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Geospatial analysis of mental health in Switzerland: Impact of environmental factors on suicide risk

GEO 511 Master's Thesis

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Abstract

This quantitative statistical work deals with the relationship between environmental factors and suicide in Switzerland. Suicide is a serious public health problem and is associated with high economic costs for society. According to the WHO, one person in the world takes own life every 35 seconds. Despite its fatal consequences, suicide is still a taboo subject in society.

The suicide rate in Switzerland has been declining since 2000, but it is still too high. Most suicides occur in spring and summer. Certain groups of people have a higher risk of taking their own lives. These include men, foreigners, the divorced, the widowed and the elderly. There are also differences between urban and rural areas and between different language regions. More people take their own lives in the countryside than in the city. The suicide rate is also lowest in the Italian-speaking part of Switzerland. Socio-cultural characteristics contribute to this pattern.

The results of this work show that environmental factors have a direct influence of more than 2% on the suicide rate, but socio-economic position and urbanity together contribute more than 10% to the suicide rate. The environmental variable that contributes most to the suicide rate is air pollution, followed by temperature. For now, the impact is relatively small, but the predictive model shows that suicide rates will be higher in the future due to climate change.

After comparing the adjusted with the unadjusted values as LISA clusters and Local Moran's I, there are no large differences between the observed suicide rates and the residuals. Only three regions show differences in residuals and observed suicide numbers pattern.

Environmental factors, together with SSEP and land type, explain 15.45% of suicide rates. The rest is influenced by other factors that will not examined in this study. There are crucial factors that influence suicide rates which are due to lifestyle habits as well as psychological and sociological characteristics. Environmental factors are therefore not the main cause of suicide.

Zusammenfassung

Diese quantitativ statistische Arbeit befasst sich mit dem Zusammenhang zwischen Umweltfaktoren und Suizid in der Schweiz. Selbstmord ist ein ernsthaftes Problem der öffentlichen Gesundheit und ist mit hohen wirtschaftlichen Kosten für die Gesellschaft verbunden. Nach Angaben der WHO nimmt sich alle 35 Sekunden ein Mensch auf der Welt das Leben. Trotz seiner fatalen Folgen ist Suizid immer noch ein gesellschaftliches Tabuthema.

Die Suizidrate ist in der Schweiz seit 2000 rückläufig, aber immer noch zu hoch. Die meisten Suizide ereignen sich im Frühling und Sommer. Bestimmte Personengruppen haben ein höheres Risiko, sich das Leben zu nehmen. Dazu gehören Männer, Ausländer, Geschiedene, Verwitwete und ältere Menschen. Es gibt auch Unterschiede zwischen städtischen und ländlichen Gebieten und zwischen verschiedenen Sprachregionen. Auf dem Land nehmen sich generell mehr Menschen das Leben als in der Stadt. In der italienischen Schweiz ist die Suizidrate am niedrigsten. Soziokulturelle Merkmale tragen zu diesem Muster bei.

Die Ergebnisse dieser Arbeit zeigen, dass Umweltfaktoren einen direkten Einfluss von mehr als 2 % auf die Suizidrate haben, aber die sozioökonomische Position und die Urbanität tragen zusammen mehr als 10 % zur Suizidrate bei. Die Umweltvariable, die am stärksten zur Selbstmordrate beiträgt, ist die Luftverschmutzung, gefolgt von der Temperatur. Im Moment sind die Auswirkungen noch relativ gering, aber das Vorhersagemodell zeigt, dass die Suizidraten in Zukunft aufgrund des Klimawandels höher sein werden.

Vergleicht man die adjustierten mit den unadjustierten Werten miteinander als LISA-Cluster und Local Moran's I, gibt es keine grossen Unterschiede zwischen den beobachteten Suizidraten und den Residuen. Nur drei Regionen weisen Unterschiede bei den beobachteten Residuen und Suizidwerte Muster auf.

Umweltfaktoren erklären zusammen mit dem SSEP und dem Landtyp 15,45 % der Selbstmordraten. Der Rest wird von anderen Faktoren beeinflusst, die in dieser Studie nicht untersucht werden. Es gibt entscheidende Faktoren, die die Selbstmordrate beeinflussen und auf Lebensgewohnheiten sowie psychologische und soziologische Merkmale zurückzuführen sind. Umweltfaktoren sind also nicht die Hauptursache für Selbstmord.

Content

List of Figures

List of Tables

1. Introduction

Suicide is defined as the human act of ending one's life through one's own fault (de Oliveira Teixeira et al., 2018). Suicide is a leading cause of death (Sinyor et al., 2017) and a serious public health problem worldwide. Suicide is the thirteenth leading cause of death worldwide (Yarza et al., 2020). Among 15-19 year olds, suicide is even the fourth most frequent cause of death (WHO, 2021a). According to the World Health Organization (WHO), approximately 800,000 people commit suicide each year, meaning that globally, one person takes their own life every 35 seconds (de Oliveira Teixeira et al., 2018). In 2008, the suicide rate for the world as a whole was estimated at 11.6 per 100,000 inhabitants (Värnik, 2012). The suicide rate is defined as the number of cases per 100,000 inhabitants per year (Obsan, 2022). In absolute numbers of suicides in the world, China and India lead, with almost half of all suicides (54%) taking place there. Around the world, the suicide rate is highest in Southeast Asia at 15.6 and lowest in the Eastern Mediterranean region at 5.6 (Värnik, 2012). Suicide is a global phenomenon that occurs in all regions of the world (WHO, 2021a). Although the world population has grown, the WHO reports a 9% decline in the absolute number of suicide deaths between 2000 and 2012 (Sinyor et al., 2017). The rates for suicide attempts are 10 to 40 times higher than the rates for completed suicides. It is estimated that there are 9 to 36 million suicide attempts per year worldwide (Bertolote et al., 2006). The most common methods of suicide worldwide include pesticide ingestion, hanging and firearms (WHO, 2021a).

In Europe, the trend in suicides is generally downward, and there is currently no Western European welfare state that is among the top ten countries in the world ranking for suicide rates (Värnik, 2012). Suicide rates in European countries vary greatly. Suicidality in Europe follows the climate-temperature gradient, which runs from south to north-east. The highest suicide rates are found in Eastern Europe and the lowest in the Mediterranean region (Fountoulakis et al., 2016). The countries Russia, Montenegro and Lithuania have the highest suicide rates in Europe in 2021, while Turkey, Cyprus and Greece have the lowest suicide rates (WHO, 2021a). According to Landberg, one of the reasons for the high suicide rates in Eastern Europe is alcohol consumption (Landberg, 2008).

The suicide rate has decreased in Switzerland in the period from 1998 to 2019. In 2019, the suicide rate in Switzerland was 12 per 100'000 inhabitants. Assisted suicide was excluded from this. Thus, 2 to 3 people die by suicide in Switzerland every day. There are regional differences. Appenzell-Innerhoden (22.2 per 100'000) is the canton with the highest suicide rate, followed by Jura and Appenzell-Ausserhoden. Geneva and Ticino are among the cantons with the lowest suicide rates

(Figure 1). In Switzerland, hanging is the most common method of suicide, accounting for almost a third of all cases, followed by firearms and poisoning. The suicide assistance rate was 13.7 per 100'000 inhabitants. The cantons with the highest rates of assisted suicide are Appenzell Innerhoden, Zurich and Glarus, while the cantons Ticino, Fribourg and Jura have the lowest rates of assisted suicide (Obsan, 2022). Assisted suicide is a special case in Switzerland, which is illegal in a large majority of countries around the world. In Switzerland, assisted suicide can also be used in the absence of an underlying life-limiting illness, in the case of unbearable suffering and insufficient further treatment options. In addition to Switzerland, active euthanasia and assisted suicide are not punishable in the Netherlands, Belgium, Luxembourg, Colombia, Canada, several US states and one state in Australia (Vyssoki et al., 2021). Assisted suicides are excluded in this thesis.

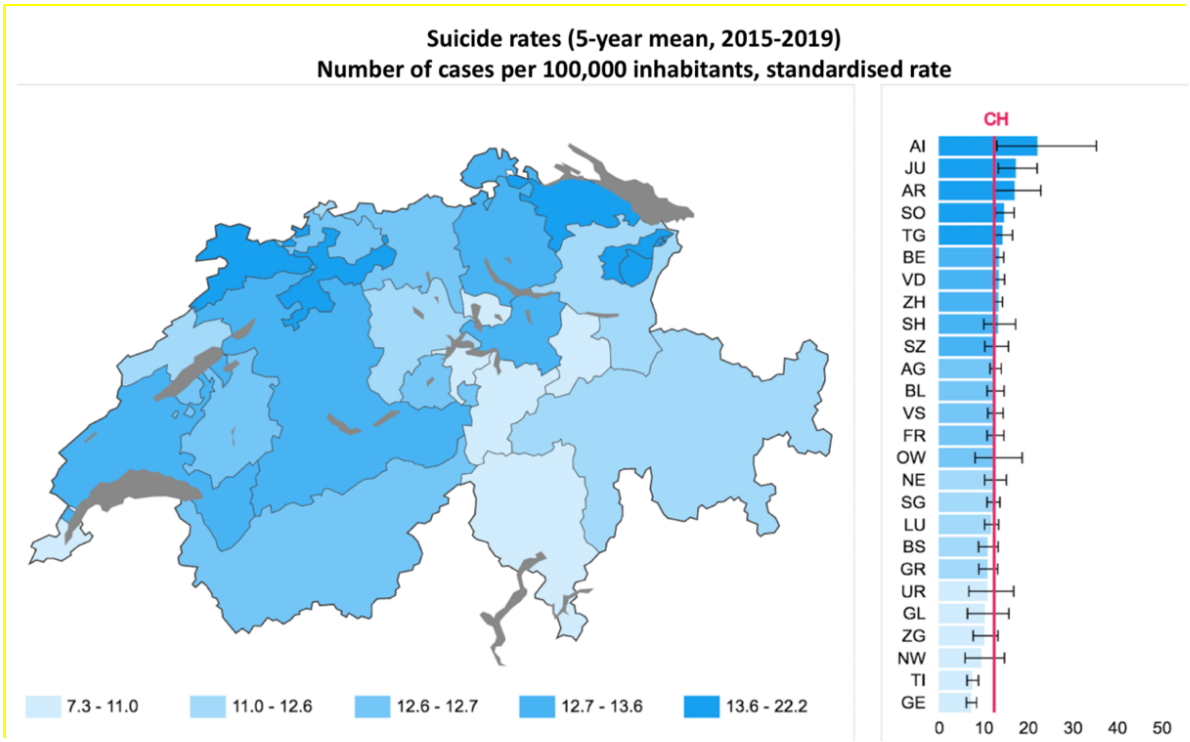


Figure 1: Suicide rate of Switzerland over the 5-year period from 2015 to 2019. Suicide rates are standardised and show the number of cases per 100,000 inhabitans. Lowest rates can be found in central Switzerland and Ticino, while northwest and northeast Switzerland have the highest rates (Source: Obsan, 2022).

The causes for committing suicide are complex and multifaceted (Sinyor et al., 2017). The greatest risk factors for suicidal ideation include low socioeconomic status, difficult family circumstances, poor childhood experiences and chronic illness (Unicef, 2021). Mental disorders and psychological factors are closely related to suicide (de Oliveira Teixeira et al., 2018). According to WHO, the individual and environmental risk factors for suicide are as follows: previous suicide attempts, alcohol dependence, financial difficulties or unemployment, hopelessness, chronic pain, suicides in the family, genetic and biological factors, relationship conflicts, loss of relationships, feelings of loneliness and lack of social support, traumatic experiences or abuse, discrimination, stressful migration experiences, natural disasters and wars, social stigmatisation of help-seeking behaviour,

insensitive media coverage, availability of lethal means and methods, barriers to accessing health care (BAG, 2019).

There are also patterns of socio-demographic factors that have an influence on suicide risk. According to the WHO, the global suicide rate is 15 per 100,000 people per year for men and 8 per 100,000 per year for women (Sinyor et al., 2017). Women have a higher rate of reported non-fatal suicides, while men have a much higher rate of completed suicides. Globally, suicide rates are higher for men in all age groups and men commit fatal suicide 3-10 times more than women (Sher, 2015). Studies from the USA show that men are almost four times more likely to take their own lives than women. Men commit about 80 % of all suicides, although the suicide attempt rate for women is estimated to be three to four times higher than for men. One of the main reasons for the large gender differences in suicide rates is the suicide method. In general, men are more likely to resort to methods that have a lethal effect than women. The most common suicide method used by men is the firearm. In contrast, women are less likely than men to commit suicide by firearm, but more likely to commit suicide by poisoning. Because women are more likely to attempt suicide by poisoning, they have a greater chance of being saved or resuscitated than men, who tend to use firearms, which are more likely to cause fatal wounds. Reasons that women choose less lethal means than men are attributed to a number of factors, including intent to die, gender socialisation and the easy availability of methods (Callanan & Davis, 2012). Despite this gender pattern of men killing themselves more often, there are exceptions. In China, the opposite is the case. China is currently the only country where the rate of suicide for women is higher than for men (Värnik, 2012).

In 2009, it was estimated that nearly 5,000 suicides worldwide were linked to the global financial crisis, with an increase in the unemployment rate from 3% to 6% accompanied by a 6.1% increase in the suicide rate (Sinyor et al., 2017). Some studies point to a link between the 2008 economic crisis, unemployment and suicide (Konieczna et al., 2021). A study that examined the issue of recession and suicide found a strong link between recession, unemployment and suicide. Economic recession leads to unemployment, loss of housing, debt and social isolation, which in turn can lead to alcoholism, depression and other mental illnesses, i.e. these are all factors that are highly correlated with suicide risk (Konieczna et al., 2021). According to Fountoulakis, male suicides correlate with a high unemployment rate in the context of a high growth rate, high inflation and low GDP per capita, while female suicides correlate negatively with inflation (Fountoulakis et al., 2016). In Greece and other European countries, government austerity measures have been associated with rising suicide rates. In Europe, the impact of unemployment rates on suicide rates was higher in countries with the lowest levels of social and financial protection for the unemployed (Sinyor et al., 2017).

In pandemics like COVID-19, the suicide issue is very present. The "Spanish flu" was a comparable pandemic and was associated with an increase in suicide rates. It is believed that the decrease in social integration and interaction during the epidemic and the fears triggered by the epidemic increased the suicide rate. COVID-19 and its consequences, such as isolation, coping with death and economic difficulties, can lead to or increase suicidal thoughts and behaviours (Zalsman et al., 2020). Vulnerable populations include people with pre-existing psychiatric disorders, people with low resilience, people living in areas with high COVID-19 prevalence, and people who have a family member or friend who has died from COVID-19 (Sher, 2020). Previous pandemics have shown that suicide rates increased during classic bubonic plague epidemics. During the "Spanish flu" of 1918-19, the United States reported an increase in deaths by suicide. During the SARS outbreak in China, suicides increased among the elderly, women and the lower socio-economic class. Ebola infection led to more self-harm and suicidality in Africa (Banerjee et al., 2021).

The other socio-demographic factor that has an impact on suicide risk is the type of area, i.e. whether it is urban or rural. A variety of collective and contextual factors appear to be of particular importance leading to the higher suicide rates in rural areas. These factors include socioeconomic decline in rural areas, facilitators and barriers to service use such as availability and accessibility of services, rural culture, community attitudes towards mental illness and help-seeking, and exposure to firearms (Judd et al., 2006). A study from the USA found that suicide rates in urban and rural areas increased overall from 2000 to 2018, with a greater increase in rural areas after 2007 than in urban areas. The difference in suicide rates between men and women in urban areas was 3.6 higher for men and in rural areas it was 3.8 higher (Pettrone & Curtin, 2020). Data from Australia show that suicide rates are higher in rural areas. Such differences between large cities and rural areas are well known internationally, with cities of more than one million people having lower rates. Sydney and Melbourne have the lowest rates of suicide in Australia. Sydney and Melbourne have many deprived neighbourhoods, but the people who live in these global cities appear to have significant social advantages, with in-migration and high population density driving innovation, economic activity, employment, international universities, arts and culture, cutting-edge architecture, major sporting events and, more generally, the quality of life in cities. A city's quality of life is made up of various indicators, some of which are related to the sociology of suicide. These indicators include higher social cohesion, better employment, low income inequality, lower crime rates, good availability of health and social services and educational opportunities (Allison et al., 2020). A study from Austria comes to the same conclusion that the risk of suicide is higher in rural areas (Kapusta et al., 2008).

Two other factors that may affect suicide risk are sexual orientation and time of birth. Young people who identify as members of the LBGT community are statistically more likely to attempt suicide. LGBT youth are four times more likely to attempt suicide than heterosexual youth (Halady, 2013). LGBT (lesbian, gay, bisexual and transgender) individuals are at increased risk for mental health problems as a result of a hostile, stressful environment (Figueiredo & Abreu, 2015). There are several factors associated with different types and aspects of suicidal behaviour that have been shown to be related to the season of birth (Antonsen et al., 2012). One study found a significantly increased risk of suicide in individuals born in spring and summer (Woo et al., 2012a). Suicide risk was found to be 17% higher for those born in the peak month (spring to early summer) than for those born in the nadir month (autumn to early winter) (Salib & Cortina-Borja, 2006). Affective temperaments have a complex and interesting relationship with time of birth and are consistently cited as risk factors for suicidal behaviour (Antonsen et al., 2012).

There is growing evidence that the internet and social media have an influence on suicidal behaviour (Luxton et al., 2012). In studies looking at suicide clusters and the influence of the media, evidence of suicide contagion is accumulating. In this context, suicide rates increase proportionally to the amount, duration and prominence of media coverage. Therefore, media counselling and guidelines for editors can help to minimise copycat suicides (Becker & Schmidt, 2004). Cyberbullying and cyberharassment are serious, widespread problems and an example of how social media can increase the risk of prosuicidal behaviour (Luxton et al., 2012). A study from Japan found that there is a link between the increase in suicides among young Japanese and the emergence of suicide pacts on the internet (Ozawa-de Silva, 2008). Internet sites, social media sites and chat rooms promote suicide, but they can also have a positive impact on suicidal people, namely as a resource to help suicidal people seek help, identify suicidal people, provide a method of communicating with suicidal people, support survivors of suicide attempts, and chat rooms can function similarly to telephone counselling services (Shah, 2010; Eggertson, 2015).

Suicide is a major public health problem with multidimensional consequences for society. A typical suicide death has a direct impact on at least six people in terms of human suffering. There are also significant economic consequences for various groups, including increased medical use, absenteeism from work and lost production (Lyszczarz, 2021). Studies from New Zealand show that the costs of suicide to society are high. The direct economic costs of suicide are not insignificant, but are small compared to the intangible costs (grief and loss of family members and friends, lost potential of shortened life) (O'Dea & Tucker, 2005). A study from Taiwan states that middle-aged adults, a group that plays the main role in the production and reproduction of society, contribute disproportionately

to the social and economic burden of suicide (Law et al., 2011). Although suicide has fatal consequences for society, social stigma hinders coping (Alfonso-Sanchez et al., 2019). The seriousness of the phenomenon of suicide is that it goes beyond the category of personal tragedy and becomes a serious public health problem, particularly because of the intensity of the pain, the years of life lost and its epidemic nature. Despite the recognition of the depth and complexity of the phenomenon, suicide is still a taboo subject (de Oliveira Teixeira et al., 2018).

There are strategies that are suicide-inhibiting and suicide-preventing. According to Sinyor et al., means restriction strategies, including barriers at suicide hotspots, firearm restrictions and limiting access to pesticides and charcoal have all prevented suicides. Other effective measures include improvements in mental health systems, treatment with selective serotonin reuptake inhibitors (SSRIs) and lithium in adolescents, and mental health awareness in schools. Protective factors of suicide include social support networks, strong life motives, religion and effective problem-solving skills (Sinyor et al., 2017). According to the WHO, there are six basic steps to prevent suicide, which are treatment of psychiatric patients, control of gun ownership, detoxification of household gas and car exhaust, control of the availability of toxic substances and mitigation of press coverage (Wolfersdorf & Etzersdorfer, 2011).

Suicide has multifactorial causes. These include physical and psychological factors of the individual, but also social, cultural, and environmental factors. In this context, the risk factors can vary depending on the geographical region and population group (Lin et al., 2016). Known risk factors for suicide mortality include mental disorders, socio-demographic and community factors, but environmental factors can also play a role (Casas et al., 2021). Risk factors for suicide in general include age, gender, rural/urban residence, month of birth, socioeconomic factors, marital status, interpersonal relationships or life events, comorbidities, current or past psychiatric illnesses, allergies, and most importantly, previous suicide attempts and violent methods used in previous suicide attempts (Woo et al., 2012a).

The environmental factors that impact the risk of suicide, include air pollution, but meteorology can also have an impact on suicide risk. Other environmental factors that may have an impact on suicide risk are green spaces, noise and water quality. In Switzerland, no studies are known to date (to author) that examine the influence of environmental factors on the risk of suicide. The aim of this work is to conduct a geospatial analysis of mental health with a focus on suicide in Switzerland using underlying environmental factors. This is explained further in the Background and Methods part.

2. Background (Environmental Factors)

2.1. Meteorology

There are numerous studies that have examined the influence of weather and climate on suicide risk (Willeit et al., 2015). Many studies have found a positive or negative correlation between suicide rates and various components of climatic influences such as high temperatures or temperature fluctuations, sunshine, cloud cover and precipitation (Asirdizer et al., 2018). Most reports suggest that suicide rates are higher during periods of high temperatures, low precipitation and more sunshine (Fountoulakis et al., 2016). Asirdizer et al. found that there is a strong positive correlation between altitude and suicide rates. Rates of depression and suicide would increase at high altitudes due to hypoxia. In addition, important risk factors for suicide such as depression, panic and anxiety disorders are also associated with high altitude (Asirdizer et al., 2018). Rates of suicide tend to be higher at higher latitudes than at lower latitudes (Ruuhela et al., 2009).

A seasonal pattern in suicide incidence has been observed in several countries. Most studies concluded that suicide rates are highest in spring and summer (Partonen et al., 2004). There is a clear peak in violent suicides in spring, while non-violent suicides tend to occur in autumn (Ruuhela et al., 2009). A study from Taiwan shows that suicidality is seasonal, regardless of gender and age, with a peak in spring (Lee et al., 2006). In Greenland, where suicide is a serious problem, a seasonality of suicides has been found, with a peak in June and a trough in winter. Greenland is the most extreme natural habitat for humans in terms of light-dark change, and it is thought that high alcohol consumption and long periods of light in summer may contribute to impulsive-aggressive summer suicides, as depression rates are low in Greenland (Björksten et al., 2005). A study from Austria also shows that there is a clear seasonal pattern in suicides. Suicide frequency is highest between March and May and lowest between November and January for both men and women. Aggressive behaviour is related to serotonin and seasonal variations in ambient light (Vyssoki et al., 2012). Studies of the seasonality of emotional disorders that depend on serotonergic activity suggest that sunlight can influence serotonergic activity in the central nervous system. Acute and rapid changes in serotonin function caused by various factors (including antidepressant use) are important in understanding changes in suicidal behaviour and explaining the sharp seasonal increase in suicides in spring. The results of another study showed a clear seasonality of long-chain n-3 polyunsaturated fatty acids in the blood. This finding could be related to the frequency of violent suicides and the expression of the serotonin transporter complex (Christodoulou et al., 2012). It is also suspected that an individual's lack of adaptation to the stimuli of the natural habitat may cause death by suicide to occur more

frequently at certain times of the year (Partonen et al., 2004). Environmental factors such as sunshine duration and the distribution of aeroallergens also vary with the seasons (Woo et al., 2012b).

However, Fountoulakis et al. concluded that suicide rates are higher in autumn and summer and lowest in winter. There is a positive linear relationship between the variation in suicide rates and latitude, and this is true for both the Northern and Southern Hemispheres, but not for the tropical zone, where there does not seem to be a seasonal pattern (Fountoulakis et al., 2016). In Colombia, where there is no marked variation in weather, no association was found between weather (temperature and precipitation) and the daily incidence of suicide among men and women. However, a statistically significant association was found between daily suicide rates and public holidays, especially long weekends. The association between suicide and public holidays persists even when there is no marked variation in weather (Fernandez-Nino et al., 2018).

In many countries of the northern hemisphere, an increase in the suicide rate in spring was observed, which was accompanied by an increase in daily sunshine duration. In Austria, sunshine duration and the number of suicides were strongly correlated. Daily sunshine duration was significantly correlated with suicide frequency regardless of the season (Willeit et al., 2015). In relation to suicide and sunshine, the effect of sunshine on hormones and neurotransmitters such as serotonin is thought to be a possible trigger in susceptible individuals. Makris et al. found a significantly increased risk of suicide with increased sun exposure in both men and women. This result disappeared after season was taken into account (Makris et al., 2016).

Temperature is often associated with suicide (Casas et al., 2021). Some studies found a higher incidence of suicide attempts on days with higher temperatures and/or more hours of sunshine, or during periods or in regions with warm and sunny weather (Deisenhammer, 2003). Climate change is leading to an increase in global average temperatures and, consequently, an increase in the global burden of disease. Mood diseases such as suicide are vulnerable to changes in ambient temperature (Casas et al., 2021). In Lisbon, a correlation between temperature and suicide was found. The number of suicides increases when the perception of heat increases (Santurtun et al., 2020). High temperatures and low precipitation have a strong effect on suicide risk, especially among people who have already attempted suicide. Studies in Israel, Sweden and the USA show that people who have already attempted suicide appear to be more vulnerable to the effects of increases in temperature on consecutive days. A rise in average temperature and extremely hot weather are associated with an increased number of visits to a psychiatric emergency room. A 5 °C rise in temperature during the summer season increases the risk of suicide. For people with psychiatric disorders, persistently high

temperatures put them at even greater risk of self-harm (Yarza et al., 2020). The study by Deisenhammer et al. found that high temperatures, low humidity and thunderstorms were associated with a higher risk of suicide. Weather is unlikely to trigger suicidal impulses in otherwise non-stressed individuals, but it may act as an additional stressor in individuals prone to suicidal behaviour (Deisenhammer et al., 2003).

A study observed that in randomly selected rural areas of India, the percentage of deaths by suicide increased by 18.75% in extremely wet growing seasons and by 3.6% in extremely dry growing seasons compared to normal growing seasons (Lester, 2021). Drought in Australia increases the likelihood of suicide (Nicholls et al., 2006). In Australia, the severe chronic drought of the last decade has been linked to negative mental health impacts, such as an increase in suicide rates. An ecological study in Western Australia concluded that salinity of drylands was used as an indicator of environmental degradation and that the level of environmental degradation was associated with an increased risk of hospitalisation for depressive disorders, regardless of socio-economic status. Climate change affects individual mental health and community well-being both directly and indirectly through acute or sub-acute weather events and longer-term or chronic environmental changes. For example, extreme weather events and natural disasters can have a direct impact on mental health, leading to problems such as acute stress or post-traumatic stress disorder. However, climate and environmental changes can also have an indirect impact on mental health by affecting ecosystems and human activities such as agriculture, or by having other consequences such as displacement of people, circumstances that can lead to increased stress, hopelessness and negative mental health outcomes such as depression and suicide (Bourque & Cunsolo Willox, 2014). Increased suicide rates are observed in some communities affected by climate change, and suicide rates are also increasing in the United States as climate change worsens (Dumont et al., 2020).

Allergy rates are higher in patients with depression. Epidemiological data suggest that seasonal peaks of aeroallergens in spring are associated with seasonal peaks of suicides in spring. It is possible that sensitisation and exposure to aeroallergens peaking in spring leads to seasonal exacerbation of risk factors for suicide such as anxiety, depression, hostility/aggression and sleep disturbance (Postolache et al., 2008). In the study by Qin et al. a significant association was found between suicide risk and pollen concentration in the air (Qin et al., 2013). Pollen is the most important seasonal aeroallergen that can act as an environmental trigger for suicide in vulnerable individuals. Airborne pollen triggers allergic reactions in sensitised individuals, which can lead to changes in brain function via molecular and cellular inflammatory mediators, resulting in affective and behavioural disorders (Woo et al., 2012b).

2.2. Air quality

There are numerous studies showing a link between air pollution and suicide risk (Sinyor et al., 2017). Air pollution threatens human health and it is estimated that 90% of people breathe polluted air (Shoib et al., 2021). Air pollution is associated with high human and societal costs (Oudin et al., 2018). Air pollution poses a health threat to human capital. It affects the brain and behaviour. There is also evidence that air pollution is negatively associated with self-rated mental health and hospitalisations for major depression (Persico & Marcotte, 2022). Several air pollutants, particularly particulate matter and nitrogen oxides, have been linked to poor mental health (Buoli et al., 2018). The presence of a psychiatric illness is thought to increase the effects of air pollution on suicide. Air pollution can thus increase depressive symptoms (Lin et al., 2016). The results of studies from South Korea, Taiwan, Canada and the USA show that higher levels of particulate matter, sulfur dioxide, nitrogen oxide and ozone are associated with an increase in suicide mortality or suicide attempts. There is a synergistic effect between summer heat and air pollution. High temperatures can amplify the effects of air pollution, so that the effects of suicidality are stronger in summer and especially during heat waves (Ng et al., 2016). An increased risk of suicidality has also been observed near coal-fired power plants, traffic and motorways, as well as chronic and acute air pollution (Dumont et al., 2020).

According to Davoudi et al. air pollution is associated with an increased risk of suicide in the general population. Air pollutants NO_2, SO_2, PM_{10} and $PM_{2.5}$ increase suicide risk with a cumulative lag of 0-1 days. Air pollution can trigger mental disorders such as depression and suicide. Carbon monoxide, nitrogen dioxide, sulfur dioxide and particulate matter can lead to a significant increase in emergency room visits for suicide attempts (Davoudi et al., 2021). Casas et al. found that PM_{10} and O_3 pollution can increase suicide rates in Belgium. Air pollution does not necessarily lead to suicide, but the findings of Casas et al. suggest that people who want to commit suicide are more likely to do so when air pollution levels are high. Furthermore, significant precipitating effects were only observed for men and violent methods in the case of O_3 pollution (Casas et al., 2017).

Studies have shown that the likelihood of visiting the emergency room for depression increases after exposure to ozone (Davoudi et al., 2021). According to Kim et al. ozone levels showed a strong association with suicide rates going back up to 4 weeks (Kim et al., 2015). A study examining ozone levels found a 7.8 per cent increase in suicides in weeks when ozone levels were 1 SD above the annual mean compared to weeks when ozone levels were 1 SD below the mean (Sinyor et al., 2017). An Italian study found that daily admissions to psychiatric emergency departments in two Italian hospitals over a two-year period suggested that ozone pollution may be associated with an increase

in psychiatric admissions (Aguglia et al., 2021). Elevated concentrations of particulate matter are associated with an increased risk of completed suicide (Kim et al., 2015). According to Buoli et al. prolonged exposure to $PM_{2.5}$ has been associated with an increased risk of recurrence of depressive symptoms (Buoli et al., 2018). In several studies conducted in the USA, Korea and Japan, particulate matter levels were higher in the days preceding suicide (Sinyor et al., 2017). A study found that an increase in PM_{10} exposure was significantly associated with an increased risk of suicide, and the risk was particularly high in people with cardiovascular disease (Min et al., 2018a). A systematic review and meta-analysis of thirty studies concluded that short-term $PM_{2.5}$ exposure was associated with a 2% increased risk of depression and suicide, while long-term exposure was associated with an 18% increased risk of depression (Shoib et al., 2021). Pollutants such as nitrogen dioxide and sulfur dioxide have also been linked to suicide in some cases (Sinyor et al., 2017). In general, long-term PM_{10}, $N0_2$ and SO_2 exposure is associated with an increased risk of suicide among adults in South Korea (Min et al., 2018a). Elevated nitrogen dioxide concentrations in summer were associated with worsening of pre-existing depressive states (Buoli et al., 2018).

Air pollution leads to an exacerbation of physical illnesses or ailments and psychological pain, and can consequently lead to suicide (Lin et al., 2016). Air pollutants such as particulate matter, nitrogen, sulfur oxides, carbon monoxide and ozone are toxic to the central nervous system (Buoli et al., 2018). The central nervous system can be affected by air pollution. This is particularly true for neurotoxic particles such as lead, mercury and manganese. In this mechanism, air pollutants exert neuroinflammatory effects due to the release of proinflammatory cytokines, which in turn leads to changes in the brain, such as altered levels of neurotransmitter cytokines. As a result, psychological behavioural changes such as depression, aggressive behaviour and suicide may occur (Davoudi et al., 2021). Particulate matter can greatly increase circulating proinflammatory cytokines and is associated with depressive moods. Cytokines are a class of proteins and are produced by immune cells in response to infection and inflammation (Persico & Marcotte, 2022). It is also suspected that $PM_{2.5}$ and PM_{10} can trigger systemic inflammation/oxidative stress or affect neurogenesis in the hippocampus and the expression of neurotrophic factors, so the pollutants could play a causal role in the occurrence of mental health problems or suicide attempts. $PM_{2.5}$ penetrates the olfactory bulb and reaches the basal nuclei (substantia nigra and striatum), causing a release of proinflammatory factors and cytokines (Aguglia et al., 2021). Biologically, ozone can affect the release of serotonin, which plays an important role in impulsivity, aggression and depression and can therefore have an impact on suicides (Gladka et al., 2018).

