Universität Zürich[UZH]

Geographisches Institut

The Impact of the 1911 Heatwave on the Population of the City of Zurich

GEO 511 Master's Thesis

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Abstract

Temperatures are rising and a majority of the warmest summers known to us, occurred in the past 25 years. As an example, on a global scale, the summer of 2024 was the warmest year ever recorded, a record that is likely to be broken in the upcoming years. But despite this, heatwaves are nothing new, also in the past such extreme weather events could occur. Regarding the ongoing climate change it is interesting to look at the impact of past heatwaves, as it can help us see what can be improved to lower the danger from heatwaves. One example was in 1911. At the time it was one of the warmest, driest and brightest summers ever recorded and until today it is still one of the dryest summers. Therefore, this thesis looks at the summer of 1911 and aims to provide new information on the situation in Switzerland and also to introduce the geographic perspective into historic heatwave research. This is done by looking at the death registry of the city of Zurich, which contains information about all the people who passed away within the boundaries of the city. To get a comparison, the data from 1911 is compared to the data from the summers of 1909 and 1910, two years without a notable heatwave. The thesis looks on one hand at the temporal aspect, to see how and when exactly the heatwave impacted the population. This part of the thesis was mainly done through statistical analysis and allowed to compare the situation in Zurich to the situation in other places, that were already studied before. On the other hand, it looks at the geographic aspect, to include a new perspective into the historic heatwave research. For this it was looked at the distribution of cases, with the help of dot maps and kernel density estimation and at the situation in the respective districts. Additionally, it was also analysed how important the proximity to recreational areas, such as greenspaces and water areas was. The results of this thesis give a good insight into the situation in Switzerland during the 1911 heatwave and provide a foundation for future research.

Keywords: Heatwave, Summer, Extreme Temperatures, Climate Change, Historical Data, Geographic Information Visualisation, GIS, Health Geography.

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1 Introduction

Heatwaves have been a regular occurrence in the past years. On a global level the summer of 2024 was the warmest ever recorded, a record previously held by the summer of 2023 (SDA 2024) and even though it just started, 2025 has already broken global heat records as well, as January 2025 has been the warmest January ever recorded (DPA 2025). As of 2018 three of the five warmest summers in the German speaking region were measured after the year 2000, with the record, up to this day, being set in 2003. Meanwhile the five coldest summers were recorded exclusively prior to the 1920s, the record stemming from 1816, the famous year without summer, due to the volcanic eruption of Mount Tambora (Börngen and Deutsch 2018). It was discovered that there has been an increase in warm extremes in the period from 1976 to 1999 and from the 90s onwards almost every summer has been above average, when comparing to the reference period 1961 – 1990 (Brugger et al. 2025; Klein Tank and Können 2003).

With all of this, it is in our interest to learn about the consequences such extreme climate conditions can have on human health. This can be done by looking at modern heatwaves, as it has been done by several studies (Arbuthnott and Hajat 2017; Brugger et al. 2025; Gasparrini et al. 2012; Koppe et al. 2003; Luschkova et al. 2021), but it can also be interesting to look back in time. At times where extreme heat events weren't as common as they are now. One such year in Europe and North America was the year of 1911, a record-breaking year at the time, that is still regarded as one of the driest years ever recorded (Billwiller 1911; Börngen and Deutsch 2018).

1.1 Motivation and Objectives

1.1.1 Research Gap

There have been a few studies looking at the heatwave of 1911, or other historic heatwaves, and its consequences on human health, like for example Rutten (2012) who looked at the mortality in the Dutch province of Limburg, Rollet (2010) who wrote about the consequences in France or Vögele (2010) who looked at the infant mortality in Germany. But the initial literature review has shown two research gaps that this thesis attempts to fill:

1. There has been no study looking at the impact of historic heatwaves in Switzerland.
2. There has been no study looking at the impact of historic heatwaves from a geographical perspective.

To fill these gaps, this thesis attempts to investigate the heatwave in 1911 by comparing its impact on the situation in 1909 and 1910 respectively. The only criteria for the other years looked at, were that they had a minimal temporal distance to 1911 and that they did not have a notable heatwave period during the summer months. All the surrounding years fulfilled these criteria. The decision to choose 1909 and 1910 and not, for example, 1912 was made randomly.

Regarding the first research gap, Zurich has been selected as the city of interest to examine the situation in Switzerland, primarily due to its status as a major Swiss city, which ensures a larger sample size. Moreover, urban areas typically experience higher temperatures than their surrounding regions, amplifying the heatwave's effects (Gehrig et al. 2018).

1.1.2 Research Objectives and Research Question

My thesis follows three objectives. The first objective is to analyse the situation in the respective year, with the help of both maps and other graphics and statistics.

The second objective is to look at the situation in Zurich and compare it to the findings in the literature.

And lastly, the third objective of this thesis is the digitization of the dataset. The death registry consists of several books full of handwritten records of people who lost their lives in the city of Zurich. The plan is to digitize the data for the years of interest and to geocode them for the use in GIS.

The goal is to answer the main research question, based on the data from the death registry of the city of Zurich (Stadtarchiv Zürich 1911):

What impact did the 1911 heatwave have on the mortality within the city of Zurich and how was it influenced by the geographic conditions?

To help answering this main research question, four additional questions were formulated, that should help answering the main research question:

1. What groups of people were especially affected by the heatwave?
2. Which causes of death did increase during the heatwave?
3. Were there areas that were more affected?
4. Did the proximity to green spaces or water areas have an influence?

These questions shall be answered from two perspectives. On one hand through a spatial analysis, to introduce the geographic perspective into historic heatwave research and on the other hand through a statistical analysis to compare the findings to past research.

2 Background

2.1 Heatwave Definition

First of all, the term heatwave should be defined, which is not easy, as there is not one universal definition of what a heatwave is, as almost every country has its own definition (Kent et al. 2014; Stocker 2018). Some definitions include just information about the temperature, while others do also include other factors, as for example humidity or wind speed (Kent et al. 2014). One problem with a general definition is that it needs to pay attention to local conditions. As described by Koppe et al. (2003): A general threshold would be reached to often in warmer climates and would potentially never be reached in colder climates.

2.1.1 Definition by SwissMeteo

As this Thesis looks at the situation in Zurich, it is especially important to look at the local definition used in Switzerland. Switzerland introduced its own heat warning system in 2004, as a consequence of the extremely hot summer in 2003 (Burgstall et al. 2021). The current warning system, which is in use since 2021 has three warning levels, that are based on the daily mean temperatures (Figure 1).

Level 2, the lowest warning level, means that the temperatures will be 25°C or more on one to two days. Level 3 means the daily mean temperatures will be 25°C or more on at least three days, while level 4 means that temperature will be 27°C or more on at least three days. Since 2021 SwissMeteo uses the term heatwave, when the criteria for warning level 3 are reached (Burgstall et al. 2021; MeteoSchweiz 2023).

	Stufe 2	**Stufe 3**	**Stufe 4**
Mittlere Tagestemperatur	≥ 25 Grad an 1-2 Ta-gen	≥ 25 Grad an mind. 3 Tagen	≥ 27 Grad an mind. 3 Tagen

Figure 1: Warning levels by MeteoSchweiz for heat based on the daily mean temperature (source: MeteoSchweiz 2023).

But it could also be interesting to look how this system exactly works, for this it is important to check on what it is based on. According to Burgstall et al. (2021) the current warning system is based on mortality data in Switzerland from 2003 to 2016. A daily mean temperature of 25°C increases the mortality rate by 18% on average in comparison to the approximate Swiss optimal temperature of 17°C, while a daily mean temperature of 27°C leads to an increase of 37% in comparison to the optimal temperature. The optimal temperature is defined as the temperature where the temperature-based mortality is at a minimum (Ragettli et al. 2024).

While the fact that the warning system is based on mortality rates might be good for the scope of this thesis, there are several arguments to assume lower thresholds for 1911:

First, the optimal temperature, like most other temperature measures, has risen since 1911. While there is no data for the year 1911, it used to be around 16°C in the 80's and has risen to around 18°C in recent years (Ragettli et al. 2024). Considering these developments, it would be plausible to assume a lower threshold for 1911. Furthermore, the technology has improved since. Though first technologies to keep fresh food cool and to lower the indoor temperature were already invented, these technologies were not yet common in private households around 1911 (Freidberg 2010; Simha 2012). Lastly, medical knowledge has much improved. In 1911 the assumption that bad milk could be the cause was discussed in the paper by Abt (1911), but at the time it was thought to be unlikely, while later studies have confirmed it as the cause.

2.1.2 Heat Day, Summer Day and Most Intensive Ten-Day Period

Another metric used by MeteoSchweiz that can be used for this thesis is the so called Hitzetag (heat day). When the temperature maximum reaches the threshold of 30°C, the day is recorded as such a heat day (MeteoSchweiz n.d.b). In this regard, it is interesting to have a look at a graphic created by Burgstall et al. (2021). Figure 2 depicts the most intensive ten-day period per year. This period is defined as the period with the highest average maximum temperature of the respective year. For this they chose the warmest ten-day period per year from the start of the measurements until 2018 and calculated the mean of the daily maximum temperatures. With this method 1911 was found to have had the 5th most intense 10-day heat period in Zurich. Figure 3, another graphic created by MeteoSchweiz (n.d.c) shows the number of summer days (where maximum temperature is 25°C or higher) per year in Zurich and makes also visible how extraordinary the year 1911 has been, as the number of summer days has not been surpassed until 2003.

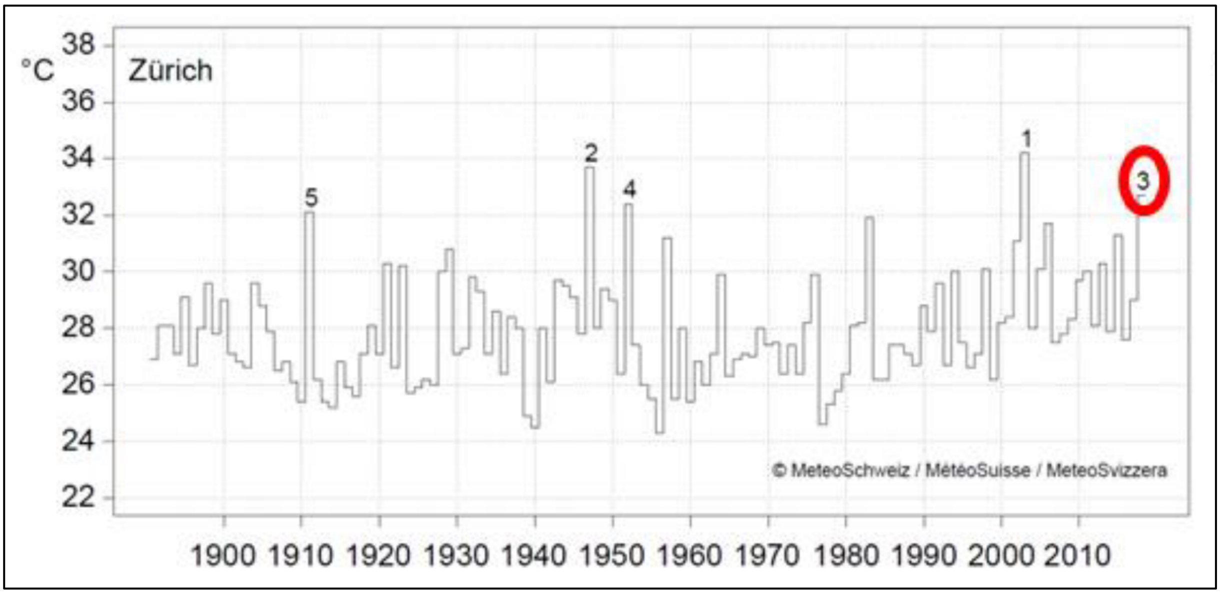


Figure 2: Plot for the station in Zurich / Fluntern showing the average temperature of the most intense ten-day-heat period of each year. The numbers on top of the bars mark the five most intense summers (source: Burgstall et al. 2021).

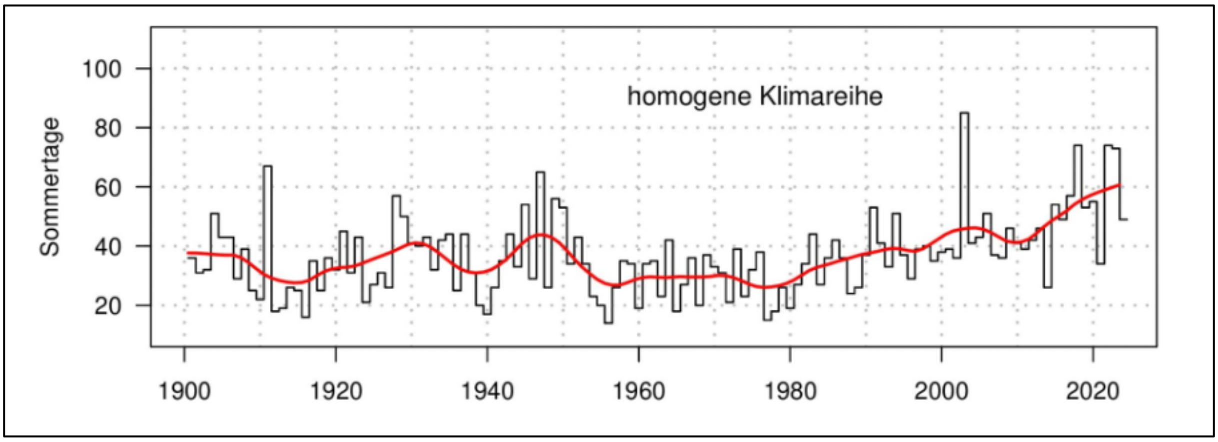


Figure 3: Number of summer days, where the maximum temperature has risen above 30°C (source: MeteoSchweiz n.d.c).

As explained before, the definition used by SwissMeteo has a limited adaptability to the conditions around 1911. For the other metrics, while they can be used to show how extraordinary the year 1911 has been, they do not provide a complete definition. Therefore, it might be interesting to look at a more adaptable definition.

2.1.3 Heatwave Definition by the World Meteorological Organization

The heatwave definition of the World Meteorological Organization is also based on the daily maximum temperature, but they define it as a heatwave, when the daily maximum temperature surpasses the average maximum temperature by 5°C or more on five or more consecutive days (Rafferty 2025). Average temperature is usually defined by a 30-year norm period, the most recent being the period 1991 to 2020 (MeteoSchweiz n.d.e). But as previously mentioned, there is again the problem with climate change. Leaving the norm period as is, would make the climate change more visible, but it would be less suitable to look at a historic weather event. As an example, in 2022 the Met Office in the UK has updated their official heatwave threshold by switching to the norm period 1991 to 2020, which for some counties led to an increase of the threshold by 1°C (McCarthy 2022). Why this was necessary can be seen in Figure 4, which shows how the average number of heatwave days per year increased based on different thresholds.

