considered.
CONCLUSION: It is evident that the relationship between environmental and mental health factors is regional and not national due to the many micro-climates that exist around the nation. However, it was observed that not all factors displayed a good relationship between the regions. We conclude that our hypotheses were partially correct, in that increased air pollution was found to correlate to increased mental health-related DHB visits. Rainfall was also highly correlated to some mental health outcomes. Higher levels of rainfall reduced DHB visits and suicide rates in some areas of the country.

Keywords: mental health, natural environmental factors, data analytics, statistical analysis, New Zealand, public mental status prediction.

Received on 21 February 2022, accepted on 04 May 2022, published on 05 May 2022

doi: 10.4108/eetpht.v8i31.789

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1. Introduction

Mental health, which refers to someone's emotional and psychological wellbeing, can be a difficult issue to quantify. This is largely due to the many factors which can affect mental health, including socioeconomic status, genetics and political environment[1,2]. Anxiety around environmental changes and climate catastrophes likely also exacerbates mental health issues, a phenomenon that has been studied in several countries worldwide [3, 4]

New Zealand is a seismically active country with many major recorded climate events, including earthquakes and volcanic eruptions, in the last several years. However, New Zealand is also home to many different micro-climates, making it difficult to judge environmental factors from a national viewpoint. The northernmost area of the country, including the Auckland and Northland regions, has the warmest weather as well as lower average air quality. In contrast, the southernmost regions, including Southland and Otago, have the coldest average temperatures, and the nearby West Coast has the highest recorded rainfall. Due to these differences, this research was thus undertaken on a regional basis to identify possible correlations between environmental factors and mental health outcomes in New Zealand.

This research aims to help further awareness and information around mental health, a known problem in New Zealand that disproportionally affects the country's population. Overall, previously undertaken research has found that almost a third of New Zealand's population has experienced mental distress, and annual spending accounts for almost $12 billion, or roughly 5% of the country's gross domestic product (GDP) [5]. However, there is a gap in the research on the association between mental health and the country's environment. Thus, our research aim is to identify possible links between environmental factors and mental health outcomes in New Zealand. The study consolidated data on natural environmental factors from various public sources and thoroughly carried out a systematic study with various viable statistical methods, which can be considered a data-driven case study of the issue. Furthermore, we endeavour to predict the number of mental health-related outcomes based on environmental trends to contribute to this area of research. This information will be important for decision-makers such as District Health Boards (DHBs), City Councils and the central government to understand where funding is required the most and to identify and implement effective solutions.

2. Literature Review

Many factors can influence poor mental health, including financial status, the industry of employment, and much more. However, it is proven that the environmental context also plays a vital role in affecting people's mental health[6, 7]. Research linking environmental factors to mental health outcomes has been undertaken in several countries worldwide and seems especially prevalent in areas with significant climate change or catastrophes. In Europe, for example, research has discovered evidence that the consequences of climate change, such as extreme weather events, have a substantial impact on mental health issues like depression and post-traumatic stress disorder [8]. Another study indicated that high levels of air pollution in Japan and China were linked to higher levels of mental health issues. Furthermore, research[9] suggests that suicide mortality is not only linked to personal characteristics and life events but also to environmental exposures.

Environment and climate greatly affect New Zealand in a variety of ways. Earthquakes, for example, are regular in New Zealand, and studies show that they might cause mental health problems[10]. The study also found that after the earthquakes in Canterbury in the early 2010s, there was a 43% rise in mental health presentations among adults and a 69% increase in child and youth mental health services [11]. Furthermore, agriculture is a significant part of the country's economy and is susceptible to climate change. For instance, the difference between a good and bad production year resulting from a severe drought can cost as much as 1.5 per cent of GDP, or more than $1 billion [12]. All these examples can negatively impact many people's mental health outcomes, causing them to experience anxiety or even worse conditions [13].

Despite these connections, environmental factors and mental health studies in New Zealand are scarce. Although there have been studies around this topic, they have primarily focused on specific populations and have not taken climate change into account. For example, mental health issues in New Zealand are much higher among certain population groups, including Māori and Pacifica residents. These groups are far more likely to have a lower socioeconomic status than their White/Pakeha counterparts and are more likely to work in outdoor industries, thus being more exposed to environmental effects [14]. Additionally, those with disabilities and the elderly are more likely to be affected by environmental problems [15]. Depression, for example, is one of the most common outcomes resulting from poor environmental conditions [16]. Research shows that the very young are also more likely to suffer extended mental health issues over time, such as depression, anxiety, and even suicide attempts, due to experiencing climate crises at a young age[17].