2.3. Water quality

There are several studies reporting the influence of certain substances in tap water on suicide risk. Lithium is used in pharmacological doses to treat and prevent manic/depressive episodes, stabilise mood and reduce the risk of suicide (Memon et al., 2020). Most studies report a negative association between suicide mortality and lithium levels in tap water. However, a few studies found either no association or a positive association. This means that the relationship between suicide mortality and lithium content in tap water is controversial (Kozoka et al., 2020; Ishii et al., 2015).

The findings of Ishii et al. suggest that lithium in drinking water may be associated with a low risk of male suicide in the general population (Ishii et al., 2015). A study from Lithuania also found that higher levels of lithium in public drinking water were associated with lower rates of male suicide (Liaugaudaite et al., 2017). Sugawara et al. found that the natural lithium content of drinking water may have a protective effect on suicide risk in women (Sugawara et al., 2013). The study by Blüml et al. showed that lithium levels in public water supplies in Texas were negatively associated with suicide mortality. The negative association between lithium levels and suicide rates remains significant even when adjusted for important socioeconomic factors for suicide (Blüml et al., 2013). Kapusta et al. also found that both the overall suicide rate and the suicide mortality rate were inversely related to drinking water lithium levels and remained significant even after sensitivity analyses and adjustment for socioeconomic factors (Kapusta et al., 2011). However, Kabacs et al. found no association between lithium in drinking water and suicide rates in the East of England between 2006 and 2008 (Kabacs et al., 2011). Kozoka et al. also came to the same conclusion (Kozoka et al., 2020). Knudsen et al. also found no significant association between an increase in five-year time-weighted average lithium exposure from drinking water and a decrease in suicide rates (Knudsen et al., 2017).

Whitaker et al. conducted an observational study to examine the relationship between chromium concentration in drinking water and mortality due to suicide in the US state of Alabama. Whitaker et al. concluded that there was a statistically significant inverse relationship between chromium concentration and suicide deaths among whites, and therefore a protective effect at least for the white population (Whitaker et al., 2020). Several studies suggest that consumption of arsenic-containing drinking water may be associated with an increased risk of depression. The findings of Rihmer et al. suggest that consumption of arsenic-contaminated drinking water may be associated with suicidality (Rihmer et al., 2015). Pompili et al. found that there are lower suicide rates at higher arsenic concentrations (Pompili et al., 2017).

2.4. Green and Blue Spaces (recreational areas)

There are numerous studies that have examined the effects of green spaces on mental health, but little is known about the link between green spaces and suicide (Jiang et al., 2021). There is growing evidence that natural outdoor environments such as green spaces (grass, forests and parks), blue spaces (visible lakes, rivers and oceans) and proximity to coasts promote mental health (Helbich et al., 2018b). Living near nature, recreating in nature and feeling psychologically connected to nature are often associated with better mental health (White et al., 2021). In terms of the health benefits of blue space, the literature is limited (Helbich, 2019). Britton et al. define blue space as natural outdoor surface waters visible to all that have the potential to promote human health and well-being (Britton et al., 2020).

There is ample evidence that parks and green spaces have a positive impact on mental health. Min et al. found a protective relationship between parks/green spaces and depression and suicide factors. Parks and green spaces can promote physical activity and social contact/interaction and reduce psychological stress, leading to a reduction in the risk of depression and suicidality indicators. Several studies show an inverse relationship between spending time in parks and green spaces and depressive symptoms. The prevalence of depression or suicide is higher among adults who live in fewer parks and green spaces. Min et al. found that the prevalence of depressive symptoms and suicidal ideation was lower in participants with moderate physical activity than in participants without moderate physical activity (Min et al., 2017). Some studies argue that diversity of land use can promote physical activity and that social cohesion and a sense of community increase in neighbourhoods with well-connected streets, which in turn promotes mental health (Helbich, 2019). As green spaces and parks promote physical activity, a low proportion of green spaces in a place can lead to a lower provision of recreational activities (Castillo Echeverria & Maroto Vargas, 2017).

Green spaces play a very important role in the urban environment. The presence of green spaces is associated with several distinct positive effects on the environment and the physical and mental health of the population. Trees reduce pollutants such as dust, ozone and heavy metals. Green spaces also reduce noise, local temperature and the effects of urban heat islands. In addition, some studies suggest that urban green spaces are associated with better self-reported and diagnosed health, higher levels of physical activity, lower mortality rates, fewer psychological symptoms, less anxiety, depression and stress, and higher levels of social cohesion (Vida, 2011).

The results of Jiang et al. showed that green spaces were related to suicide mortality and that this relationship depended on the shape of the green space, the degree of urbanity and demographic characteristics. Urban green spaces and rural forests could have a protective effect against self-injurious behaviour (Jiang et al., 2021). Shen and Lung's findings showed a negative association between suicide rates and the area of green space, but a positive association with fragmentation and removal of green structures (Shen & Lung, 2018). The amount of green space in a community is an important component of improving mental health (Lee & Lee, 2019). Communities with a large amount of green space have a lower risk of suicide than communities with less green space in Austria (Sun et al., 2020). The findings of Helbich et al. suggest that green space as a whole is inversely and non-linearly related to antidepressant prescription rates. The results thus suggest that a greater supply of green space in a community may contribute to a decrease in antidepressant prescriptions (Helbich et al., 2018a). According to Song et al. those who lived in a greener area were less likely to suffer from depression and less likely to develop depression (Song et al., 2019).

According to White et al., people who lived in greener/coastal areas reported higher positive well-being, but this association largely disappeared when controlling for leisure visits. Frequency of visits to green spaces, inland blue spaces and coastal blue spaces in the past four weeks was positively associated with positive well-being and negatively associated with psychological distress. Associations with visiting green spaces were relatively consistent across seasons and countries, while associations with visiting blue spaces showed greater heterogeneity. Connectedness to nature was also positively associated with positive well-being and negatively associated with psychological distress, and together with visiting green spaces, was associated with a lower likelihood of taking medication for depression. In contrast, visiting blue landscapes was associated with a higher likelihood of taking anti-anxiety medication. Although green and blue landscapes share many characteristics (e.g. cooling effect, biodiversity), blue landscapes also provide alternative recreational opportunities (e.g. swimming) and have additional features (e.g. unique soundscapes) (White et al., 2021).

No association was found between suicide and blue spaces or living near the coast (Chang et al., 2018). Coastal proximity is negatively associated with suicide mortality, so blue space visibility does not necessarily correlate with mental health. A retrospective study found that higher visibility of blue spaces was associated with lower psychological distress (Matyas, 2019). A study from England and Wales has shown that suicides are more common in coastal areas (Chang et al., 2018).

2.5. Noise

The World Health Organisation (WHO) considers noise to be an environmental risk factor for poor health and an important environmental problem. A strong link between poor sleep quality and mental health problems is widely recognised (Sygna et al., 2014). Noise is defined as unwanted, unpleasant or harmful sound. Noise can cause negative feelings, mental health problems and even lead to an increased risk of suicide (Min & Min, 2018b). Numerous studies show a statistically significant association between environmental noise and adverse health effects for both short- and long-term noise exposure (Barcelo et al., 2016). A 2011 WHO study in Europe showed that 40% of the population in EU countries are exposed to traffic noise levels above 55 dB(A), 20% are exposed to levels above 65 dB(A) during the day and 30% are exposed to levels above 55 dB(A) at night (Diaz Jimenez & Linares Gil). Noise can have acute and chronic effects on health and lead to a variety of health problems (Tangermann et al., 2022). Noise exposure is associated with an increased risk of mental illness, including suicide (Hahad et al., 2020).

There is evidence that noise exposure is a mediator between noise exposure and depression and mental illness (Stansfeld et al., 2021). In particular, environmental noise from road, air and rail traffic is known to have a strong influence on sleep disorders (Kohlhuber & Bolte, 2011). Poor sleep leads to measurable endocrine and metabolic disturbances and is associated in the form of a stress response in adults and children (Halperin, 2014). Sleep disturbances and general sleep complaints have been associated with increased levels of suicidal ideation and depression, as well as attempted and completed suicide (Bernert & Nadorff, 2015). Sleep problems are a marker of suicide risk. A US study found that poor sleep quality was associated with increased suicide risk. Sleep disturbances are a common symptom of psychiatric disorders, representing the strongest single risk factor for suicide (Bjorngaard et al., 2011). Sygna et al. found weak evidence of an association between road traffic noise exposure and mental health, and only among those with poor sleep quality (Sygna et al., 2014).

Noise pollution is one of the main causes of declining well-being among a country's inhabitants and can affect people's overall quality of life. Some studies investigated the possible effects of a certain level of noise exposure on life satisfaction. Most results indicated that high noise exposure is associated with a high risk of depression and has a significant negative impact on life satisfaction (Yang et al., 2022). According to Diaz et al. traffic noise can be considered an important risk factor for illness, anxiety and depression, and suicide in the city of Madrid. An association has been found between exposure to traffic noise and mental illness and the use of medication for depression and anxiety. Traffic noise is a variable related to hospitalisations for personality disorders such as anxiety

and depression, as well as suicide in the city of Madrid (Diaz et al., 2020). According to Klompmaker et al., road traffic noise was only positively associated with the prescription of anxiolytics, while rail traffic noise was only positively associated with mental disorders. Mental distress was strongest with a combination of air pollution, rail traffic noise and less green space in the neighbourhood (Klompmaker et al., 2019). Dzhambov and Lercher found very weak evidence that increasing exposure to road traffic noise may be associated with depression and anxiety (Dzhambov & Lercher, 2019).

Min and Min (2018) found a significant association between nighttime noise exposure and suicide risk among adults in the Republic of Korea, meaning that chronic nighttime noise exposure can increase suicide risk among adults. The effects of noise-related stress or noise pollution may be exacerbated in people who are already at high risk of suicide. Some studies have found that people who are chronically or severely exposed to noise have a higher risk of litigiousness, nervousness, anxiety and depression than people who are exposed to less noise. Negative emotions and mental health problems have long been considered risk factors for suicide. When a person experiences mental distress from external influences or stressors and has difficulty coping, the likelihood of committing suicide increases. Therefore, noise exposure that causes annoyance and psychological distress may contribute to an increased risk of suicide (Min & Min, 2018b). Repeated exposure to noise may increase the risk of elevated stress hormone levels, which could be linked to a range of mental disorders (Gong et al., 2022).

A study examining the negative health effects of living near a major London airport found that high levels of aircraft noise exposure led to both acute and chronic irritability and depressive symptoms among residents (Yoon et al., 2014). Social and community surveys and other research indicate that airport noise is a major cause of community reactions and social disturbances. There is evidence that aircraft noise is associated with sleep loss and awakening, reduced sleep quality and EEG changes (Morell et al., 1997). More generally, some health effects, such as increased prescriptions for medication near major airports or increased admissions to psychiatric hospitals, are also associated with night-time noise exposure (Muzet, 2007). A meta-analysis of five aircraft noise studies found that the risk of depression increased by 12 % per 10 dB LDEN. It can thus be said that exposure to aircraft noise increases the risk of depression (Hegewald et al., 2020). However, in another study that took socio-demographic variables into account, no association was found between aircraft noise and the number of psychiatric hospitalisations. The Caerphilly study, which is based on a prospective study, also found no association between mental disorders and traffic noise after controlling for sociodemographic factors (Yoon et al., 2014).

2.6. Research Questions

Suicide is a global public health priority. As mentioned in the introduction, an estimated 800,000 people die by suicide each year, which is more than war and homicide combined (Chang et al., 2018). The United Nations has created 17 Sustainable Development Goals (SDGs) for the 2030 Agenda. The 3rd goal of these 17 goals includes health and well-being, which means ensuring a healthy life for all people at all ages and promoting their well-being. Goal 3.4 describes: "By 2030, reduce by one third premature mortality from noncommunicable diseases through prevention and treatment, and promote mental health and well-being" (EDA, 2020). Suicide is one of the two indicators of this goal number 3.4 (Chang et al., 2018).

In most studies on suicide prevention, great attention is often paid to psychological and physical factors. The influence of environmental factors in suicide prevention is very rarely discussed. Climate change is also an issue that will be of great concern to society in the near future. How humans treat the planet has direct consequences on human health. A Stanford study concluded that up to 21,000 additional suicides can be expected in the U.S. and Mexico by 2050 if the earth continues to warm as much as currently predicted due to unchecked climate change (Horton, 2019). There are many studies from other countries that have examined the relationship between environmental factors and suicide risk. For Switzerland, almost no studies are known. Researching this topic is important because the costs to society and the economy are great and every suicide victim is one too many.

The literature often refers to meteorological variables, water quality, air quality, noise and recreational areas. Therefore, meteorological variables such as temperature, precipitation, sunshine hours and humidity are studied. The literature often refers to water quality or lithium content and other substances and suicide risk. However, lithium, chromium, arsenic or lead are not systematically recorded in Switzerland, as these elements are very rare in Swiss drinking water. Therefore, water quality is omitted from this research. Air quality is often mentioned in the literature as increasing the risk of suicide. The largest air pollutants are particulate matter, sulfur oxide, nitrogen oxide and ozone, which are also taken as variables for air quality in this paper. Noise and recreational areas are also frequently mentioned in the literature to influence suicide risk. Therefore, variables such as traffic areas, green spaces and blue areas are considered here for the research. The literature found both positive associations, no associations, or negative associations with suicide risk for all variables.

Thus, the following environmental variables for this thesis are examined in terms of how they influence suicide risk:

- Meteorological variables (temperature, humidity, sunshine hours and precipitation)
- Air quality (NO_2, SO_2, O_3, PM_{10})
- Recreational areas (blue spaces & green spaces)
- Noise (traffic spaces)

To account for bias, the following control variables are added:

- Urban/Rural
- Socioeconomic status (SES)

Thus, this is an ecological study that examines the influence of environmental factors on suicide risk. The research gaps lead to three research questions, which are explored here:

1. What is the spatial and temporal distribution of suicide rates in Switzerland across the years 2000-2019?
2. What is the relationship between environmental factors and suicide in Switzerland?
3. How is the spatial pattern of suicide risk when environmental factors have been adjusted?

3. Methods and Data

3.1. Data

3.1.1. Suicide data

The Swiss suicide data come from the death register and was provided by the University of Zurich, the Epidemiology, Biostatistics and Prevention Institute (EBPI). The Swiss suicide data includes the years 2000 to 2019, which also has information on month, sex, nationality (Swiss/Non-Swiss), age group and marital status. In this study assisted suicides are excluded. The data is at the MobSpat level. There are 106 regions at the MobSpat level. There are restrictions on the data. No information is known where the person committed suicide, only the person's place of residence at MobSpat level is available. It is also unknown which method the person chose to commit suicide. In addition, there is no information on whether the person suffered from other mental illnesses. In the data, everything that was classified as a suicide by the doctors and police officers was counted as a suicide. Mobspat regions (MS regions) stand for mobilité spatiale. MS regions are used in particular as an intermediate microregional level for numerous scientific and regional policy purposes and emerged from a research project in 1982. The 106 regions were formed from existing mountain regions and spatial planning areas and are characterized by a certain spatial homogeneity and obey the principle of small labor market areas with a functional orientation towards centers. In addition, some of the 106 regions are also cross-cantonal (BFS, w.y.).

3.1.2. Demographic data

In order to have relative figures, i.e. suicide rates for each MobSpat level, data on population are necessary. The data on the number of population at the MobSpat level were taken from Federal Statistical Office. It was available at the municipality level. Therefore, the data had to be aggregated from municipality level to MobSpat level. The methods section explains in more detail how to transform individual communities into mobspat regions. As data was not available for all the years required and there were municipality mergers and no constant population growth, the mean value of the population of the years 2015 to 2017 was taken. In addition to the mean population size, there was also information on the number of population that are between 0 and 19 years old, between 20 and 64 years old and seniors over 65 years old. There was also information on the number of foreigners and about the marital status of whole Switzerland. In addition, the Federal Statistical Office

had data on population density by municipality, which was relevant for dividing the regions into urban and rural areas.

3.1.3. Socioeconomic status data

The data on socio-economic status come from the University of Bern. There are the three variables SSEP1, SSEP2 and SSEP3. In addition, there was the variable GISID and the coordinates of each of these GISIDs. The Swiss Socioeconomic Position (SSEP) is a combination of four variables, which are income, education, occupation, and housing conditions. For this research SSEP3 was taken, because it is a hybrid version of SSEP1 and SSEP2. This socioeconomic position (SEP) was developed because of a lack of area-based measures for it in Switzerland that could be suitable for epidemiological research. Therefore, Panczak et al. developed the Swiss neighborhood index of SEP (Swiss-SEP). This involved using data from the 2000 census and the street network to define neighborhoods of 50 households whose boundaries overlapped. The mean rent per square meter, the proportion of households with one person with primary education or less, the proportion of households with one person with manual or unskilled labor, and the mean number of persons per room were analyzed as variables in a principal components analysis. This index was then compared to independent income data, thus defining 1.27 million overlapping neighborhoods (Panczak et al., 2012).

3.1.4. Suicide methods data

To analyze suicide rates over time, it is useful to compare suicide methods over time. In the suicide data, there was no information on the methods people used when they committed suicide. In Obsan, there were data on suicide methods, but they were annual, so there is no indication in which month or season which suicide method is used more often. The Obsan data also differentiated by gender.

3.1.5. Air quality data

The data on air pollution comes from the Federal Office for the Environment (FOEN). Data on the air pollutants NO_2, SO_2, PM_{10} and O_3 have been obtained and these are annual mean values. Unfortunately, there is no data available on a monthly basis and thus assumptions must be made as to how air pollution is distributed throughout the year. These four air pollutants were taken, because they are the major air pollutans in Switzerland. Basically, it can be said that air pollutant emissions in Switzerland have decreased since the 1990s. Three of the four air pollutants considered, i.e. sulfur

dioxide, nitrogen oxides and particulate matter, have been greatly reduced since 1990. Sulfur dioxide fell by about 89%, nitrogen oxides by about 62% and particulate matter by about half. Nevertheless, these three are still among the largest air pollutants and therefore an analysis is important. The stations that were within the respective mobspat level were taken. In some cases, there were no stations within the Mobspat level, in which case the nearest station to this Mobspat level was taken into account (BAFU, w.y.).

3.1.6. Meteorological factors data

The data on sunshine hours, temperature, pollen, humidity and precipitation come from the Federal Office of Meteorology and Climatology (MeteoSwiss). For sunshine duration, relative humidity, temperature and precipitation, the stations that lie within a MobSpat level were selected and their mean value taken. In some cases, there was no data within the MobSpat level, which was filled with an interpolation procedure (nearest station). For precipitation, the granularity month was taken with the unit millimetre, i.e. it is the monthly sum. The humidity is the relative humidity 2m above ground, i.e. the monthly mean in the unit of percent. The temperature is the air temperature 2m above ground in the unit of degrees celsius, so it is the monthly mean. The sunshine duration is available in the granularity of month and has the unit hours. This means that it is the monthly sum. Ragweed, birch, oak, alder, ash, grasses, hornbeam, hazel and herbs are typical pollens in Switzerland that cause allergy and therefore they were included in the work. The monthly integral of the pollen concentration was taken in the unit pollen per cubic metre. For pollen species, certain ones had not been seen permanently over the 20 years. Some were mostly constant over the years, while others fluctuated and some were not seen at all after a certain time.

3.1.7. Green spaces, blue spaces and traffic spaces data

The data on blue and green areas come from the Federal Statistical Office. The transport areas were also taken from the FSO. For blue areas, standing waters and watercourses were taken and for green areas, forests, green and recreational areas were taken. The area statistics are from 2013 to 2018. It is assumed that the proportion of areas for green, blue and traffic remained constant between 2000 and 2019. Traffic areas were taken on the assumption that localities that have a higher traffic area percentage also have higher noise. Traffic areas seem to be more appropriate than the railroad and traffic noise data from FOEN, since aircraft are also taken under traffic areas. According to the list, which municipality belongs to which region, the percentage of traffic, blue and green spaces was calculated for each region.

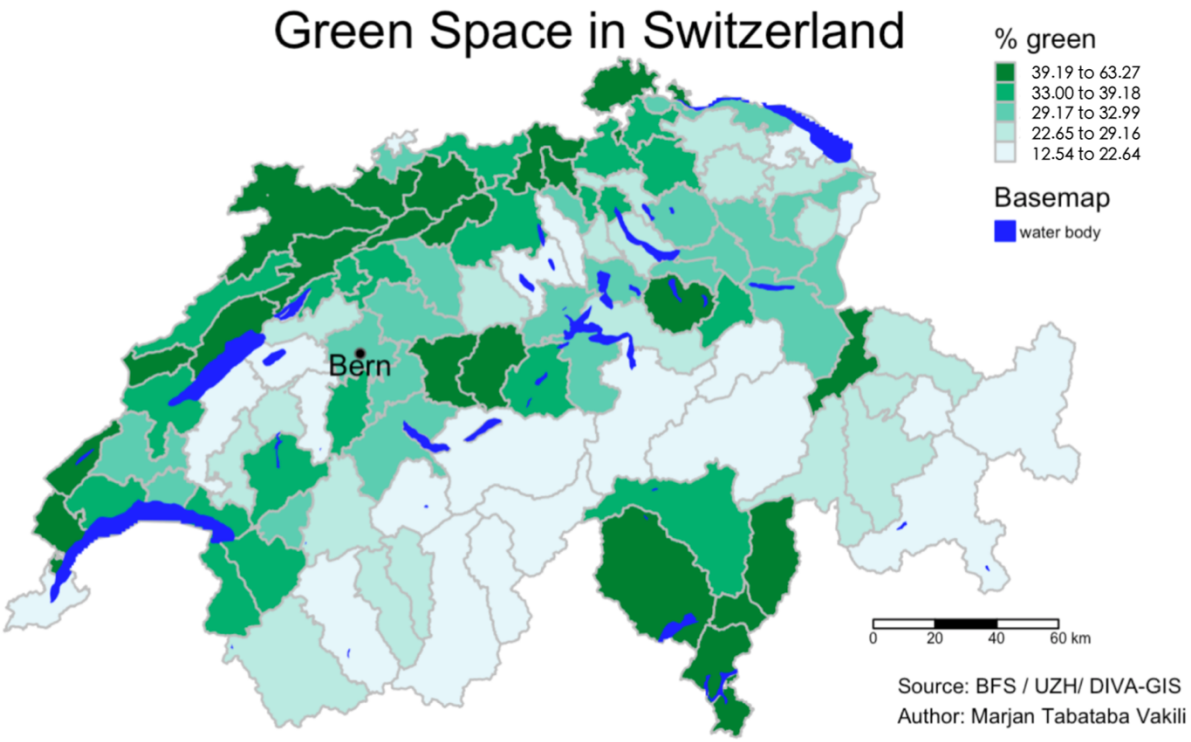


Figure 2: Green spaces in Switzerland. The highest percentage of green spaces are found in the southern part of Switzerland (southern of Ticino) and in western part canton Neuchâtel. This map shows the percentage of green space in a region per area.

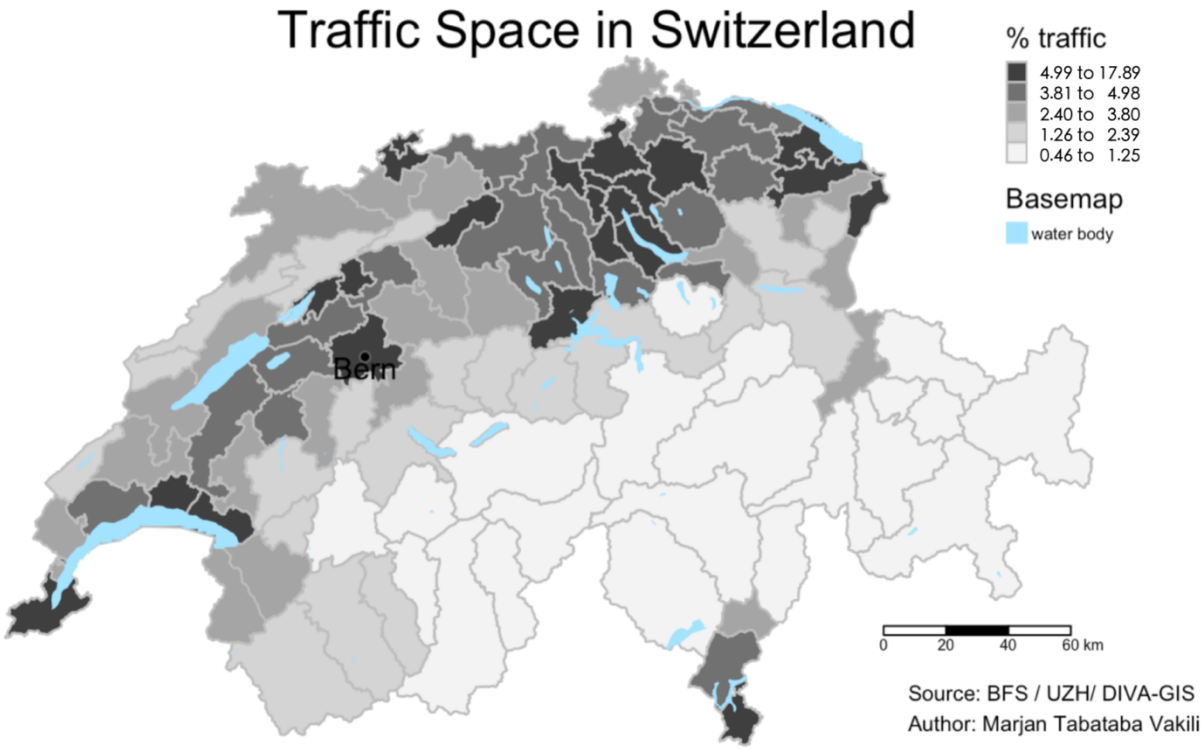


Figure 3: Traffic space in Switzerland. The highest percentage of traffic spaces are found in the area of Zurich, Basel, Lausanne and Geneva. This map shows the percentage of traffic space in a region per area.

3.2. Methods

3.2.1. Transform Municipality level to Mobspat level

To find out which municipalities are located on which Mobspat region, the two shapefiles, i.e. shapefile of Switzerland on municipality level and shapefile of Switzerland on Mobspat level, are first compared in R. The shapefile at Mobspat level was provided by the University of Zurich and the shapefile at community level was provided by the federal office of topography, swisstopo. First, the coordinate system is compared to see if both shapefiles are in the same system. The crs of the shapefile at the community level is available in CH1903+ / LV95. The mobspat shapefile is available in CH1903 / LV03. Therefore, the coordinate system of the shapefile of the Swiss municipalities is converted from LV95 to LV03. For that the function *st_transform()* from the sf packages have to be used. The function *st_transform()* transform or convert coordinates of simple features.

The following code was given to transform the crs system:

st_transform(shapefile_municipality_ch$geometry, 21781)

The number 21781 was indicated, because it is the EPSG code for LV03. In the next step the function *st_intersects* from sf packages was used to see, which municipality is in which Mobspat level.

The following code was given to get a list with the information which municipality is in which region:

st_intersects(shapefile_mobspat, shapefile_municipality)

There are certain municipalities that are located in two regions. Here, the region where the larger area of the municipality is located was taken. This list was also used to assign the stations from MeteoSwiss and FOEN to these respective regions, but also for the demographic data and data for blue space, green space and traffic space.

3.2.2. Transform SSEP data to Mobspat level

For socioeconomic status data, there were a total of 1'527'173 observations. In addition to information on GISID and SSEP3, there was also information on x and y coordinates. The coordinates are given

in LV95 and must be converted to LV03 because the shapefile is present in LV03. The function *st_as_sf* of sf package is used to transform it into LV03. The EPSG code for LV03 is 21781.

The following code was given to transform the coordinates from LV95 to LV03:

st_as_sf(data, coords=c("x","y"), crs=21781).

In the next step to get a list on which GISID is in which region, the function *st_intersects()* is used.

The following code was given to get the list with the information which GISID is in which region:

st_intersects(ssep_data, shapefile_mobspat).

Now this was changed to a dataframe with the function *data.frame()*. In addition the column names were changed to merge it later with the ssep data and for that *names()* was used.

In the next step the following code was used to calculate in the next step the mean of ssep3:

merge(data_gisid_region, ssep_data, by= "gisid")

To calculate the mean of SSEP for every region the package tidyverse was used to get it and the following code was indicated:

list_meanssep3_region %>% group_by(Region) %>% summarize(ssep3 = mean(ssep3))

The list with the mean ssep3 of all regions are provided after the above code.

3.2.3. Pollen data and MobSpat Level

There are only 18 stations in the pollen data. And there are 106 regions in total. This means that a method should be used so that for all regions have pollen data available. Therefore, Voronoi diagrams were used to determine which region was closest to which pollen station. Therefore, the dataset with the 18 stations was created with their coordinates. The coordinate reference system was for both shapefile and datapoint the same. To find for each region the nearest station the function from the sf package *st_nearest_feature* is used.

The following code is given:

shapefile_mobspat$nearest_station = st_nearest_feature(shapegile_mobspat, stationspointdataset)

In the next step the function plot was used to indentify which region belongs to which station, for that the following code was given:

plot (shapefile_mobspat$geometry, col= shapefile_mobspat$nearest_station, border="color")
plot (stations$geometry, add=TRUE, pch=24, col="color", bg="color")

With that data for all regions are available with the idea of Tobler's first law of geography, that everything is related with everything else, but nearer things are more related than further things.

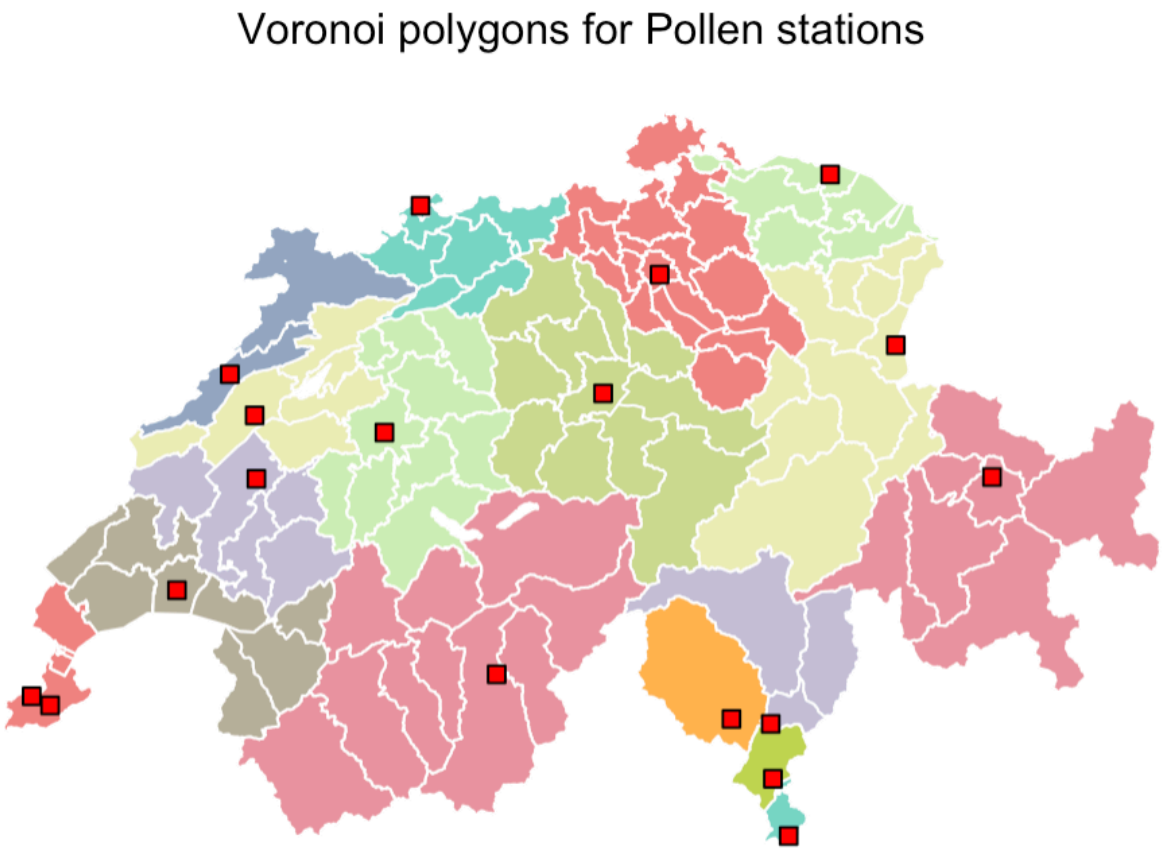


Figure 4: Voronoi polygons for detecting which pollen station belongs to which regions.