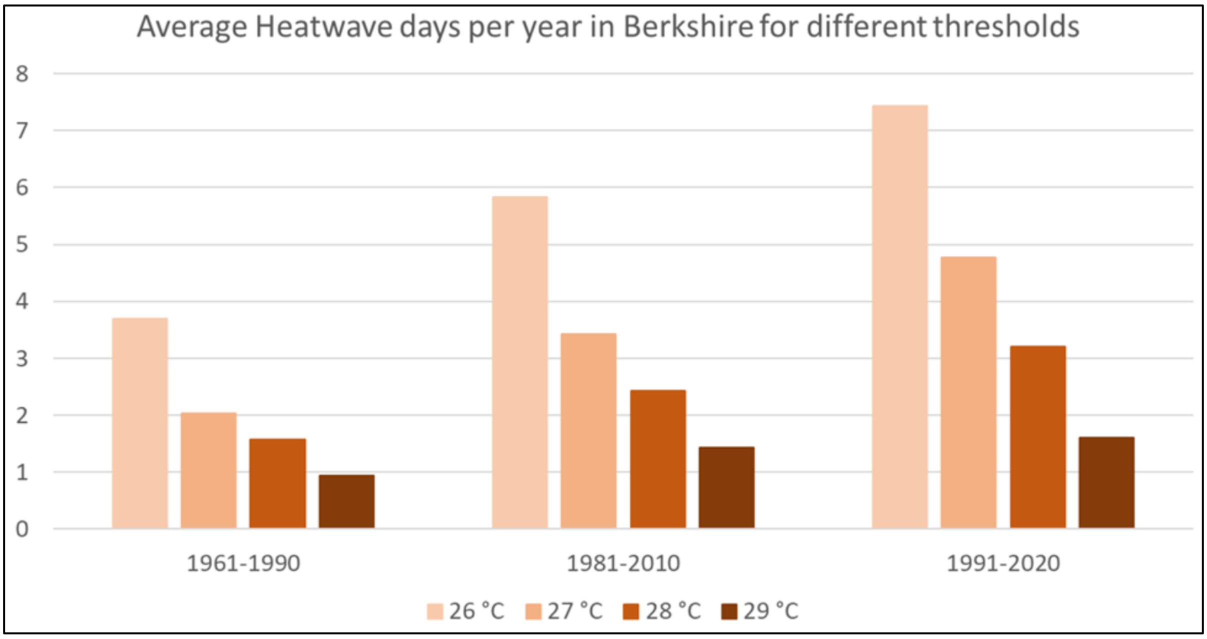


Figure 4: Plot from the county of Berkshire in the UK, showing how the average number of heatwave days per year has increased throughout different norm periods, based on different thresholds (source: McCarthy 2022).

To use the definition by the World Meteorological Organization this thesis therefore needs its own norm period, as the threshold of the modern norm periods would possibly be too high. For this norm period I'll use the average maximum temperatures in July, how it was also done by the UK Met Office (McCarthy 2022). The reason for this is, that July usually is the warmest month of the year (MeteoSchweiz n.d.d). The norm period for this thesis will last from 1881 to 1910, though it will only cover the measurements of 28 years, as there is no maximum temperature data from Zurich prior to September 1st 1881 and because the maximum temperature data for the year 1890 is missing. This should not be a problem, as the guidelines by the WMO state that the minimum years available for calculating the norm should be 80% (24 years) (WMO 2017).

This leads us with a mean maximum temperature of 23.02°C for the month of July in the norm period 1881 to 1910 for the station Zürich / Fluntern. Figure 5 shows that this threshold has been reached multiple times in 1911. Twice it lasted five days or longer: First during a 16-day period from July 19th to August 3rd and then after a break of one day during an 11-day period from August 5th to August 15th. In 1909 and 1910 on the other hand the threshold was only reached on three and two days respectively.

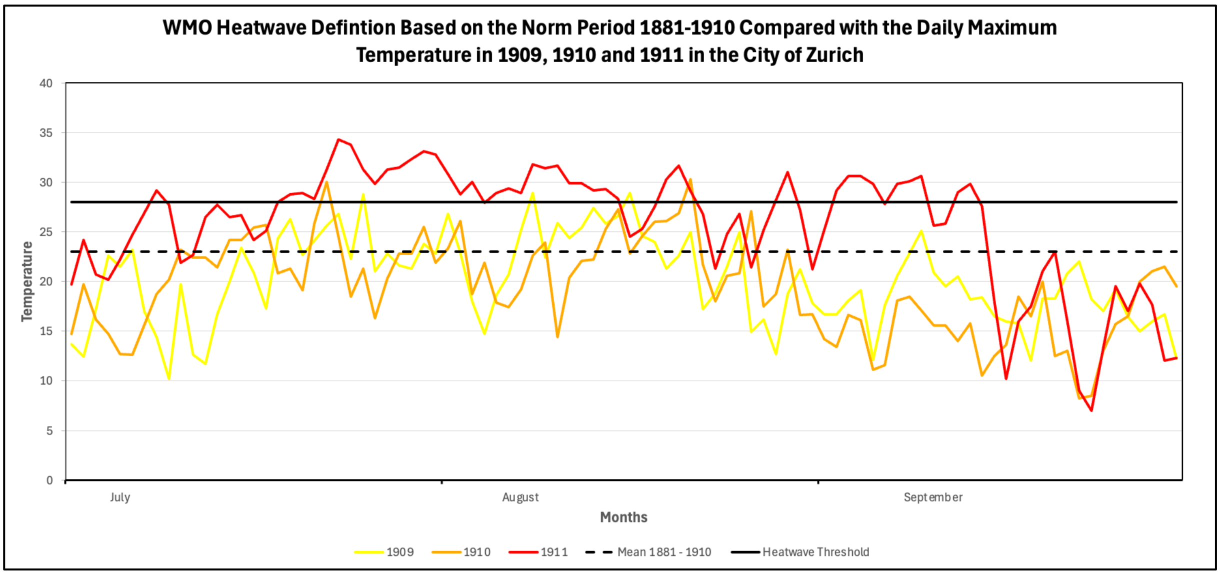


Figure 5: Plot showing the daily maximum temperatures in comparison with the threshold calculated according to the WMO heatwave definition (data source: MeteoSchweiz n.d.a).

2.2 Heat Islands

Looking at heatwaves, one thing to mention are the so-called heat islands. Temperatures are often higher in urban areas than in rural areas (Gehrig et al. 2018). As it can be seen in Figure 6, which shows the difference in temperature between a more urban measurement station at Zurich-Stampfenbachstrasse and a more rural station in Zurich-Affoltern. The difference is usually present throughout the day, but it is highest during the night. Now it is interesting for the thesis, to look at where these islands are located in Zurich. Sadly, there is no dataset about urban heat islands in Zurich in 1911, but there is a dataset from 2018 (Geoinformation Kanton Zürich 2018). Because the city has grown between 1911 and 2018, this is not very accurate, but as it can be seen in

Figure 7 areas in the city centre are mostly coloured in purple or black, which means they were already built-up areas in 1911, so it can be assumed that some sort of heat island effect was present in these parts of the city.

Figure 8 shows that most of the modern heat islands are located in exactly that area, in district 1, the eastern parts of district 3 and the northern parts of district 2.

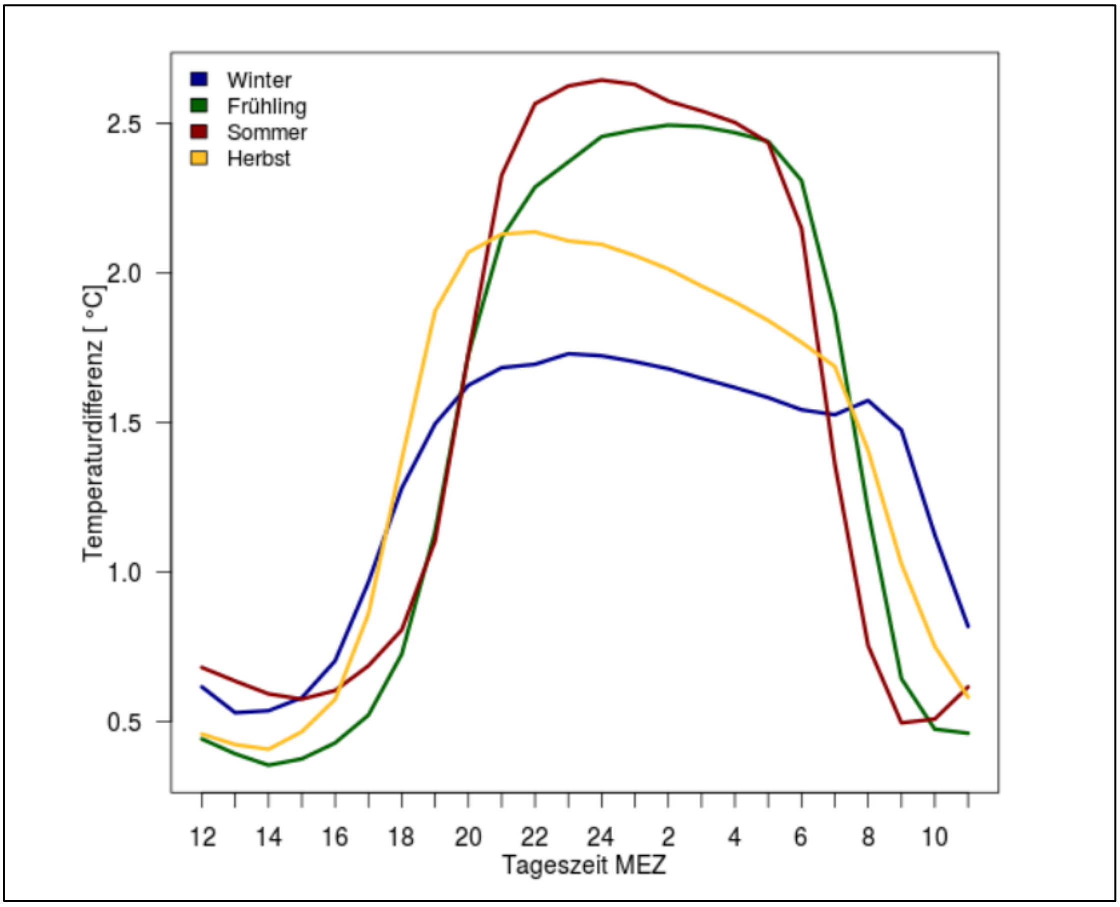


Figure 6: Temperature difference between urban and rural areas in Zurich with data from 2004 to 2016 (source: Gehrig et al. 2018).

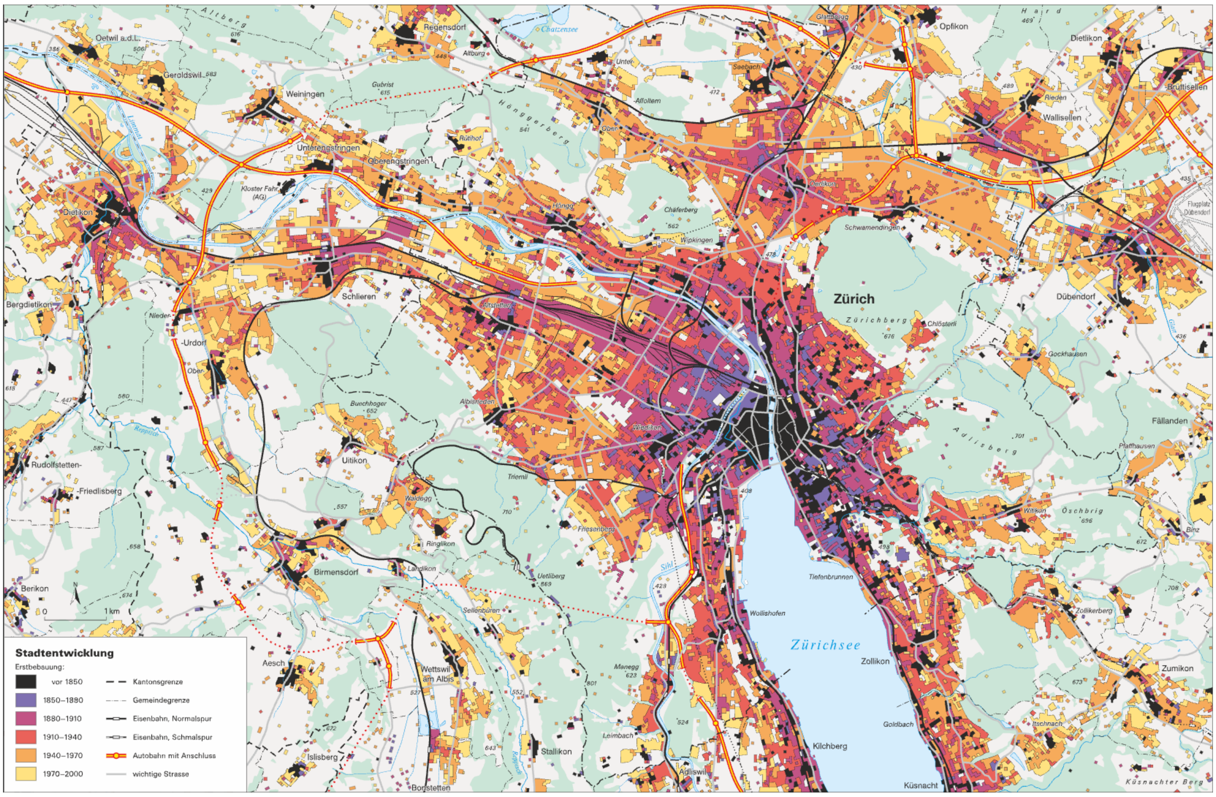


Figure 7: Development of urban area in Zurich (source: (Brodbeck and Hermann 2012))