3. Hypotheses

Many international studies show that earthquakes significantly impact individuals' mental health [18]. New Zealand is a seismically active country because it is situated at the meeting point of two major tectonic plates [19]. Recent major earthquakes in New Zealand include magnitude 7.1 and 6.3 in 2010 and 2011 in Christchurch and a magnitude 7.8 earthquake in Kaikoura in 2016 [20]. Therefore, we make our first hypothesis:

Hypothesis 1: Earthquakes positively correlate to mental health outcomes and suicide attempts.
In addition, as previously mentioned, air pollution has been shown to have a negative impact on depression symptoms in countries such as China and Japan. Even though New Zealand has lower levels of air pollution than many other countries, increased industrial activities and traffic in large cities have deteriorated air quality in many regions. As a result of these findings, we make our second hypothesis:
Hypothesis 2: Air pollution levels positively correlate to mental health outcomes and suicide attempts.
Furthermore, research from Mullins and White [21] finds that in America, higher temperatures lead to more visits to the emergency service for mental illness, suicides, and self-reported days of poor mental health. Bad weather, such as rainy days, is also proven to negatively impact individuals' mental health [22]. New Zealand has a diverse range of microclimates, and therefore climate factors such as rainfall and temperature vary vastly in different regions [23]. Consequently, we created our third and fourth hypotheses:
Hypothesis 3: Rainfall positively correlates to mental health outcomes and suicide attempts.
Hypothesis 4: Temperature positively correlates to mental health outcomes and suicide attempts.
While the data analysis conducted for this research was primarily quantitative, the insights gained through this literature review have been applied to our final analysis to account for factors missing from the numerical evaluation of these issues.

4. Data Source and Wrangling

Based on the hypotheses and research data sets were aggregated from various sources for all four environmental factors, as well as the two mental health indicators. This section discusses the origin of the data sets, as well as their unique challenges and what was done to them to prepare them for analysis and use for predictions. All data ranges from 2016 up until 2020, with varying levels of completeness.

4.1 Earthquake

Earthquake data has been recorded under GNS Science's Geonet Project since 1960, and the relevant metrics and information for each earthquake can be publicly accessed[24]. Earthquake magnitudes, which measure the energy released during an earthquake, as well as the depth of the earthquake are important factors to measure the overall shaking intensity. Geonet uses the Modified Mercalli intensity scale to indicate the effects of an earthquake on people and the environment. The scale ranges from 1 to 12, where 1 represents weak shaking and 12 depicts complete destruction[25].
The earthquake data was completely sourced from Geonet, and included all earthquakes recorded from 2016 to 2020. The earthquakes were assigned to regions in New Zealand, to allow us to analyse them in the regional setting predicted by mental health data. As earthquakes are only recorded with their longitude and latitude, the only reliable way to assign regions to them is using reverse geocoding. Reverse geocoding refers to a practice where an address is assigned to a location based on its coordinates [26]. For this process, the Google Maps Geocoding API was used, which is capable of only returning the state of the address associated with the coordinates as a hash, which directly could be incorporated into the earthquake data frame. Afterwards the regions the API returned were renamed to fit the regions of the mental health data. Lastly, only the relevant columns were retained, which are region, date, magnitude, etc. The earthquake data contains 2801 records. To better understand the earthquake data, we plotted the data overlaying the geographical map of New Zealand(Figure 1).

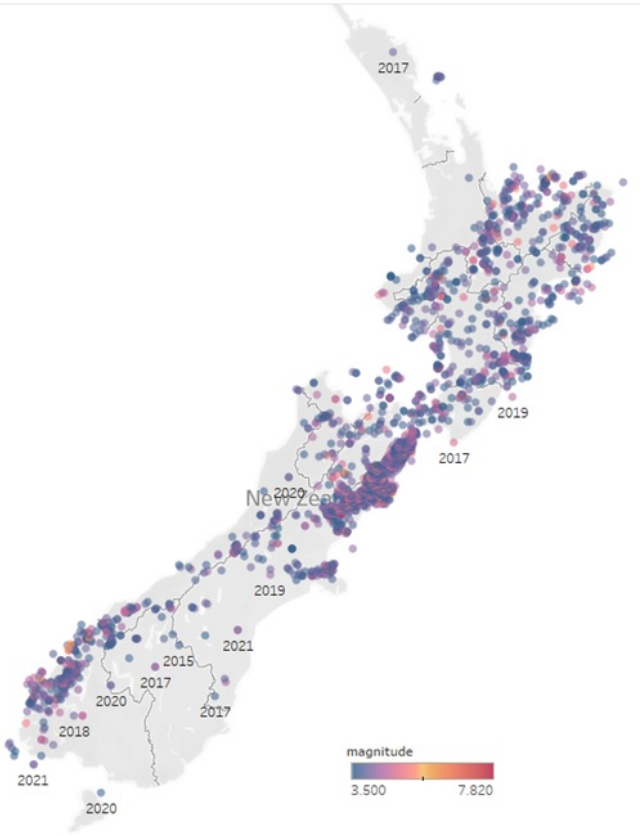

Figure 1. The earthquake data visualization of New Zealand (2016-2022)

4.2 Air Quality

PM10 records are taken as the measurement for air quality. PM10 is defined as "suspended coarse particulate matter, either solid or liquid, with a diameter of 10 micrometres (μm) or less" [27]. This includes particulate matters such as smoke from fireplaces and chimneys, dust, motor vehicle exhaust or industrial sources. Air quality data is sourced from Land, Air, Water Aotearoa [28], with measurements recorded daily in

almost every region in New Zealand with varying levels of consistency. A higher PM10 value signifies great air pollution. Due to its size, PM10 can be inhaled, and exposure can cause "cardiovascular and respiratory health problems, such as heart attack, stroke, lung cancer and premature death"[29]. The air quality data contains attributes such as the latitude and longitude of the air quality sensor device, the town/city names, the site type(e.g. residential or industrial), the date and the PM10 values. Figure 2 shows the average PM10 values from 2016 to 2020 in the regions of our study. There are 134,066 records PM10 records in our data.