3.2.4. Find nearest station for areas without a proxy station

In very rare cases there were no stations within the MS-Region for variables of air pollution and weather. To fit data, one assumes that the nearest station is similar to that region and for that the same method was used like in the pollen data process, the function *st_nearest_feature*. Tobler's first law of

geography was also applied here. With the function *st_nearest_feature*, one gets the index of the nearest feature.

3.2.5. Create a column for the four seasons

In order to be able to observe in which season over the years most suicides were committed, an additional column is created with the four seasons. It is assumed that the months of December, January and February belong to winter and the seasons of March, April and May to spring. The months of June, July and August are counted as summer and the months of September, October and November are counted as autumn. It is a simplification because the suicide data is only at the monthly level and there is no information on which day of the month the suicide occurred. Normally, in reality, it would not be the division of the seasons into months.

For creating this column, the following code was given in R:

```
data$Season <- c('Winter', 'Spring', 'Summer', 'Fall')
              [ 1 + (match(data$Month, month.name) %/% 3) %% 4]
```

3.2.6. Create a column for urban/rural and the four language regions of Switzerland

To distinguish between the effect of several variables to suicide risk in rural and urban areas, the regions are divided in to urban and rural areas. Every region that is mostly urbanic is belong to urban region, but also some intermediate regions that are part of agglomeration are in the category of urban areas. The categorisation is based on BFS, but also on the decision if intermediate regions have more urban or rural character and the criterias were population size and population density.

To also compare the suicide patterns between the different language region, a column with the language was created. For the rumantsch part, the areas that were according to BFS rumantsch dominated were part of the Rhaetoromanic Switzerland. The regions that belong to Rhaeto-Romanic Switzerland are Engiadina Bassa and Surselva. One MS region was multilingual. In the Upper Engadine, German, Rumantsch and Italian are spoken. Since the majority of the communities that speak both German and Rumantsch are German-speaking and the only Italian community Maloja has fewer than 500 inhabitants and is therefore even less than Romansh, the Upper Engadine region was counted as a German-speaking region.

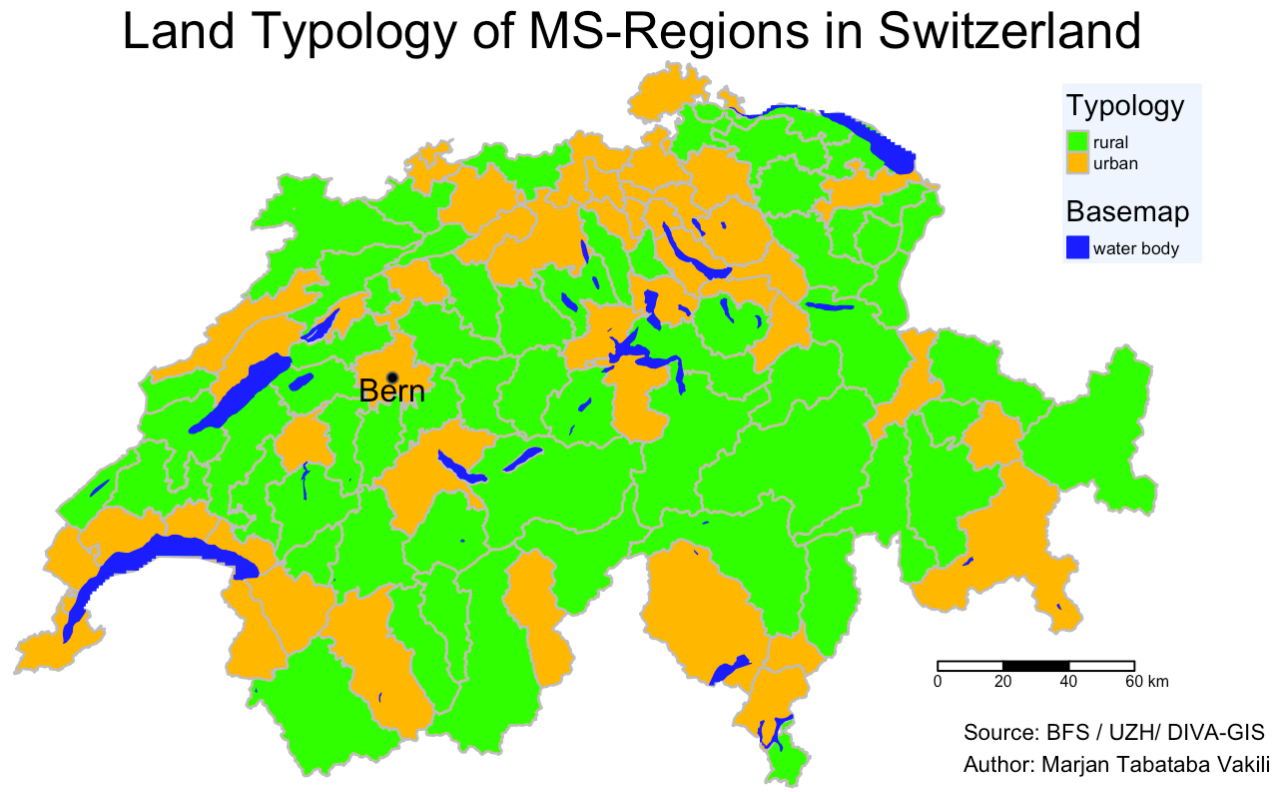


Figure 5: MS-Regions divided in to urban and rural areas. Especially the areas around Zurich and Geneva are urbanised, but also Lausanne, Basel and other areas in Switzerland.

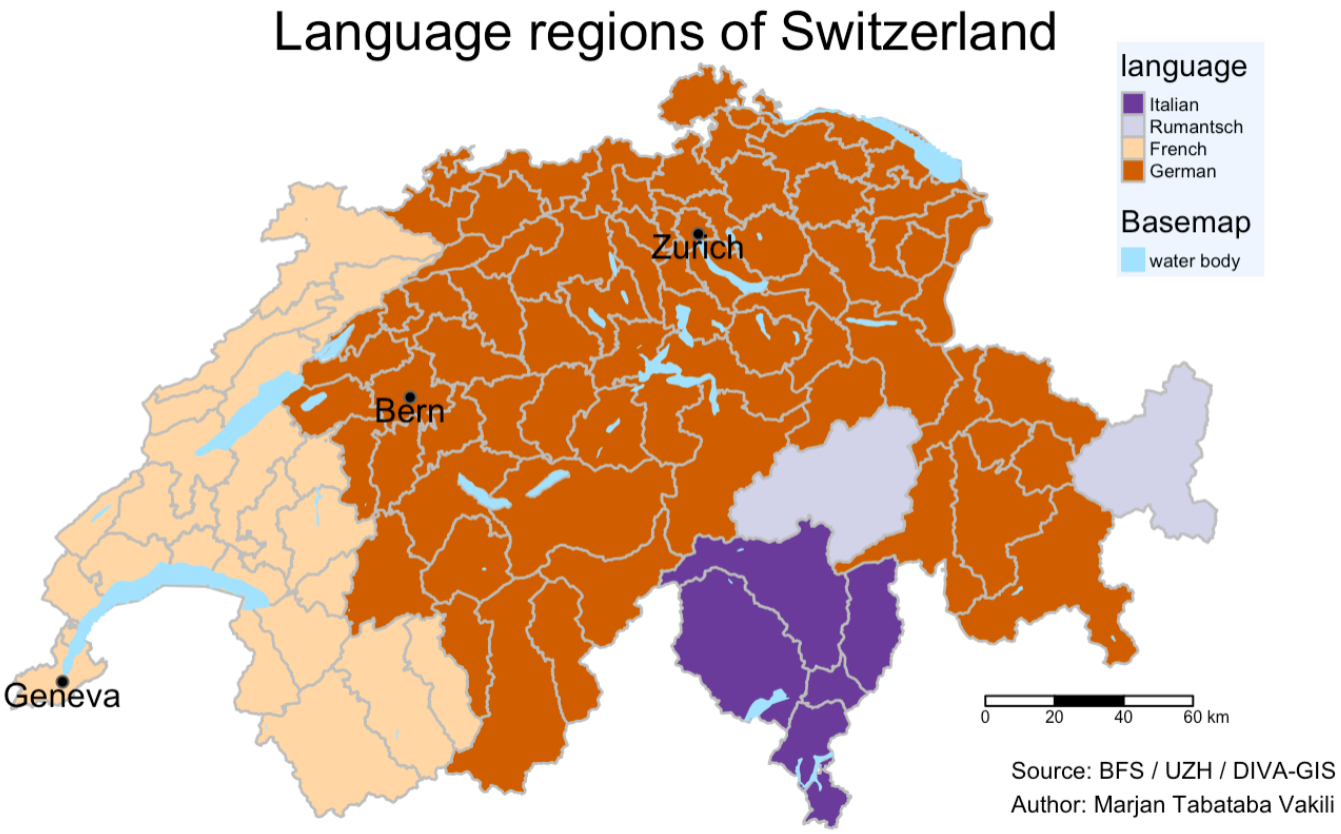


Figure 6: Four language regions of Switzerland. One can see that most regions are German-speaking part, followed by French.

3.2.7. Descriptive statistics

To have an overview, the first step is to visualize with the data. For this, one uses descriptive statistics to create maps and histograms (research question 1).

For creating maps in R the function *tmap()* is used. To create a map, a shapefile of the MS regions (University of Zurich) and a shapefile of the lakes in Switzerland (DIVA GIS) are needed. The watershapefile and the mobspatshapefile should be in the same crs system, for that the watershapefile was transformed into LV03 with the function *st_transform(watershapefile$geometry, 21781)*. In the next step the csv file with the information of suicide rate and other variables was merged with the mobspatshapefile by using the function *inner_join(csv_file, mobspat_shapefile, by="Region")*. And this new dataset was transformed with the function *st_as_sf()*.

The code for create a map is the following:

tm_shapefile(inner_join_file) + tm_borders("color") + tm_fill("suicide rate") + tm_layout(title="Suicide rate in Switzerland from 2000 to 2019 on the Mobspat level") + tm_shape(watershapefile) + tm_fill("color") + tm_scale bar() + tm_credits().

This code above is the overview code.

To create histograms the function *ggplot()* is used. The following code was given:

ggplot (data, aes(x=variable_1, y=variable_2, fill=variable_1)) + geom_bar(stat="identity") + ggtitle("").

To create a line graph the function ggplot() is used too. The following code was given:

ggplot(data, aes(x = variable_1, y = variable_2, color = variable_3)) + geom_line() + ggtitle("") +xlab("") + ylab("")

3.2.8. Choice between linear and logistic regression model

The prerequisites for a univariate linear regression are:
- Linear relationship between the dependent and the independent variable
- Dependent variable must be scaled metrically
- Error terms E(e)= 0 must be normally distributed for test and confidence interval
- Homoscedasticity
- Error terms must be independent (no autocorrelation)

The first requirement is met, because if one chooses ggplot and stat_smooth method="lm", then a linear relationship can be seen for all variables and the suicide rate. A linear relationship is also evident from the visualization with the method="glm". The second requirement is also met since the suicide rate is a ratio scale and is therefore metric. But the error terms are not normally distributed, because all p-values are below 0.05, but it is not relevant, because the data is very large. So, the confidence intervals are approximative. Homoscedasticity is not relevant too, because of a large dataset. The same is for no autocorrelation. So, the prequisites for the linear model are fulfilled and for that the linear regression is chosen for this model.

3.2.9. Univariate Linear Regression

The univariate linear regression whether there is a relationship between the dependent variable and the independent variable (relevant for research question 2). The simple regression analysis can be used to examine how closely the relationship between the examined variables is and how the dependent variable changes when the independent variable changes.

To perform univariate linear regression, the following code was entered:

lm(dependent variable~independent variable, data)

3.2.10. Multiple linear Regression

Multiple linear regression analysis explains the dependent variable using multiple independent variables.

The prerequisites for a multiple linear regression are:

- Linear relationship between independent variables and the dependent variable
- Metric scaled dependent variable
- Normally distributed error terms
- Homoscedasticity
- No autocorrelation
- Independence of the error terms
- No multicollinearity (excessive correlation of the x-Variables with each other)

The first five conditions are met because they were also tested for simple linear regression. There are two methods to check multicollinearity. The first is with a correlation table. There it can be seen that no value is above 0.8 and therefore there is no multicollinearity. VIF is another method that can be used to calculate multicollinearity. VIF stands for Variance Inflation Factor and expresses in a number how much the independent variable is responsible for the multicollinearity. To calculated in R the package car is needed and the multiple linear model is defined and the function *vif(multiple linear model)* is given to calculated the VIF values. From the output there is no vif-value above 10, so there is no multicollinearity. Therefore, the prequisites for the multiple linear regression are met.

Temperature	Humidity	Sunshinehour	Precipitation	PM10	O3	NO2
3.851643	2.392036	5.092738	1.285145	2.144442	1.825935	3.262988
SO2	Ragweed	Birch	Alder	Ash	Hazel	Oak
1.213901	1.153041	2.452844	2.137292	1.867245	2.129657	1.442551
Grasses	Herbs	Hornbeam	Greenspace	Bluespace	Trafficspace	SSEP
1.496679	1.139114	1.664516	1.113143	1.109017	2.741323	2.129834

Figure 7: Output of VIF code in R.

3.2.11. Principal component analysis (PCA)

Besides correlation, principal component analysis also serves as a support to reduce the number of variables and consistent analysis of causality. Therefore, the package *factoextra* is used in R. Principal component analysis is a statistical technique that reduces the number of variables by grouping them into compnents. Therefore, it also serves as a support, which variables have similar variability.

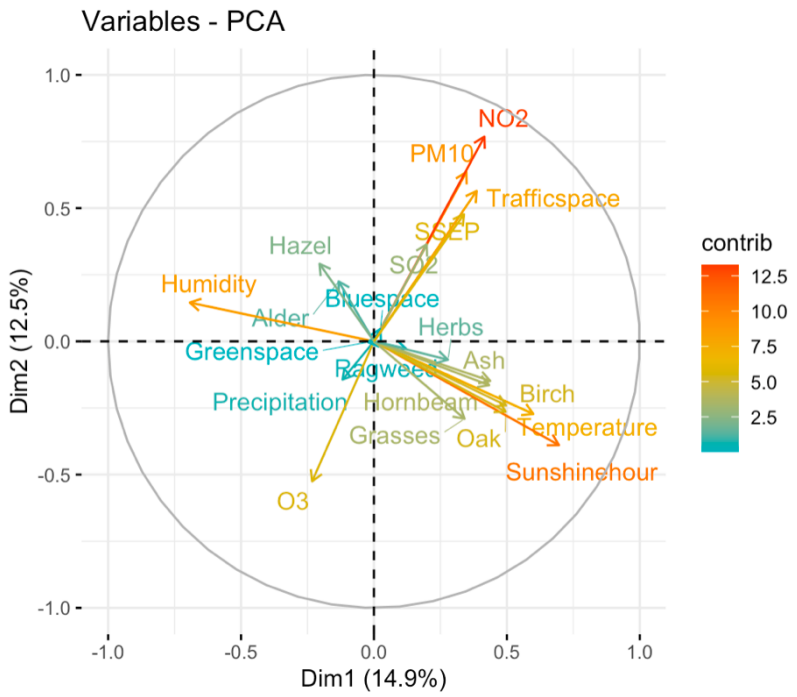


Figure 8: PCA with all variables to see which are relevant for omitting in the multiple regression analysis.

Figure 8 shows all environmental variables in a two-dimensional space. The variables that are close to each other have similar data patterns. For example, one can see that the SSEP and the traffic areas are very similar. Then, if one looks at Figure 9, one can see that no variable is close to each other, so they are independent.

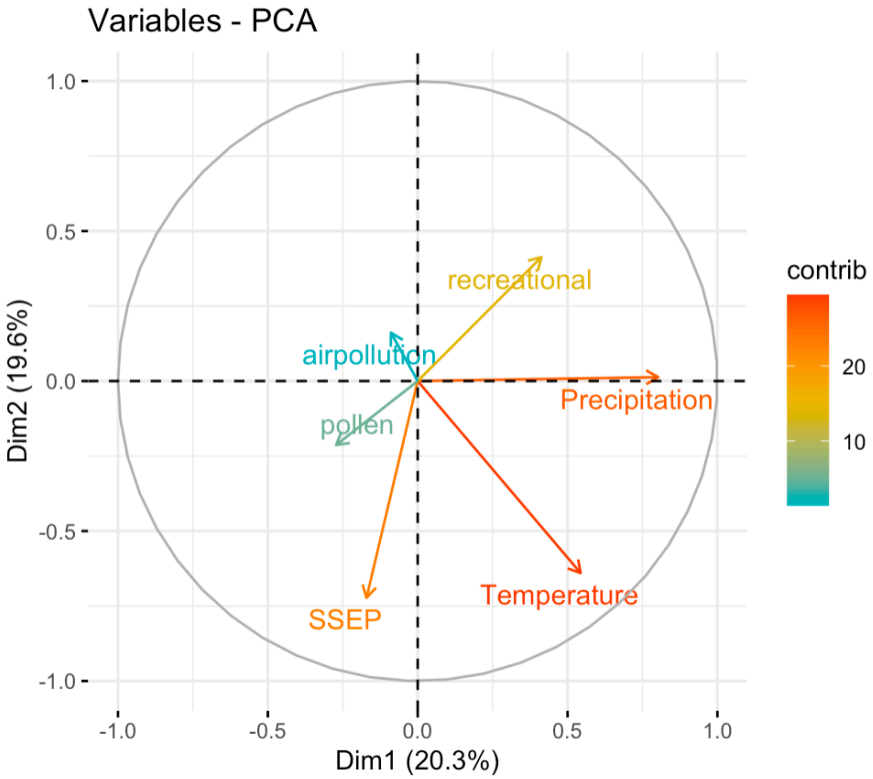


Figure 9: PCA second version to control that the chosen variables for the multiple linear regression are not similar with each other.

3.2.12. Predict

To see how suicide rates change with climate change, a scenario is developed using the function *predict()* of the package EnvStats.

The following code is given:

predict(model, newdata=new)

By model is meant the defined multiple regression and by newdata, the new data that are suspected how temperature and air pollution might change in the future. Precipitation has remained more or less the same in Switzerland, while temperature has increased. Also, the ozone values have an increasing tendency.

For temperature, the trend between 2010 and 2019 was compared. The temperature has risen significantly in recent years and if this trend continues, temperatures will be 2.5° C higher in 2050. Therefore, the average of these temperature data for the last 10 years was taken for every region and added with 2.5° C.

An increase was also observed for ozone between the years 2010 and 2019. Therefore, it is assumed that the concentration of the two air pollenants ozone and sulfur dioxide will be 30µg higher in 2050. Here, too, the mean value of the last 10 years of the airpollution for every region was added with 30µg.

3.2.13. Local Moran's I, Global Moran's I and LISA Cluster

To see what the suicide rates look like when the environmental factors are adjusted, Global Moran's I and Local Moran's I is used (research question 3). A LISA Cluster map is also created. LISA is useful to indentify hot spots and other spatial phenomena. The Cluster Map of observed suicide rate and the residuals of the multiple linear regression are compared with each other. The appendix lists the calculation and code for the Local and Global Moran's I and the LISA clusters.

4. Results

4.1. Spatial and temporal distribution of suicide rates in Switzerland (2000-2019)

4.1.1. Temporal Pattern

In Switzerland, there were 23,383 registered suicide cases from 2000 to 2019. This corresponds to an average of about 1,169 suicides per year during this period (20 years). The suicide rates have been declining since 2000. In 2002, the most suicides were committed, followed by 2000 and 2007. 2018 was the year with the lowest number of suicides, followed by 2010 and 2016. The greatest decrease in suicides occurred between 2008 and 2009. Since 2009 there has been a downward trend in suicides in Switzerland. From Figure 10, one can see that the number of suicides per year has decreased since 2000. A look between the three periods before, during and after the financial crisis, the mean of the absolute number of suicides was highest before the financial crisis and lowest after the financial crisis. The gap between before the finance crisis and during the finance crisis is high, but during the finance crisis and after the finance crisis, there is a large difference. The mean value for committed suicide before the finance crisis was 1,332, while during the finance crisis it was 1,258 and after the finance crisis it was 1,039.

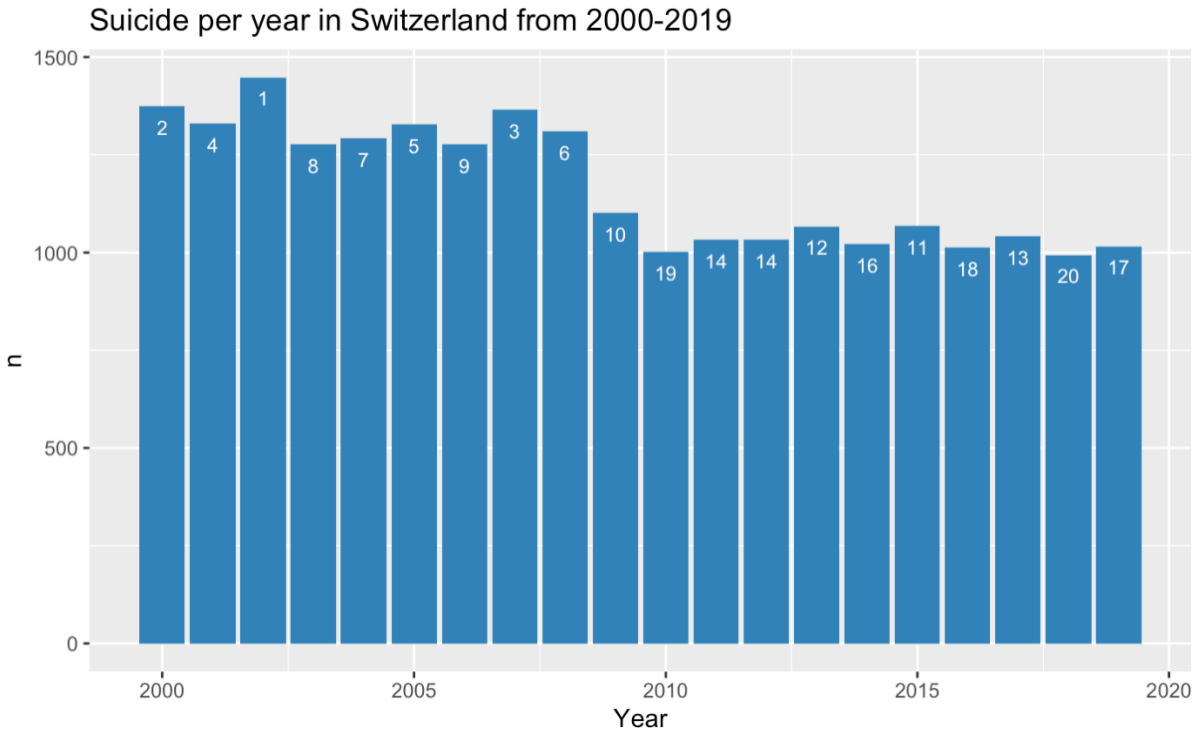


Figure 10: Suicide per year in Switzerland. There is a downward trend in the total numbers of suicide. Generally, before 2009 the total numbers of suicide were relatively high and since 2010 the numbers of committed suicide are more or less at the same level and definitely lower than before 2009. The numbers at the top of every bar show the rank. 2002 has the rank 1, because in this year most suicides were observed.

There are also differences in suicide patterns during a year. The month of January has the highest absolute suicide numbers, followed by March and August. The lowest suicide numbers are in February, September and December (Figure 11). There is also a seasonality in the suicide patterns. The suicide rate is lowest in autumn and winter, while it is highest in spring, followed by the summer. From 2000 to 2019, 5,689 suicides were commited in fall, 6,047 were committed in spring, 5,958 in summer and 5,689 in winter. Thus, the warmer seasons have a higher absolute number of suicides (Figure 12). In general, the most suicides were observed in January of 2002, while the fewest suicides were observed in September 2018.

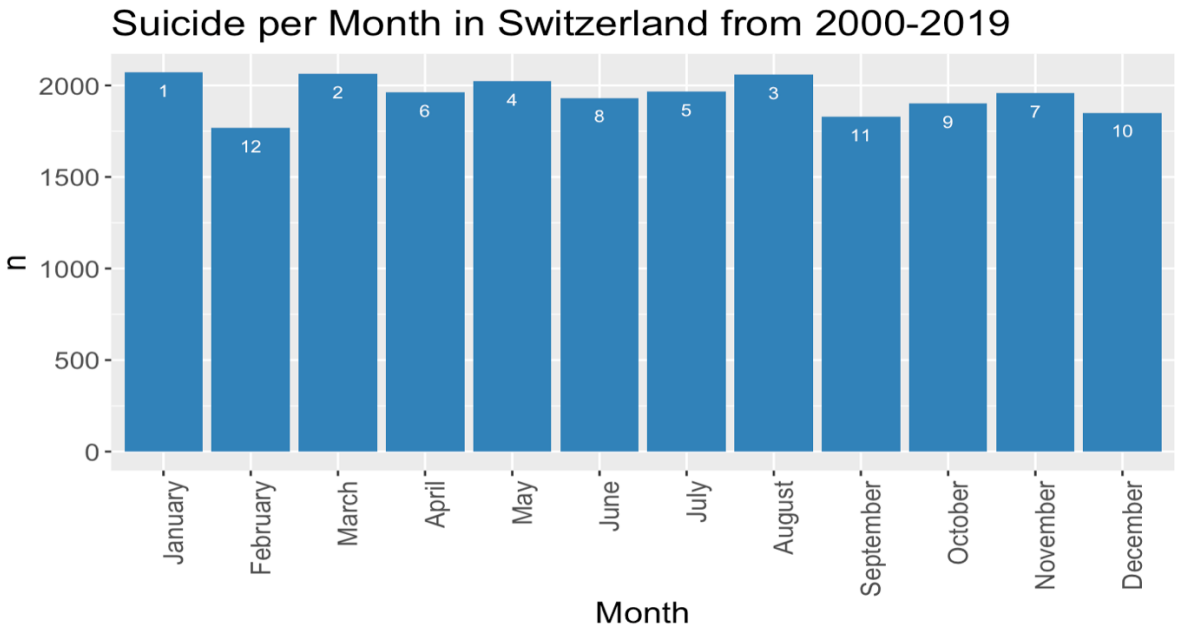


Figure 11: Suicide per month in Switzerland from 2000 to 2019. January has the highest numbers of committed suicide, while February has the lowest suicide numbers. Generally, warmer seasons have higher suicide cases than colder seasons. The number at the top of every bar is the corresponding rank. February is the month with the lowest suicide counts and therefore it has rank 12.

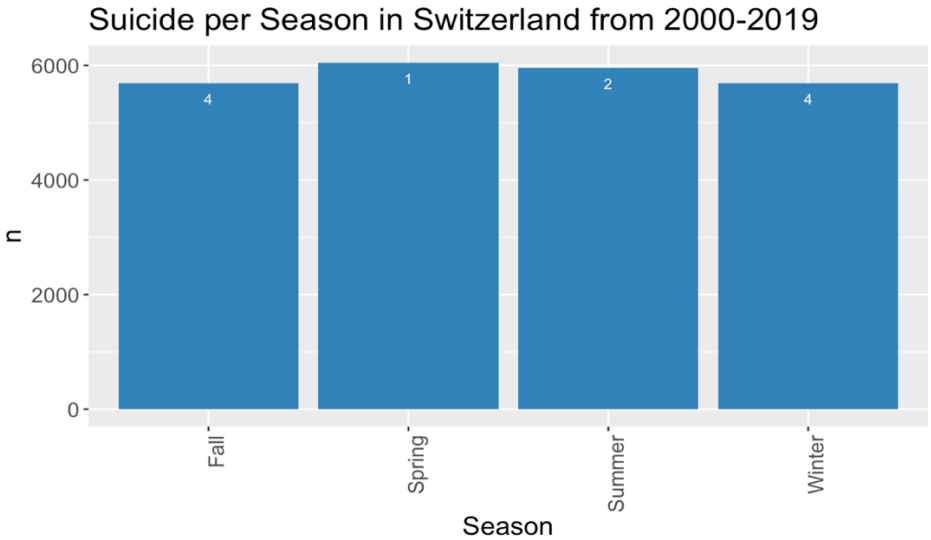


Figure 12: Suicide per Season in Switzerland from 2000 to 2019. Spring has the highest numbers of committed suicide, while Winter and Fall the lowest suicide numbers (the numbers of observed suicide are equal for winter and fall).

4.1.2. Gender patterns

Of these 23,383 people, 70.55% were male and 29.45% female. This means that of the 23,383 people who committed suicide between 2000 and 2019, 16,496 were male and 6,887 were female. Thus, more than twice as many men than women committed suicide. Looking at gender and season, men commit suicide most in spring, followed by summer. The low point for men is in the winter season. Women also commit suicide most often in spring, followed by summer, but the low point for women is in autumn. Suicide rates for women were relatively very high before 2009. From 2008 to 2009, the suicide rate decreased by about 40% and since 2009 it has also been about the same level and relatively lower compared to before 2009. Suicide rates for men were also much higher before 2009 than after 2009. The biggest drop occurred between 2008 and 2009. However, there was only a decrease of about 13% here. Most men commit suicide in the month of August, followed by January and May. For women, on the other hand, it is March, followed by January and April.

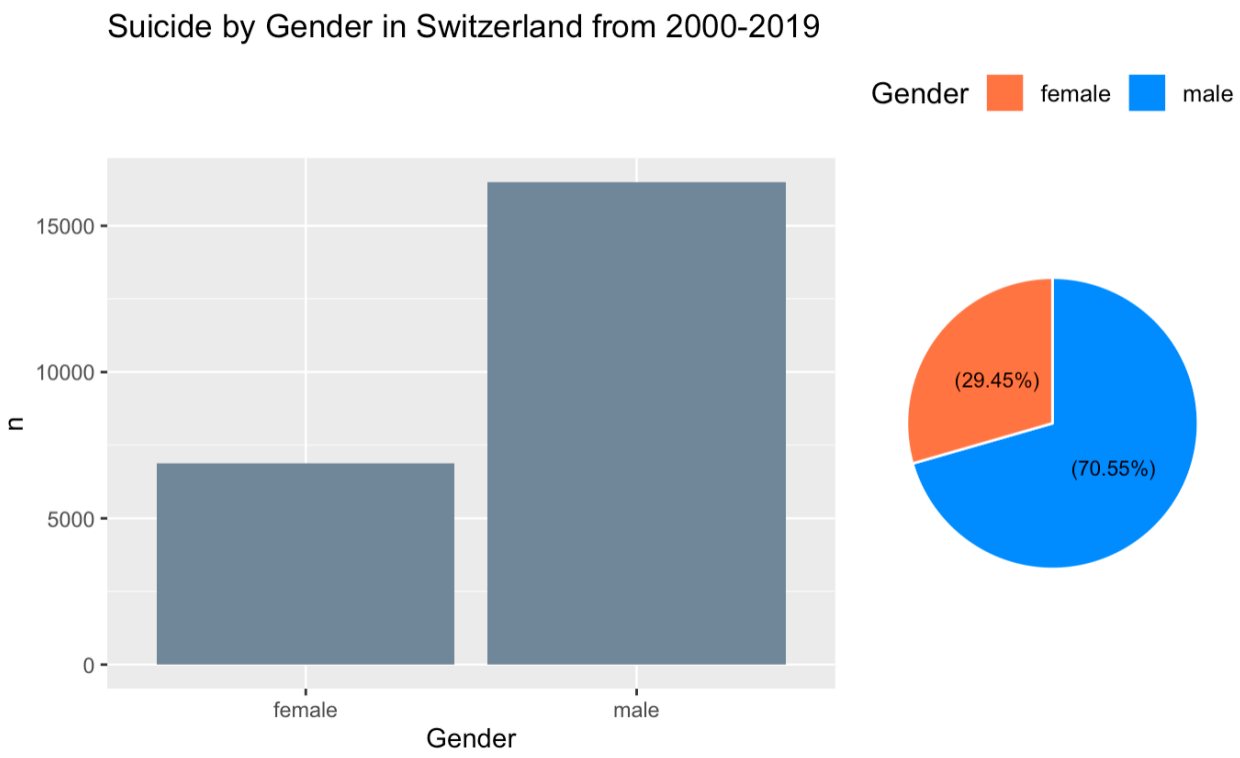
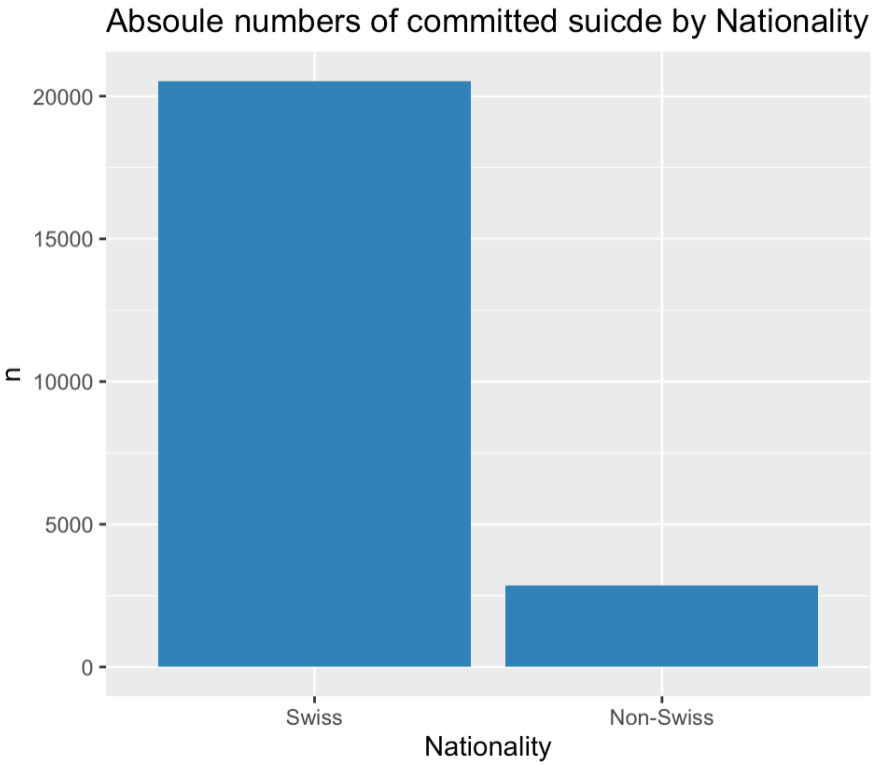


Figure 13: Gender-specific suicide patterns. The left side shows a histogram with the number of committed suicides by gender and the right side shows the gender composition of completed suicide.