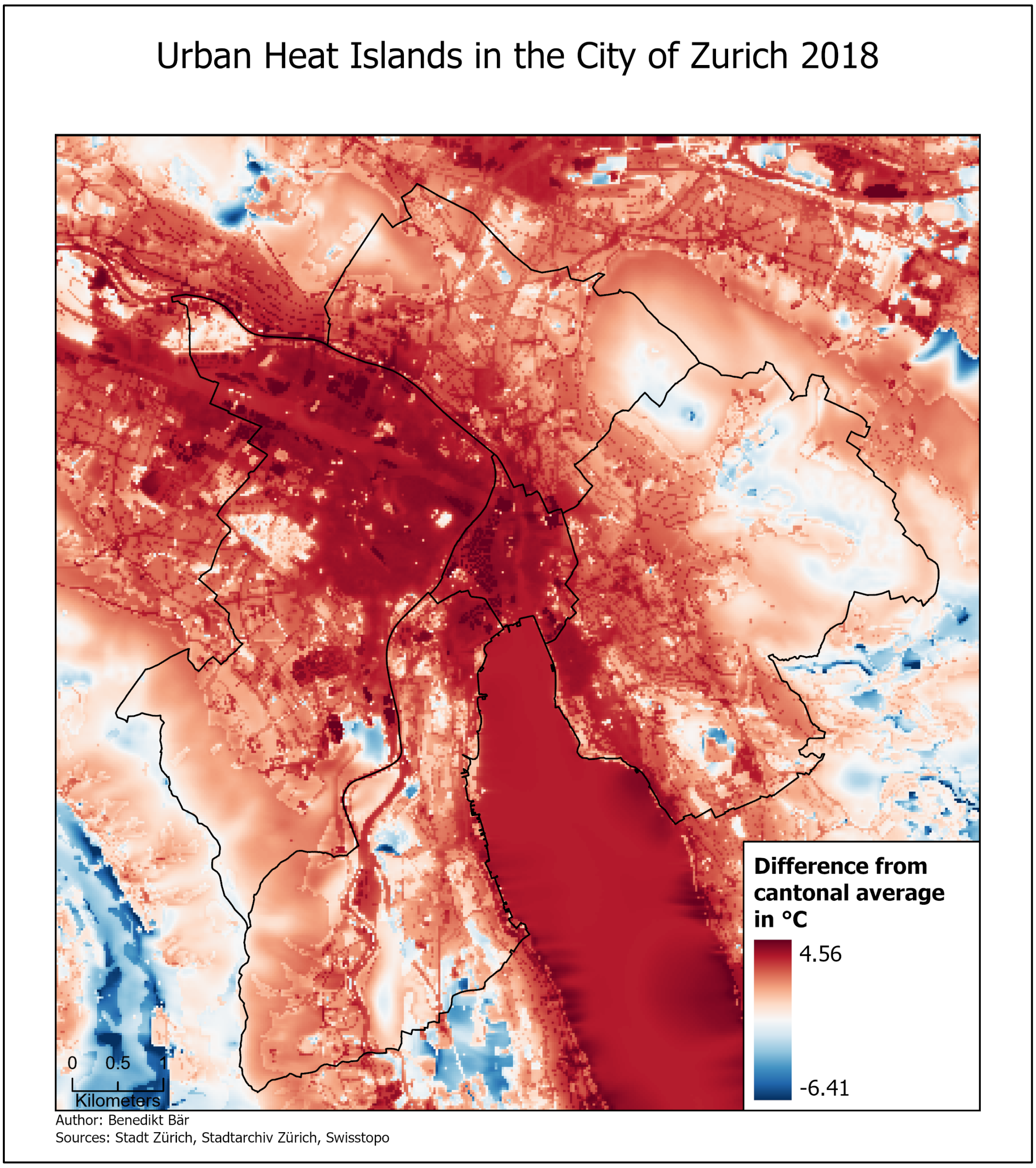


Figure 8: Heat islands in Zurich. Blue areas are colder than the cantonal average, red areas are warmer (data source: Geoinformation Kanton Zürich (2018).

2.3 Health Impacts of Heatwaves

But what do extreme temperatures mean for the human body? Koppe et al. (2003: 152 (translated from German)) writes in his paper, that *"a human is tightly connected to the atmospheric environment through his heat balance"*. A healthy human should be able to adapt to different conditions, but under extreme conditions there is an increased pressure on important systems, such as the cardio-vascular system or the respiratory system. How a human perceives temperature depends not only on the current air temperature, but also on various other factors, such as the wind, the humidity and the radiation, furthermore, it can be influenced by for example clothing. Due to this Koppe et al. (2003) uses perceived temperatures. The perceived temperature is defined as the temperature a human would feel, when he walks with a constant 4km/h, in the shadow, with no wind and a humidity of 50%, while wearing clothing adapted to the respective temperature (from typical central European winter clothing in winter to typical summer clothing in summer). In Table 1 it can be seen how certain perceived temperatures are perceived according to Koppe et al. (2003) and how much pressure the respective perceived temperature put on the human body.

Table 1: Table showing the heat stress level and thermal perception for certain perceived temperatures. It shows that the heat stress level rises, with increasing temperatures (source: Koppe 2003, for this Thesis temperatures below 0 were not included).

Perceived temperature	Thermal perception	Heat stress level
≥38°C	very hot	extreme
≥32°C and <38°C	hot	strong
≥26°C and <32°C	warm	moderate
≥20°C and <26°C	slightly warm	low
≥0°C and <20°C	comfortable	none

There has been a decent amount of research looking at impact of extreme summer temperatures on human health in the 21st century. Past studies have either looked at specific summers with extreme temperature (an der Heiden et al. 2019; Heudorf and Meyer 2005; Koppe et al. 2003; Ragettli et al. 2024) or at a longer time frame (Arbuthnott and Hajat 2017; Brugger et al. 2025; Gasparrini et al. 2012; Luschkova et al. 2021). All the studies came to similar conclusions.

Gasparrini et al. (2012) looked at the situation in England and Wales during the summers (defined as June to September) of 1993 to 2006. Their research came to the conclusion that rising temperature led to an increase in mortality no matter the cause. The main cause was found to be cardiovascular causes, followed by problems with the respiratory system. The latter was found to have the steepest increase in the mortality rate with rising temperatures. In general, they discovered that in England and Wales 1% of all deaths during the summer months can be attributed to temperature. Furthermore, they state, that the effect of heat increases by age.

The higher risk for elderly people has also shown in other studies, such as Arbuthnott and Hajat (2017), Heudorf and Meyer (2005) or Luschkova et al. (2021). Heudorf and Meyer (2005) states for Frankfurt am Main a 2.9 times increase for the mortality of people over 90 years of age in August 2003 compared to previous months, while there was no increase in mortality for adults below 60 years of age. Luschkova et al. (2021) looked in general at consequences of the ongoing climate change and they state that the heat-related mortality for people in the age group 65+ has increased by 53.7% between 2000 and 2018. Arbuthnott and Hajat (2017) on the other hand looked at the effect of heat on health in the UK. They found that in the UK women are more at-risk during heatwaves and that there is no consistent connection between heat related mortality and the socio-economic status. But for both, they mentioned, that this might differ between different countries. An example would be the findings by Schwartz (2005) that non-whites are at a greater risks in the US. As non-whites tend to have a lower socio-economic status in the US (American Psychological Association 2017), this is likely to be caused by the socio-economic status.

But what about the previously mentioned gastrointestinal diseases among infants?

Nowadays such increases are barely mentioned. While some mention an increased risk for children (Brugger et al. 2025), others do not mention them as a group at increased risk (Arbuthnott and Hajat 2017). A comparison of different papers looking at child mortality during heatwaves, performed by Xu et al. (2014), with the goal to find out whether there is an increased risk for children, was not able to find a definitive answer to the question. While some papers found a significant increase, others did not. Finally, Xu et al. (2014: 246) conclude that *“Reasearch provides evidence that children are more likely to be associated with heat-related morbidity”*, especially the youngest. Wu et al. (2014) also cite Rollet (2010) about the heatwave 1911 in France, which found that from 40’000 deaths associated with the heatwave, 29’000 were children.

And various studies looking at the 1911 or other hot summers at the time show similar results. Vögele (2010) mentions that the cold summer of 1902 has a low infant mortality, while the hot summer in 1911 had a high infant mortality. Vögele noticed a clear increase of infant deaths as it can be seen in Figure 9 created by Vögele (2010) showing age specific deaths in the Düsseldorf area. While the data from 1911 does not really show an increase of deaths for elderly people in Düsseldorf, there is a clear spike in infant deaths. He was able to make similar findings in Bavaria, as can be seen in Table 2. There, compared to 1910, the number of infant deaths in the summer months 1911 rose by up to 68.8%.

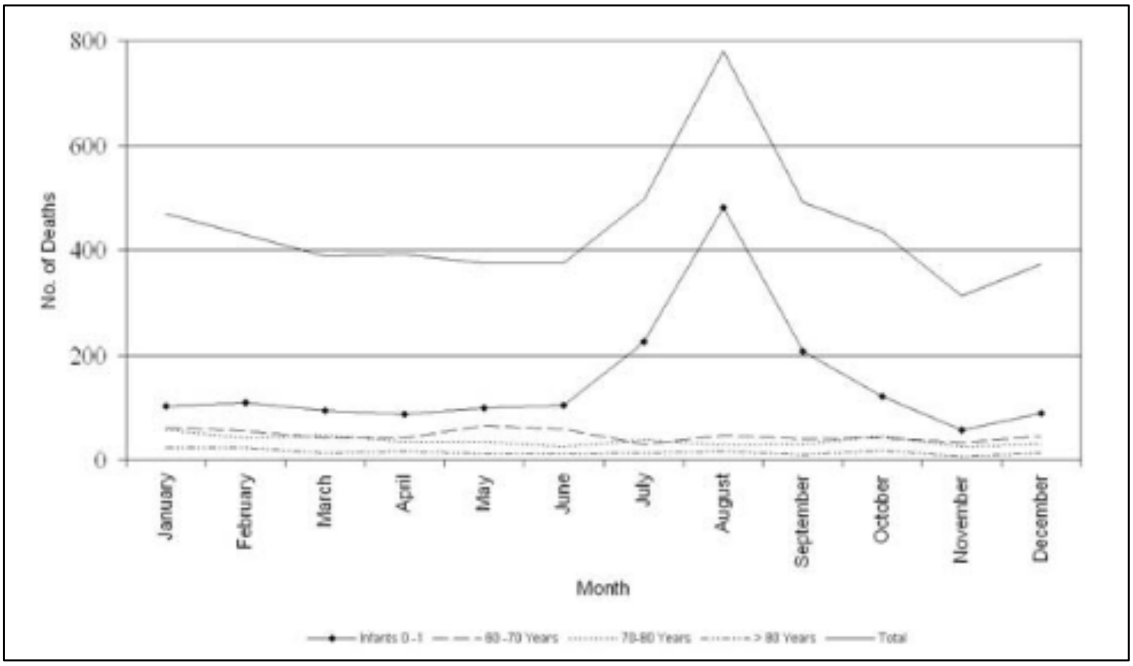


Figure 9: Plot from Düsseldorf (Germany) depicting how the number of deaths has changed during the year 1911, showing a notable rise of infant deaths during the summer months (source: Vögele 2010).

Table 2: Table showing the increase in infant deaths in Bavaria during the summer of 1911 compared to the summer of 1910 (source: Vögele 2010).

	1910	1911	Increase %
July	3749	4602	22.8
August	4222	6368	50.8
September	3646	6146	68.8

Abt (1911), Rollet (2010), Rutten (2012) and Vögele (2010) all mention milk as a possible origin of these gastro-intestinal diseases. Abt wrote in 1911 that the greatest death rate among infants occurred during summer and is caused by gastro-intestinal diseases (Abt 1911). At the time this was an epidemic of barely known origin. Rollet (2010) reports for example that at the time in France they assumed a possible connection to the foot-and-mouth disease. Rollet cites an inspector who wrote the following:

"[...] it's safe to assume that the milk of sick animals, which kills 50% of young calves, contains toxins that make it dangerous for feeding young children."
– Metton-Lepouzé, cited in Rollet (2010: 123), translated from French.

Nowadays it is known that the foot-and-mouth disease cannot be the reason behind the gastro-intestinal diseases. But why was milk suspected as the reason? The reason is, that mostly bottle-fed children were affected by gastro-intestinal diseases, while breast-fed children mostly stayed healthy. Rollet (2010) mentions that between August 14th and 27th 1898 550 children in Paris died from diarrhea, among those only 57 were not bottle-fed. Vögele (2010) has made this also visible in a graph based on the statistical yearbook of Berlin. Figure 10 shows the distribution of Infant mortality in Berlin 1908 based on whether they were breastfed or not and it shows that there is a peak in deaths among bottle-fed children during the summer months.

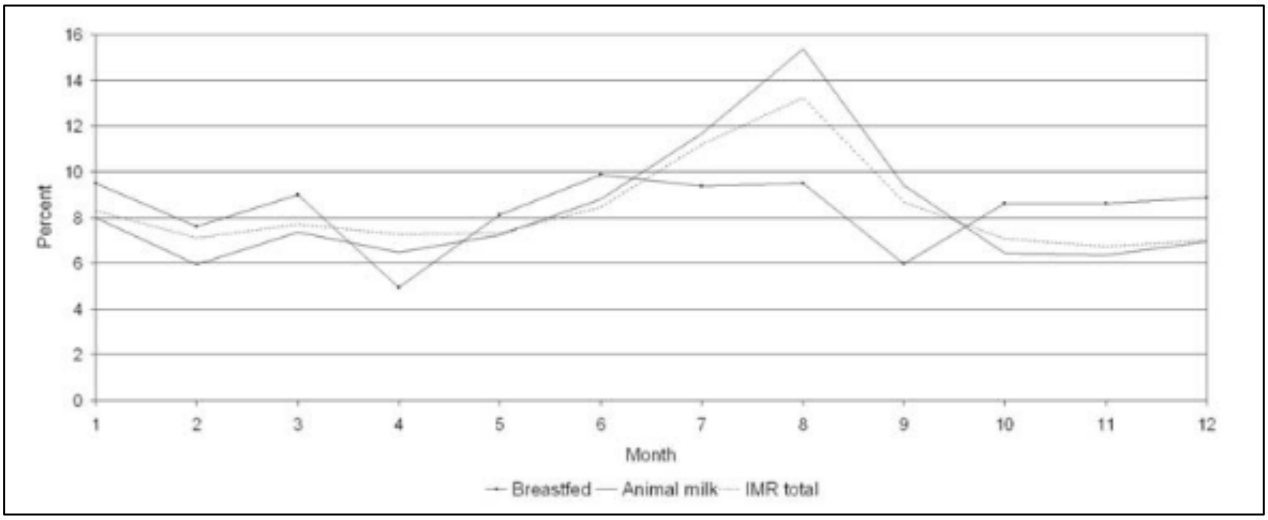


Figure 10: Plot depicting the infant deaths during the year 1908 in Berlin, comparing breastfed children with bottle fed children. It's visible that there has been a clear rise in deaths of bottle-fed infants (source: Vögele 2010).

In this regard 1911 was a turning point. As Rutten (2012) stated it was the last year with such an infant mortality in Limburg, as afterwards authorities started to campaign to eliminate bottle-feeding. Also, Rollet (2010) and Vögele (2010) mention campaigns against the use of cow milk in France and Germany respectively. Figure 11 shows an example of such a campaign in Germany.