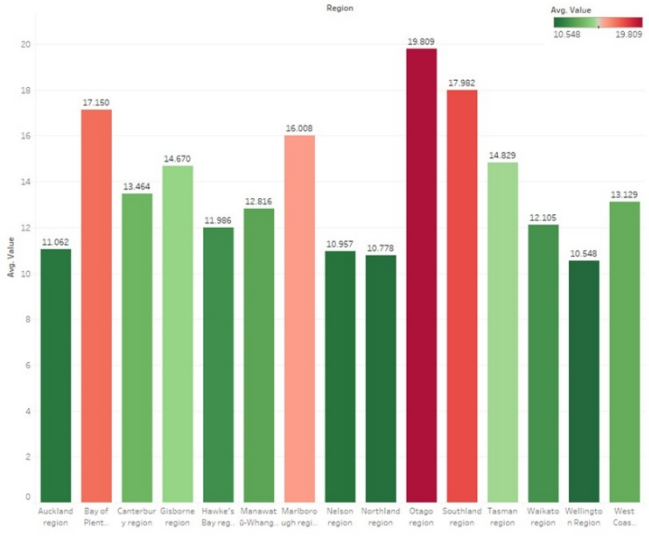

Figure 2. The average PM10 values of regions in New Zealand (2016-2020)

4.3 Rainfall

Rainfall varies across the country, with mountain chains throughout New Zealand providing a barrier for westerly winds resulting in different climate regions. In the upper half of Northland, most rainfall can be observed in winter and autumn. In contrast, winter has the least rainfall for much of the southern part of New Zealand[23]. Rainwater is an essential part of the country's environment, supplying fresh water for drinking and growing food, as well as ensuring a healthy ecosystem and electricity supply. Thus, rainfall changes can greatly affect the country's agriculture, energy and recreation as well as the environment[30].

The rainfall dataset used for this study was filtered to the proper time range (2016-2021), as some stray entries from 2015 and before were in the raw data set. And, as with the other datasets, the region had to be adjusted to reflect the DHB regions. Lastly, only the columns of interest were retained, to cut down on storage and processing. The rainfall data contains attributes of the region name, date, and rainfall values, and there are 43,560 records in the period of time.

4.4 Temperature

The degree Celsius is taken as the measurement for temperature. Temperature data is sourced from LAWA [28], with measurements recorded daily throughout every region. In New Zealand, the mean annual temperatures range between 10°C to 16°C from south to north. July is the coldest month, while the warmest periods are the summer months of January and February. The variations in temperature in New Zealand are small between the seasons but can reach up to a variation of 14°C inland and in the east of the regions. Temperatures are recorded at NIWA's 30 stations around the country reporting annual and seasonal average, maximum and minimum temperatures and trends. Changes in temperature affect agriculture, energy, ecosystems and recreation. Temperature data is relevantly simple. It contains the data/time, the locations (latitudes and longitudes) and the temperature in degrees celsius. There are 1798 records.

4.5 Mental Health

Our mental health data comes from Stats NZ, New Zealand's official data agency, as well as the Coronial services of New Zealand. These sources aggregate the data provided by the regional DHBs throughout New Zealand. The mental health indicators chosen are the number of people seen by DHB for mental health reasons and the statistics on suicide deaths. These factors were chosen as they represent the most complete datasets around mental health, while other information is often poorly recorded. Unfortunately, the data for mental health comes with a couple of difficulties. First, it is mostly qualitative data, which is difficult to quantify. In addition, much of the data is self-reported and hence introduces a certain degree of variance. Lastly, mental health data is also impacted by social factors, such as ethnicity and income. This makes the data overall hard to compare across regions. Additionally, the data is only available in summarised form with annual reporting. We consolidate the mental health data. Figure 3 shows the snapshot of the mental data.

Region	Clients seen by DHB service	Provisional suicide deaths by DHB	Year	Total Population	% of population seen by DHB	% of population death by suicide
Auckland	57,498	193	2018	1,654,800	3.47500	0.0120000
Central North	25,994	98	2018	796,400	3.26400	0.0120000
Gisborne	1,929	14	2018	49,500	3.89700	0.0280000
Hawkes Bay	4,692	29	2018	172,400	2.72200	0.0170000
Taranaki	5,765	11	2018	121,200	4.75700	0.0090000
Manawatu-Whanganui	8,815	44	2018	247,500	3.56200	0.0180000
Wellington	18,323	61	2018	525,900	3.48400	0.0120000
Upper South	5,629	12	2018	155,400	3.62200	0.0080000
West Coast	1,492	8	2018	32,400	4.60500	0.0250000
Canterbury	14,764	92	2018	622,800	2.37100	0.0150000
Southern	10,330	65	2018	335,500	3.07900	0.0190000
Total	162,078	668	2018	4,899,600	3.30800	0.0140000
Northland	7,019	33	2019	189,600	3.70200	0.0170000
Auckland	58,794	190	2019	1,680,500	3.49900	0.0110000
Central North	27,953	122	2019	813,500	3.43600	0.0150000

Figure 3. the snapshot of the mental health data of our study

5. Analysis Methods and Implementation

This research was based primarily on the relationship between environmental data and mental health data in different regions of New Zealand over the time period of 2016 to 2020. The independent variables (or inputs) were environmental data sets, including air pollution levels, average temperatures, seismic activity and average rainfall. The dependent variables (or outputs) were two mental health data sets: mental health patients seen by regional District Health Boards (DHBs) and recorded regional deaths by suicide.