4.1.3. Nationality pattern

In addition, 87.8% of the suicide victims (2000-2019) were Swiss nationals and 12.2% were non-Swiss nationals (in absolute numbers and not in relation to the proportion in the overall population). 20,530 people who commit suicide were Swiss and 2,853 were non-Swiss. In relative terms, non-

Swiss people have a higher risk of suicide than the Swiss. The suicide rate for non-Swiss is 0.0134 and for Swiss 0.00382. Thus, the suicide risk for foreigners is 3.5 times higher. The Swiss take their own lives most in spring, followed by summer, while non-Swiss take their own lives most in summer, followed by spring and winter. Looking at it over the 20-year period, the trend was downward for Swiss, while there was no trend for non-Swiss. Suicide rates for foreigners fluctuated widely. Swiss suicides were highest in January, March and August, while non-Swiss suicides were highest in July, May and August. Among Swiss males, there was a decrease in suicide rates for all age groups, and there was also a decrease in civil status for all types, except for divorced, where no trend was seen. The same was also observed for Swiss women. Among non-Swiss females, there was also a decrease in all age groups and also in marital status, except for divorced, where no trend was seen. The same trend for marital status and age was observed for male non-Swiss.



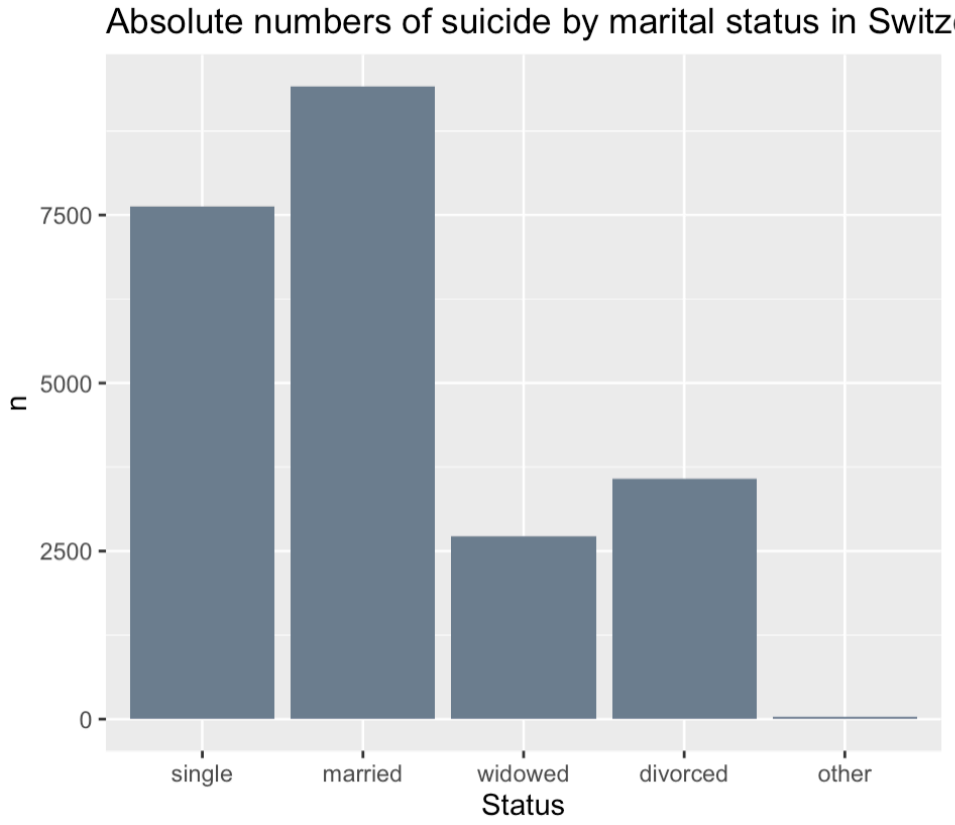
Nationality	relative suicide rate
Swiss	0.00382
Non-Swiss	0.01340

Figure 14: Committed Suicide by Nationality. The suicide rate for Non-Swiss people is higher. Swiss people committed suicide 3.5 times less than foreigners in relative term. The suicide rate is defined as the number of committed suicide per population. It is the mean suicide rate per region for Swiss and non-Swiss.

4.1.4. Marital status pattern

Of all the suicide victims (23,383) between the years 2000 and 2019, 32.64% (7,633) were single, 40.27% (9,416) were married, 11.65% (2,724) were widowed, 15.27% (3,571) were divorced and 0.17% (39) belonged to another group. Thus, married persons commit suicide the most, followed by unmarried persons. Significantly fewer suicides are committed by widowed and divorced persons in

absolute numbers. People with the marital status single and married take their own lives most in spring. For widowed persons, autumn is the season with the highest suicidality. Divorced persons commit suicide most in summer. Among singles, married and widowed, suicide rates declined from 2000 to 2019 (for both genders), while no trend was observed among divorced. The highest suicide rates for married, widowed, and singles was observed in 2002, while for divorced was observed in 2004. According to the FSO, 3,961,500 people in Switzerland are single, 3,580,100 are married, 403,600 are widowed and 767,300 are divorced. Thus, the risk of suicide is 0.1926% for single people, 0.263% for married people, 0.4653% for divorced people and 0.6749% for widowed people. Thus, compared to the population, widowed people commit more suicides, followed by divorced people.



Status	% relative suicide rate
single	0.1926
married	0.2630
divorced	0.4653
widowed	0.6749

Figure 15: Suicide by marital status. Widowed people committed suicide the most in relative terms. In absolute terms married people comitted suicide the most.

4.1.5. Age pattern

In terms of the age, of the 23,383 persons who committed suicide from the period 2000 to 2019, 1717 persons belonged to the age group 15-24 years, 2316 belonged to 25-34 years, 3278 belonged to 35-44 years, 4451 belonged to 45-54 years, 4117 belonged to 55-64 years, 3092 belonged to 65-74 years, 2881 belonged to 75-84 years and 1531 belonged to 85-99 years. People in the 45-54 age group commit suicide the most, followed by those aged 55-64 and those aged 35-44. Suicide nevertheless

affects all age groups. Looking at age and season, 15-24 years old take their own lives the most in autumn, while 25-34, 35-44, 45-54 and 55-64 years old commit suicide the most in spring. Among 65-74 years old, summer has the highest suicide rate. For 74-84 years old, the season summer has the highest suicidality and for the over 85 years old it is autumn. Look at suicide numbers over time, there is a downward trend in suicide numbers for all age groups and for both genders. The 45-54,55-64,65-74 years old commit suicide most in the month of March, while the 35-44 years old take their own lives most in January, the 75-84, 85-99 and 15-24 years old commit suicide most in the month of November, the 25-34 years old commit suicide most in the month of May. According to the FSO, 1,741,100 people in Switzerland are between 0 and 19 years old, 2,282,200 are between 20 and 39 years old, 3,051,700 are between 40 and 64 years old, 1,189,400 are between 65 and 79 years old and 472,100 belong to the 80 years and older. Thus, those over 65 have a suicide risk of 0.4516%. For those over 40 it is 0.3881%. 0.1014% for the over 20 years olds and 0.0986% for the under 20 years olds. Thus, older age increases the risk of suicide.

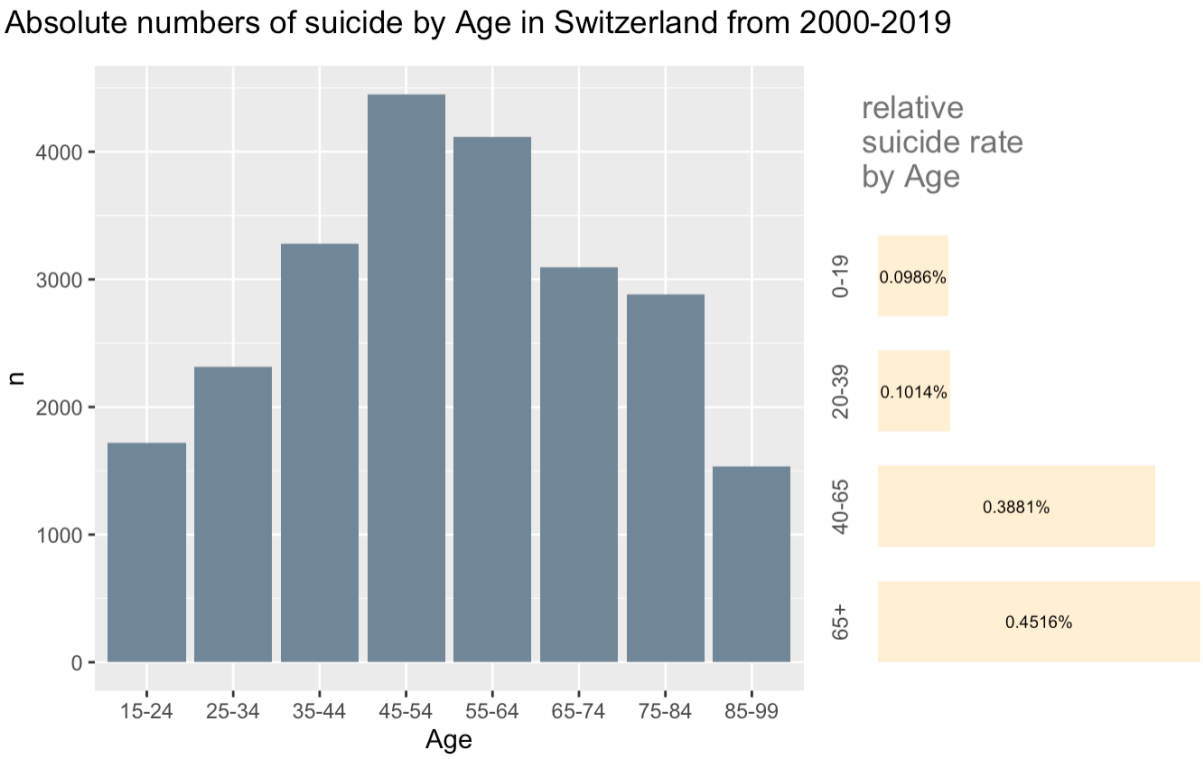


Figure 16: Suicide by Age. The higher the age, the greater the risk of suicide.

4.1.6. Spatial pattern

The results also show that the mean suicide rates of rural regions are higher than those of urban regions (rural: 0.0029; urban: 0.0028). German-speaking Switzerland has the highest suicide rate with a value of 0.0029, followed by French-speaking Switzerland, while Italian-speaking Switzerland has

the lowest value with 0.0019. Rhaeto-Romanic Switzerland has the second lowest suicide rate. The region with the highest suicide rate is Pays d'Enhaut, which is rural and located in the French part of Switzerland. Schanfigg has the second highest suicide rate and Appenzell Ausserhoden the third highest, and both are also rural regions. Bellinzona is the region with the lowest suicide rate and is urban. Mendrisio has the second lowest suicide rate but is rural. However, both regions are in the Italian-speaking part of Switzerland. Upper Engadine has the third lowest suicide rate and is an urban area. In general, northeastern Switzerland, central western Switzerland, some parts of Grisons and the Bern area have higher suicide rates than other parts of Switzerland (see Figure 29). If one still considers the socioeconomic position, one sees that the places that have a high suicide rate also have a low socioeconomic position. The only region in the top ten with the highest suicide rates and a high socioeconomic position is Zurich (Figure 30).

4.1.7. Weather variables patterns

Basically, except for ozone, air pollutants of NO_2, SO_2 and PM_{10} have decreased since 2000. As a result, air pollutants NO_2, SO_2 and PM_{10} have fallen over time, as have suicide rates.

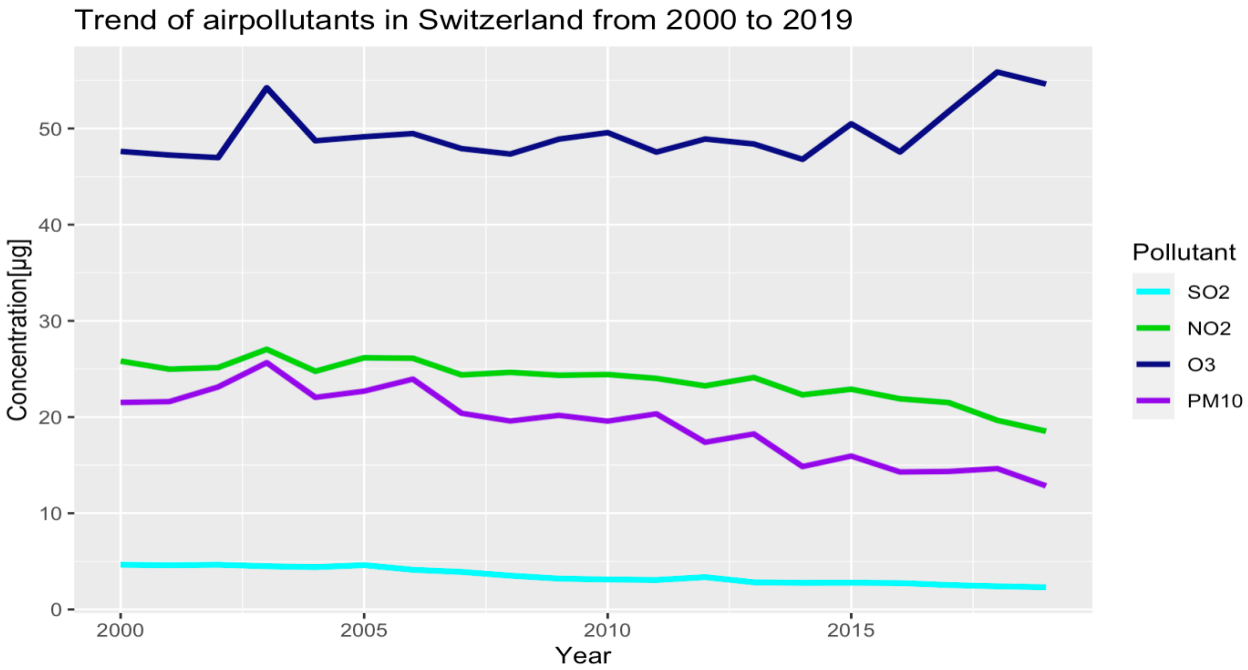


Figure 17: Trend of air pollutants in Switzerland. O_3 has the highest concentration and is the only weather variables that decreased since 2000.

When it comes to weather variables, one sees differences over the months and over time. Most precipitation falls in the summer months. August is the wettest month while February is the driest. There was also a large fluctuation over the 20-year period. 2002 was the month with the highest precipitation, while 2003 had the lowest precipitation. The temperatures show that they have

increased over time. July is the hottest month, followed by August while January and February are the coldest months. The hours of sunshine were very variable over these 20 years. 2003 was the year with the most hours of sunshine and most of them are in the summer months. The month of July has the most hours of sunshine. Humidity has been more or less the same over the 20 years, being lowest in the summer months and highest in the winter months. Most suicides occur in the warmer seasons, i.e. spring and summer, when precipitation, sunshine hours and temperatures are highest and humidity is lower.

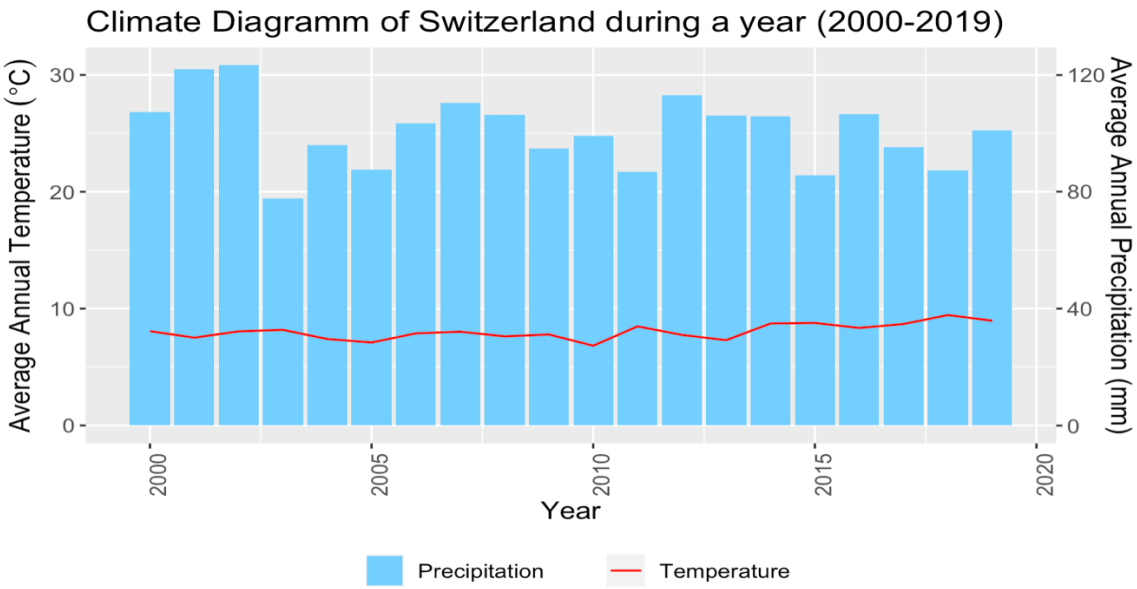


Figure 18: Average annual climate diagram from 2000-2019. The temperature increased over the 20-years period. Precipitation fluctuated widely over the 20-years period.

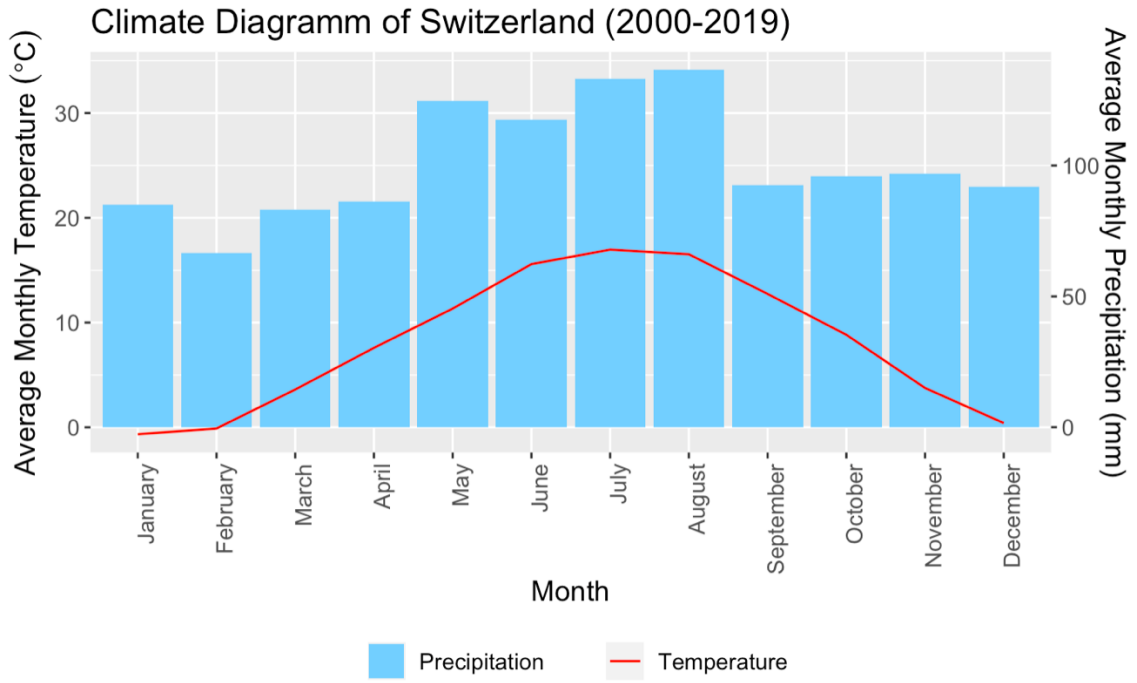


Figure 19: Climate diagramm from 2000-2019. The summer months have the highest temperatures and precipitations. January is the month with the lowest temperature and February is the month with the lowest precipitation.

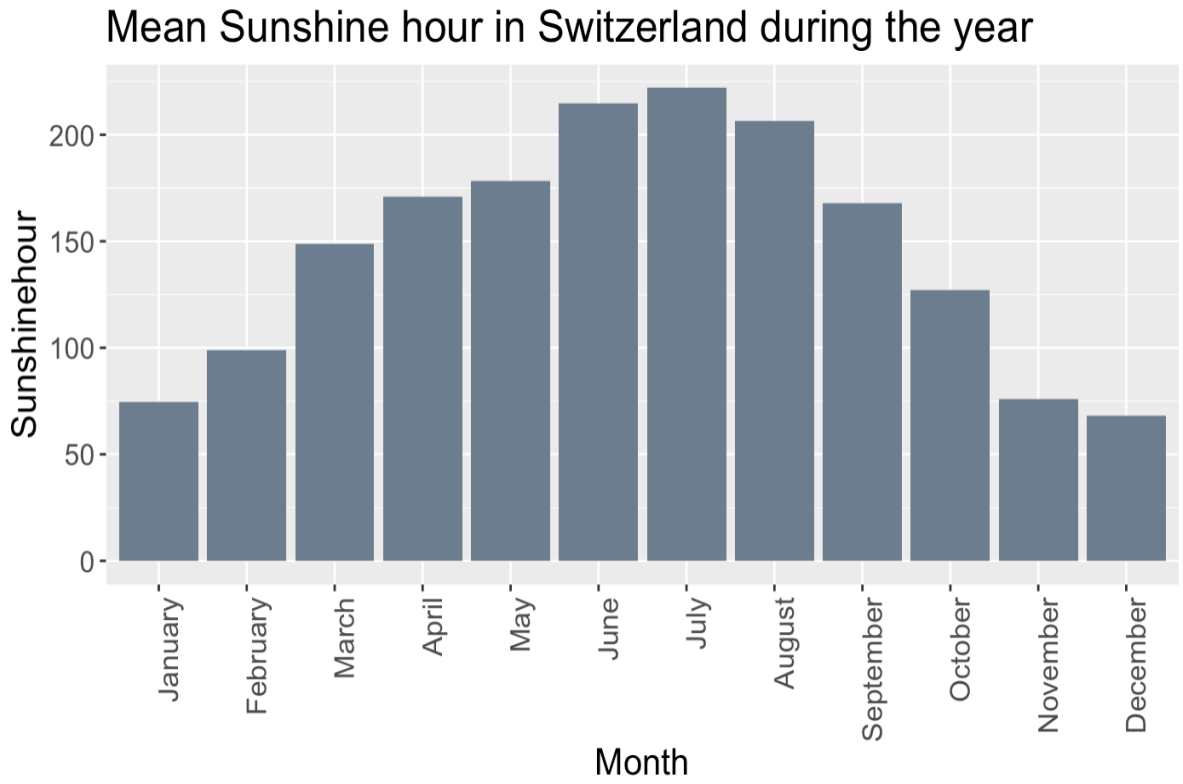


Figure 20: Sunshine hour during the year. The summer months have the highest hours of sunshine.

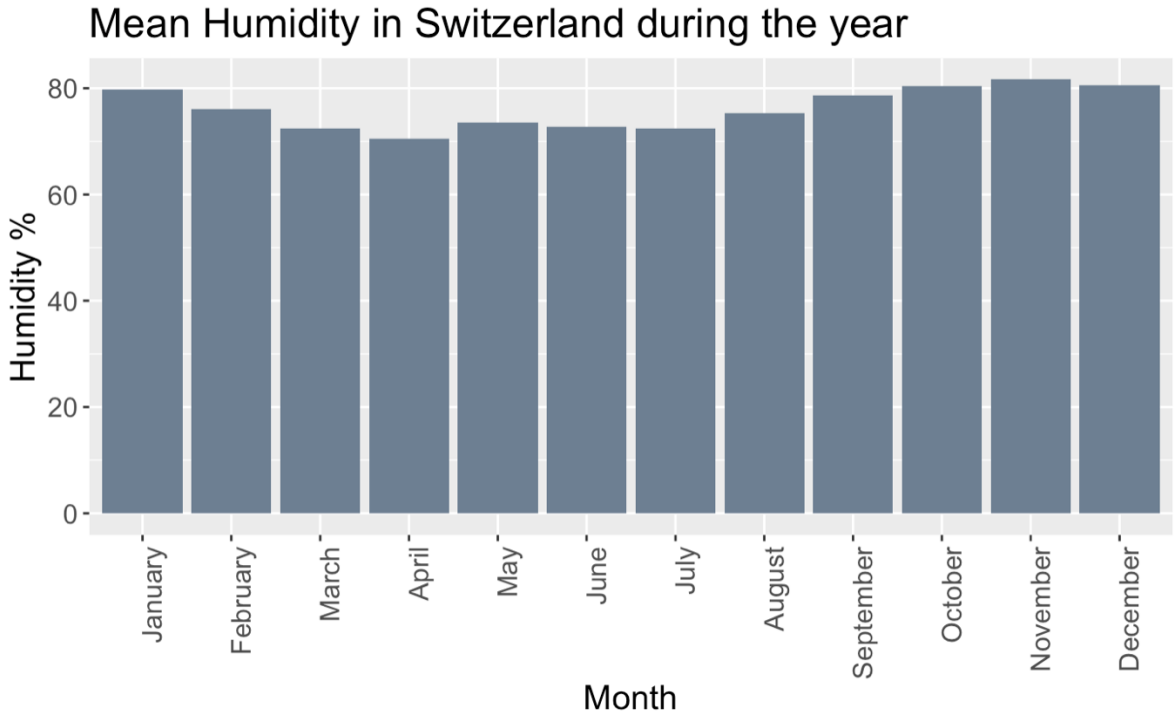


Figure 21: Humidity over year. Humidity is relatively constant but is higher in the winter months.

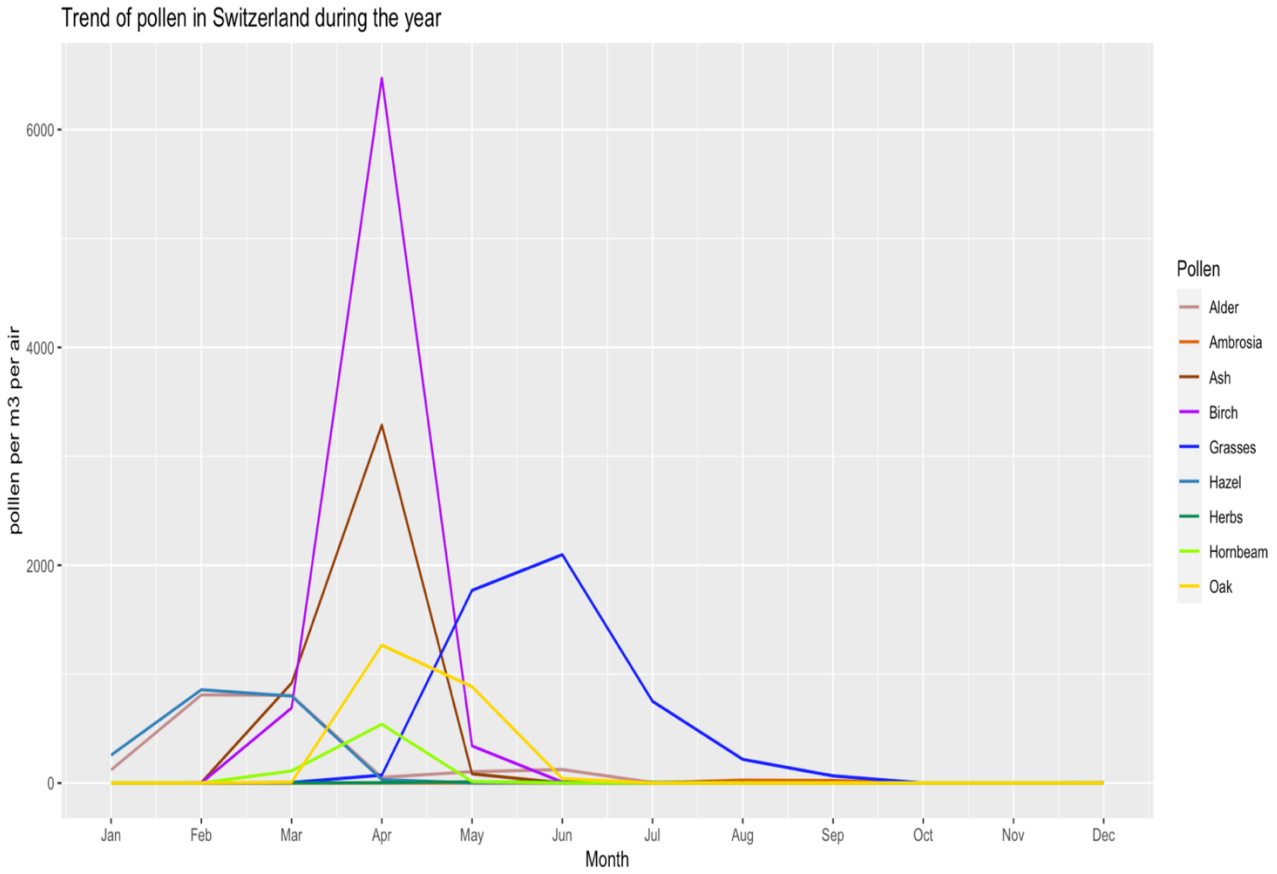


Figure 22: Pollen over the months. Spring and summer are the high pollen season.

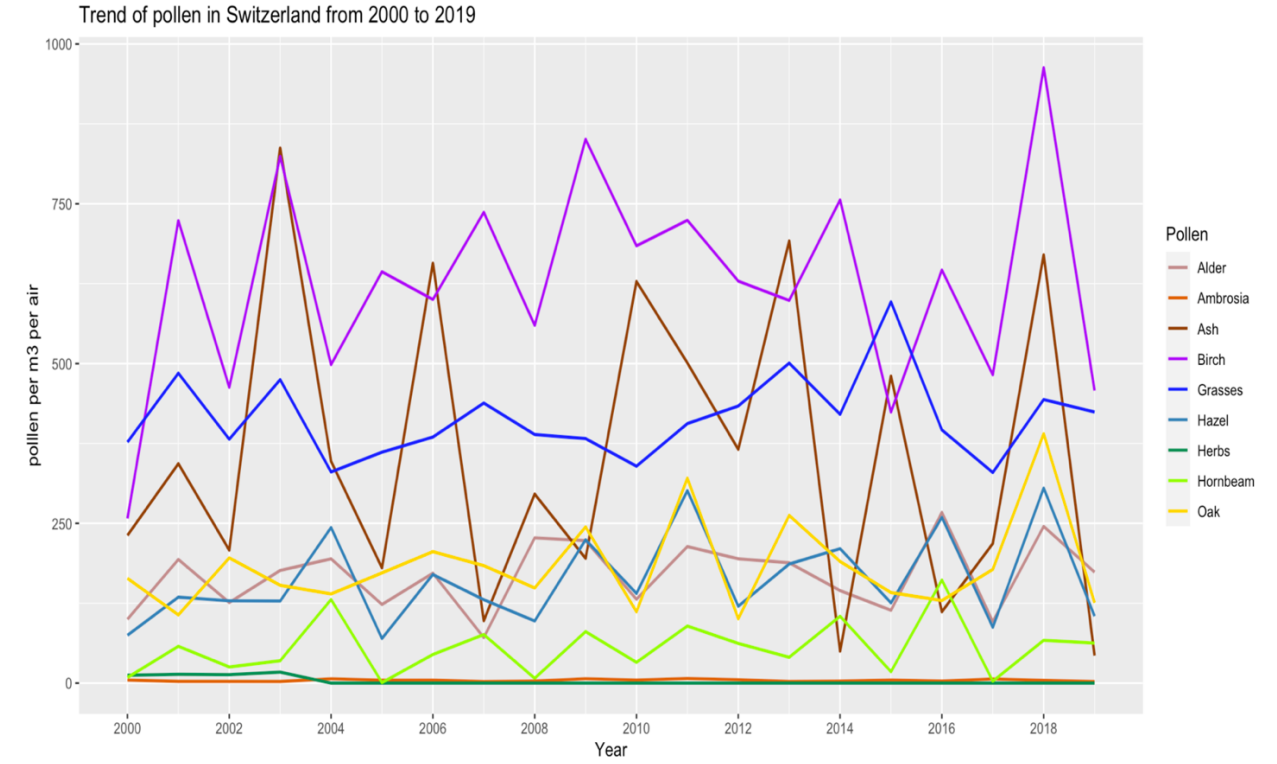


Figure 23: Pollen trend from 2000 to 2019. There are strong fluctuations in most types of pollen.