Figure 11: Campaign poster to promote breastfeeding in Germany (source: Vögele 2010).

2.4 Homogenisation of climate data

Temperature values used for the analysis in this thesis might slightly differ from values mentioned in reports that were written at the time. The reason for this difference is the homogenization of climate data performed by MeteoSchweiz (Füllemann et al. 2011; MeteoSchweiz n.d.c). Homogenization makes it possible to compare climate data throughout the time as it can be clearly seen in Figure 12, which was made by MeteoSchweiz. In the unhomogenized climate series the years prior to 1970 the graph shows that there were more summer days than we have nowadays. A summer day is here defined as a day where the maximum temperature is at 25°C or higher. But why is this process needed? Throughout the time the way how the data was gathered has changed. Specifically for the Station in Zürich/Fluntern, which was used for this thesis, MeteoSchweiz (n.d. c) writes that on one hand it was moved by 80 meters in altitude in 1949 and they changed the type of weather station. Both changes lead to a lowering of the measured temperatures and made the measurements before and after the change not comparable.

This thesis generally uses homogenized data to make them comparable with today's data, if unhomogenized data is used, this will be mentioned.

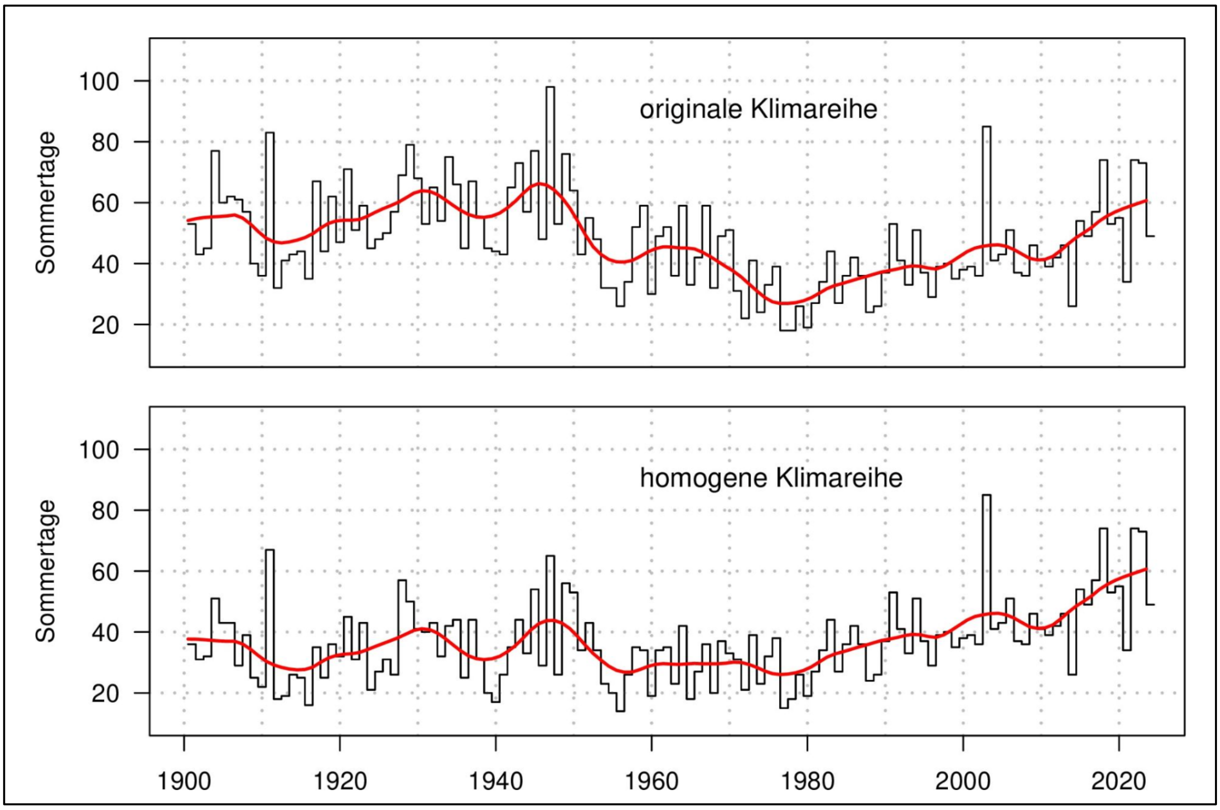


Figure 12: Comparison between homogenized and unhomogenized climate data. The top plot uses the originally measured data, while the bottom plot depicts the homogenized data (source: MeteoSchweiz n.d.c).

2.4 Weather History

2.4.1 The Summer of 1911

For this thesis Summer is defined as the months July, August and September, the reason for this is that the heatwave lasted from early July to mid-September (Billwiller 1911). This can also be seen when looking at Figure 13. From July to mid-September the mean temperatures in 1911 have been consistently higher than the temperatures in 1909 and 1910, except for some temperature peaks in 1910. Similar observations can be made when looking at Figure 14 and Figure 15 depicting the temperatures at 1am and 1pm respectively (for the rest of these thesis, these will usually be called minimum and maximum temperatures, respectively).

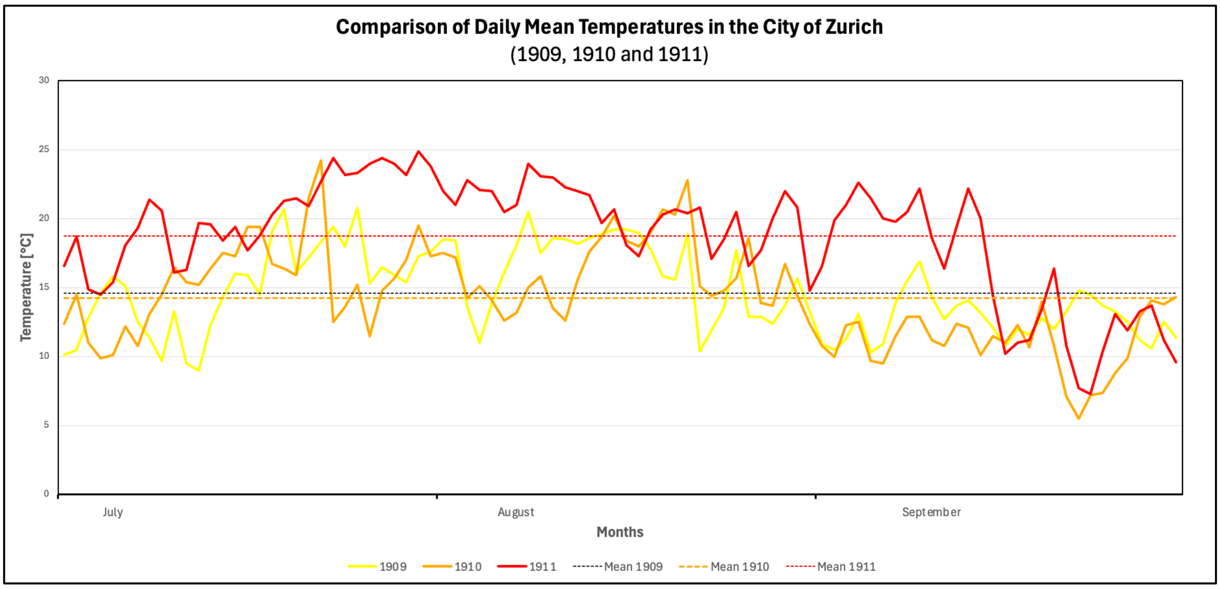


Figure 13: Comparison of the daily mean temperatures during the summer months from 1909 to 1911 (data source: MeteoSchweiz n.d.a).

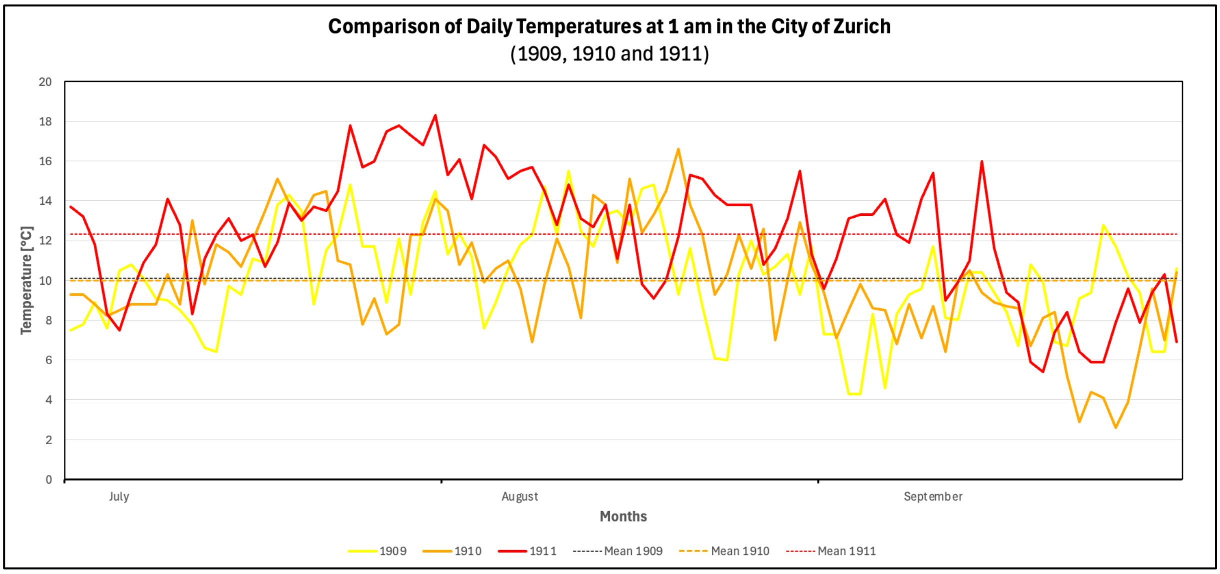


Figure 14: Comparison of daily temperatures at 1am (minimum temperature) during the summer months from 1909 to 1911 (data source: MeteoSchweiz n.d.a).

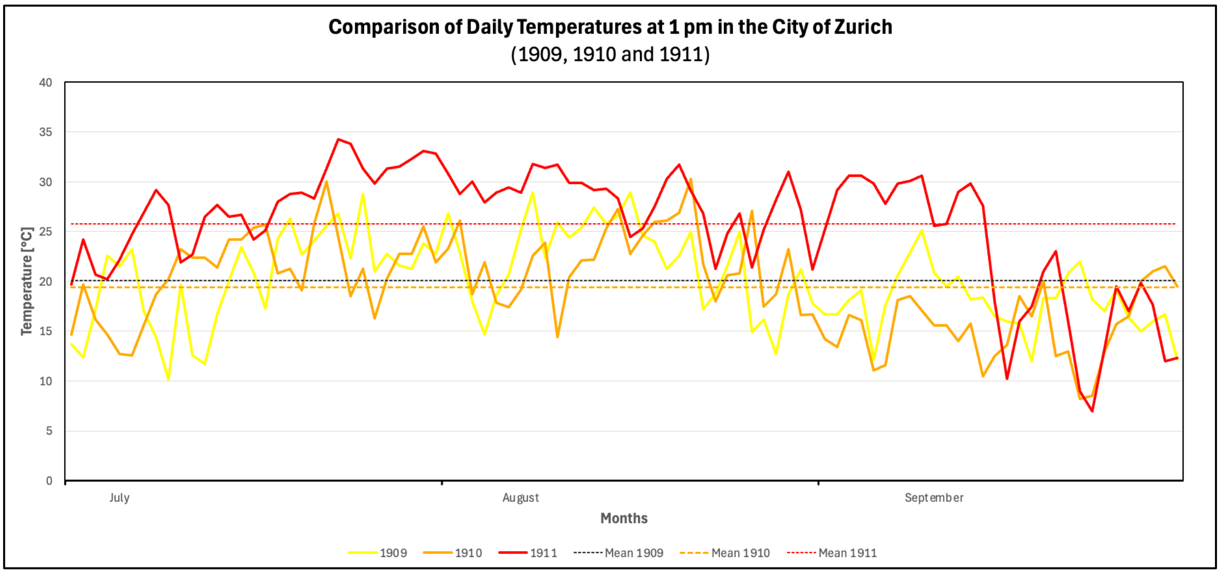


Figure 15: Comparison of daily temperatures at 1pm (maximum temperature) during the summer months from 1909 to 1911 (data source: MeteoSchweiz n.d.a).

Back in 1911, Billwiler (1911: 4) wrote that *"August 1911 was 1.5 times warmer than the next warmest August (1899) of the official observation series"* and that there had not been a single rainy day in Switzerland during 2.5 months between June 28th and September 14th. The only precipitation during this period in Switzerland came from smaller local thunderstorms (Billwiller 1911).

"Very warm, very dry and exceptionally bright"
– Translated from Billwiller (1911: 3)

That's how Billwiler (1911) described the month of July 1911. After an unexceptional June, July was a month that was one of the warmest, driest and brightest since the start of the meteorological records in Switzerland. Looking at the sunshine duration (Figure 16) the monthly average was around 200 minutes per day longer, than the respective average in the two previous years. The month started with some precipitation, due to a low-pressure area over northern Europe, though the precipitation was mostly limited to some mountain valleys, but starting on the 4th Switzerland came under the influence of a high-pressure area, which lasted for the rest of the month. This led to a first temporary temperature peak on the 8th and 9th, before an increase of pressure over the British Isles and a simultaneous decrease of pressure in the south-east of the continent lead to a little cooling in Switzerland, due to a northerly wind.