Mental health data were converted to the percentage of the regional population in order to remove possible distortion due to variance in population size. However, it is also important to note that some data is missing as some patients seek help from non-governmental organisations (NGOs) rather than their local DHB [31]. Additionally, reported suicide numbers include some estimates as the nature of suicide can be difficult for coroners to identify [32]. The results should therefore be read as overall trend indicators and not as individual cases.

To allow cross-compatibility with the environmental data, several regions had to be combined, which resulted in the following regional groups: Northland, Auckland, Central North (Waikato and Bay of Plenty), Gisborne, Hawke's Bay, Taranaki, Manawatū-Whanganui, Wellington, Upper South (Nelson, Marlborough and Tasman), West Coast, Canterbury and Southern (Southland and Otago). This grouping was necessary as some DHBs cover areas belonging to two geographic regions (e.g. Lakes DHB). As their reported data cannot be split between the geographic regions the only solution was to combine regions to cover the required DHB regions.

5.1 Initial Exploratory Analysis

To find which regions were most affected by the chosen environmental factors, averages were taken from across these variables. Two linear models were created for each dependent mental health factor to guide the initial analysis. These showed that for suicide rate the only environmental factor with impact is rainfall, while for number seen by DHB air quality, rainfall and temperature show correlation. These models do not show causality, but they were a valuable to provide some direction for the initial exploratory analysis.
Next, the environmental data was graphed along with mental health outcomes in regional facet charts. These visualisations allowed for further analysis of several correlations, which led to additional exploration to understand these trends. Based on the information from the linear models the data that was graphed are the amount of average rainfall and suicide rate by population rate, air pollution and population rate seen by DHB, as well as average temperature and population rate seen by DHB.

Figure 4 shows average rainfall and suicide per rate of population, from which a mix of correlations can be identified between these factors. Canterbury and Gisborne both show direct correlation, while the West Coast and Hawke's Bay show inverse correlation trends. After some investigation, it was found that the West Coast, which typically has higher rates of negative mental health outcomes compared to other regions, began an initiative in 2018 to reduce mental distress through community outreach and awareness programmes [33].

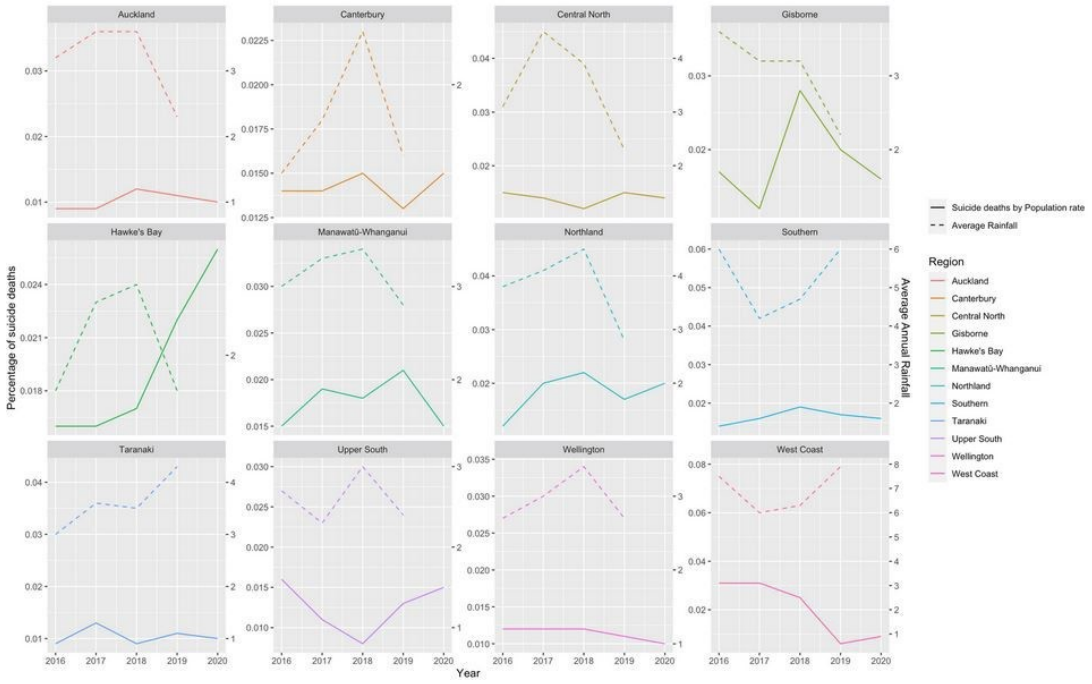

Figure 4. Annual rainfall compared to the percentage of deaths by suicide

Thus, the reduced suicide rate shown post-2018 is likely due to external factors rather than a direct result of changes in rainfall. Conversely, Hawke's Bay is a region with a large amount of farming and thus a reliance on rainfall for local industry. The inverse relationship shown here represents a known issue, the effects of drought on population wellbeing. Many farmers have significantly reduced income due to roughts, which can cause anxiety and other negative mental health outcomes. Conversely, Hawke's Bay is a region with a large amount of farming and thus a reliance on rainfall for local industry. The inverse relationship shown here represents a known issue, the effects of drought on population wellbeing. The inverse relationship shown here represents a known issue, the effects of drought on population wellbeing.