The suicides also coincide with the time of year when it is high season for most pollen species. Spring is high season for pollen. Most of the pollen have also increased over the years. Spring also has the

highest suicide rates. Blue areas are most prevalent in Rhaeto-Romanic Switzerland, followed by German-speaking Switzerland, but green areas are most prevalent in Italian-speaking Switzerland, where suicide rates are lowest. It appears that green spaces have a protective effect against suicide. Traffic areas are also significantly less in Italian- and Rhaeto-Romanic-speaking Switzerland, where suicide rates are also lower.

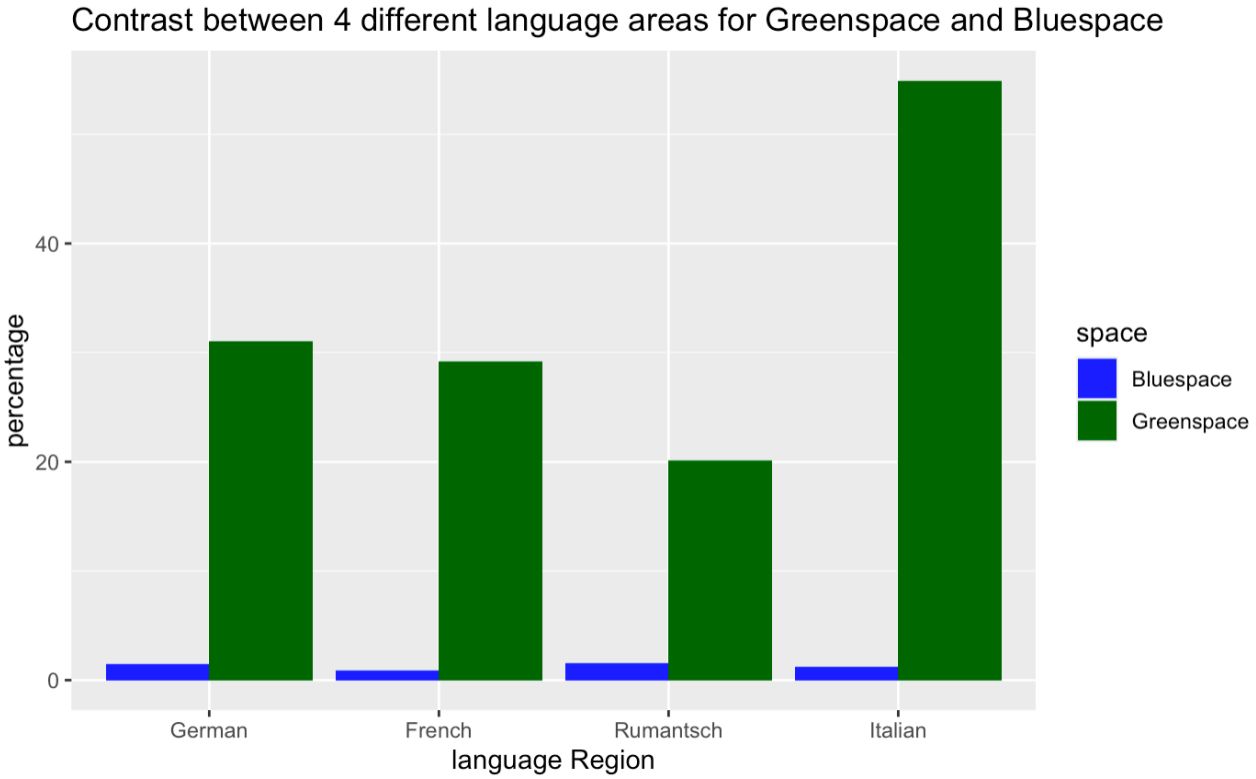


Figure 24: Percentage of blue and green space by language region.

4.1.8. Suicide methods pattern

Hanging, firearms, and poisoning are the most commonly used suicide methods over the years 2000 to 2019. While the trend of firearms and drowning suicide methods has decreased, rail suicide has increased. No trend is apparent for the other suicide methods. The least used methods were rail suicide and drowning. Looking at the suicide methods among the genders, there are big differences in the choice of methods. Men use hanging and firearms as suicide methods the most. These two most common suicide methods have decreased since 2000. The other suicide methods have remained more or less the same among men. Among women, drowning, poisoning, and falling are the most common methods of suicide. Among women, there has been a decrease in most suicide methods since 2000.

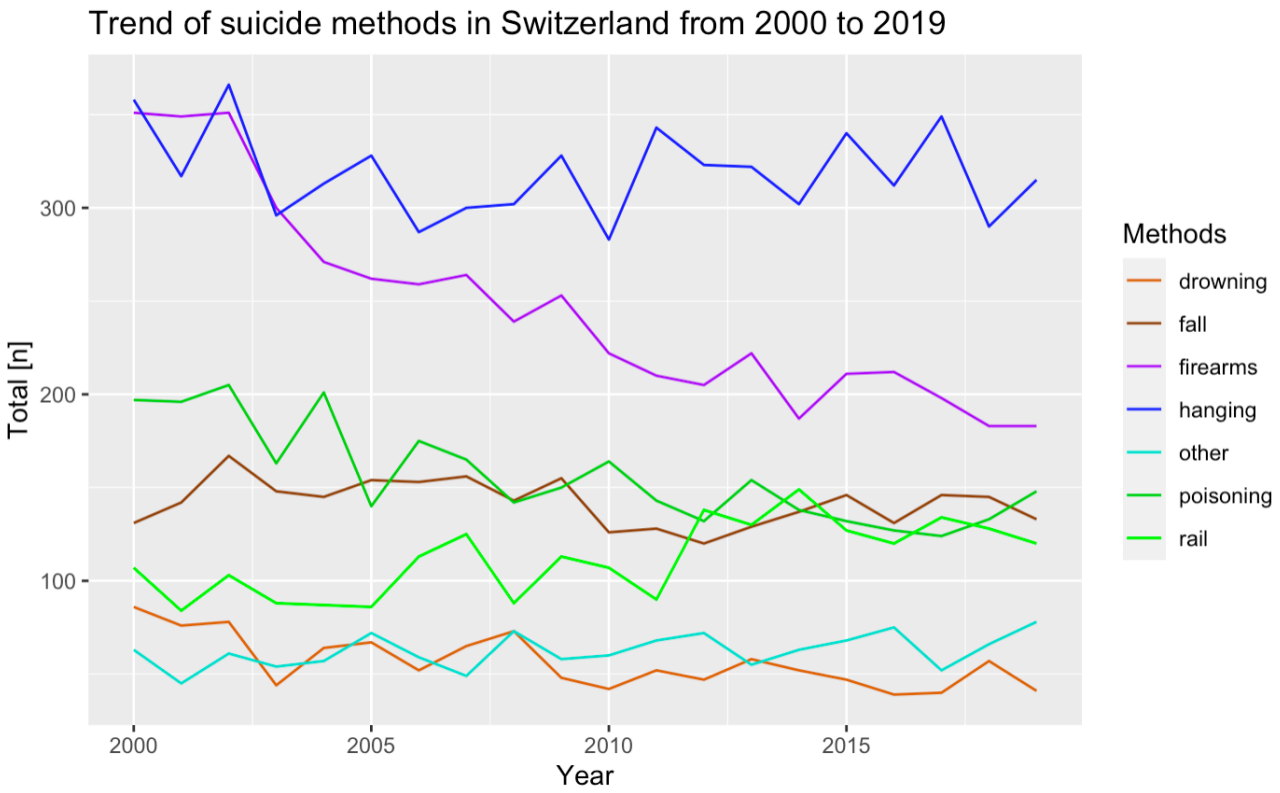


Figure 25: Suicide methods in overall population.

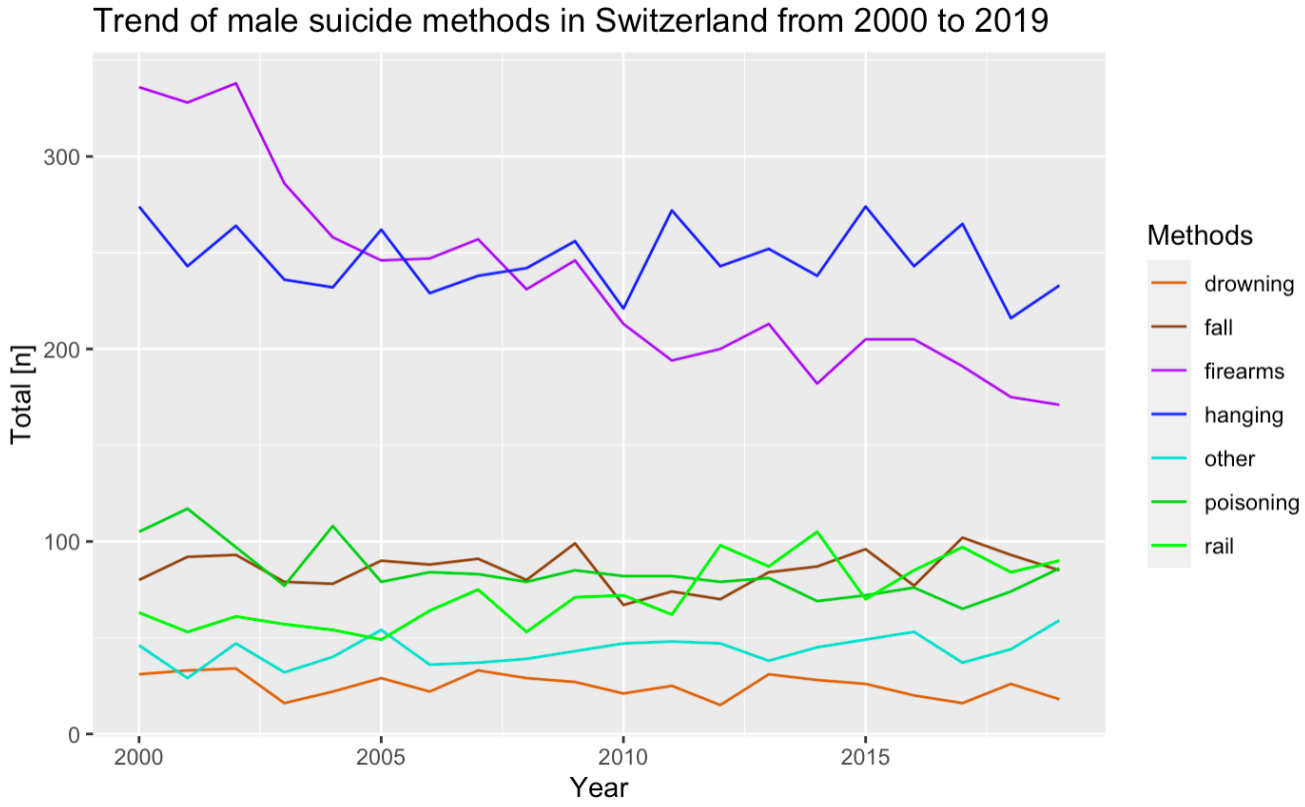


Figure 26: Suicide methods in male population.

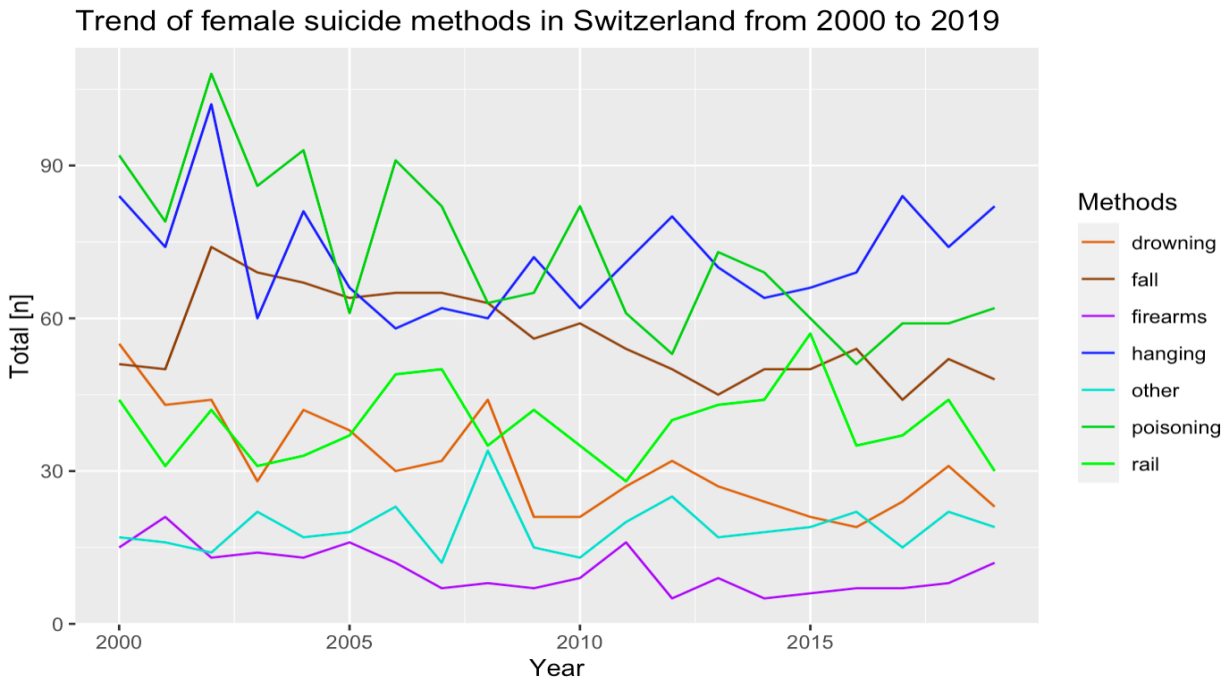


Figure 27: Suicide methods in female population.

4.1.9. Time-Series Plot and overall pattern

Overall, one can say that suicide rates have decreased over time since 2000. Most suicides happened in the months of January, March and August and in the seasons of summer and spring. From the Figure 28 it can be seen that the trend of suicidality is decreasing and that there are large fluctuations over the year. Most suicides seem to occur when the temperature, hours of sunshine and precipitation seem to be at their highest. There are also regional differences. Rural areas have a higher risk of suicide than urban areas. Also, Italian-speaking Switzerland has the lowest suicide rates and also has the highest proportion of green spaces. Air pollution has decreased in Switzerland since 2000, with the exception of the pollutant ozone. Certain groups are at higher risk for suicide. Figure 13, for example, shows that most suicide victims are male. Divorced and widowed persons also have a higher suicide risk. Suicide risk also increases with age. Foreigners also have a higher risk of suicide compared to Swiss. Among suicide methods, 4 methods showed a downward trend, while 2 were more or less constant over this 20-year period. The only method that increased over this 20-year period was rail suicide.

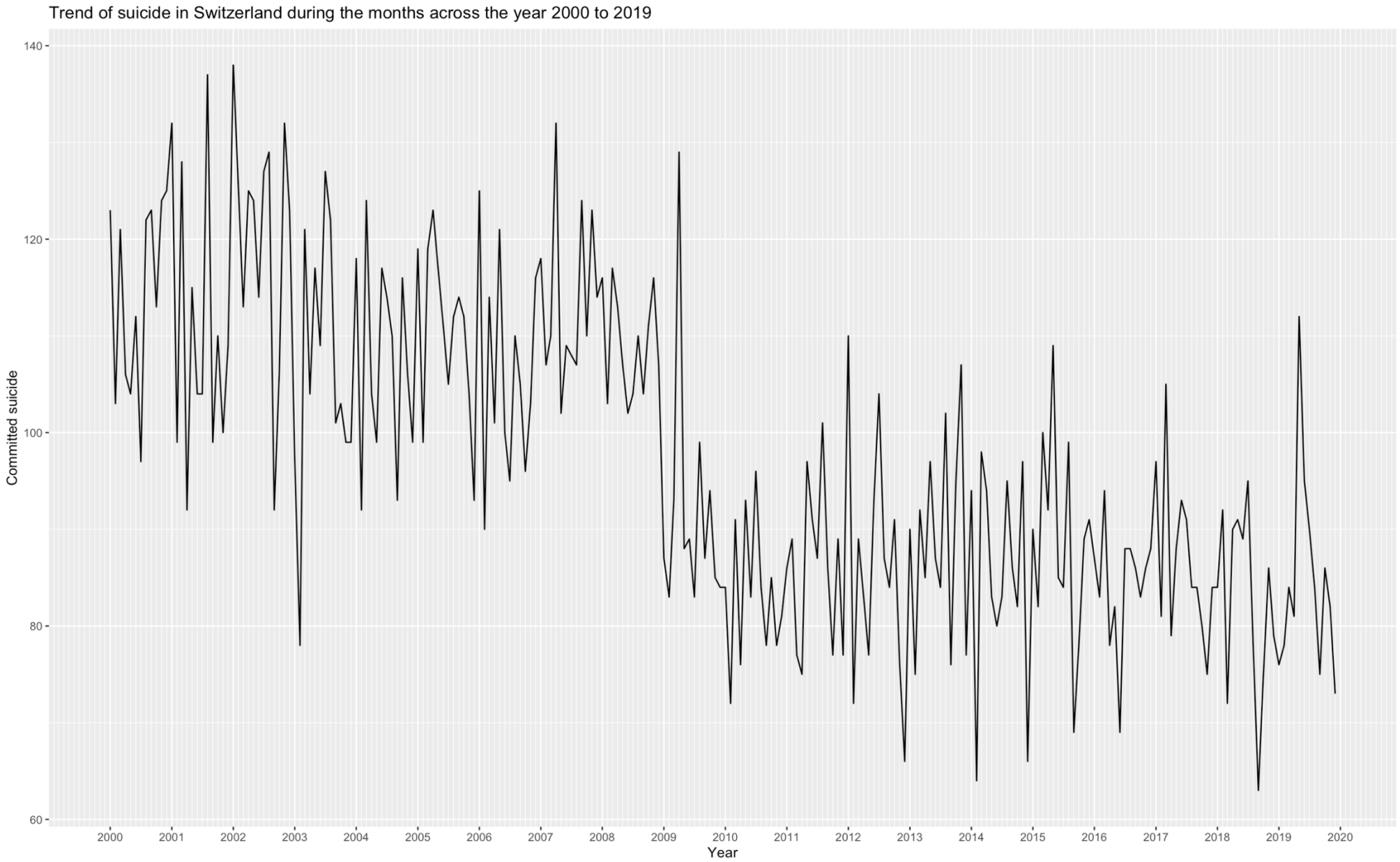


Figure 28: Time series of suicide. This plot shows the monthly trend of committed suicide.

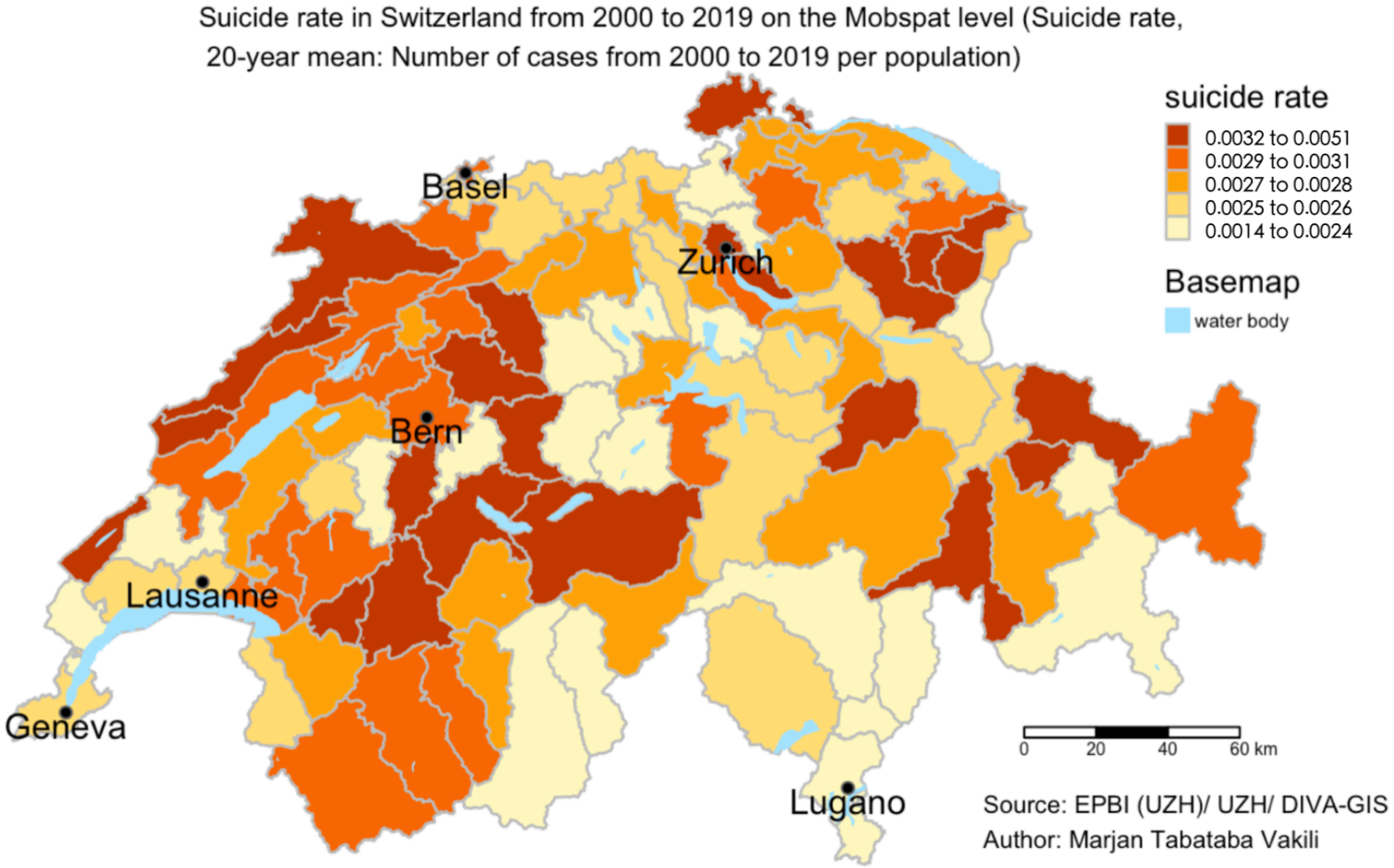


Figure 29: Suicide rate in Switzerland on the level of MS-Regions. It shows six cities in Switzerland and the suicide rate of all 106 Regions. The Italian-speaking part of Switzerland has the lowest suicide rates, while the highest are found in the German-speaking part of Switzerland.

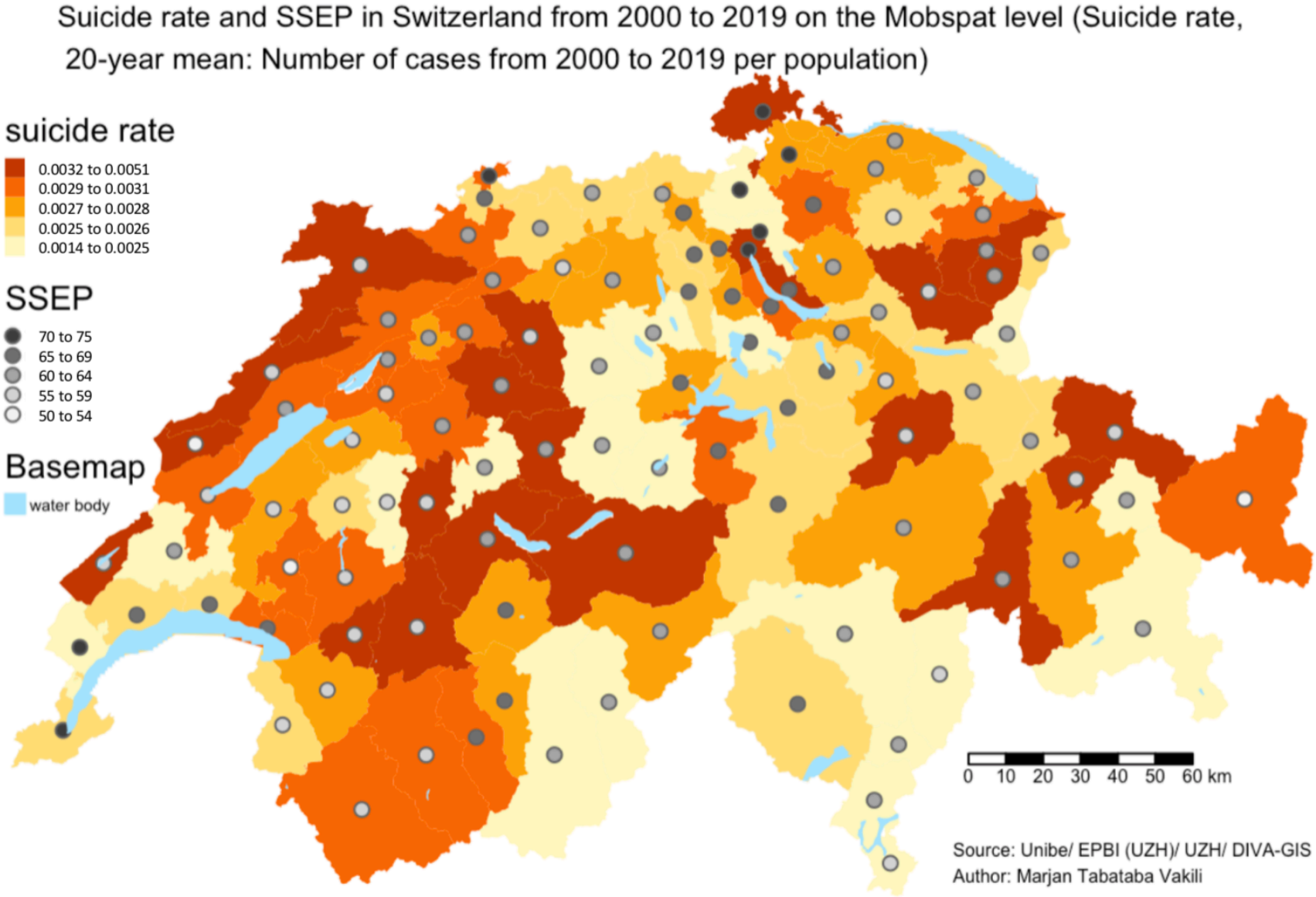


Figure 30: Map of Switzerland with the variables socioeconomic position and suicide rate. Dot represents the SSEP and it shows that lighter SSEP points mostly have higher suicide rate.