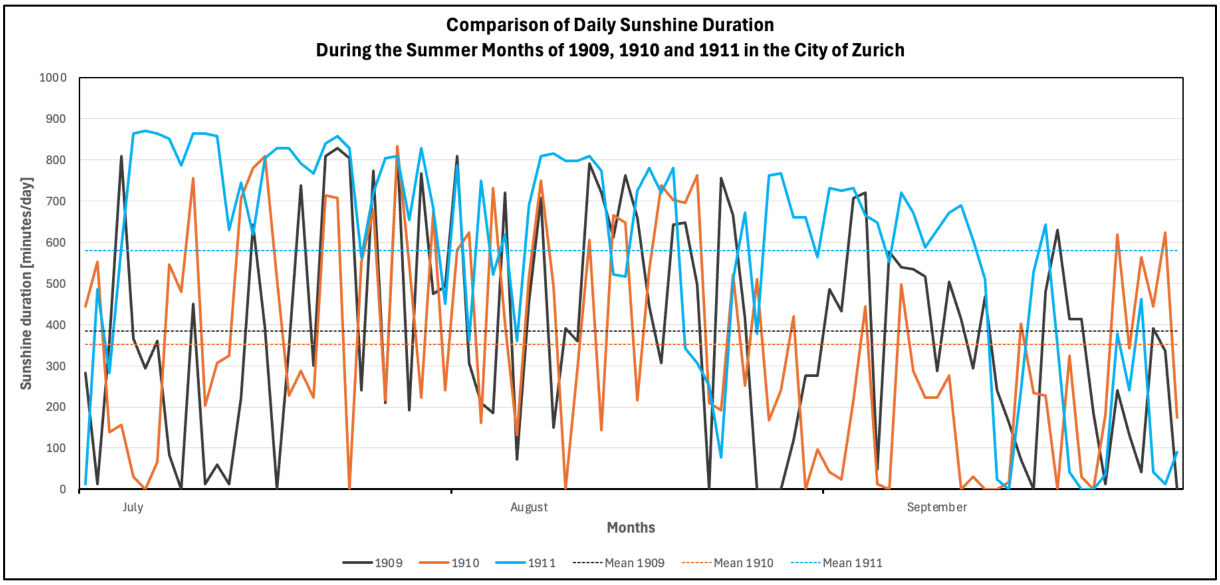


Figure 16: Plot showing the daily sunshine duration during the summer months of 1909, 1910 and 1911 in the City of Zurich (data source: MeteoSchweiz n.d.a).

During the first few days of July, most news articles at the time were about heat events in North America and Russia (Burgdorfer Tagblatt 1911; Neue Zürcher Nachrichten 1911a; Walliser Bote 1911). On July 8th the Neue Zürcher Nachrichten (1911b) reported that the heatwave has now also reached the UK and on July 11th the same newspaper reported about extreme temperatures in France (Neue Zürcher Nachrichten 1911d).

In the following days, as the pressure gradients decreased according to Billwiler (1911), some minor thunderstorms in the afternoons between the 13th and the 16th led to some precipitation on a local level. Back in 1911, Billwiler (1911) reported that from July 19th until the end of the month every day reached temperatures above 30°C in Zurich (prior to data homogenization).

Reports from this time about the temperatures were mostly quite positive towards the high temperatures, as for example on July 20th:

"As a result of the persistent intense heat, the drought is already making itself felt here and there; the farmers, however, are very happy with this wonderful summer weather, as experience has shown that the hot years are not among the worst."
– Translated from (Neue Zürcher Zeitung 1911a)

As already visible in above quote, the much bigger topic at the time seems to have been the drought. In a weather report from July 22nd the Neue Zürcher Zeitung wrote:

"Normally, on average, every second day of July is a rainy day; this year, the situation simply throws all statistics out of the window, because we have been counting the raindrops on our fingers for two weeks; there are none."
– Translated from Neue Zürcher Zeitung 1911b)

According to Billwiler (1911), the only day with a notable rainfall event during this period was the 24th of July.

August started how July ended, with temperatures quite consistently over the 30°C mark. Around the 6th, a low-pressure area coming from the north-west lead to a cloud cover over Switzerland and light rainfalls were recorded throughout the country. But this was only short-lived, as another high-pressure area moved over Central Europe and lead to another series of sunny days with temperatures consistently above average (Billwiler 1911). In August, the heat also had further consequences. According to the (Neue Zürcher Nachrichten 1911e) the canton of Lucerne ordered that schools should at least stop teaching in the afternoon and if it is deemed necessary, they should close the school entirely until the heat is over. It is also reported that the Swiss federal bank in Zurich closed its offices from 12:00 until 15:00 due to the heat (Neue Zürcher Nachrichten 1911f).

Around the 16th and 17th, a high-pressure area in the north-west and a low-pressure area in the North-East caused northerly winds in Switzerland leading to slightly lower temperatures. The general weather conditions changed after the 20th, as a low-pressure area moved over Central Europe and brought a more consistent cloud cover with it, which also lead to more, though still mostly minor, thunderstorms. August 31st was the only day of the month on which temperatures fell slightly below the multi-year average (Billwiller 1911).

A stable high-pressure area led to a dry, warm and bright start of the month of September. On nine out of the first 13 days of the month temperatures rose above 30°C, according to the non-homogenized data from Billwiller (1911), and no notable rain fall events were recorded during this time. When looking at the homogenized data (MeteoSchweiz n.d.a) the threshold of 30°C was only reached on five days, but the daily temperature around 1pm remained above 25°C for the first 14 days of the month.

"And the heat and humidity is always almost the same as in July and August"
– Translated from (Der Freisinnige 1911)

On September 14th, low-pressure area forming in the North put an end to the warm and dry summer, bringing rain and cooling down of temperatures.

"The season of our new open swimming pool is coming to an end. The number of visitors has decreased somewhat recently: Firstly, because the heat has become more bearable and secondly because it only takes a small downpour to immediately reduce the crowds."
– Translated from (Neue Zürcher Nachrichten 1911c)

2.4.2 The Summer 1911 Compared to 1909 and 1910

The summer of 1911 was quite exceptional at the time. Since the start of the official records in 1864, it was considered the fourth warmest July in Zurich, nationwide it was the warmest August on record, and even though the heatwave ended mid-September, the month of September was still above average (Billwiller 1911), when looking at the surrounding years. In Figure 17 the summer of 1911 was the only year that reached an average temperature above 18°C.

In comparison, the year 1910 was quite different to 1911. As it is visible in Figure 17, it was on average one of the colder years at the time, though it was not exceptionally cold. But where it differed the most, was in the precipitation (Billwiller 1910).

"The year 1910 will always remain memorable in the weather history of our country with regard to the rainfall regime."
– Translated from Billwiller (1910: 11)

With this sentence, Billwiller started his report in the *Annalen der Schweizerischen Meteorologischen Zentral-Anstalt 1910*. His findings can also be validated in the historical data from MeteoSchweiz. With 1400mm of precipitation throughout the entire year, 1910 was the year with the highest amount of precipitation during the 11-year period from 1905 to 1915. And even though the most notable rainfall events occurred in January, June and November, and not during the summer months, it is still the year with the second highest summer precipitation during this time period, as it can be seen in Figure 18. This figure also shows once more how dry the year 1911 has been. With 728.3mm it had almost 200mm less precipitation than any other year during this time.

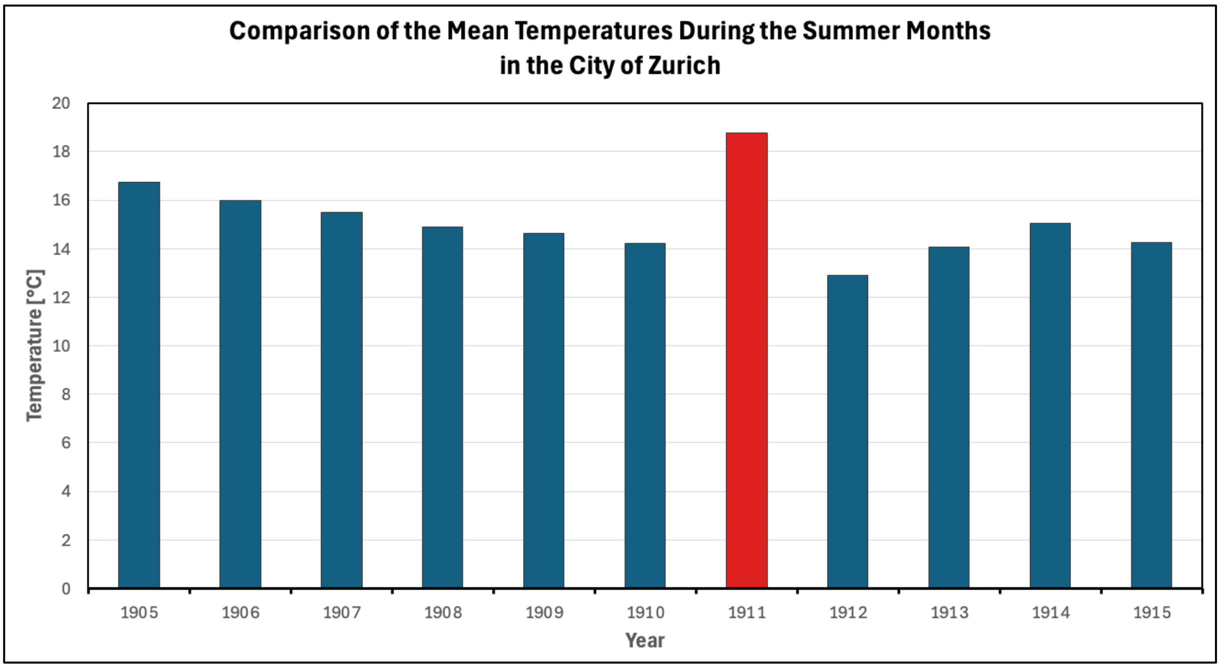


Figure 17: Comparison of the mean summer temperatures from 1905 to 1915. 1911 is marked in red (data source: MeteoSchweiz n.d.a).

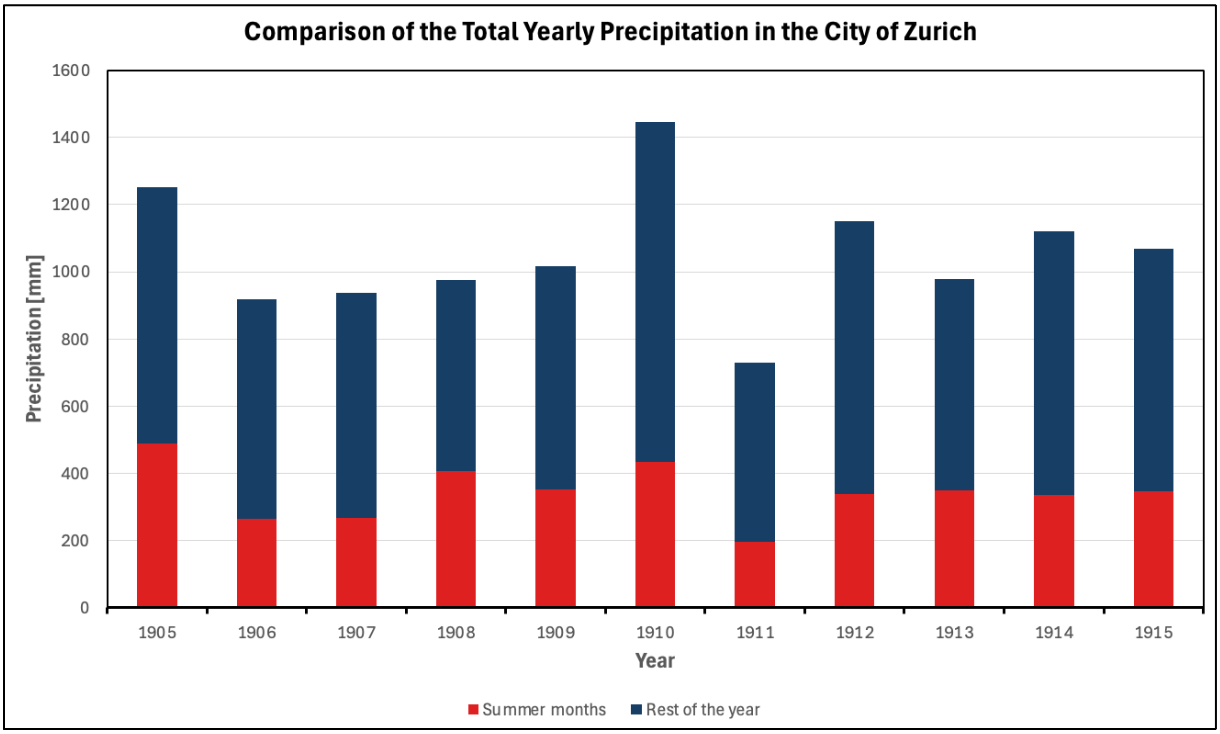


Figure 18: Comparison of the total yearly precipitation in the City of Zurich (data source: MeteoSchweiz n.d.a).

The summer of 1909 was a pretty average year, as comparisons with data (MeteoSchweiz n.d.a) from other years show. As can be seen in Figure 17 it was temperature-wise pretty similar to 1910 and Figure 18 and Figure 19 show that neither temperature nor precipitation during the summer months were especially noteworthy. Though it is to note, that the first three months of the year were extremely dry. (Billwiller 1909) wrote that the dry period started with an exceptionally dry October in 1908, where the precipitation corresponded only to 8% of the usual October precipitation, while there was more precipitation in the subsequent months, the amount was still below average up till March 1909, causing many lakes to reach historically low water levels.

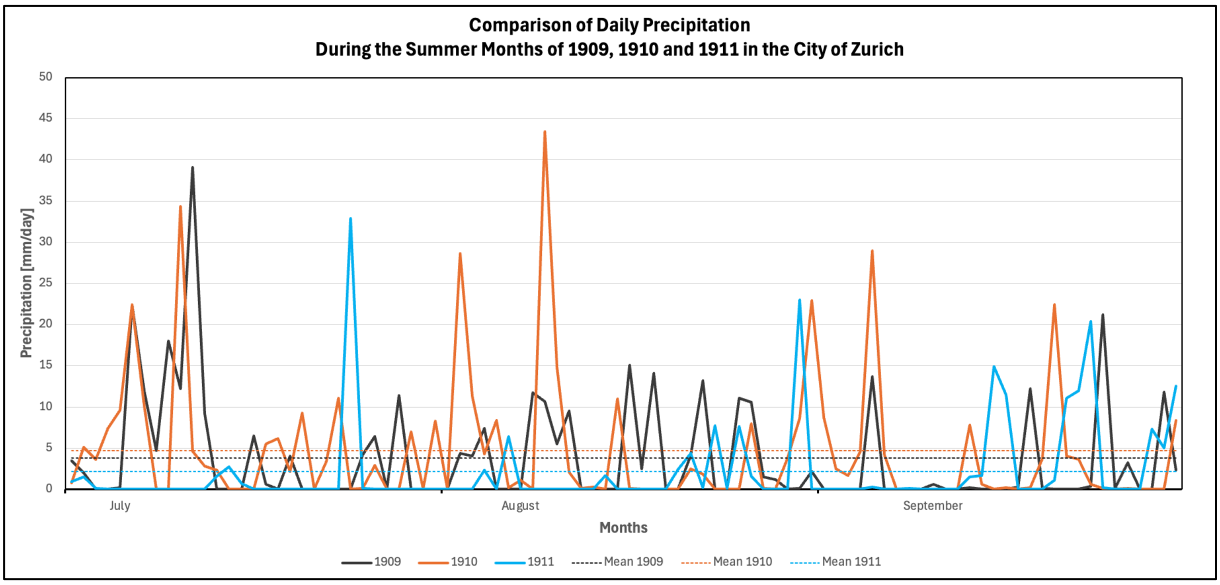


Figure 19: Daily precipitation during the summer months in 1909, 1910 and 1911 in the City of Zurich (data source: MeteoSchweiz n.d.a).