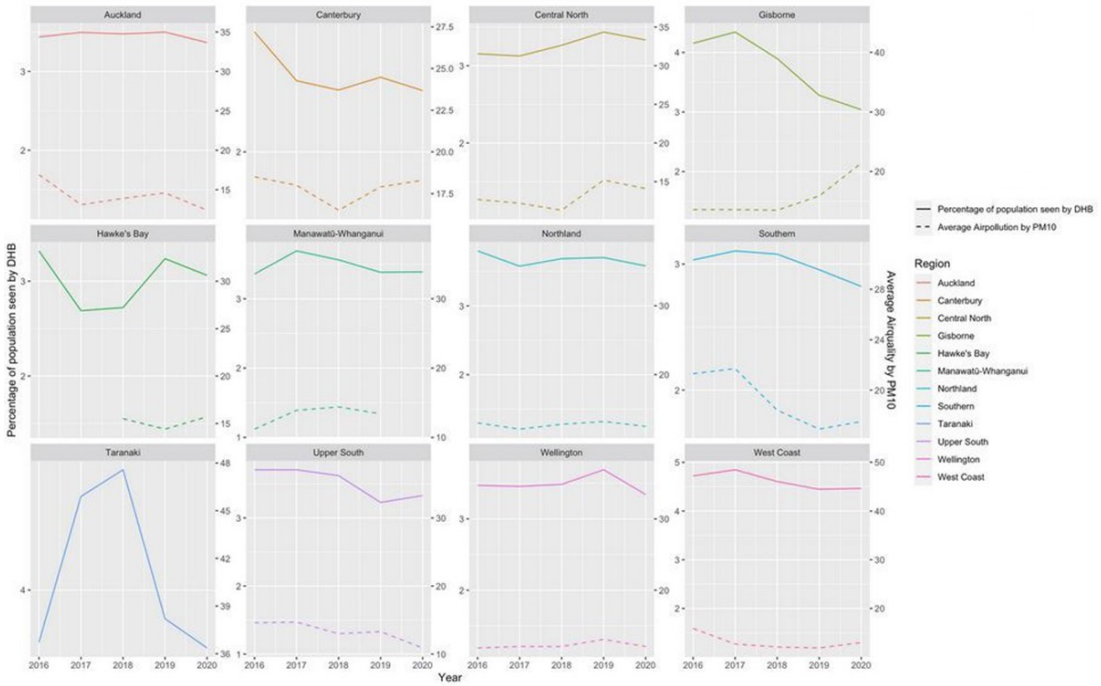

Figure 5. Average air pollution levels compared to the rate of the population seen by DHB

Many farmers have significantly reduced income due to droughts, which can cause anxiety and other negative mental health outcomes. Consequently, a decision was made to focus on the effects of rainfall on mental health in Hawke's Bay, as well as predicting these numbers for the following years.

Figure 5 shows average air pollution compared to the rate of the population seen by regional DHBs for mental health issues. Unfortunately, data on New Zealand air pollutants is disjointed, resulting in several missing values, which can be seen in Hawke's Bay, Manawatū- Whanganui and Taranaki. Several direct correlations can be observed, especially in Canterbury, Wellington and the Central North. Canterbury and Wellington are aware of these pollution issues and currently have ongoing programmes to reduce air pollutants by creating a series of 'Clean Air Zones' with different rules for home heating, including which types of heaters can be installed and used (GWRC, 2020).