4.2. Relationship between environmental factors and suicide in Switzerland

4.2.1. Univariate linear regression

4.2.1.1. Significance code

A significance code is used for the tables. Three asterisks mean that the p-value is between 0 and 0.001. Two asterisks mean the p-value is between 0.001 and 0.01. An asterisk means the p-value is between 0.01 and 0.05. Anything with an asterisk also means that the variables are significant. A dot means the p-value is between 0.05 and 0.1 and is not significant. And no symbol means the p-value is between 0.1 and 1.

```
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Figure 31:Significance codes for the table of parametres.

4.2.1.2. Weather variables

4.2.1.2.1. Precipitation

Monthly suicide rates range from 0.000002042 to 0.000568. If one looks at weather variables, one can see that precipitation has a significant relation to the monthly suicide rate. It's not a big contributor, but it contributes 0.38% to the suicide rate. The estimate for precipitation is 0.0000000291, which means that if precipitation increases by one unit, the suicide rate increases by 0.0000000291. The standard error for precipitation is relatively small and the confidence interval is not very large. Therefore, the uncertainty is not large.

The regression equation between the dependent variable suicide rate and the independent variable precipitation is thus:

$$suicide\ rate = 0.00002285 + 0.0000000291 * Precipitation$$

Table 1: Parametres of Precipitation.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002285	0.0000002719	0.00002232	0.000023385
Precipitation	***	0.00000002291	0.00000000242	0.0000000182	0.00000002766

4.2.1.2.2. Temperature

The variable temperature also has a significant contribution to the suicide rate. R^2 here is 0.01017 and thus has a larger contribution than precipitation because it contributes 1.017% to the suicide rate. The suicide rate decreases by 0.0000003098 when the temperature increases by one unit. The standard error for temperature is relatively small and the confidence interval is not very large. Therefore, the uncertainty is rather small.

The regression equation between suicide rate and temperature is:

$$suicide\ rate = 0.00002792 - 0.0000003098 * Temperature$$

Table 2: Parametres of Temperature.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002792	0.0000002321	0.000027465	0.000028375
Temperature	***	-0.0000003098	0.00000001999	-0.000000349	-0.00000027

In Italian-speaking Switzerland, temperature seems to increase the risk of suicide. Temperature contributes 0.724% to the suicide rate. Temperature increases the risk of suicide by 0.0000002503 for every one unit increase in temperature.

If one looks at the influence of temperature on the seasons separately, one sees that even in the hotter months, the higher the temperature, the lower the suicide rate. In spring, the temperature has a significant contribution of 3.56% on the suicide rate. When the temperature increases by one unit, the suicide rate decreases by 0.0000009030 in spring. Also in summer, temperature has a significant contribution of 8.53%. If the temperature increases by one unit in summer, then the suicide rate decreases by 0.000002093.

4.2.1.2.3. Sunshine Hour

The variable duration of sunshine has no significant contribution to the suicide rate. For sunshine duration the standard error is very large. Also, the confidence interval is very large and therefore the uncertainty is large.

Table 3: Parametres of Sunshine hours.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002539	0.000000319	0.00002476	0.0000260133
Sunshine hours		-0.0000000023	0.000000002	-0.000000006	0.0000000015

In urban areas, sunshine duration has a relation of 0.042% to the suicide rate. If the sunshine duration increases by one unit, then the suicide rate decreases by 0.000000003126.

4.2.1.2.4. Humiditiy

The weather variable humidity has a significant contribution to the suicide rate, but it is very small at 0.1304%. If humidity increases by one unit, then the suicide rate also increases by 0.00000009732. Humidity has a large standard error and also a large confidence interval, therefore the uncertainty is large.

The regression equation for the relationship between humidity and suicide rate is:

$$suicide\ rate = 0.00001768 + 0.00000009732 * Humidity$$

Table 4: Parametres of Humidity.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00001768	0.000001342	0.00001505	0.0000203135
Humidity	***	0.0000000973	0.00000001762	0.0000000628	0.00000013186

In rural areas, however, it seems that the humidity has a protective effect. Humidity has a relatively significant contribution of 0.9% and the suicide rate decreases by 0.0000003968 when humidity increases by one unit.

4.2.1.3. Air pollution

4.2.1.3.1. Ozone

Looking at air pollution variables, all have a significant contribution to the suicide rate. Ozone is the only air pollutant that has increased over time. Ozone has a significant contribution of 0.1332% and the suicide rate increases by 0.0000002453 when ozone increases by one unit. Ozone has a rather small standard error. The confidence interval is also relatively small and thus the uncertainty is also rather small.

The regression equation for the air pollutant ozone is:

$$suicide\ rate = 0.00001345 + 0.0000002453 * O3$$

Table 5: Parametres of O3.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00001345	0.0000006682	0.00001214	0.00001476
O3	***	0.000000245	0.0000000138	0.000000218	0.000000272

4.2.1.3.2. Particulate matter

The trend of particulate matter (PM_{10}) has been decreasing since 2000. PM_{10} seems to have a protective effect on the suicide rate. PM_{10} has a significant contribution of 0.5%. If the fraction of particulate matter increases by one unit, then the suicide rate decreases by 0.0000002884. For particulate matter, the standard deviation is not large, but the confidence interval is large and therefore the uncertainty is large.

The regression equation for PM_{10} is:

$$suicide\ rate = 0.00003092 - 0.0000002884 * PM10$$

Table 6: Parametres of PM10.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00003092	0.0000005383	0.000029863	0.000031973
PM10	***	-0.00000028	0.0000000256	-0.000000338	-0.000000238

4.2.1.3.3. Nitrogen dioxide

NO_2, like PM_{10}, also appears to have a protective effect on suicide rates. NO_2 has a significant contribution of 2.937%. If NO_2 increases by one unit, then the suicide rate decreases by 0.0000003726. NO_2 has a small standard error and also a small confidence interval, thus the uncertainty is rather small. The regression equation for NO_2 is:

$$suicide\ rate = 0.00003513 - 0.0000003726 * NO2$$

Table 7: Parametres of NO2.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00003513	0.0000004034	0.000034338	0.00003592
NO2	***	-0.000000373	0.000000014	-0.0000004	-0.00000035

4.2.1.3.4. Sulfur dioxide

SO_2 has a negative impact on suicide rates. SO_2 has a significant contribution of 0.7341%. If SO_2 increases by one unit, then the suicide rate increases by 0.0000008202. SO_2 has a large confidence interval and therefore the uncertainty is very large.

The regression equation for SO_2 is:

$$suicide\ rate = 0.00002231 + 0.0000008202 * SO2$$

Table 8: Parametres of SO2.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002231	0.000000252	0.00002182	0.0000228054
SO2	***	0.00000082	0.0000000624	0.000000698	0.0000009425

However, SO_2 seems to have a protective effect in French-speaking Switzerland. SO_2 has a significant contribution of 0.182% and if SO_2 increases by one unit then the suicide rate decreases by 0.0000005267.

4.2.1.3.5. Air pollution (SO2, NO2, PM10, O3)

All four air pollutants variables taken together have a protective effect on the suicide rate. The four variables together have a significant contribution of 0.347% and decrease the suicide rate by 0.0000001011.

The regression equation is:

$$suicide\ rate = 0.00003497 - 0.0000001011 * airpollution$$

Table 9: Parametres of air pollution.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.000035	0.000001108	0.000032797	0.000037139
air pollution	***	-0.000000101	0.0000000112	-0.000000123	-0.000000079

The variables PM_{10} and NO_2 had a protective effect and this was observed before, during and after the financial crisis. Also O_3 and SO_2 had the same effect on suicide rate before, during and after the financial crisis, the two air pollutants increased it. Considering all air pollutants together, they all have a protective effect for all three times (before, during and after the financial crisis).

In rural areas, air pollution appears to increase suicide rates. It has a significant contribution of 0.75% and the suicide rate increases by 0.0000002371 when air pollution increases by one unit. In Italian-speaking Switzerland, air pollution seems to increase the risk of suicide. It has a contribution of 0.59% and increases the suicide rate by 0.0000001014. This is partly due to high intercept (rural).

4.2.1.4. Pollen

Looking at the nine allergy-causing types of pollen, Ragweed has a significant contribution of 0.176% to the suicide rate. If Ragweed increases by one unit, then the suicide rate decreases by 0.00000004741. Alder has a significant contribution of 0.091% and decreases the suicide rate by 0.000000001376. Ash has also a significant contribution of 0.019% and decreases the suicide rate by 0.0000000002045. Birch is the only pollen species that does not have a significant contribution to suicide rates. Grasses also has a small significant of 0.021%, reducing the suicide rate by 0.0000000003414. Hazel has a significant contribution of 0.164% and decreases the suicide rate by 0.000000001789. Hornbeam has a significant contribution of 0.064% and decrease suicide rate by 0.000000001679. Oak has also a significant contribution. It contributes by 0.066% to the suicide rate and decreases it by 0.000000000754. Herbs are the only type of pollen that has a significant contribution, increasing the suicide rate for a unit increase. However, herbs have a small contribution of 0.025% and thus the suicide rate increases by 0.00000002439. Considering all pollen as one variable, they have a significant contribution of 0.049% and reduce the suicide rate by 0.000000000116.

The regression equation for Ragweed is:

$$suicide\ rate = 0.00002528 - 0.00000004741 * Ragweed$$

Table 10: Parametres of Ragweed.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002528	0.0000001452	0.000024995	0.000025564
Ragweed	***	-0.000000047	0.0000000074	-0.000000062	-0.0000000329

The regression equation for Alder is:

$$suicide\ rate = 0.00002528 - 0.000000001376 * Alder$$

Table 11: Parametres of Alder

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002528	0.00000015	0.00002499	0.000025578
Alder	***	-0.0000000014	0.0000000003	-0.000000002	-0.0000000008

The regression equation for Ash is:

$$suicide\ rate = 0.00002514 - 0.0000000002045 * Ash$$

Table 12: Parametres of Ash.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002514	0.00000015	0.00002485	0.00002542
Ash	*	-0.0000000002	0.0000000001	-0.0000000004	-0.00000000001

The regression equation for Grasses is:

$$suicide\ rate = 0.0000252 - 0.0000000003414 * Grasses$$

Table 13: Parametres of Grasses.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.0000252	0.000000156	0.0000249	0.00002551
Grasses	*	-0.0000000003	0.0000000002	-0.0000000006	-0.00000000004

The regression equation for Herbs is:

$$suicide\ rate = 0.00002497 + 0.00000002439 * Herbs$$

Table 14: Parametres of Herbs.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.000025	0.00000015	0.00002468944	0.0000252578
Herbs	*	0.000000024	0.00000001	0.00000000448	0.0000000443

The regression equation for Hazel is:

$$suicide\ rate = 0.00002536 - 0.000000001789 * Hazel$$

Table 15: Parametres of Hazel.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002536	0.000000149	0.00002506	0.00002565
Hazel	***	-0.000000002	0.00000000029	-0.0000000024	-0.000000001

The regression equation for Hornbeam is:

$$suicide\ rate = 0.00002518 - 0.000000001679 * Hornbeam$$

Table 16: Parametres of Hornbeam.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002518	0.000000145	0.0000249	0.00002546
Hornbeam	***	-0.000000001679	0.00000000043	-0.000000003	-0.0000000008

The regression equation for Oak is:

$$suicide\ rate = 0.00002522 - 0.000000000754 * Oak$$

Table 17: Parametres of Oak.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002522	0.00000015	0.0000249	0.00002551
Oak	***	-0.000000000754	0.0000000002	-0.000000001	-0.0000000004

Birch is the only pollen with no significant contribution.

Table 18: Parametres of Birch.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002504	0.00000015	0.0000248	0.0000253
Birch		0.000000000015	0.00000000006	-0.0000000001	0.00000000014

The regression equation for pollen is:

$$suicide\ rate = 0.0000253 - 0.000000000116 * pollen$$

Table 19: Parametres of pollen.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.0000253	0.000000159	0.000025	0.0000256
Pollen	***	-0.000000000116	0.00000000003	-0.0000000002	-0.00000000005

4.2.1.5. Land cover

4.2.1.5.1. Green space

Looking at the different types of areas, green areas seem to increase the suicide rate. Green areas have a significant contribution, contributing to 0.0485%. If the green area increases by one unit, then the suicide rate increases by 0.00000005448.

The regression equation for Greenspace is:

$$suicide\ rate = 0.00002335 + 0.00000005448 * Greenspace$$

Table 20: Parametres of greenspace.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002335	0.000000527	0.0000223	0.00002438
Greenspace	***	0.00000005448	0.0000000163	0.0000000226	0.0000000864

In German-speaking Switzerland, green spaces seem to have a protective effect. They have a significant contribution of 0.6432% and lowers the suicide rate by 0.0000002578. Green spaces also seem to have a protective effect in Italian-speaking Switzerland. Green space has a contribution of 26.77% in Italian-speaking Switzerland, reducing the risk of suicide by 0.000001168 if the proportion of green space increases by one unit. In Rhaeto-romanic Switzerland, green spaces seem to have a large contribution to the risk of suicide (59.03%). If the proportion of green space increases by one unit, then the suicide rate increases 0.00006096.

4.2.1.5.2. Blue space

Blue areas have no significant contribution to the suicide rate. In rural areas, blue areas appear to have a 0.12% contribution to suicide risk. If the proportion of blue areas increases by one unit, then the suicide rate increases by 0.000001584. In the French-speaking part of Switzerland, blue areas seem to have a protective effect too, as blue areas have a significant contribution of 1,632% and the suicide rate decreases when the proportion of blue areas increases by one unit. In the Rumantsch-speaking part of Switzerland, blue areas seem to have a protective effect. Blue areas also have a large contribution to the risk of suicide (59.03%). Blue areas decrease the suicide rate by 0.0001321 if the proportion of blue areas increases by one unit.

Table 21: Parametres of bluespace.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00002509	0.000000205	0.00002469	0.000025491
Bluespace		-0.00000002561	0.000000111	-0.000000243	0.000000192

4.2.1.5.3. Traffic space

Traffic areas appear to have a protective effect. Traffic areas contribute 9.9% to the suicide rate. If the traffic areas increase by one unit, then the suicide rate decreases by 0.000001707.

The regression equation for traffic space is:

$$suicide\ rate = 0.00003506 - 0.000001707 * Trafficspace$$

Table 22: Parametres of trafficspace.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00003506	0.0000002386	0.0000345915	0.000035527
Trafficspace	***	-0.000001707	0.0000000337	-0.000001774	-0.00000164

4.2.1.6. Control variables

4.2.1.6.1. Socioeconomic position

Socioeconomic position has a significant impact of 6.54% on the suicide rate. If the suicide rate increases by one unit, then the suicide rate decreases by 0.000001089.

The regression equation for SSEP is:

$$suicide\ rate = 0.00009539 - 0.000001089 * SSEP$$

Table 23: Parametres of SSEP.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00009539	0.00000175	0.000091972	0.00009881
SSEP	***	-0.000001089	0.0000000264	-0.000001142	-0.00000104

In French-speaking Switzerland, SEP contributes 14.7% to reducing the suicide rate. At 59.03%, the SEP has a major impact on the suicide rate in Rumantsch-speaking Switzerland. If the SEP increases by one unit, then the suicide rate decreases by 0.00001278.

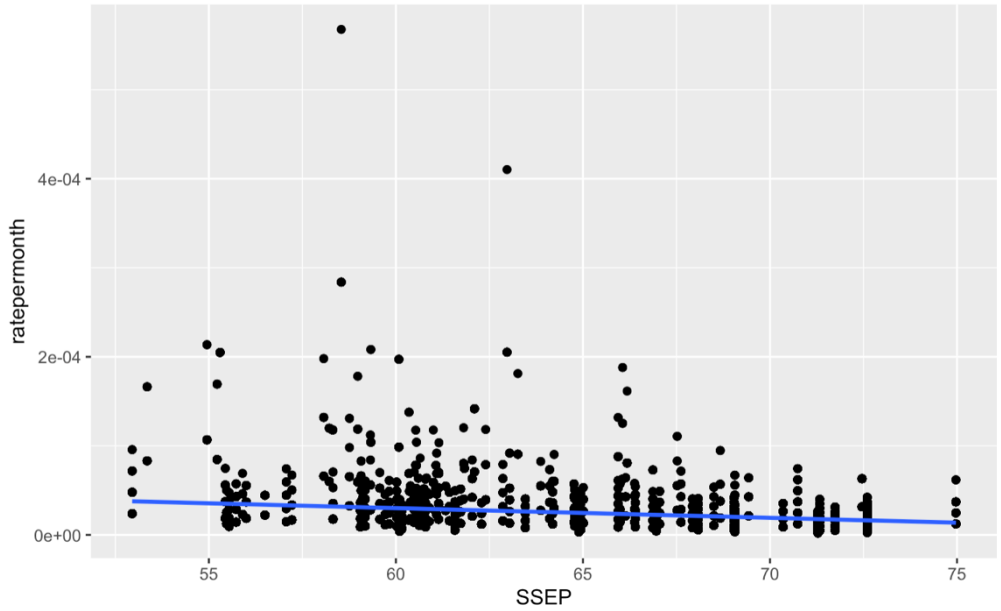


Figure 32: Univariate regression for SSEP and suicide rate per month.

4.2.1.6.2. Urbanity

If one also looks at the contrast between city and country, one can see that the land type has a 12.7% contribution to the suicide rate. In rural areas, the suicide rate increases by 0.0000167.

The regression equation for landtype is:

$$suicide\ rate = 0.00001997 + 0.0000167*rural$$

Table 24: Parametres of Landtype.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00001997	0.000000158	0.0000196621	0.000020281
rural	***	0.0000167	0.0000002864	0.0000161415	0.000017264

Overall, it can be seen that environmental factors do not have a large effect on suicide rates in the univariate linear model. The socioeconomic position has a great influence. Even greater than socioeconomic position, land type appears to influence suicide rates. Land type has a significant contribution of 12.7% in the univariate linear model on suicide rate. That is, the risk of suicide increases by 1.670e-05 in rural areas.

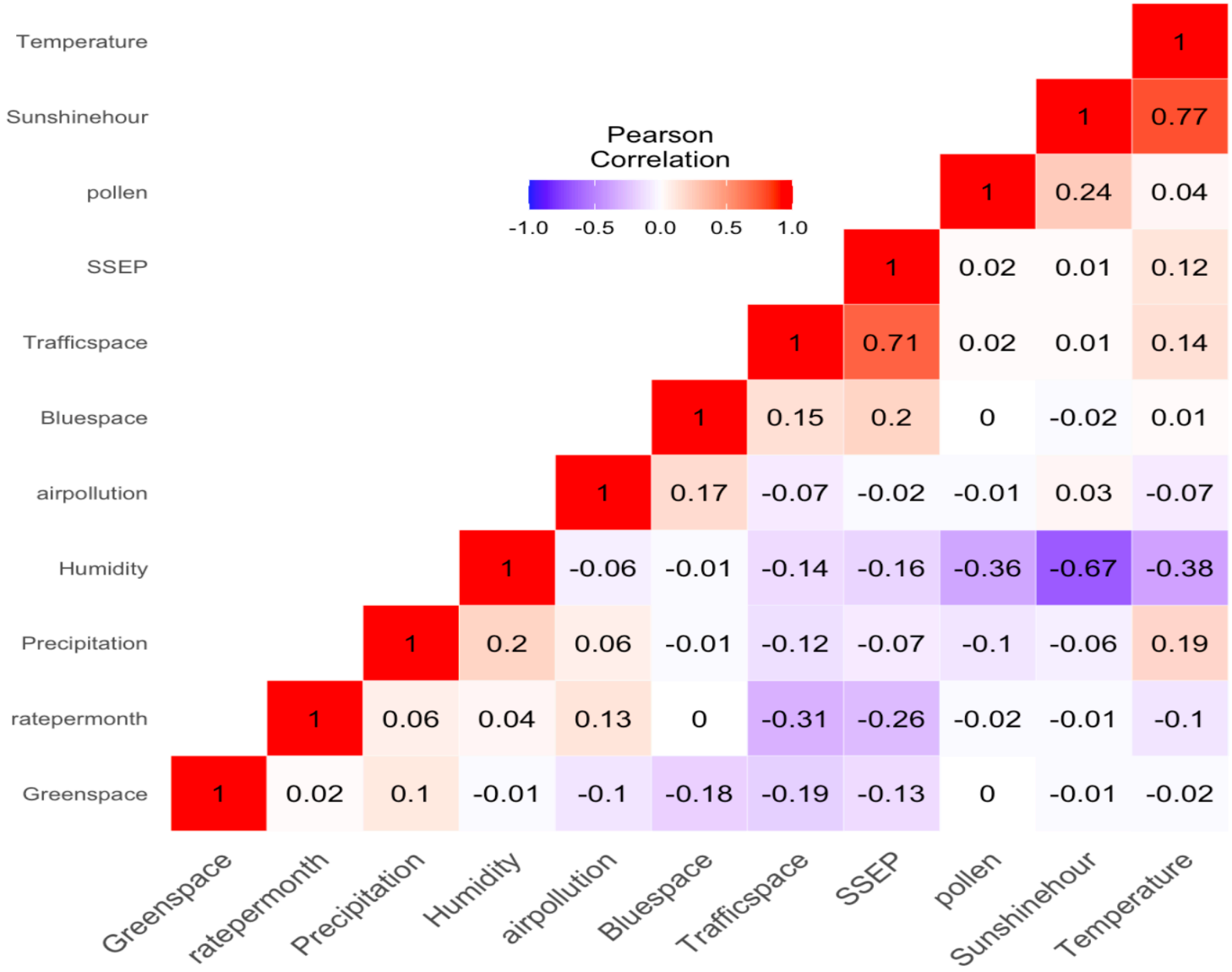


Figure 33: Correlation matrix of all used variables.

4.2.2. Multiple linear regression

4.2.2.1. Environmental factors, SSEP and landtype

In a first step the number of variables is reduced, because there are too many variables. There are four weather variables Humidity, Precipitation, Temperature and Sunshinehour. Temperature, Sunshinehour and Humidity are highly correlated with each other and for that reason only Temperature is taken. The two air pollutants SO2 and O3 are taken together under the name airpollution. The other two air pollutants NO2 and PM10 are not included here under air pollutants because their levels have decreased over time, as have suicide rates. The different pollen types are grouped together as the variable pollen. Pollen is grouped under one variable because its content is distributed very differently. Bluespace and Greenspace are a variable called recretional areas. Trafficspace is highly correlated with SSEP and also moderately with airpollution and is for that reason omitted. SSEP is included as a control variable and also the land type to have the contrast between urban and rural.

The variables that consider here are:
- Temperature
- Precipitation
- air pollution (SO2 and O3)
- Pollen
- Recreational areas (bluespace and greenspace)
- SSEP (control variable)
- urbanity (contrast between rural and urban areas)

Considering all these variables together in multiple linear regression, they have a 15.45% contribution to the monthly suicide rate.

The multiple regression equation is:

$$suicide\ rate = 0.00003068 + (-0.0000001613) * Temperature + (0.00000001277) * Precipitation + (0.0000001619) * recretional + (0.0000002113) * airpollution + (-0.00000000005585) * pollen + (-0.0000003957) * SSEP + (0.00001424) * rural$$

Table 25: Parametres of the variables in the multiple linear regression.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00003068	0.000002245	0.0000263	0.000035082
Temperature	***	-0.000000163	0.0000000192	-0.000000199	-0.000000124
Precipitation	***	0.0000000128	0.00000000332	0.00000000823	0.0000000173
airpollution	***	0.0000002113	0.00000001281	0.0000001862	0.0000002364
pollen	.	0.0000000000559	0.0000000000318	0.000000000118	0.000000000006372
recreational	***	0.0000001619	0.00000001585	0.00000013082	0.000000193
SSEP	***	-0.000000396	0.00000002994	-0.0000004544	-0.00000033705
rural	***	0.00001424	0.0000003331	0.000013585	0.0000148906

From the regression equation it can be seen that environmental factors have a small impact on the suicide rate compared to land type and socioeconomic position. High temperatures appear to have a protective effect against suicide rates because if temperature increases by one unit, then the suicide rate decreases by 0.0000001613. Precipitation, on the other hand, leads to suicidal thoughts. If precipitation increases by one unit, then the suicide rate also increases by 0.00000001277. Air pollution also increases the suicide rate and has a higher contribution than precipitation. Air pollution would increase the suicide rate by 0.0000002113 if it increases by one unit. Pollen have not a significant contribution to suicide rate. Blue and green areas are counted as recreational areas. The recreation areas also contribute to the increase in the suicide rate. If the proportion of recreation areas increases by one unit, then the suicide rate increases by 0.0000001642.

Socioeconomic position has a protective effect. The higher the SSEP, the lower the suicide rate. If the SSEP increases by one unit, then the suicide rate decreases by 0.0000003957. The country type also influences the suicide rate. Rural areas worsen the suicide rate. For a rural area, the suicide rate increases by 0.00001424. From the regression equation it can be seen that land type is the main contributor to the suicide rate. The SSEP has the second greatest impact on the suicide rate. But their impact is low compared to the land type. From the simple regression it was also evident that the country type has a greater influence on the monthly suicide rate than the socio-economic position.

The environmental factor that has the most impact on the suicide rate is air pollution. The two air pollutants SO2 and O3 increase the suicide rate the most of all environmental factors. Precipitation is the environmental factor that contributes least to the suicide rate. The two variables temperature and pollen are the only environmental factors that have a protective effect on suicide rates, with pollen having no significant contribution.

In a second step, the multiple regression was tested to see if any environmental variables were unnecessary and could be removed. Therefore, the package *MASS* with the function *stepAIC* was

used. And as a result, it turned out that all variables used in the mutliple regression are significant except of pollen.

The regression equation after using *stepAIC* is:

*suicide rate = 0.00003059 + (-0.0000001632) *Temperature + (*0.00000001321*) *Precipitation + (*0.0000001613*) *recretional + (*0.0000002111*) *airpollution + (*-0.0000003961*) *SSEP + (*0.00001423*) *rural*

Table 26: Parametres of all variables after using stepAIC.

Variables	Significance	Estimate	Std. Error	CI 2.5%	CI 97.5%
(Intercept)	***	0.00003059	0.000002245	0.000026186	0.000034986
Temperature	***	-0.0000001632	0.00000001913	-0.0000002007	-0.0000001257
Precipitation	***	0.00000001321	0.000000002303	0.000000008697	0.00000001773
airpollution	***	0.0000002111	0.00000001281	0.00000018604	0.00000023624
recreational	***	0.0000001613	0.00000001584	0.00000013029	0.0000001924
SSEP	***	-0.0000003961	0.00000002994	-0.0000004548	-0.0000003374
rurl	***	0.00001423	0.0000003331	0.000013582	0.0000148876

4.2.2.2. Environmental factors, SSEP, landtype and language

In the next step, the language is also taken into account. If the language is also considered than the multiple regression equation would be:

suicide rate = 0.00002845+ (-0.0000001616) *Temperature + (0.00000001484) *Precipitation + (0.0000002326) *recretional + (0.0000002188) *airpollution + (-0.0000004006) *SSEP + (0.00001384) *rural + (-0.000001174) *French + (0.00003534) *Rumantsch + (-0.000006841) *Italian

If one still considers the language regions, all variables together have a contribution of 16.75%. Again, SSEP and temperature acts as suicide protective. However, suicide rates increase when the region is Rumantsch-speaking and decrease when the region is French- and Italian-speaking.

When considering the three non-environmental variables, i.e., SSEP, land type, and language region, land type is the most reliable. The language regions have uncertain parameters, which is why they are not considered further in the third research question. Overall, the language regions increase the contribution, but only by almost 1%. The most decisive factor is still the country type.

4.2.2.3. Prediction

To see how climate change might affect suicide rates in the future, a model was developed to predict future suicide rates. This assumed that SSEP, percentage of green space, and precipitation would remain the same, while temperature and air pollution could increase. It is assumed that temperature will increase by 2.5 degrees Celsius in the future. Ozone pollution will also increase due to climate change. According to current developments, there could be 30 µg more ozone by 2050.

Looking at the Predict, we see that suicide rates may develop a different trend in the future. While the mean of monthly suicide rates from 2010 to 2019 is 2.505476e-05, by 2050 suicide rates could be 3.186922e-05. That is, suicide rates will be higher in the future if air pollution and temperature increase due to climate change. Suicide rates in the future could range from 1.777974e-05 to 5.306932e-05. It can be seen that climate change has a negative impact on suicide rates and thus suicide rates will increase in the future.

The regions of Mesolcina, Mendrisio and La Vallée are strongly affected by climate change. These regions will have the highest suicide rates in 2050 according to the calculated climate change scenario. Glattal-Furttal, Geneva and Lucerne might have the lowest suicide rates.

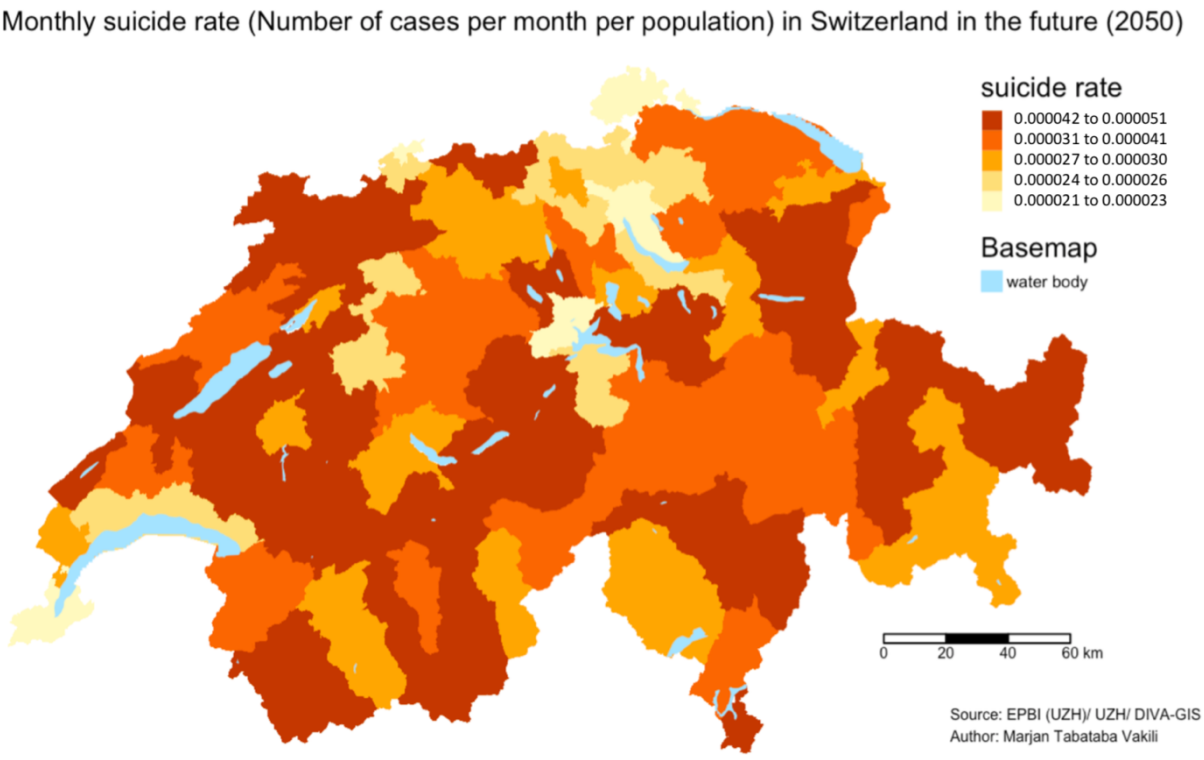


Figure 34: Monthly suicide rate in the future with the predict function.

4.3. Spatial pattern of suicide when environmental factors have been adjusted

To compare how suicide rates look when environmental factors are adjusted, the three multiple regressions are compared.

The first multiple regression equation includes all variables (environmental factors, SSEP, landtype):

*suicide rate = 3.059e-05 + (-1.623e-07) *Temperature + (1.321e-08) *Precipitation + (2.111e-07) *airpollution + (1.613e-07) *recreational + (-3.961e-07) *SSEP + (1.423e-05) *rural*

The second multiple regression equation includes only SSEP and landtype:

*suicide rate = 5.098e-05 + (-4.684e-07) *SSEP + (1.423e-05) *rural*

The third multiple regression equation includes only environmental factors:

suicide rate = 1.051e-05 + (-3.230e-07)*Temperature + (2.676e-08)*Precipitation + (2.584e-07)*airpolllution + (5.718e-08)*recreational

Comparing these equations, it can be seen that environmental factors have no impact on land type, but a greater impact on SSEP. If the environmental factors are not taken into account, then the SSEP has a greater impact on the suicide rate. The suicide rate is reduced by 0.0000004684 instead of just 0.0000003961. A partial F-test is used to determine whether or not the coefficients equal zero or whether or not there is a statistically significant difference between a regression model and a nested version of the same model. The full regression model is the model that includes all variables, that is, control variables and environmental factors, while the nested regression model includes only environmental factors.

The output of the partial F-Test is as follows:

```
Analysis of Variance Table

Model 1: ratepermonth ~ SSEP + factor(urbanity)
Model 2: ratepermonth ~ SSEP + factor(urbanity) + Temperature + Precipitation +
    recreational + airpollution
  Res.Df        RSS Df  Sum of Sq      F    Pr(>F)
1  23380 9.3904e-06
2  23376 9.1945e-06  4 1.9591e-07 124.52 < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 35: Output of partial F-test.

Since F=124.52 (p-value=2.2e-16), the null hypothesis can reject at the 5% level of significance. It appears that the variables Temperature, air pollution, recreational areas and Precipitation contribute significant information to the suicide rates once the variables SSEP and land type have been taken into consideration.

To detect spatial clusters, LISA Cluster and Moran's I are calculated for the suicide rate and residuals. The Global Moran's I for suicide rates is 0.196. The p-value is 0.0001791 and the statistic standard deviate is 3.5691. The Expectation is -0.009523810 and the variance is 0.003304165. This means that suicide rates are weakly positively autocorrelated. The Global Moran's I for residuals is 0.186, which means that the residuals are weakly positively autocorrelated. The p-value is 0.0002888 and the statistic standard deviate is 3.4419. The expectation is -0.009523810 and the variance is 0.003224231.

In Local Moran's I for suicide rates, one sees that north-eastern Switzerland, Zurich and Aargau, together with Espace Mittelland, Geneva, some areas in Ticino and Grisons show a positive spatial autocorrelation, while southern north-eastern Switzerland, western Switzerland and some areas of central Switzerland show a weak or negative autocorrelation. For the Local Moran's I of the residuals, the pattern does not look much different.

The LISA Cluster for both residuals and suicide rate shows that most regions have no significant local autocorrelation. Regions that have high values and similar neighbours are known as hot spots and this feature correspond to suicide rate for the most regions in the canton Grisons (Prättigau, Davos, Schanfigg, Mittelbünden). Regions with low values and similar neighbours are known as cold spots. This feature corresponds for the suicide rates for the regions Chur, Uri and Visp. Regions with high values and low value neighbours and also regions with low value but high value neighbours are know as spatial outliers. For the suicide rate, there are three regions, that are spatial outliers. These three regions are Oberengadin, Tre Valli and Brig. And all these three regions have high values with low value neighbours.

The LISA Cluster for residuals are more or less the same. All regions that have no significant local autocorrelation are the same for residuals and suicide rate. The cold spots for residuals are the same as for suicide rate, in addition there is Tre Valli by residuals. Six regions are indentified as hot spots and these are Brig, Oberengadin, Prättigau, Davos, Schanfigg and Mittelbünden. The cluster (hotspots) becomes larger for the residuals compared to the observed suicide rates.

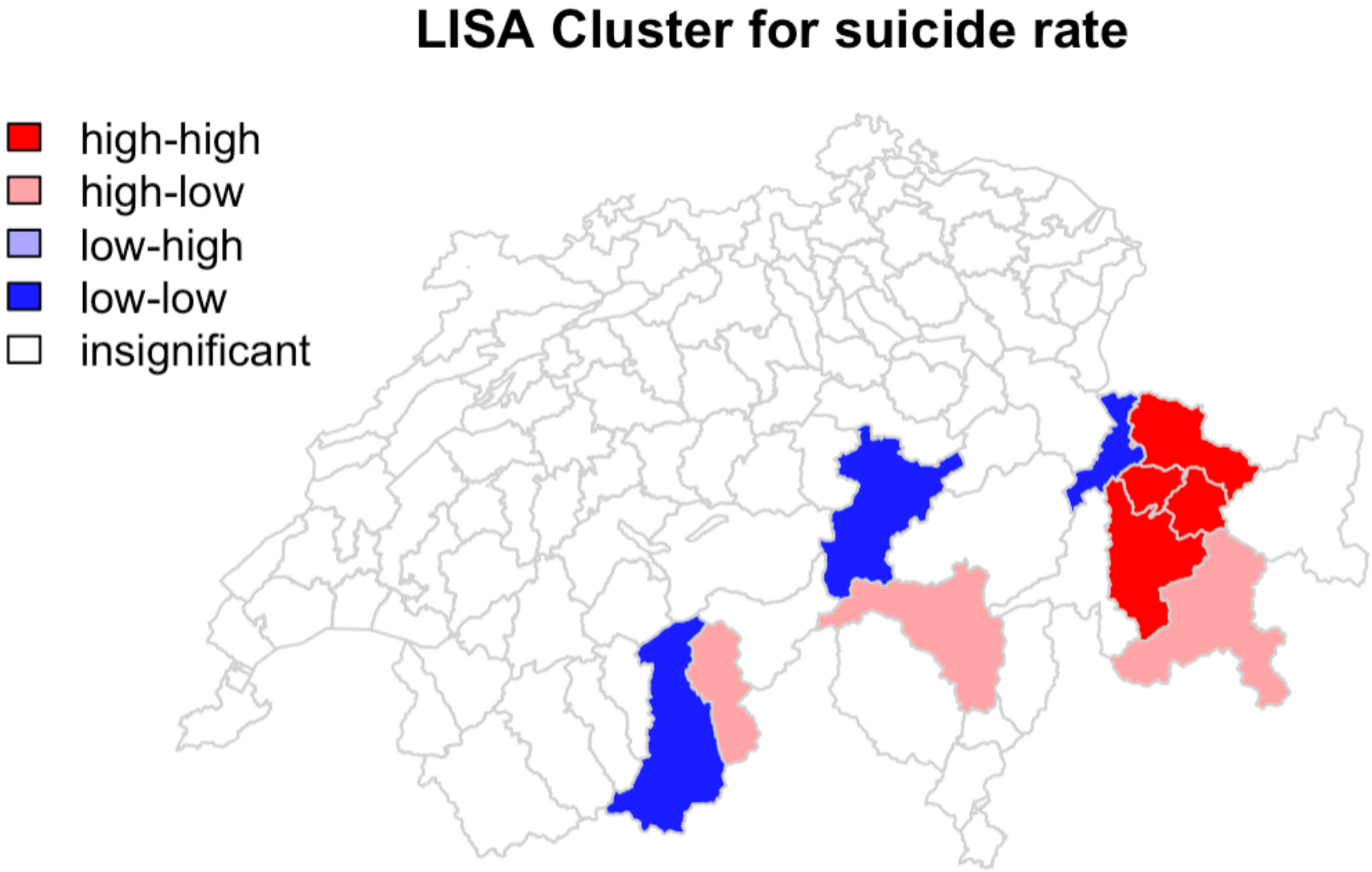


Figure 36: LISA Cluster for suicide rate.