2.5 The City of Zurich

2.5.1 Population Growth During the 19th Century

Zurich changed a lot during the 19th century. In 1812 the city only had 9715 inhabitants, and its area only covered the later district 1. Up to this time these numbers did not change much for the past 300 years (Kurz 2022). As described by Kurz (2022) and as visible in the old city map by (Scheuermann and Breitinger 1847) (Figure 20), which shows Zurich around 1814, it was, at the time, constrained by its historic city walls. Those were torn down in 1833, following the new liberal constitution in 1831, to make room for a territorial expansion of the urban area (Behrens et al. 2015; Kurz 2022). By the middle of the 19th century the population of Zurich had almost doubled, reaching 17'040 in 1850. The construction of the railway in 1847 and the foundation of the Schweizerische Kreditanstalt in 1856 helped the city to become an important transport hub, as well as a centre for both, industry and banking, and led to a further growth of the city (Behrens et al. 2015; Kurz 2022). Until 1888 the city grew to 27'644 inhabitants, almost three times more than at the beginning of the 19th century (Kurz 2022).

Figure 20: Map of Zurich around 1814 (source: Scheuermann & Breitinger 1847).

But the rapid growth also led to social segregation. As a reaction to the population growth the city planned a prestige project: The renovation of quarters between the main station and the lake. These quarters were characterized by broad streets in a grid pattern and the design was influenced by what was done in Paris a few years prior (Kurz 2022). The photos in Figure 21 and Figure 22 were both taken from Saint Peter church in the direction of the lake. On the bottom of both pictures the Rathausbrücke is visible. The photo in Figure 21 was taken in 1865, prior to the renovation of the quarter, while that of Figure 22 was taken in 1887, just after the construction of the new quay was finished.

Figure 21: View from the Sankt Peter church towards the lake in 1865 (source: Baugeschichtliches Archiv 2025).

Figure 22: View from the Sankt Peter church towards the lake in 1865 (source: Baugeschichtliches Archiv 2025).

The newly renovated quarters became mainly accessible for the upper class, driving lower class population out of large parts of the city. Similarly to the city, the neighbouring municipalities to the east, such as Enge, Hottingen or Fluntern, also became popular among upper class citizens, as people who did not want to live in the more crowded and busier city moved there and led to these villages being characterized by exclusive residential areas. A different picture can be seen in the west of the city. In villages, such as Wiedikon and Aussersihl, where industrial buildings and cheap apartment buildings for the workers of the city were constructed. Figure 23 provides an overview where the previously mentioned neighbourhoods are located in the city.

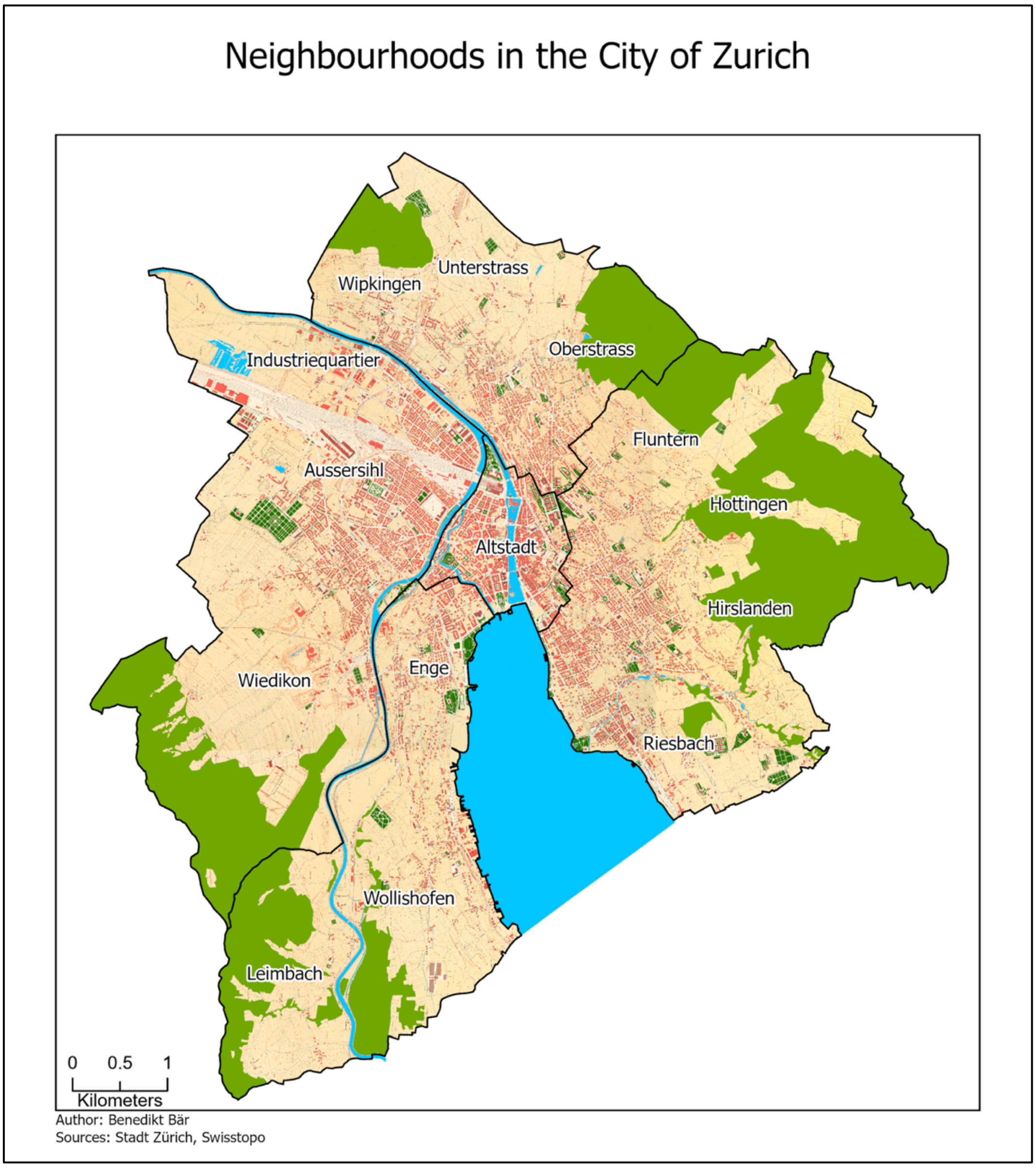


Figure 23: Map of Zurich showing the different neighbourhoods of the city. Prior to the expansion, Leimbach was part of the municipality of Enge, while the Industriequartier belonged to the municipality of Aussersihl.

The difference between these municipalities is visible in Table 3 which was created by Kurz (2022). It shows the taxable assets per capital in 1886, and it shows that the people in Enge had around 16 times as many assets as people in Aussersihl.

Table 3: Table showing the average taxable assets per capita in 1886 (source: Kurz 2022).

Stadt Zürich	9024.–
Enge	9767.–
Hottingen	4618.–
Riesbach	4539.–
Fluntern	4328.–
Wollishofen	4040.–
Unterstrass	2695.–
Hirslanden	1691.–
Oberstrass	1352.–
Wipkingen	1296.–
Wiedikon	777.–
Aussersihl	605.–

As described by (Behrens et al. 2015; Kurz 2022) many of the suburban municipalities were overwhelmed by the high level of immigration, especially Aussersihl, which petitioned in 1885 for the unification of itself and ten other municipalities with the city of Zurich, leading to a cantonal vote on August 9th 1891, where 60.31% of the population accepted the expansion of the city (Behrens et al. 2015; Kanton Zürich n. d.; Kurz 2022). With the expansion Zurich became the biggest city in Switzerland (Behrens et al. 2015). Also, after the expansion, the city continued to grow. Between 1889 and 1898 the city grew by around 8000 people each year. The growth was mainly due to immigration, as it made up 80% of the population increase. But also, because the birth rates were the highest Zurich ever had (Kurz 2022).

2.5.2 Zurich from 1909 to 1911

This lays the foundation for the situation in Zurich in 1909, 1910 and 1911. This thesis considers the period between the two major expansions the City of Zurich had (as can be seen in Figure 24). It got the borders it had during the time between 1909 and 1911 in 1893 when the neighbourhoods Leimbach, Wollishofen, Enge, Wiedikon, Aussersihl, Wipkingen, Unterstrass, Oberstrass, Fluntern, Hottingen, Hirslanden and Riesbach were incorporated into the city of Zurich (Rebsamen et al. 1992).

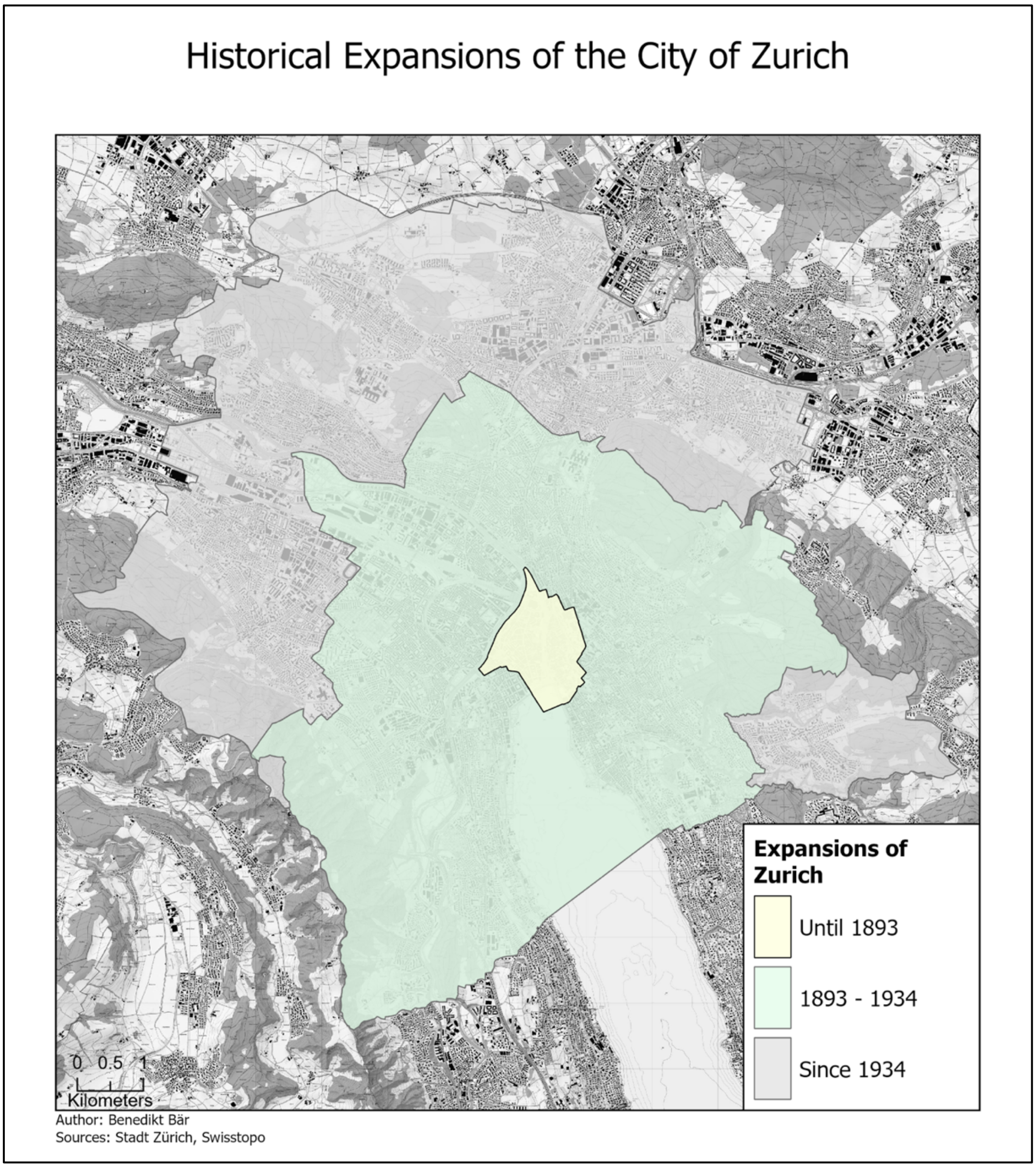


Figure 24: The expansions of the City of Zurich. The core of the city is shown in yellow and presents the city before 1893, green shows the area between the two expansions (the extent Zurich had around 1911), and grey shows areas that were incorporated later.

This thesis covers a period, where the developments during the 19th century are still visible when looking at the demographic data. The high population density in the former villages Wiedikon and Aussersihl was still visible in 1911, as district 3 was still the most densely populated, apart from district 1, which only contains urban area (Figure 25). Even more extreme is the situation when looking at the rental prices, which are a good indication for the socio-economic status of the residents of each district. Here district 3 has by far the lowest price level with just CHF 715 as an average price.