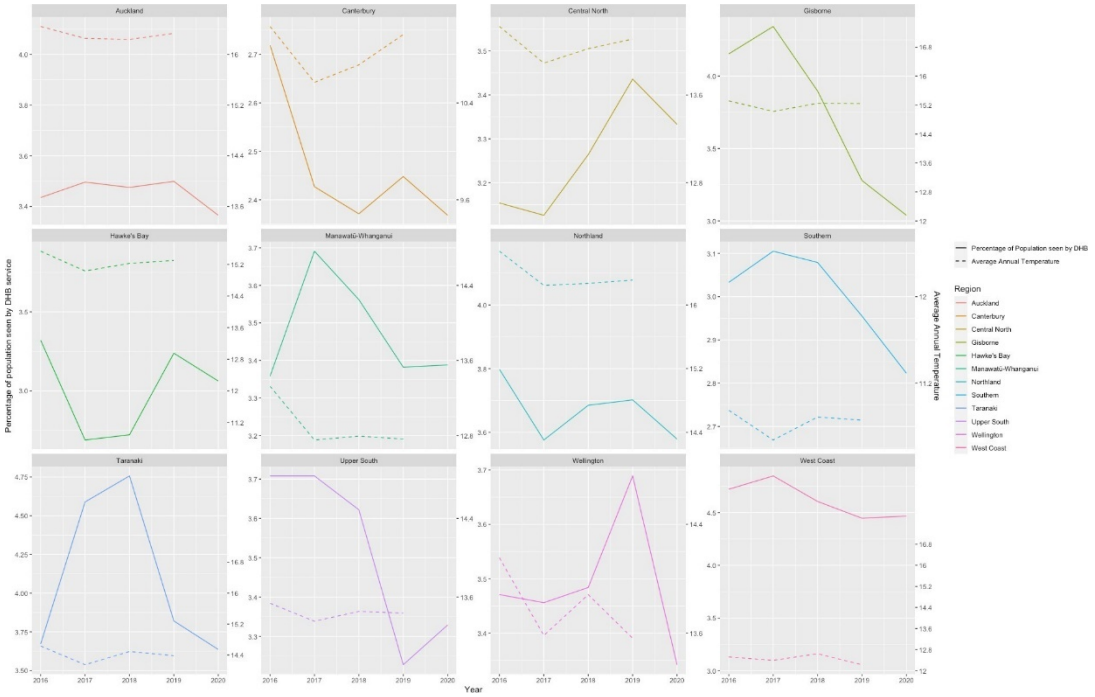

Figure 6 Regional facet chart of average temperature compared to the rate of the population seen by DHB

Figure 6 shows the average annual temperature compared to the percentage of the population seen by DHBs for mental health-related services. Correlations can be seen in Canterbury, Central North and Northland, with an inverse correlation seen in the Southern regions and Manawatū-Whanganui. Heatwaves and high temperatures have been found to be much harder on the elderly population, who are often more susceptible to heat-related illnesses and have overall less mobility[34]. The regions with the highest elderly populations in New Zealand are Canterbury and Northland, with Manawatū-Whanganui being one of the regions with the least amount of elderly people [35]. Thus, the mental health outcomes seen here are likely exacerbated by external social issues, making this facet chart difficult to interpret at face value. These insights motivated the choice to further investigate the relationship between temperature and mental health in Canterbury specifically

Earthquakes, when visualised with mental health data, did not show any obvious immediate correlation (Figure 7). This seems to be against our initial hypothesis, in which we assumed that earthquakes would be a major factor for certain mental health issues, such as anxiety and PTSD. Our understanding is that earthquakes, unlike other environmental factors, are natural events/disasters. Some of its consequences on mental health may not be observed and manifest immediately after the event. Some research has shown that the Canterbury earthquake did have some adverse effects on mental health [36]

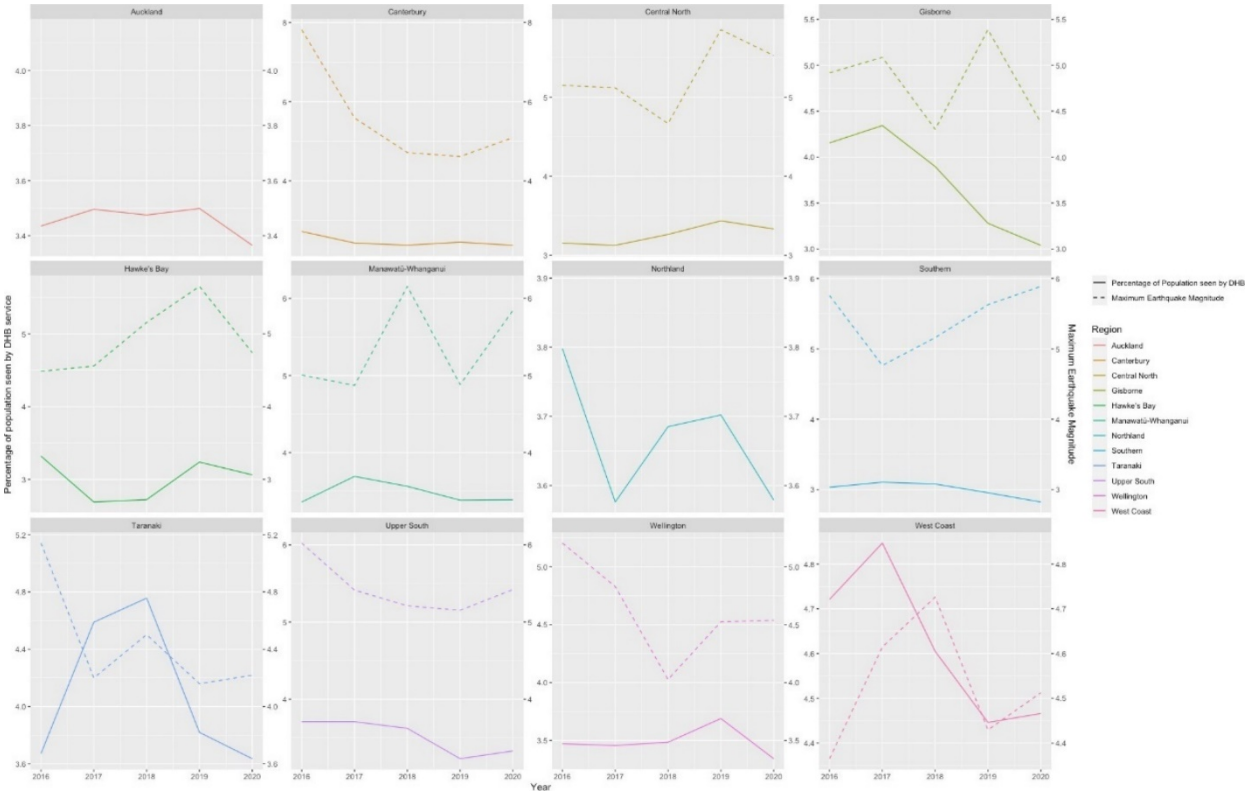

Figure 7. Maximum Earthquake Magnitude compared to Rate of Population seen by DHB