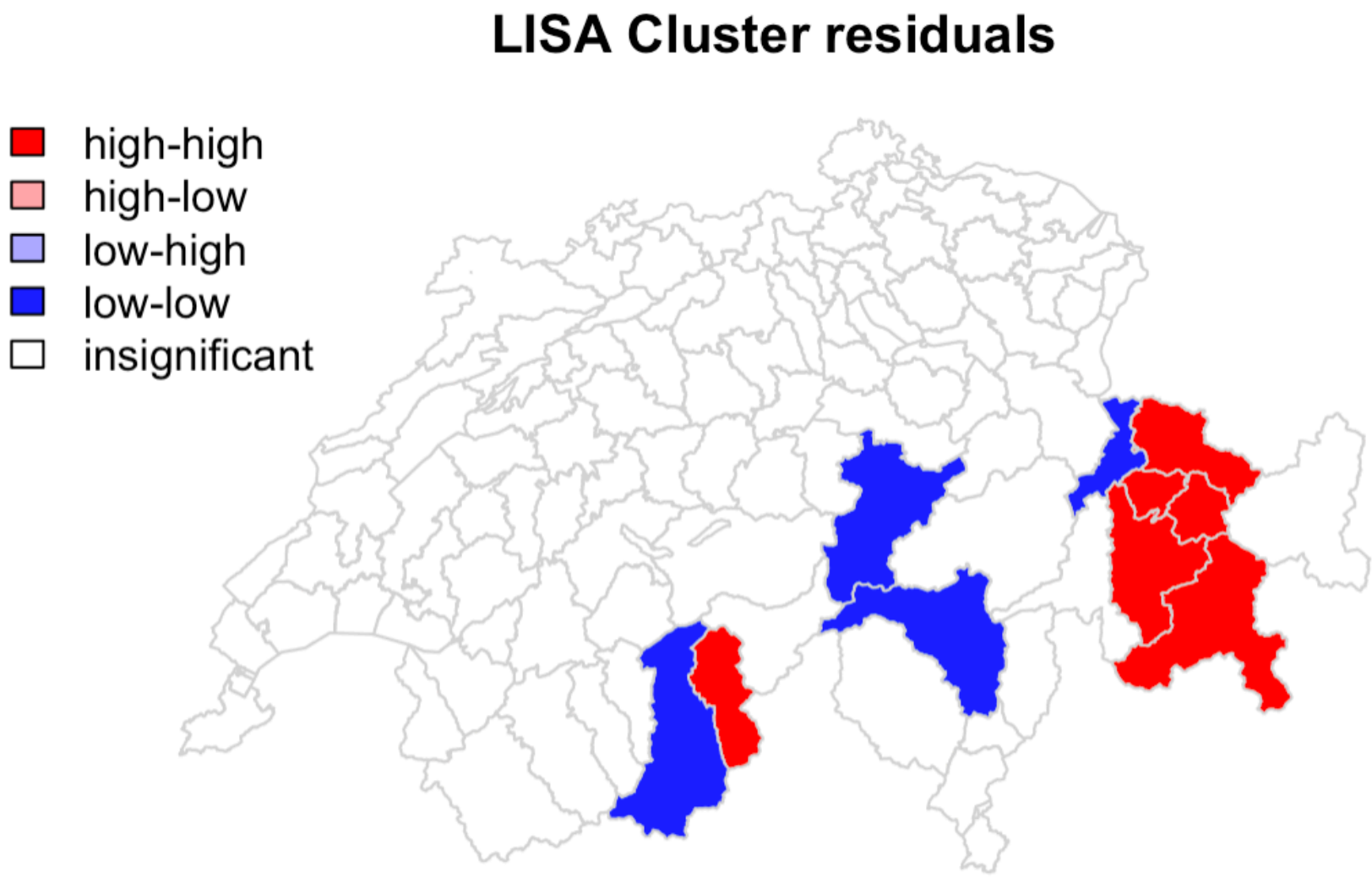


Figure 37: LISA Cluster for residuals.

5. Discussion

5.1. Spatial and temporal distribution of suicide across the years 2000 to 2019

5.1.1. Overall

One of the research questions was what the spatial and temporal distribution of suicide rates was over the years 2000 to 2019. In summary, suicide rates have decreased in Switzerland since 2000, with a clear downward trend for urban areas, but no clear trend for rural areas. In terms of language regions, there was also a downward trend for the language regions of German, French and Italian-speaking Switzerland, while no trend was apparent for Romansh-speaking Switzerland. However, it can be observed that the two Rhaeto-Romanic regions are rural. Suicide rates in German-speaking Switzerland have been on a downward trend since 2002, while French-speaking Switzerland saw an increase between 2000 and 2007 and has only seen a downward trend since 2007. For Italian-speaking Switzerland, there was a peak in 2006, but since then suicide rates have been declining. Also, the seasons of spring and summer had higher suicide rates. In addition, there were also patterns in sociodemographic factors. The results showed that the suicide risk was higher for foreigners than for Swiss. It was also higher for divorced and widowed persons. Age also had a large influence. The higher the age, the higher the suicide risk. The results also show that men have twice the suicide risk as women. In addition, suicide risk was higher in rural areas. Low socioeconomic status also increased suicide risk.

5.1.2. Decreasing suicide rates

Suicide rates in Switzerland have been declining since 2000. In the last 20 years, the absolute numbers of suicides have decreased despite a population growth. This phenomenon can be observed worldwide. In the 20 years between 2000 and 2019, both age-standardized suicide rates and age-group-specific rates declined (WHO, 2021b). Suicide rates also declined in Russia, Kazakhstan, Bulgaria, Estonia, Finland, Hungary, Latvia, Slovenia, Turkmenistan, Venezuela, Panama, and Ukraine, as well as in Switzerland. However, there are countries such as Greece and Guatemala, as well as Mexico, the United States, the Netherlands, Uruguay, Australia, the United Kingdom, Brazil, and Macedonia, where an increase in suicide mortality was observed (Alicandro et al., 2019). Värnik also reported a decrease in suicide rates in Europe (Värnik, 2012). Suicide rates for urban areas in Switzerland are declining, while for rural areas no clear trend was observed. To consider the four

language regions in Switzerland, there was an observed downward trend for the German-, French- and Italian-speaking Switzerland, while for the Rumantsch-speaking Switzerland no trend was observed. In Switzerland, the downward trend was observed for both genders and for all age groups.

In some countries, such as Greece, the Netherlands and the United Kingdom, the downward trend was followed by an increase that coincided with the global crisis in 2008, while in countries such as Germany, Italy and Spain, the downward trend stalled before the crisis (Alicandro et al., 2019). In Switzerland, no interruption in suicide rates was observed during the financial crisis, but a further decrease was observed during and after the financial crisis. However, it was higher in 2008 than in 2009 and 2010, but very low compared to the years before 2008, which could be due to the fact that the unemployment rate in Switzerland was not very high compared to other European countries. Between 2008 and 2015, unemployment rates increased significantly in Greece, the Netherlands, Italy, and Spain, leading to a corresponding increase in suicide mortality in Greece and the Netherlands and a leveling off of the pre-crisis downward trend in Italy and Spain (Alicandro et al., 2019). There are three well-known studies that have examined the impact of the economic crisis by analyzing the unemployment rate and suicide mortality in several countries and the result was a correlation between suicide mortality and unemployment, although weak or not significant (Santana et al., 2015). Since Switzerland was not severely affected by the financial crisis, the suicide rate fell steadily.

The reasons for the decline in suicide rates since 2000 may lie in improvements in the treatment of psychiatric disorders, particularly depression. Other international studies with a pharmacoepidemiological approach see the increased prescription of antidepressants, especially selective serotonin reuptake inhibitors (SSRIs), as a reason for the decline in suicides. However, limiting the availability of lethal agents is also seen as a means of preventing suicides. These include detoxification of household gases, laws and regulatory measures to limit the availability of firearms, and the introduction of catalytic converters. Because suicide crises are often temporary and the time between the decision and the suicidal act is often very short, limited access to a particular method might be sufficient to prevent suicides (Hepp et al., 2010). Suicide rates in Switzerland are declining, and most of the lethal suicide methods used are also declining, with the exception of rail suicide. In recent decades, efforts have been made in Switzerland to train general practitioners in the recognition and treatment of depressed and suicidal individuals. This has improved access to psychiatric and/or psychotherapeutic treatment, and the costs have been covered by health insurance. In addition, efforts have been made to destigmatize mental disorders, making it easier for depressed and suicidal people and their families to seek professional help. In principle, it is not possible to increase the prescription

rate of antidepressants without increasing the number of people seeking help from (mental health) professionals (Hepp et al., 2010). Since professional help is more difficult to take in rural areas, this could be one reason why suicide rates in rural areas have not decreased.

5.1.3. Sociodemograhic pattern

5.1.3.1. Nationality

In this study, people who did not have a Swiss passport had a suicide rate 3.5 times higher than people with a Swiss passport. There are few studies that have examined suicide patterns between immigrants and natives. Some studies have shown that immigrants and ethnic minorities are at higher risk for suicide compared to the general population. However, some studies have reported lower rates of suicide attempts. Overall, most studies showed higher rates of suicide attempts among immigrants than among the native population (Forte et al., 2018).

A study from Belgium showed that Belgian men and women have a higher risk of suicide than individuals with foreign passports. In addition, the study took into account the migration generation and found that the risk was higher for second-generation groups than for the first generation. Bauwelinck et al. concluded that the risk for minorities is generally lower than for the majority population, but the results across migration generations highlight the increased vulnerability of minorities to suicide over time (Bauwelinck et al., 2017). A study from Sweden examined suicide risk between refugee and non-refugee migrants and showed that there were no significant differences in suicide risk and both groups had low suicide risks than Swedish-born. However, the risk of migrants in Sweden became higher the longer they stayed in Sweden. This is because during the first 5 years, no migrants in Sweden died by suicide, but after 21-31 years, their risk of suicide was the same as that of the Swedish-born population (Hollander et al., 2020). In Switzerland, the risk for foreigners to commit suicide was higher than for Swiss at the Mobspat level. However, there were no data available on the foreigners' country of origin and how long they had lived in Switzerland. Also, for the Swiss, it was not known whether those who committed suicide had an immigrant background and in which generation they were, making comparisons with Sweden and Belgium difficult. However, the result in Switzerland is consistent with most studies that say migrants are at greater risk for suicide.

According to Forte et al., risk factors for suicide among migrants and ethnic minorities include language barriers, worries about family back home, and separation from family. However, lack of

information about the health care system, loss of status, loss of social network, and acculturation were also found to be possible triggers for suicidal behavior. This is because socioeconomic factors such as poor socioeconomic status, social exclusion, discrimination, or deprivation are more clearly associated with suicidal behavior than migratory status itself (Forte et al., 2018).

5.1.3.2. Marital Status, Age and Gender

The results of other sociodemographic factors such as a higher risk for widowed and divorced, men and elderly people are also in good agreement with the literature. According to Lantos, men, the elderly, and the unmarried are more likely to take their own lives (Lantos et al, 2021). However, in Switzerland, single people had the lowest suicide risks, but the risk of suicide was higher for widowed and divorced people.

Alicandro et al. also confirmed that suicide rates were higher for men than women, with sex ratios ranging from three to five in most countries (Alicandro et al., 2019). In Switzerland, the sex ratio was 2. The dominance of men in suicide rates is known worldwide, with the exception of China (Värnik, 2012). The reason for the gender difference in suicide rates lies in suicide methods, as it is known that men use more violent methods than women (Callanan & Davis, 2012). In Switzerland, men tended to use more lethal suicide methods than women. Men tend to commit suicide by firearms in Switzerland, in addition to hanging, while poisoning comes second for women. However, traditional masculinity is also a major risk factor that promotes too emotional closed-mindedness and unwillingness to seek help (Möller-Leimkühler, 2003). Firearms ownership for men in Switzerland like some other countries is not difficult.

There are also studies that show that suicide risk increases with age. According to Shah, there was a significant increase in suicide rates with increasing age among men and women in 25 to 27 countries. However, there was no significant increase in suicide rate with increasing age among men and women in 29 to 31 countries (Shah, 2007). According to Beghi et al., the risk factors more strongly associated with suicide attempts and frequently associated with suicidal behavior in old age are depressive disorders, self-injury methods (especially poisoning), and psychotropic drug use, followed by psychological factors and disability, but also poor health, stressors/grief, and living alone (Beghi et al., 2021). According to Gaxiola-Robles et al., single men have twice the risk of committing suicide, while for women, suicide risk is not associated with marital status. In addition, the risk of suicide among married men increases gradually with age. Marriage may be a health state and also brings other benefits. Marriage provides security and social support, which is why married people are

happier than unmarried people (Gaxiola-Robles et al., 2009). Status of parentship is tied with extra responsibility.

Suicide methods are a reason why the suicide ratio between women and men is 1:2. Married and single people are less likely to commit suicide than widowed and divorced people. Since divorced and widowed people have personal losses and a new life situation, which are risk factors for suicide, this could contribute to a higher rate. However, single people in Switzerland are the least likely to commit suicide, perhaps because most single people are young and social isolation is not an issue, and marriage is very likely in the future.

5.1.3.3. Land type

The results for this thesis also agree well with reference to the rural type. Most studies report that there is a higher risk of suicide in rural areas and this phenomenon can be observed worldwide. In China and India, rural suicide rates are more than twice as high as in urban areas, but countries such as Belarus, Brazil, Cameroon, United Kingdom, Kosovo, Taiwan, Iran, Italy, Sri Lanka, Romania, and the Nordic countries (Finland, Sweden, Norway) have also been observed to have much higher suicide rates in rural areas (Hirsch & Cukrowicz, 2014).

Several authors pointed out that urban areas have many deprived and poor areas, but they also promote neighborhood interaction, access to services, walkable urban green spaces, and social support networks. Suicide mortality is overrepresented in rural, less populated, and more deprived areas, especially among men (Santana et al., 2015). Helbich et al. also found differences in suicide rates between rural and urban areas. The reason for the difference is often thought to be that living in rural areas can lead to social isolation, which increases the risk of suicidal behavior (Helbich et al., 2017). As already mentioned in the introduction, in Australia big cities have deprived neighbourhoods, but the people who live in these global cities appear to have significant social advantages (Allison et al., 2020).

A variety of collective and contextual factors appear to be of particular importance leading to the higher suicide rates in rural areas. These factors include socioeconomic decline in rural areas, facilitators and barriers to service use such as availability and accessibility of services, rural culture, community attitudes towards mental illness and help-seeking, and exposure to firearms (Judd et al., 2006). Cultural elements such as masculinity, reluctance to admit one's difficulties, shame about loss of identity, rural perspectives on aging, and the difficulties of aging in a rural area are often cited in

sociology as causes of higher rates of suicide in rural areas. However, knowledge of mental health resources and shame about seeking help also occur more frequently among rural residents, which is why suicide risk is higher. However, some studies report that rural areas have lower rates of suicidal behavior than urban areas, in the countries of Mexico, Nigeria, Spain, and South Africa. However, suicide rates in urban areas also used to be prevalent in some countries such as Austria and New Zealand, but this gap is narrowing due to the rapid increase in suicides in rural areas (Hirsch & Cukrowicz, 2014). Rural areas in different countries could have different characteristics.

There were also differences in suicide rates between the language regions in Switzerland. The Italian-speaking part of Switzerland has the lowest suicide rates. This is a bit surprising, because the cantons of Geneva and Ticino have the lowest suicide rates, but also a high alcohol consumption. And alcohol consumption is a risk factor for suicide. However, high-risk drinking is lowest in Ticino, which may be one reason for the lowest suicide rates. But religion may also be a reason for the lower rates in Italian-speaking Switzerland (Obsan, 2022). Religion is listed in many studies as a protective factor for suicide (Sinyor et al., 2017).

5.1.3.4. Socioeconomic Position

In addition to land type, socioeconomic position appears to have the greatest influence on suicide rates. It became apparent that lower socioeconomic status increased suicide risk. With the exception of Zurich, all regions with the 10 highest suicide rates were rural areas with relatively low SEP compared to the rest of Switzerland. Most studies suggest that lower levels of SEP are associated with increased risk of suicide or suicide attempts, although results are not consistent across and within countries. Knipe et al. found that lower SEP increased the likelihood of suicide or suicide attempt in lower- and middle-income countries in South and Southeast Asia. One of the reasons could be that individuals with lower SEP experience higher levels of adversity/stress and lower and uncertain life quality, which could increase their susceptibility to mental illness and psychological distress, leading to the increase in suicide risk. In addition, this phenomenon may be exacerbated by the fact that individuals with lower SEP are less likely to use or seek health services (Knipe et al., 2015). Burrows and Laflamme did a comprehensive review of studies that examined the association between socioeconomic status (SES) and suicide attempts over a 20-year period.

Overall, they state that greater socioeconomic disadvantage is often, but not necessarily, associated with higher rates of suicide attempts. Most studies have found that the risk of self-harm generally increases with lower social status (Burrows & Laflamme, 2010). In the results, it was evident that the

variable land type, i.e. whether a region is rural or urban, is constant, while environmental factors influence SSEP. High SSEP served as a protective effect in both models (with and without environmental factors considered). However, it appears that some environmental factors are included in the Estimate of SSEP, because without considering the environmental factors, SSEP had a greater effect on the suicide rate.

5.1.4. Seasonality

The results showed that suicide rates were higher in spring and summer than in winter and autumn seasons. The peak was observed in spring and the second highest suicide rate was in summer. The difference between spring and winter/fall was 6% in Switzerland. This agrees well with the literature, as most studies reported suicide frequency in spring and summer. In many countries in the Northern Hemisphere, an increase in suicide rate was observed in spring (Willeit et al., 2015). There is a positive linear relationship between variations in suicide rates and latitude for both the Northern and Southern Hemispheres, but not for the tropical zone, where there appears to be no seasonal pattern (Fountoulakis et al., 2016). A seasonal pattern in suicide deaths is well documented, with a peak in spring. In New Zealand, the number of suicides also peaks in spring, reaching a low point in winter, but the magnitude of seasonal variation is small (Williams et al., 2015). In Austria, suicide incidence was highest between March and May, in spring, while it was lowest between November and January (Vyssoki et al., 2012). A suicide peak in spring was also observed in Taiwan (Lee et al., 2006). However, Fountoulakis et al. concluded that the suicide rate is higher in autumn and summer and lowest in winter (Fountoulakis et al., 2016). No spring or summer peak in suicides was found in England and Wales. Suicide occurred most frequently in January. Seasonal variations in suicides have been observed for more than a century, with studies generally showing an increase in suicide frequency in spring and early summer (Page et al., 2007).

Sociological explanations suggest that social behaviors that trigger suicide are influenced by climatic variables. These social mechanisms could include increased alcohol consumption on hot days, especially in the summer months. It is known that increased alcohol consumption is associated with an increased risk of suicide (Biermann et al., 2009). In Greenland too, alcohol consumption in summer is responsible for the suicide peak (Björksten et al., 2005). The reason for the peak in January could be that January is basically a critical month associated with holidays and new changes (Vyssoki et al., 2014, Fernandez-Nino et al., 2018). The pollen season also coincides with spring and summer, so this could also be a reason why people who have allergies commit suicide at this time of year. There were limitations because there was no information on pollen allergy among the suicide victims.

5.2. Relationship between environmental factors and suicide in Switzerland

5.2.1. Overall

The second research question was the relationship between environmental factors and suicide in Switzerland. The environmental variable that had the greatest impact on suicide rates was air pollution followed by temperature. The environmental factors contribute around roughly 2% to the suicide rate. But the predictive model indicates that due to climate change, suicide rates will be higher in the future than they are now. Temperature was the only environmental variable that had a protective effect on suicide rates. The other environmental factors (recreational areas, precipitation and air pollution) increase suicide rates. Pollen generally did not make a significant contribution.

5.2.2. Temperature and Precipitation

5.2.2.1. Temperature

In the univariate model, temperature had a protective effect on suicide rate. The higher the temperature, the lower the suicide rate. In the univariate model, temperature explained only 3.6% of suicide rates. However, temperature also had a protective effect in the mutliple regression. This may be contradictory, since suicide rates are higher in spring and summer than in winter and fall. But on closer inspection, one finds that even in the colder months, when temperatures were higher, suicide rates are less than in the same month with colder years. This is not entirely consistent within the literature. Existing evidence on the effects of temperature on suicide is conflicting in the literature. Some studies have found a positive relationship between temperature and suicide incidence, while other studies have found a negative relationship (Williams et al., 2015). 2018 was the year with the lowest suicide rate and it was also the year with the highest annual temperature. 2010 had the second lowest suicide rates, but was the coldest year in this 20-year period.

In New Zealand, hotter times of the year were not consistently associated with higher suicide risk. After controlling for age and ethnic differences between regions, the association became negative, meaning warmer areas had lower suicide rates (Williams et al., 2015). Also, a study in Taiwan concluded that the most influential factor was temperature, which was negatively correlated with suicide (Tsai, 2010). In the model of this thesis, temperature was the second most influential factor after air pollution. However, most studies reported that temperature was positively associated with suicide rate (Fountoulakis et al., 2016; Yarza et al., 2020). Many studies found a higher incidence of

suicide attempts on days with higher temperatures and/or more hours of sunshine or during periods or regions of warm and sunny weather (Deisenhammer, 2003). Another study from Taiwan confirmed that ambient temperature increases suicide rate even after calculating the trend of seasonality (Lee et al., 2006). In Belgium, the incidence of violent suicide was positively correlated with sunshine duration as well as ambient temperature and a temperature increase in the weeks preceding the suicide (Vyssoki et al., 2014). A study in Portugal also showed a positive correlation between temperature and suicide. Thus, a higher risk of suicide was found at higher temperatures and especially when heat was perceived (Santurtun et al., 2020). In the data for analysis in Switzerland, there were no high monthly average temperatures. There was no data on which day of the month there was heat. It could be that the suicides that were committed in the summer happened just around the hot days.

5.2.2.2. Precipitation

Most reports suggest that suicide rates are higher during periods of high temperatures, low precipitation, and more sunshine (Fountoulakis et al., 2016). According to Yarza et al, high temperatures and low precipitation have a strong effect on suicide risk, especially among individuals who have already attempted suicide (Yarza et al., 2020). In Australia, drought was found to increase the likelihood of suicide (Bourque & Cunsolo Willox, 2014; Nicholls et al., 2006). In rural India, both extremely wet and extremely dry growing seasons were observed to increase suicide rates, with extremely wet being 6 times higher than extremely dry (Lester, 2021). The study by Deisenhammer et al. found that high temperatures, low humidity, and thunderstorms were associated with higher suicide risk (Deisenhammer et al., 2003). As can be seen, the results of the various studies are contradictory with respect to precipitation. Precipitation explained only 1.0% of the univariate model of suicide rates. Precipitation and suicide rates are positively correlated, meaning that when precipitation is higher, suicide rates are higher. February is the month with the least precipitation and the lowest suicide rates. The month with the most precipitation is August and has the highest suicide numbers. The results of this thesis agree well with Deisenhammer et al., which say that suicide rates are higher in spring and summer, but humidity and precipitation are also higher (Deisenhammer et al., 2003).

5.2.2.3. Reasons

In model for analysis in Switzerland, environmental factors contributed only 2.3% to the suicide rate. But it seems plausible that high temperatures have a protective effect on suicide rates and high

precipitation has a negative effect. This is because there is a widespread belief that bad weather makes people depressed (Huibers et al., 2010). In their study, Xu et al. found that overcast skies were the most common weather condition for depressive symptoms, when surveyed, individuals were more likely to report depressive symptoms in overcast weather than in sunny weather. In addition, the results of Xu et al. showed that even short-term changes in weather can have an impact on people's mood perceptions. Another study found that the number of sunless days was positively correlated with the onset of depressive disorders. The reason given for an overcast day increasing depression is that an overcast day is referred to as a cross-sectional weather condition that usually occurs before rainfall, causing changes in atmospheric pressure, temperature, light, and others that can have an impact on people's current emotions. In particular, a lack of natural light is associated with depressive symptoms. Also, wetness and rain are thought to affect health more than other types of weather. There is also evidence that older people living in areas with higher levels of rainfall have more severe depressive symptoms (Xu et al., 2020).

Another reason could be social and physical activities. Bélanger et al. found, accounting for age, sex, and month, that the average number of physical activities per day was 2-4% lower when 10 mm of rain fell and 1 to 2% higher when temperature rose 10 °C. Each 10 cm of snowfall increased the activity rate by 5%, but physical activity was lower on days with snowfall. Physical activity was lower in winter and increased in warmer months. However, even regardless of season, physical activity was slightly higher on warmer days and on days without rain. Several studies among adults report that bad weather is perceived as a barrier to physical activity and that daily physical activity increases with increasing ambient temperature and decreases with rain and snowfall. Participation in organized community physical activity is lower in winter and fall, but higher in spring and summer (Bélanger et al., 2009). In addition, the study showed that suicide rates in Switzerland have been declining since 2000. However, this could change soon due to climate change. The analysis showed that suicide rates may increase in the future. This phenomenon has also been observed in the U.S., where suicide rates increase in areas that are severely affected by climate change (Dumont et al., 2020).

5.2.3. Recreational Areas

In this thesis, a positive correlation was found between recreational areas and suicide rate. That is, the higher the proportion of recreational areas in an area, the higher the risk of suicide. Recreational areas are defined as blue and green spaces. Also in the simple linear regression, green spaces were positively associated with suicide rate, this means that green spaces increase suicide rate. In addition,

no difference was found in the between urbanity level, that is, it was the same for urban and rural. Only in Italian Switzerland did green spaces have a protective effect. The confidence interval is small and thus the uncertainty is small. This is not entirely consistent with the literature, as numerous studies show a protective effect of green spaces on mental health (White et al., 2021; Min et al., 2017; Vida, 2011; Lee & Lee, 2019; Shen & Lung, 2018). There have been conflicting analyses on blue spaces (White et al., 2021; Helbich et al., 2018b; Helbich et al., 2018a; Chang et al., 2018; Matyas, 2019; Chang et al., 2018). In the univariate model, blue spaces led to fewer suicides, but the contribution was not significant.

In this model, parks and forests were counted as green spaces. However, access to green space also plays a role. Here, recreation areas and forests were counted among green spaces, but it is unknown how accessible they are to the population, also there are a few times entrance fees. According to Wüstemann et al, wastelands also have a negative impact on life satisfaction. They also found that forest and water do not have a significant impact on life satisfaction. Life satisfaction is an important determinant of suicide. The more satisfied one is with life, the lower the risk of suicide (Wüstemann et al., 2017). According to Pickford et al., the interplay between the two environmental factors of green space and air pollutants matters. This is because many studies show an inverse spatial correlation between vegetation and concentrations of air pollutants. Therefore, increasing the amount of green space in a city is often suggested to reduce negative effects of air pollutants. However, the interaction between air pollutants and green spaces may vary depending on the perspective. For one thing, reduced air pollutants could be causally involved in the observed positive associations between green spaces and health. Also, it is not always necessarily the case that green spaces lead to reduced air pollutants, i.e. that they are strongly negatively correlated with each other. Looking at the correlation matrix, one sees that the correlation between green spaces and air pollutants is practically close to zero. Therefore, it may be that high air pollutants cause green spaces to be positively associated with suicide rates (Pickford et al., 2017).

In addition, it has been claimed that little light has a negative effect on mental health, and forests usually have little light and can become confusing. There was no information on how dense the forests are. When the trees are close to each other, it is darker and thus creates a depressive mood. In addition, Japan has the famous Aokigahara Forest, where many people who are tired of life go and commit suicide, and it is also known as the forest of suicide. That doesn't mean forests are risky. Also, forests make it easier to access suicide methods such as hanging. In addition, there are other suicide methods where forests provide good access such as bridges. In addition, people may be more likely to commit suicide in the forest out of shame, because it is much more difficult to find someone in the forest and

dissuade them from their plan. Blue areas make it also easy for the suicide method drowning (Krüger, 2020). In the univariate model, blue areas had no significant contribution to suicide rates. They had a negative contribution, so more blue spaces would lower the suicide rate. When blue areas were considered together with green areas, both had a bad influence on the suicide rate. There was a limitation in this study because it was not known if these recreational areas were also associated with free time visits and according to White et al., individuals report positive well-being with green and coastal areas, but the association disappears when it is controlled for recreational visits (White et al., 2021). According to Matyas, the blue area does not necessarily correlate with mental health (Matyas, 2019). A study from England and Wales showed that suicides are more common in coastal areas (Chang et al., 2018).

5.2.4. Air pollution

In this thesis, a positive correlation was found between suicide rates and air pollution (SO_2 and O_3). In the univariate model, NO_2 and PM_{10} had a negative correlation with suicide rates, but it is because their levels have decreased since 2000. Therefore, only SO_2 and O_3 were considered for analysis in multiple linear regression. Air pollution increases suicide rates and the confidence interval is very small and thus the uncertainty is also small. Moreover, air pollution was the variable that had the greatest impact on suicide rate. Air pollution could also contribute to the seasonality of suicide rates. Air pollutants were only available as annual averages, but ozone smog is a problem in summer and warmer weather (Flückiger, 2012). Ozone levels tend to be higher on warm days (Yang et al., 2019). Also, in Casas et al. a statistically significant inverse association between O_3 and suicide was observed in winter, which can be explained by the known strong negative correlation between this pollutant and winter PM_{10}, as well as other common pollutants (Casas et al., 2017).

The results of this study agree well with the literature. There are numerous studies showing an association between air pollution and suicide risk (Sinyor et al., 2017). Most studies show that air pollution is associated with an increased risk of suicide (Davoudi et al., 2021; Dumont et al., 2020; Buoli et al., 2018; Sinyor et al., 2017; Min et al., 2018a). According to Casas et al. air pollution alone does not necessarily lead to suicide, but the results suggest that people who want to commit suicide are more likely to do so when air pollution is high (Casas et al., 2017). A study looking at ozone levels found an increase in suicides in weeks when ozone levels were above the annual mean (Sinyor et al., 2017). A study from China also found that a significant increase in suicide risk was associated with an increase in sulfur dioxide concentration (Lin et al., 2016). A study from Taiwan found that there was no apparent evidence of an association between short-term exposure to O_3 and an increased

risk of dying from suicide. However, a positive, not insignificant, increase in suicide-related mortality rate was found for days with higher O_3 levels, suggesting that outdoor O_3 exposure may increase the rate of daily suicide-related mortality (Yang et al., 2019). Another study from Taiwan found that there was no apparent evidence of an association between short-term exposure to O_3 and an increased risk of dying from suicide. However, a positive, not insignificant, increase in suicide-related mortality rate was found for days with higher O_3 levels, suggesting that outdoor O_3 exposure may increase the rate of daily suicide-related mortality (Yang et al., 2019). However, another study from Taiwan found that PM_{10} plays a significant role in suicide, while SO_2, NO_2, and O_3 were found to be not significant. Another study found that elevated particulate matter was associated with a seasonal increase in suicide rates, and that sulfur dioxide (SO_2) and elevated ozone (O_3) concentrations were associated with longer-term increases in suicide rates (Tsai, 2014).

Ozone can affect the release of serotonin, which plays an important role in impulsivity, aggression and depression, and thus influence suicidality (Gladka et al., 2018). Exposures to O_3 can negatively affect the serotonin system, including negative effects on neurobehaviour. Also, other imaging studies show that air pollution is associated with lower functional integration and segregation around key brain networks relevant to both internal mental processes and stimulus-driven mental operations (Casas et al., 2017). Exposure to low levels of ozone can stimulate the immune system, causing hypersensitivity reactions, autoimmunity, or suppression that lead to infection. This can result in neoplasia or a reshaped response to any type of stress (Biermann et al., 2009). Also, several authors proved that SO_2, NO_2, and O_3 are related to the symptoms of depression, and depression is among the risk factors for suicide (Tsai, 2014).

5.2.5. Pollen

In the univariate model, with the exception of birch, a significant association with the suicide rate was found for all other pollen types. With the exception of herbs, all other pollen types had a protective effect. In the multivariate model, where all pollens were combined as one variable, no significant contribution could be found. The literature often indicates that seasonal peaks of aeroallergens in spring are associated with seasonal peaks of suicides in spring (Postolache et al., 2008). However, Qin et al. and Woo et al. also found an association between pollen and suicide rates, where these seasonal aeroallergens exacerbate suicide rates (Qin et al., 2013; Woo et al., 2012b). However, no association between pollen and suicide rate was found in this study. Since there was no information whether the suicide victim had a pollen allergy or not, it seems plausible that no connection was found, because it would only trigger a reaction in people with allergy.