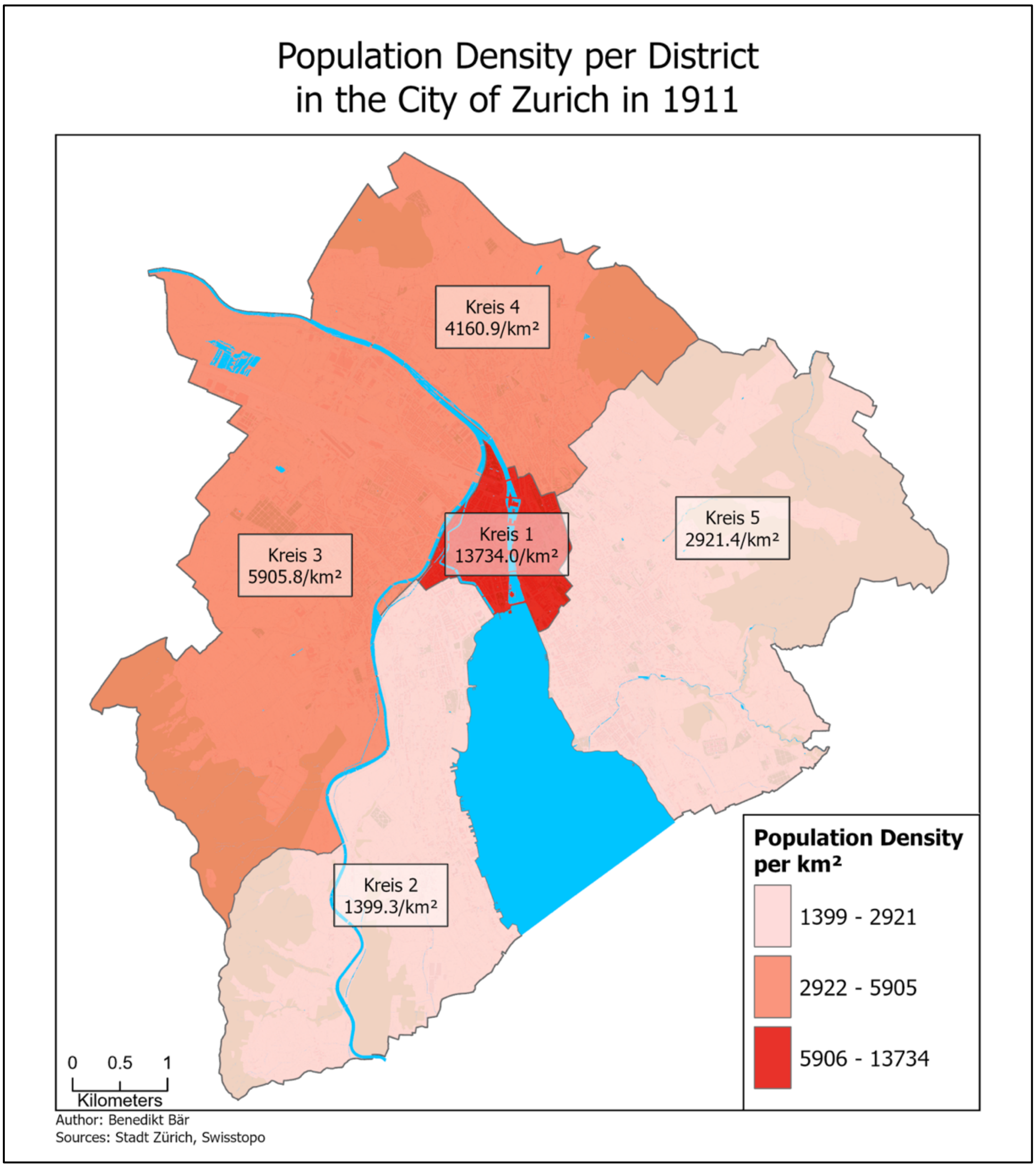


Figure 25: Map showing the population density per km² by district in the city of Zurich (data source: Statistik Stadt Zürich (1910 & 1914)).

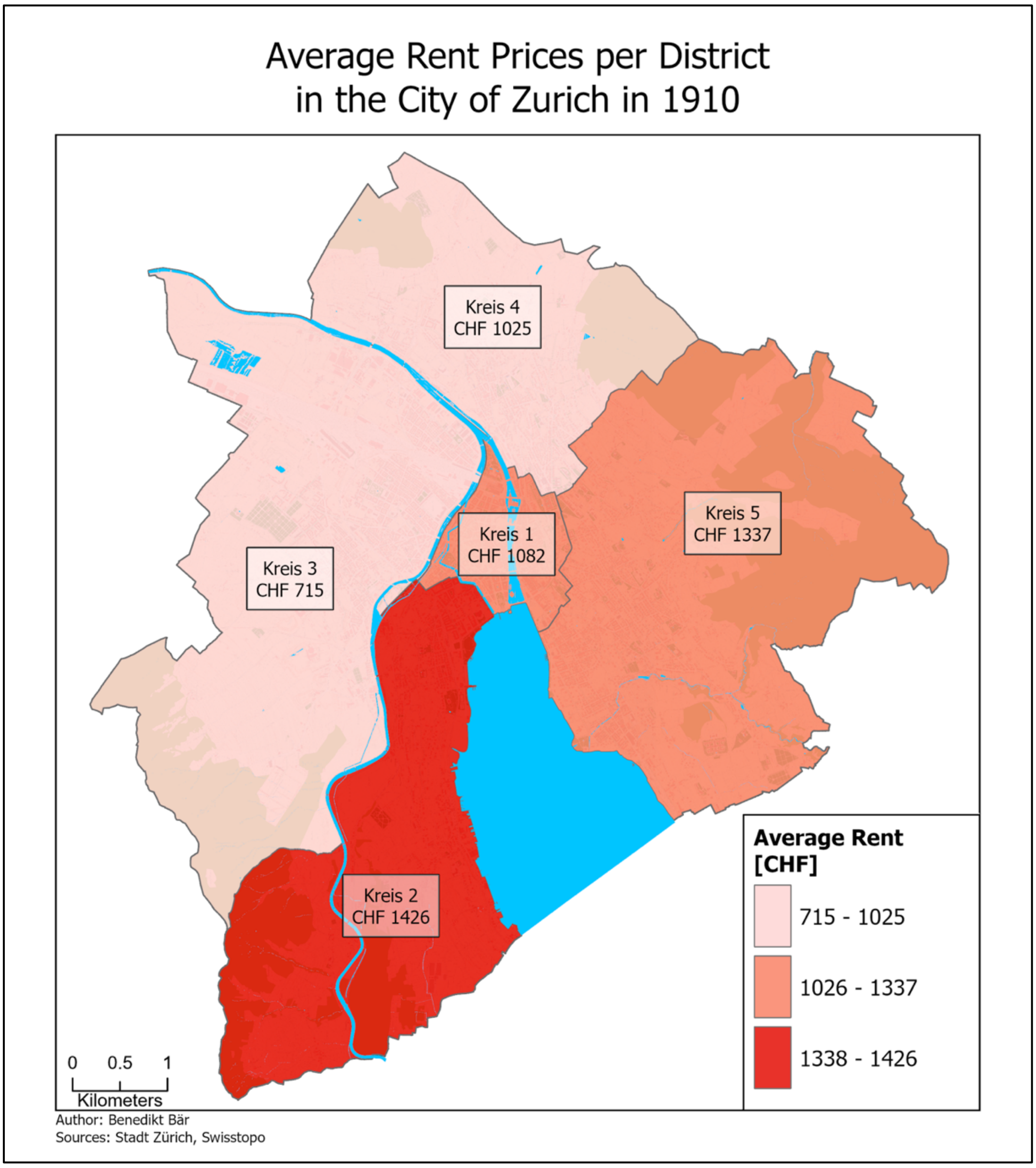


Figure 26: Map showing the average rent by district in the city of Zurich (data source: Statistik Stadt Zürich (1910 & 1914)).

Looking at the population of entire city, Zurich had 193'800 in 1911 (average number of inhabitants during the year, according to Statistik Stadt Zürich (1914)) and the number of inhabitants had been steadily growing since the beginning of the century as can be seen in Figure 27.

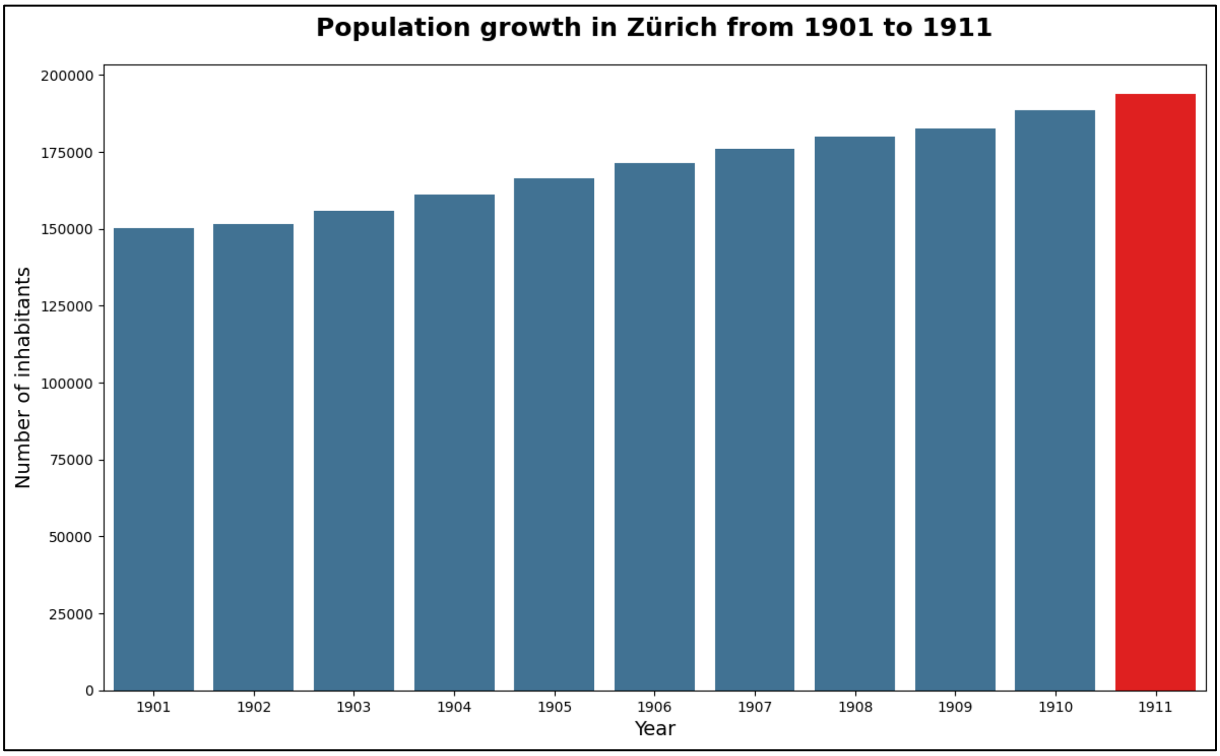


Figure 27: Population growth in the city of Zurich from 1901 to 1911. 1911 is marked in red (data source: Statistik Stadt Zürich (1914)).

As it can be seen in Figure 28 the age distribution of the population was generally lower in 1910 than it is today, with the largest age group being in their early 20s and the life expectancy in Switzerland being 51.3 years for men and 54.7 for women respectively (Federal Statistical Office 2024; Stadt Zürich 2018).

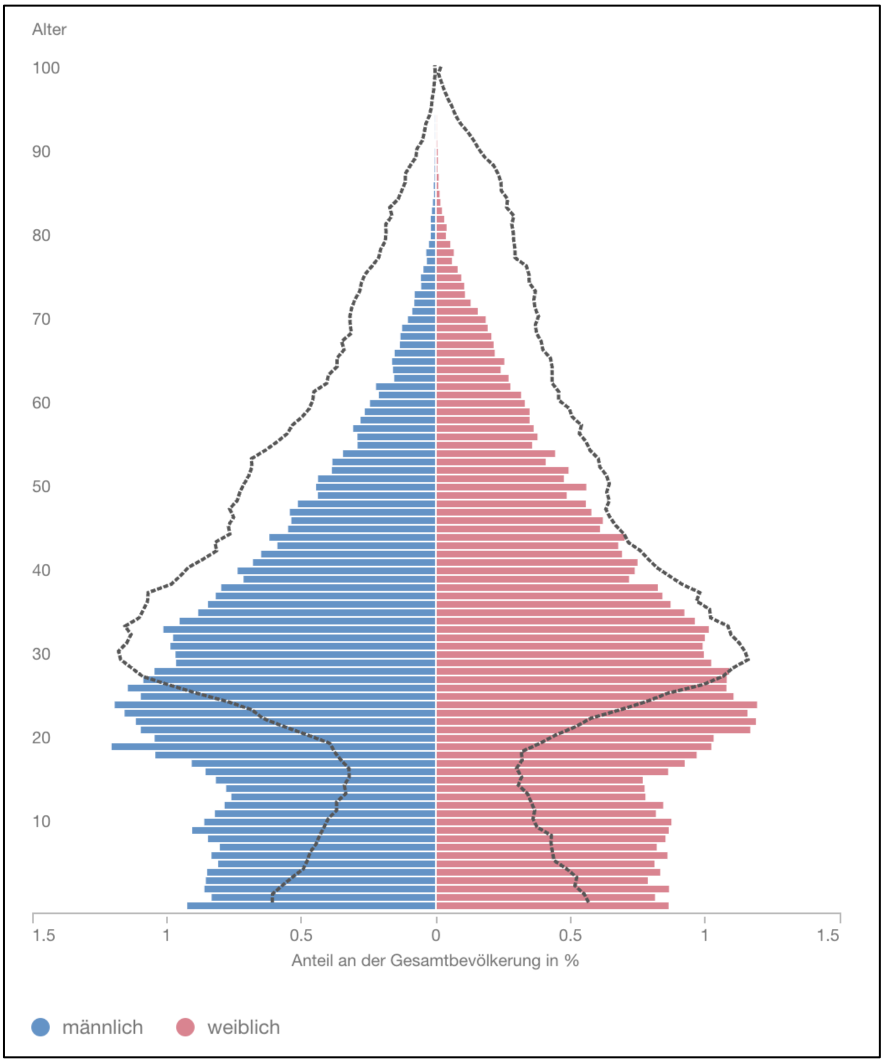


Figure 28: Demographic pyramid of the city of Zurich in 1910. The black line shows the respective pyramid in 2018 (source: (Stadt Zürich 2018)).

3 Methods

3.1 Data and Data Preparation

3.1.1 Map Material

3.1.1.1 Basemap

The base map (Figure 29) used for the thesis is an old city map of Zurich from 1913. It was initially created by the *Vermessungsamt* of the city of Zurich and was later digitized by the *Amt für Städtebau* of the city of Zurich. For this thesis, it was acquired from *Geomatik + Vermessung Zürich*. The base map is a hand-drawn map from 1913, covering the area of the city of Zurich at the time. It is at a 1:2500 scale, one pixel has a resolution of 0.42 meters and was digitized and georeferenced by the city of Zurich.

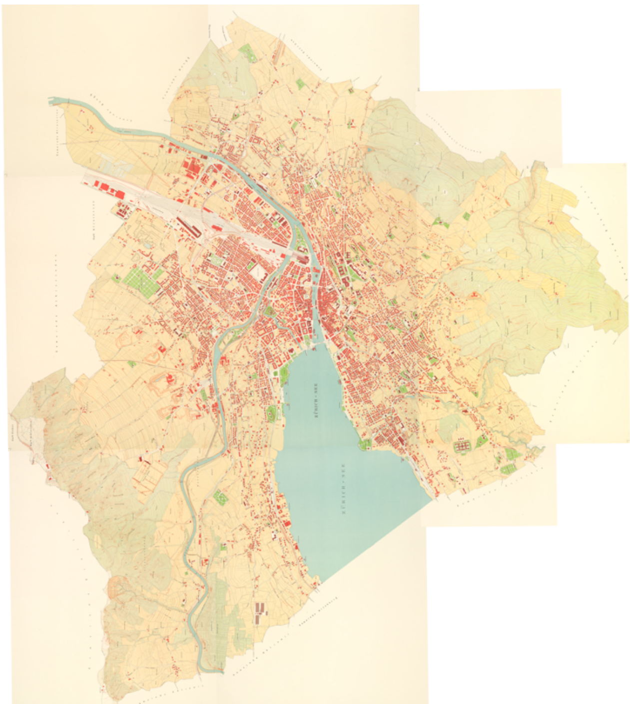


Figure 29: Map of the city of Zurich 1913 which functions as a base map (source: Vermessungsamt der Stadt Zürich 1913).