5.2 Time Series

A time series model was chosen to visualise temporal trends better as most of the data consisted of a series of ordered data points. Based on the initial analysis results, the three environmental factors; rainfall, air quality and temperature and their respective regions; Hawke's Bay, Wellington and Canterbury, were plotted onto a time-series graph. Data was plotted daily from 2016 until 2020.

An ARIMA(Auto-Regressive Integrated Moving Average) model forecasting algorithm was then performed on the time series to predict future environmental data for the next two years. ARIMA was chosen because it can use time series to predict future values, and works for both seasonal (non-stationary) and non-seasonal (stationary) data. It can convert non-stationary data into a stationary time series by using differencing. In our data set, temperature and air quality were observed as seasonal data due to repeated annual trends. In contrast, the random patterns observed in rainfall in Canterbury were likely stationary.

In this section we only choose to cover some results of our time series predictions and the predicted mental health outcomes based on the environmental factors. The three case studies are rainfall in Hawke's Bay, air pollution in Wellington and temperature in Canterbury with factors of interest, Suicide rate and DHB visit Rate.

Using predicted results for the time series, outputs for mental health were then projected from the ridge regression. These predictions can be seen below in Table 1. As can be seen from the predicted changes from 2020 data, both DHB and suicide rates were increasing or decreasing concurrently for rainfall and air quality. This further indicates some relationship between the environmental factor and mental health. However, this is found to be inconsistent for temperature, as suicide rates and DHB rates were found to contradict each other for the same year, further indicating that temperature is not a good predictor.

Some of the changes in suicide rates may appear to be quite large. This is due to suicide rates in general being very low compared to the whole population. Hence, even a large percentage may only mean a small number of suicide deaths for the whole population.

For air quality in Wellington, it can be observed that compared to 2020 data, 2021 shows a slight decrease in air quality, and 2022 shows a slight increase. However, DHB rates and suicide rates are both forecasted to increase. As only one year shows that an increase in air pollution results in an increase in negative mental health outcomes, this implies that further analysis and improvements are required with this environmental factor to strengthen conclusions.

For rainfall in Hawke's Bay, predicted rainfall levels are increasing over the next two years. Coincidently, DHB visits and suicides are also forecasted to decrease. This shows that

rainfall in Hawke's Bay is likely a strong indicator for mental health data.

Table 1. Predicted Mental Health Data based on environmental predictions

City	Variable Tested	Environmental Inputs	Suicide/DHB Rate	Projection	%Δ from 2020 data
Wellington	AQ_pm10	2020:12.10/m3 2021: 11.83/m3 2022: 12.14/m3	Suicide	2021: 0.0108 2022: 0.0109	2021 8% ↑ 2022: 9% ↑
			DHB Rate	2021: 3.421 2022: 3.452	2021 2% ↑ 2022: 3% ↑
Hawke's Bay	Rainfall	2020: 2.80 mm 2021: 2.97 mm 2022: 2.98 mm	Suicide	2021: 0.0201 2022: 0.0203	2021: 22% ↓ 2022: 22% ↓
			DHB Rate	2021: 2.97 2022: 2.93	2021: 3% ↓ 2022: 5% ↓
Canterbury	Temperature	2020: 9.26 C 2021: 9.27 C 2022: 9.27 C	Suicide	2021: 0.0142 2022: 0.0142	2021 5% ↓ 2022: 5% ↓
			DHB Rate	2021: 2.465 2022: 2.464	2021: 3%↑ 2022: 3% ↑

5.3 Ridge Regression

Ridge Regression model is chosen as it is ideal for analysing small datasets. This is a method whereby the independent variables are first reduced to their most important data points, constituting a reduction of the overall dataset, and are then normalised for correlation within the variables themselves. This makes it a good candidate for small datasets, as the data will be reduced to a small size regardless of its initial state

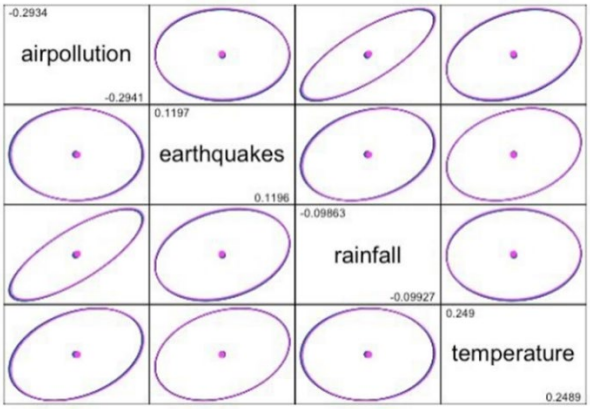

Figure 8. Pair Plots for Ridge Regression

Figure 8 shows pair plots for the ridge regression model, which checks for collinearity within the independent variables. The shape of the ellipse plotted between two variables is an indicator of the overall shape of the graphed data points, with a diagonally skewed ellipse representing a linear relationship. As can be seen in Figure 5, variables' air pollution' and 'rainfall' show a high level of relation, likely due to rain washing particles and pollen from the air, resulting in higher air quality [37].