5.3. Spatial pattern of suicide when environmental factors have been adjusted

Comparing the residuals and suicide rates has shown that the pattern is approximately the same. Only two regions showed differences when comparing residuals and suicide rates. In the LISA cluster of the residuals, one can see that the hotspots are getting bigger. If all factors are taken into account, that are relevant for suicide rate, one would not expect a cluster. But in Valais and Grisons there are hotspot clusters. This means that for these two areas, some factors are crucial for the suicide rate that were not taken into account in the model.

These two areas share some similarities. The areas are alpine cantons and tourist regions. As these are mountainous areas, access to health care could potentially be worse than in other areas. Both places also have many communities that are very sparsely populated, i.e. less than 10 people per square kilometer. And this could lead to social isolation, which is a risk factor for suicide. In this study, the rural-urban contrast was taken into account, but the population density was not taken into account. Comparing also between rural areas, population densities vary by municipality and therefore social isolation is higher in some rural areas than others. The population has also stagnated in the mountain regions in recent times. So, many young people might leave for work and only older people would stay, which can also lead to loneliness. These can be reasons for factors that have not been considered here. There are also many farmers living in the mountain areas who have a strenuous job, which could also be a reason. The availability of lethal agents may also be more readily available in these regions, which may also be a reason why these two regions have unconsidered factors for suicide (BAG, 2019). Asirdizer also mentioned that the suicide rate would increase with altitude due to hypoxia. The two regions in Valais and Graubünden also have many municipalities that are located at high altitudes. Altitude was not considered in this work and could be a factor influencing the suicide rate in these two areas (Asirdizer et al., 2018). It may also be that the influence of the neighboring regions spills over into these two areas.

There are unexplained reasons for risk factors for suicide, which are crucial for areas in Valais and Grisons, and were not considered in this work. Future work should therefore examine the suicide patterns in these areas and find more possible reasons.

6. Conclusion

It can be said that suicide rates in Switzerland have been declining since 2000 and are therefore on a good path, but they are still too high, because on average around 1000 people in Switzerland take their own lives per year. It has been shown that more people commit suicide in the seasons of spring and summer, which could be due to air pollution on the one hand, but also to people's behaviour, such as alcohol consumption, which seems to be higher in the hot days. Environmental factors have a small influence on the suicide rate, the proportion is very small when compared to socio-economic factors. This regression model could only explain 15.45% of suicide cases. Air pollution turned out to be the environmental variable with the greatest influence. Air pollution and green space should actually be strongly correlated. No correlation was found here. Green spaces only improve mental health if they are strongly negatively correlated with air pollution. It should therefore be examined with appropriate data whether green spaces are really effective in reducing air pollution.

In addition, there were differences between the language regions. Why there are the fewest suicides in Italian-speaking Switzerland is difficult to answer. There were also hidden factors for areas in Valais and Grisons that were not taken into account in this model. Future studies should therefore perhaps focus on the differences in social life between the language regions and whether these could lead to differences in suicide rates. They should also focus on what is different in Valais and Grisons from the rest of Switzerland. The study also showed that rural regions are more suicidal than urban regions. Therefore, counselling services in rural areas should be improved so that people are not ashamed to seek help.

In the end, this was an ecological study that had many limitations and uncertainities. Suicide figures were only available at the monthly level and by region. There was no precise information on which day of the month the person committed suicide. In addition, the meteorological data were only monthly averages. This means that it was not precisely examined whether there were many heat days in a month and whether the person may have committed suicide on a day with heat or after a heat wave. There was also no health information on the suicide victims as to whether they had pollen allergies, which was also a limitation of this work. It was also not possible to take a close look at drinking water because lead, lithium, arsenic and other trace elements are not systematically recorded in Switzerland.

7. References

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8. Appendix

Between the years 2001 and 2002, there was an increase in the suicide numbers of women, while between 2002 and 2008 the numbers of committed suicide were more or less at the same level. Since 2008, there was an observed decrease in the absolute numbers of committed suicide.

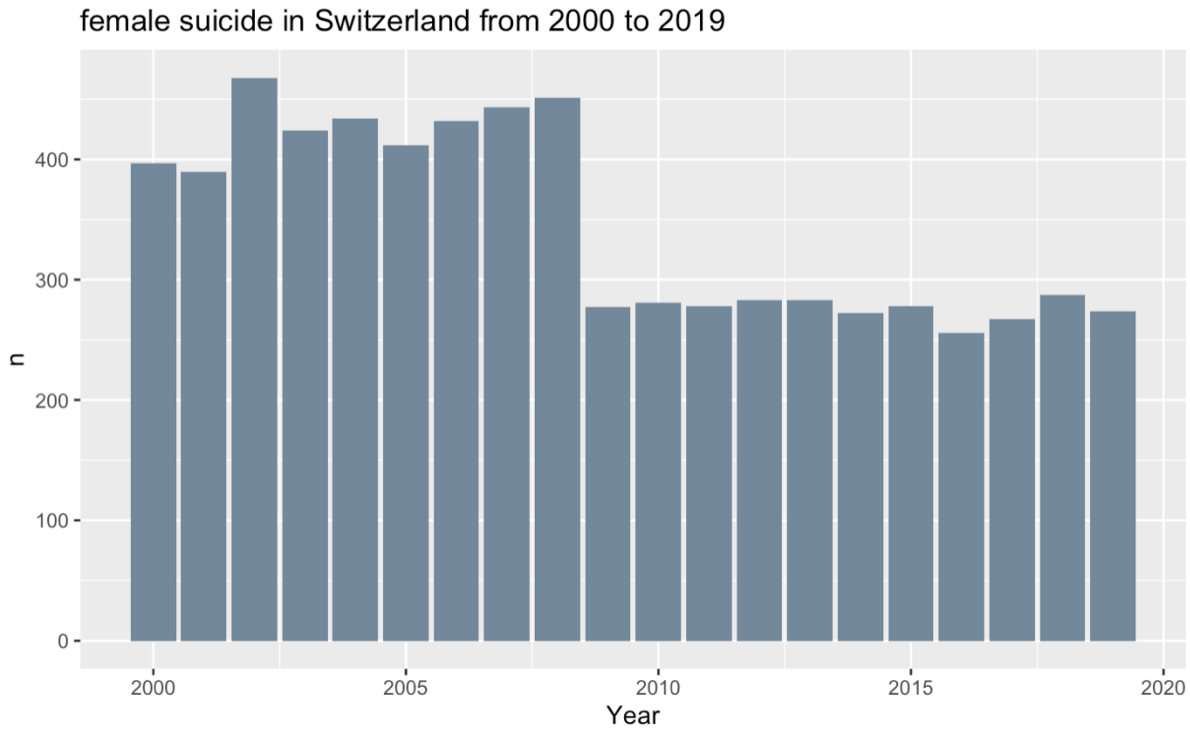

Figure 38: Absolute numbers of committed suicide by women.

There is a downward trend in the absolute numbers of committed suicide by men.

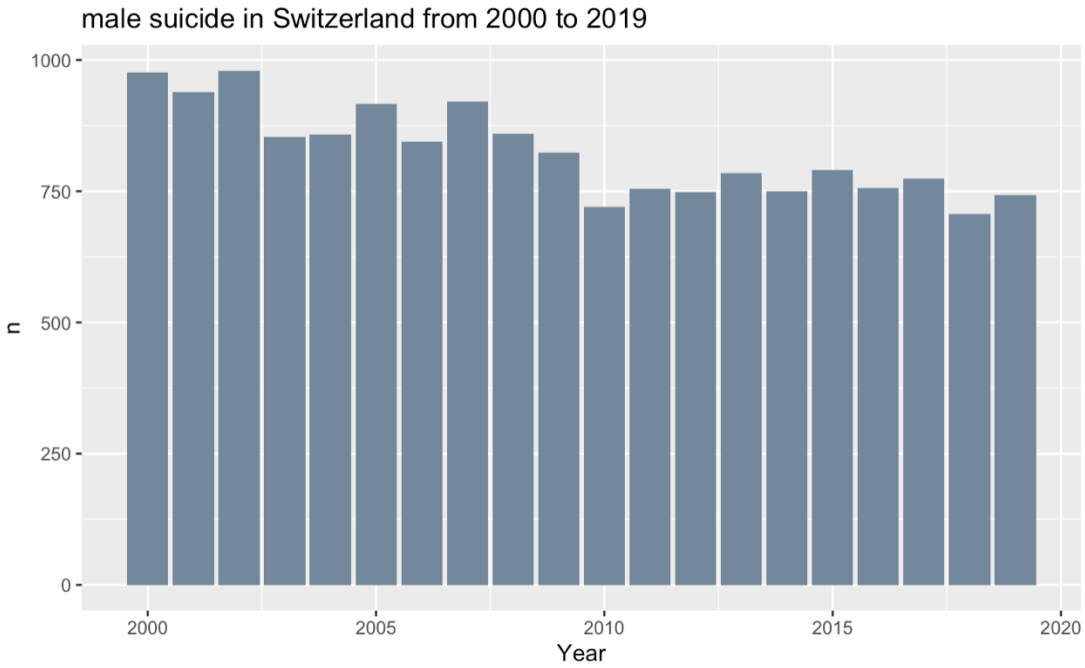

Figure 39: Absolute numbers of committed suicide by men.

There is a downward trend observed in the absolute numbers of committed suicide in urban areas.

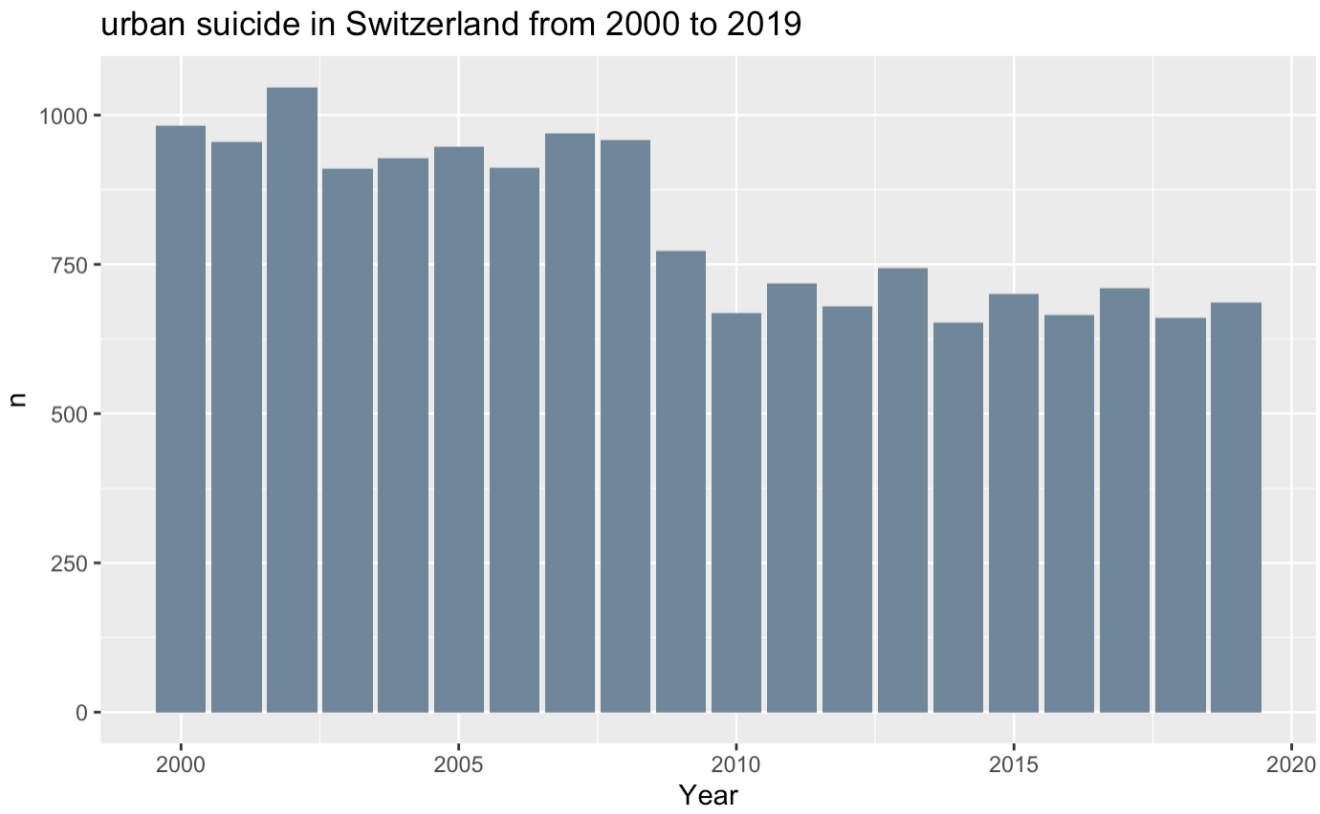

Figure 40: Absolute numbers of committed suicide in urban areas in Switzerland.

In rural areas, no clear trend was observed in the absolute numbers of suicide.

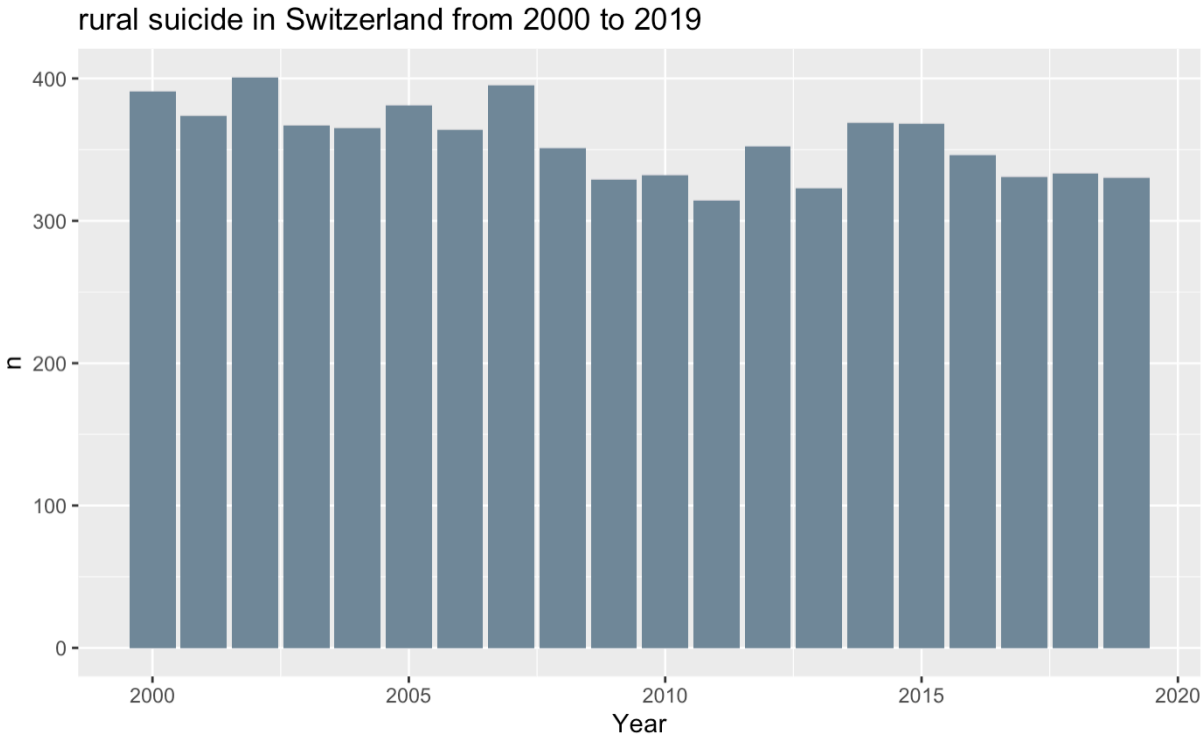

Figure 41: Absolute numbers of committed suicide in rural areas in Switzerland.

Since 2007, there is a downward trend for the German-, Italian- and French-speaking part of Switzerland.

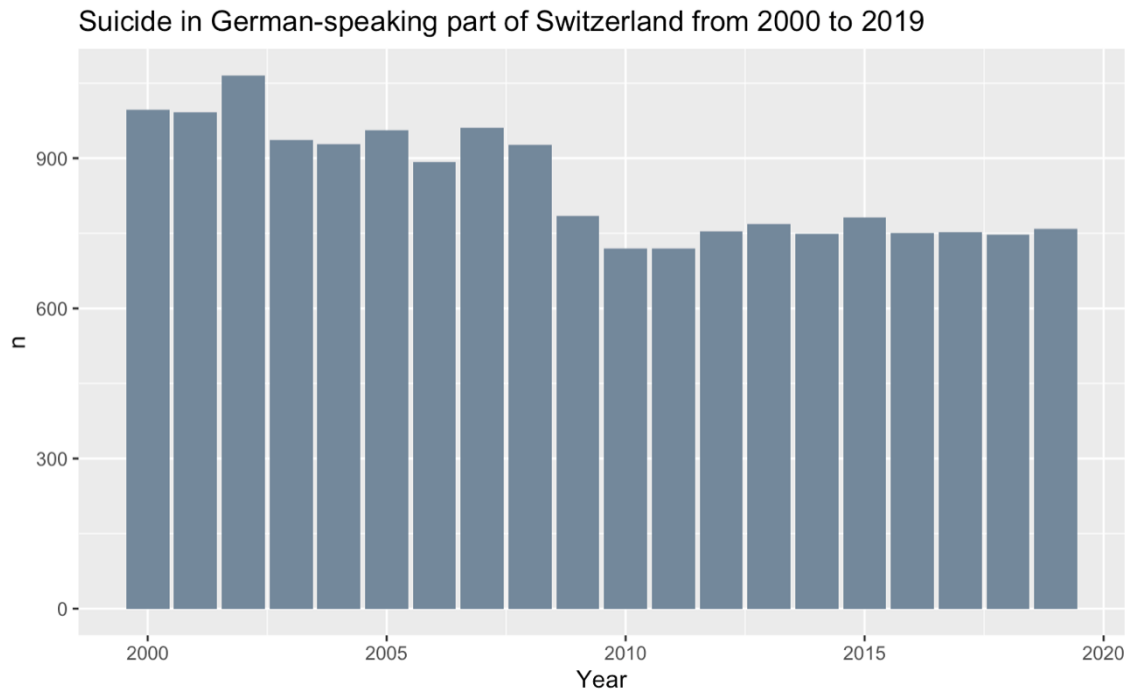

Figure 42: Absolute numbers of committed suicide in German-speaking part of Switzerland.

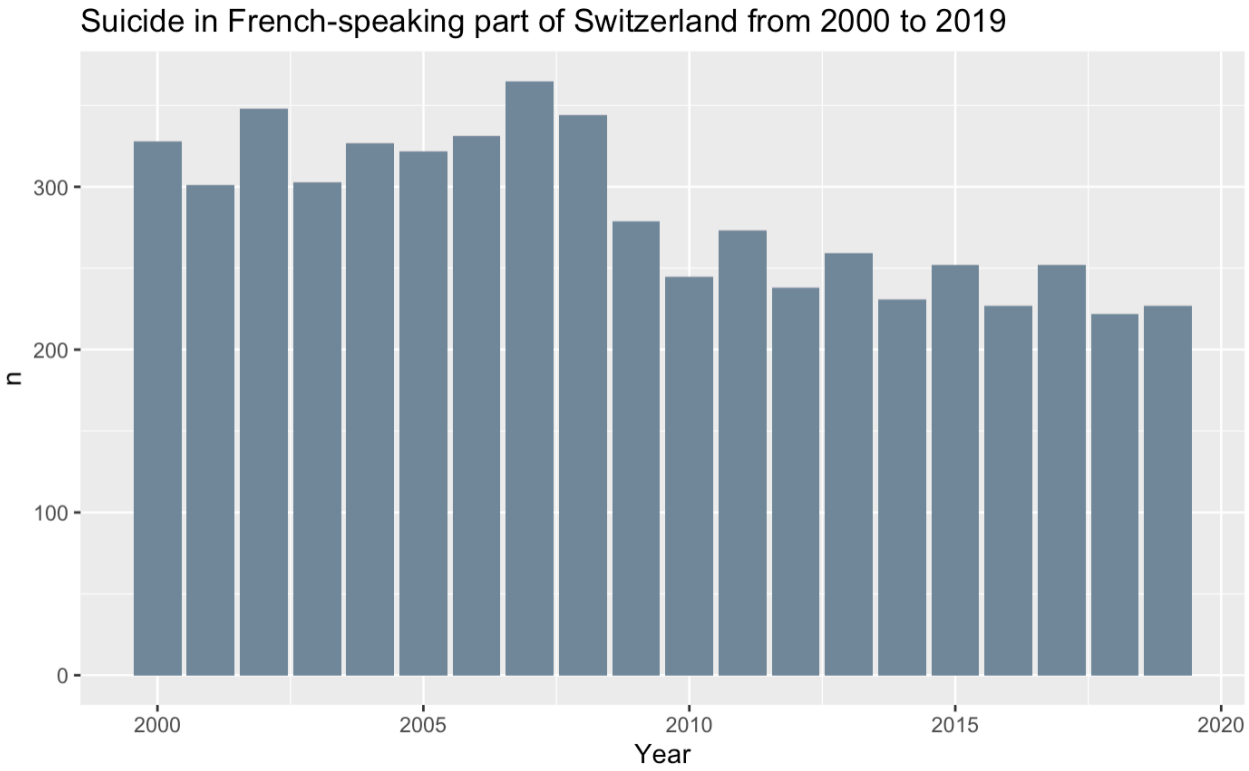

Figure 43: Absolute numbers of committed suicide in French-speaking part of Switzerland.

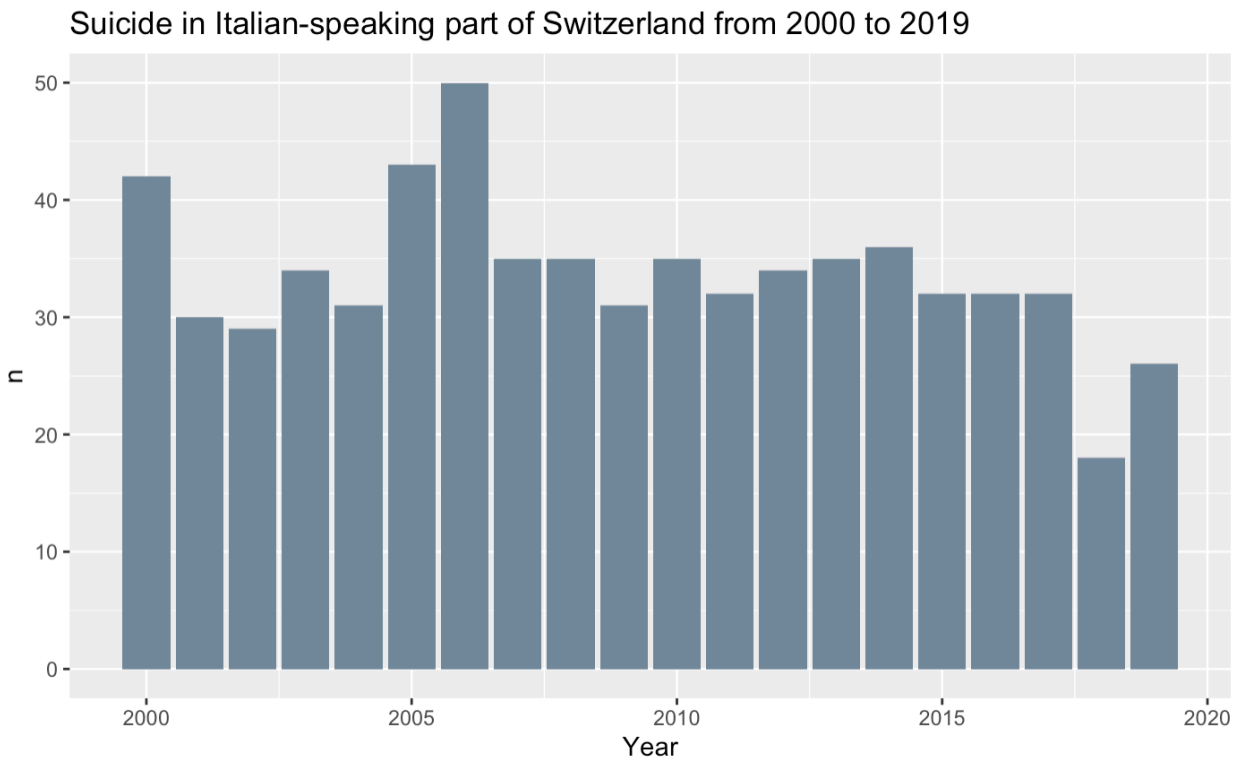

Figure 44: Absolute numbers of committed suicide in Italian-speaking part of Switzerland.

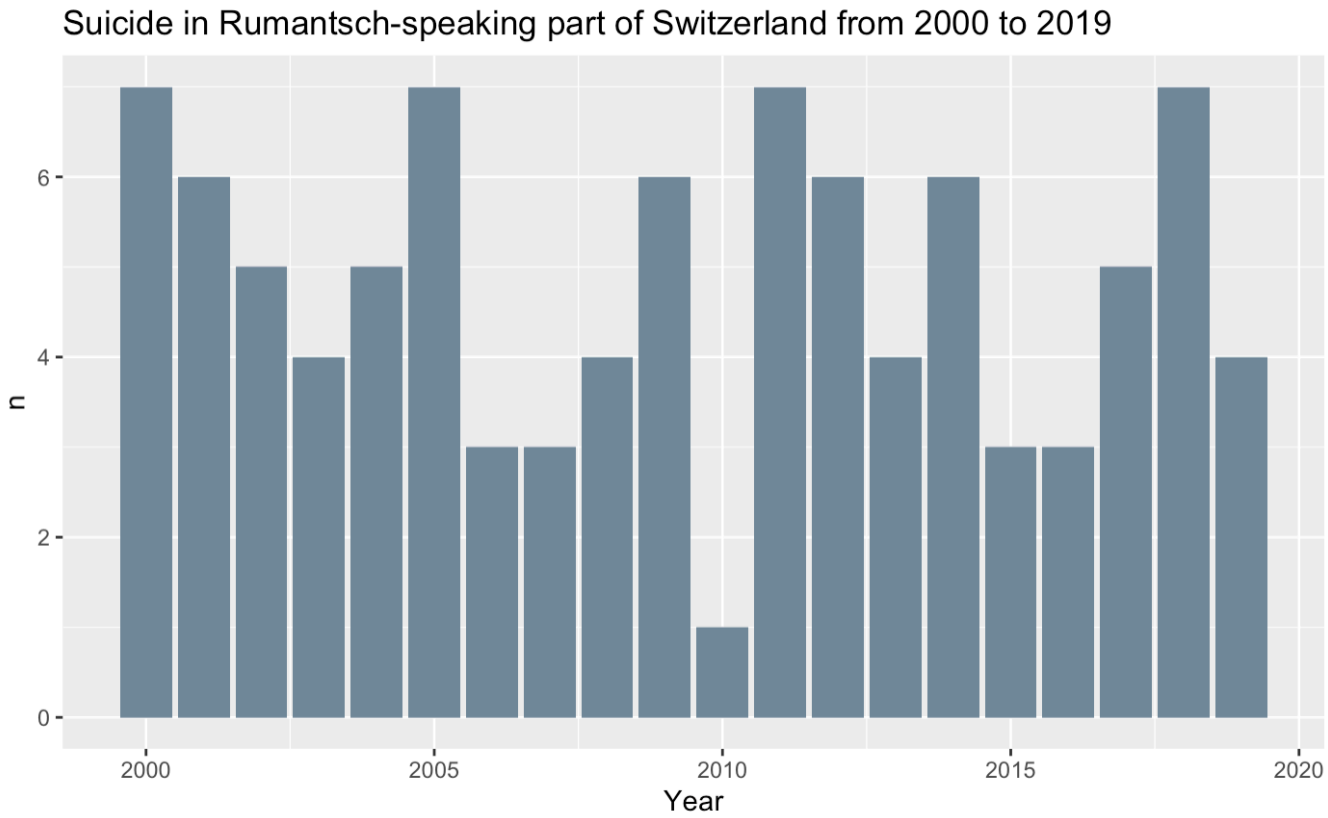

Figure 45: Absolute numbers of committed suicide in Rumantsch-speaking part of Switzerland.

```
library(tidyverse)
library(sf)
library(sp)
library(spdep)
library(rgdal)
library(rgeos)
library(tmap)
library(tmaptools)
library(spgwr)
library(grid)
library(gridExtra)
rq <- merge(rq3,ms_shp, by="Region")
rq_sf <- st_as_sf(rq)
tm_shape(rq_sf) + tm_fill("ratepermonth",palette = "Reds", style = "quantile",  title = "% suicide rate per month")
+tm_borders(alpha=.4)
neighbours <- poly2nb(rq$geometry)
neighbours_sf <- poly2nb(rq_sf)
neighbours2 <- poly2nb(rq$geometry, queen = FALSE)
listw <- nb2listw(neighbours2)
globalMoran <- moran.test(rq$ratepermonth, listw)
globalMoran[["estimate"]][["Moran I statistic"]]
globalMoran[["p.value"]]
moran <- moran.plot(rq$ratepermonth, listw = nb2listw(neighbours2, style = "W"))
local <- localmoran(x = rq$ratepermonth, listw = nb2listw(neighbours2, style = "W"))
moran.map <- cbind(rq_sf, local)
tm_shape(moran.map) + tm_fill(col = "Ii",style = "quantile",
         title = "local moran statistic") + tm_layout(title = "Local Moran's I for suicide rate")
quadrant <- vector(mode="numeric",length=nrow(local))
m.rate <- rq$ratepermonth - mean(rq$ratepermonth)
m.local <- local[,1] - mean(local[,1])
signif <- 0.1
quadrant[m.rate >0 & m.local>0] <- 4
quadrant[m.rate <0 & m.local<0] <- 1
quadrant[m.rate <0 & m.local>0] <- 2
quadrant[m.rate>0 & m.local<0] <- 3
quadrant[local[,5]>signif] <- 0
brks <- c(0,1,2,3,4)
colors <- c("white","blue",rgb(0,0,1,alpha=0.4),rgb(1,0,0,alpha=0.4),"red")
plot(rq_sf,border="lightgray",col=colors[findInterval(quadrant,brks,all.inside=FALSE)])
legend("topleft",legend = rev(c("insignificant","low-low","low-high","high-low","high-high")),
       fill=rev(colors),bty="n")
title("LISA Cluster for suicide rate")
```

Figure 46: LISA Cluster code for suicide rate.

```
rq <- merge(rq3,ms_shp, by="Region")
rq_sf <- st_as_sf(rq)
tm_shape(rq_sf) +
  tm_fill("full.residuals",
          palette = "Reds",
          style = "quantile",
          title = "residuals") +
  tm_borders(alpha=.4)
neighbours <- poly2nb(rq$geometry)
neighbours_sf <- poly2nb(rq_sf)
neighbours2 <- poly2nb(rq$geometry, queen = FALSE)
listw <- nb2listw(neighbours2)
globalMoran <- moran.test(rq$full.residuals, listw)
globalMoran[["estimate"]][["Moran I statistic"]]
globalMoran[["p.value"]]
moran <- moran.plot(rq$full.residuals, listw = nb2listw(neighbours2, style = "W"))
local <- localmoran(x = rq$full.residuals, listw = nb2listw(neighbours2, style = "W"))
moran.map <- cbind(rq_sf, local)
tm_shape(moran.map) +
  tm_fill(col = "Ii",
          style = "quantile",
          title = "local moran statistic")  + tm_layout(title = "Local Moran's I for residuals")
quadrant <- vector(mode="numeric",length=nrow(local))
m.rate <- rq$full.residuals - mean(rq$full.residuals)
m.local <- local[,1] - mean(local[,1])
signif <- 0.1
quadrant[m.rate >0 & m.local>0] <- 4
quadrant[m.rate <0 & m.local<0] <- 1
quadrant[m.rate <0 & m.local>0] <- 2
quadrant[m.rate>0 & m.local<0] <- 3
quadrant[local[,5]>signif] <- 0
brks <- c(0,1,2,3,4)
colors <- c("white","blue",rgb(0,0,1,alpha=0.4),rgb(1,0,0,alpha=0.4),"red")
plot(rq_sf,border="lightgray",col=colors[findInterval(quadrant,brks,all.inside=FALSE)])
legend("topleft", legend = rev(c("insignificant","low-low","low-high","high-low","high-high")),
       fill=rev(colors),bty="n")
title("LISA Cluster residuals")
```

Figure 47: LISA Cluster code for residuals.

«Personal declaration: I hereby declare that the submitted Thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the Thesis.»

“Persönliche Erklärung: Ich erkläre hiermit, dass ich die vorliegende Arbeit selbständig verfasst und die den verwendeten Quellen wörtlich oder inhaltlich entnommenen Stellen als solche kenntlich gemacht habe.”