Once calculated, this correlation between variables is removed from the final dataset, allowing for clearer visualisation of independent variable effects on the dependent variable(s). Once fitted with data from all regions across New Zealand, this ridge regression model displayed an R squared value of around 0.7, showing a relatively high accuracy for predicting mental health outcomes based on environmental data. Figure 9 displays a biplot built from this data, in which the x and y axes are mapped to dimensions three and four, which the model chose as the most well-fitted dimensions for visualisation of the correlative relationship [38]. Factors graphed nearer to the x-axis (dimension 3) show the highest level of overall correlation between the independent and dependent variables. In this case, Ridge Regression found that air quality and rainfall were the most highly correlated variables to the rate of patients seen for mental health

services by DHBs. Conversely, temperature and earthquakes were shown to be far less significant for mental health-related DHB visits on a national level. The shape of the ellipse indicates deviations in the data, with the standard deviation around equal to the radius, in this case around 0.05. This, along with the relatively thin shape of the ellipse, shows a low level of outliers within the dataset.

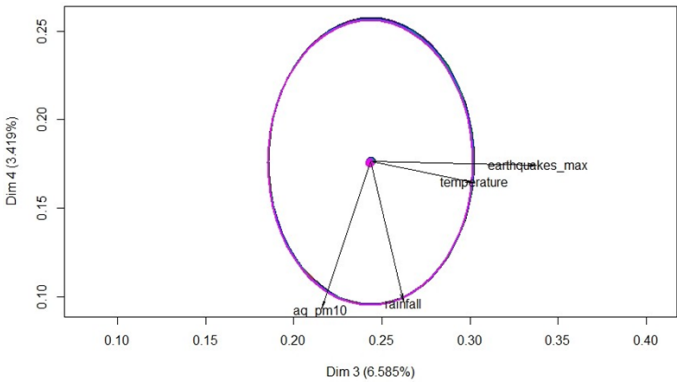

Figure 9. Pair Plots for Ridge Regression

6. Discussion and Conclusion

Several environmental factors were chosen for this research which attempts to best represent the New Zealand environment. It is evident that the relationship between environmental and mental health factors is regional and not national due to the many micro-climates that exist around the nation. From the results, it was observed that the clients seen by DHB services and suicide rates in the Wellington region displayed similar trends when compared to the air quality values. Results from the air quality time series showed that there is a general increase up to 2019 before a significant drop in 2020. Air quality was observed as a good environmental predictor due to the analysed outcome, which did not show a significant lack of fit, however, the model used to predict mental health outcomes still required improvement. Low values in 2020 are likely due to decreased industrial activities resulting from the COVID-19 lockdown. Further, reductions in air pollutants could also be due to the government's announcement in February 2020 regarding the phasing out of high particle-emitting wood burners. In addition, In March 2021, the Greater Wellington Regional Council began to offer support for homeowners in replacing wood burners located in Masterton and Wainuiomata with heat pumps[39]. However, it is interesting to note that Wellington is the least polluted capital city due to its extreme winds [40]. Thus, as some of these policies regarding air quality have just come through in the last year, more research would be required to understand if air pollution is a major contributor to mental health.

Similar trends and accuracy were also observed between the rainfall and mental health data in Hawke's Bay. From the ARIMA model, it can be observed that compared to 2020 data, rainfall predictions showed an increase and thus led to a lower percentage of clients seen by DHB services as well as lower suicide rates. It was also observed that the ridge regression model, which used rainfall to predict clients seen by DHB service, showed the highest accuracy. Predictions are also limited regarding the rate of DHB service use as the data was only available in an annual format. If there was a higher level of data granularity in the mental health data, then more solid comparisons could be made with the environmental data sets, as many of these are recorded daily. For example, if a particular month had very heavy rain, and there were more or fewer people seeing DHB services, then more justified comparisons could be made. Low rainfalls in other months may cancel out the months with higher rainfall, making it difficult to form solid conclusions as the data is only available annually. In addition, more data about the respondents would also be helpful. For example, if there was information about respondents being farmers, then the correlation between Hawke's Bay and rainfall would show a more justified connection.

In addition, mental health is a very subjective topic. The same environmental factor may impact different people differently, e.g., one may feel moody during a rainy day, whereas another one may feel relaxed, peaceful and a good time to have a nap on rainy days. People can experience different types of mental health conditions, and the severity can vary greatly. Others may experience mental health issues but may not consult a professional for help. In addition, there are many services available in New Zealand to help with mental health illnesses, such as depression helplines or other private services. Thus, clients seen by DHB and suicide rates represent only two subsets of the country's mental health data.

In future, the study can be further improved. 1) More environmental factors could also be undertaken to find more trends. This could include wind, snow or sunlight. The analysis period could also be extended to 10 years to capture more data and form stronger conclusions. 2) multicollinearity analysis may be put forward for building a stable regression model. 3) The study may incorporate comprehensive hypothesis testing.

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