3.1.1.2 Improvements of the Basemap

In a first step the historical districts were added to the base map. As the historical districts were not available, a shapefile of the modern neighbourhoods was downloaded from the GeoServer of the city of Zurich and was then altered according to Rebsamen et al. (1992) and Statistik Stadt Zürich (1914), so that they represent the districts of Zurich at the time.

This included:

- Removal of neighbourhoods that were not part of the city of Zurich in 1911. These were: Albisrieden, Altstetten, Höngg, Affoltern, Oerlikon, Seebach, Schwammendingen and Wittikon.

- Editing of the outer city boundaries of the remaining neighbourhoods, so that they match the extent of the 1913 map (see Figure 30).
- Merging the neighbourhoods into the five historic districts (Figure 31).
    - The neighbourhood Altstadt remains unchanged and forms District 1.
    - Enge, Wollishofen and Leimbach form District 2.
    - Wiedikon, Aussersihl and Industriequartier form District 3.
    - Wipkingen, Unterstrass and Oberstrass make up District 4.
    - Fluntern, Hottingen, Hirslanden and Riesbach are merged into District 5.

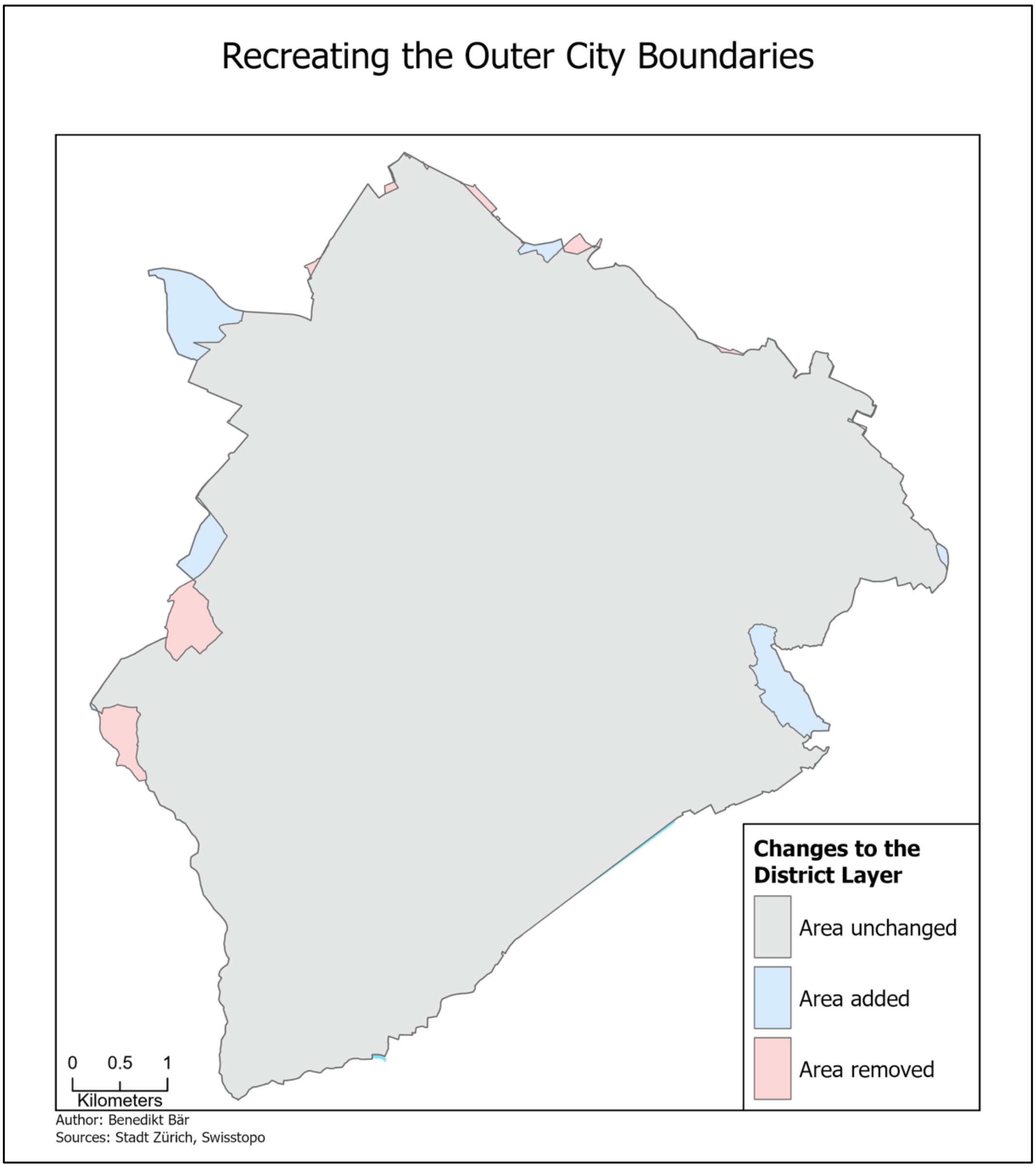


Figure 30: Changes made to the outer boundaries to resemble the borders of 1911. Red areas were removed, blue areas were added. The changes were made based on the old city map of 1913.

To make the final maps looking better, the districts were then used to clip the base map to the area of interest.

Furthermore, green surfaces and water areas were emphasized on the base map. To do this the information was directly taken from the base map using segmentation and classification tools in ArcGIS Pro. The following paragraph is based on ESRI (n. d.):

First, the Segmentation Mean Shift tool was used to segment the map. It uses a moving window that calculates the average pixel value to determine to which segment a pixel should belong. In a subsequent step training data was manually generated, which then was used with the Classify Raster tool to perform a maximum likelihood classification. Lastly, the classified raster dataset was converted into vector data using the Raster to Polygon Conversion tool. Wrongly classified areas were then manually corrected.

This method was used to obtain the vector data for the parks and the water areas at the time, which then were overlayed over the base map. Originally it was also planned to use this method to extract the forested areas, but due to complex polygons and too many wrongly classified areas, the forest features on the map were then manually created.

The final product used as a base map can be seen in Figure 31, this version also inclued district labels.

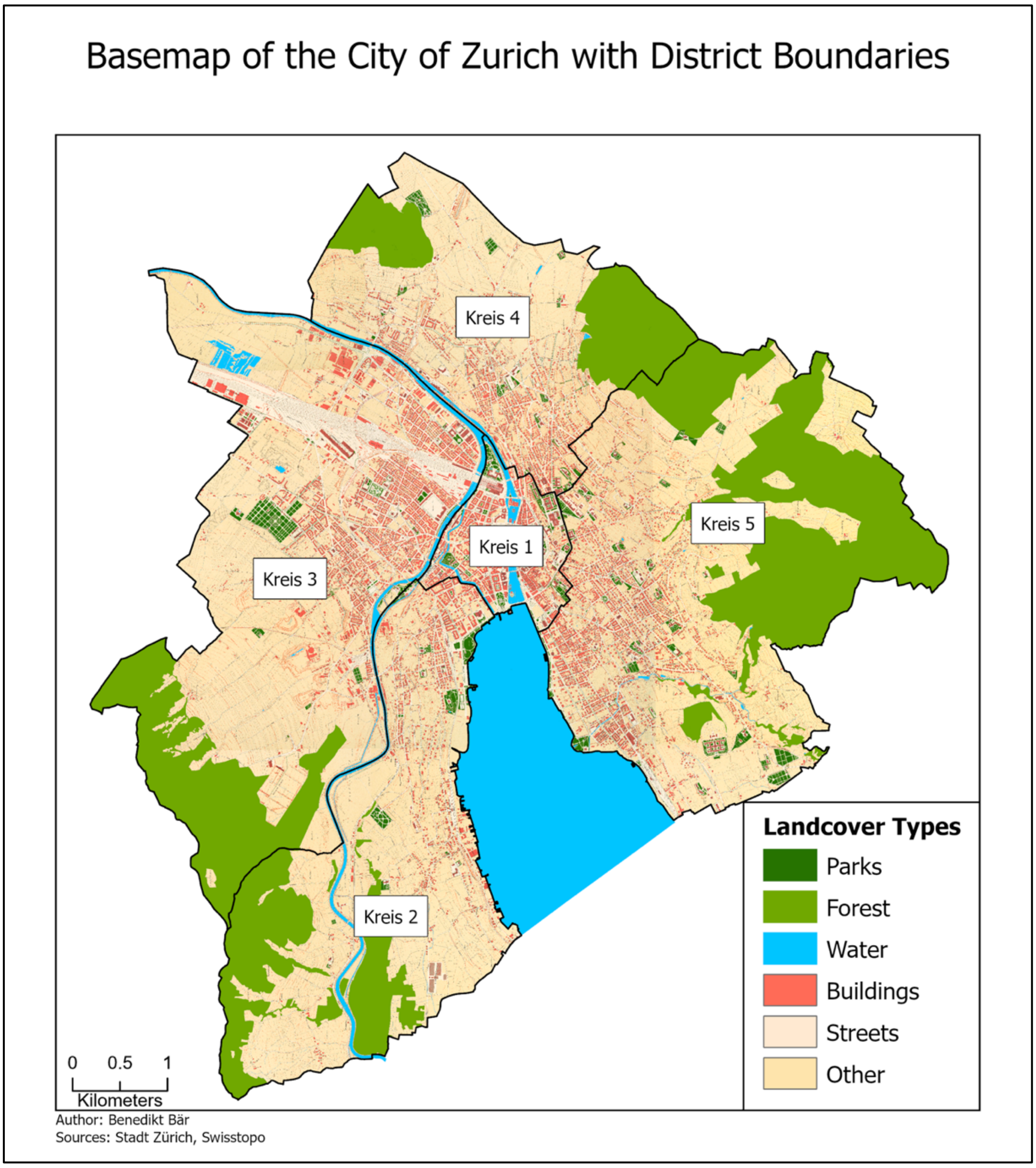


Figure 31: Final base map with the districts labelled.

3.1.2 Death Registry

This thesis is mainly based on entries in the death registry (Toten-Register) of the city of Zurich, which is stored in the archive of the city of Zurich (Stadtarchiv Zürich 1911). All deaths that occurred within the limits of the city of Zurich are registered in these books. During the time of interest, every year consisted of four books, with each book containing the deaths that occurred during three months. Book one contained the months January, February and March, book two the months April, May and June, the months July, August and September were stored in book three and finally, October, November and December were a part of book four. Due to this, the third book of each of the relevant years was selected for this thesis. Each entry in the register contains information about the name, the date and time of death, the place of death, the cause of death, the profession, the names of the parents, the place of origin, the place of residence and the date and place of birth. For this thesis, the date of death, the location of death, the profession, the place of residence, and the date of birth were considered as relevant. Furthermore, the sex was derived from the name of the deceased, the kinship terms used and/or the title of the profession. The required information was manually transcribed into an Excel spreadsheet. Unreadable or hard-to-read entries were initially marked in the spreadsheet and later double-checked by my supervisor and me. In the end, out of the 1908 entries, no entry was completely unreadable, and all the entries could be deciphered so that at least a basic categorization was possible.

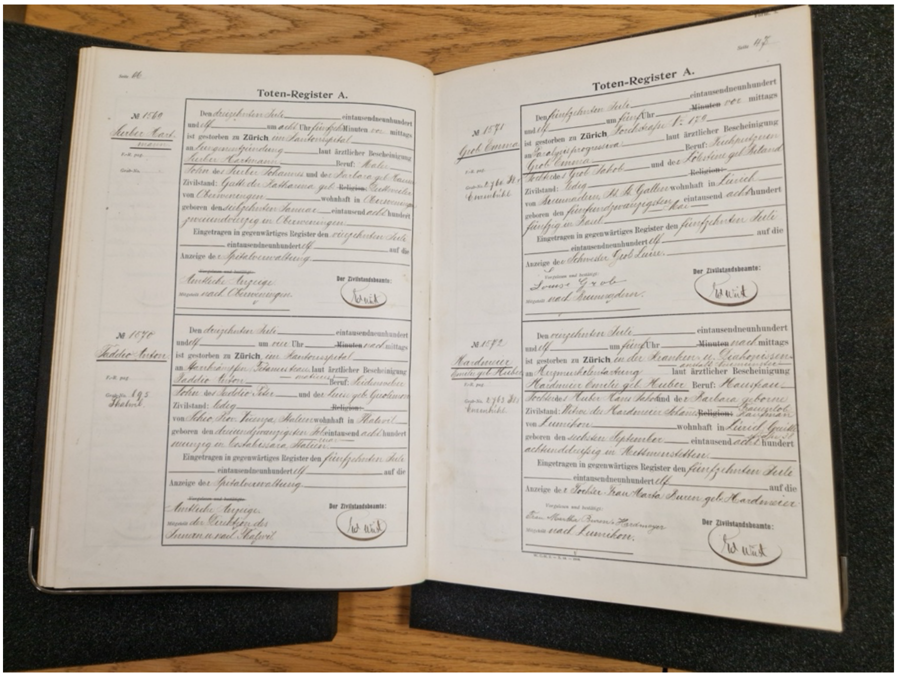


Figure 32: Example of a page in the death registry. Each double page contains four entries.

The preparation of the data continued with the classification of the professions. For this the hisclass classification was used (Van Leeuwen and Maas 2010). Hisclass is a classification scheme that allows to get information on the social class of historical people, based on their profession. It divides the people into four classes:

- 0 for people with no occupation.
- 1 for people in a lower social class. This contains simple workers, servants and day labourers.
- 2 for people in a higher social class. This contains mainly craftsmen. Housewives are also grouped into this category.
- 3 for people of the highest social class. This contains, among others, teachers, doctors, lawyers and academics.

The causes of death were loosely classified by the ICD10 classification scheme (Reid et al. 2024). The classification of deaths was further simplified by only classifying causes that were deemed to be more likely affected by heat. Therefore, they were classed into eight classes: acute gastroenterological diseases, acute problems with the cardiovascular system, drowning, heat strokes, stillbirths and pre-natal births, respiratory diseases, deaths due to weakness and other deaths.

The last step of preparation for the death registry dataset was about geocoding the addresses so that the entries could be used for geographic analysis. For this, the Geocoder from Swisstopo was used. The Geocoder is an Excel tool where postal addresses within Switzerland can be converted to geographical coordinates (Swisstopo 2023). The output includes both the, LV95, as well as the WGS84 coordinates, but as this thesis only looks at the city of Zurich, the Swiss LV95 coordinates were used, as they are specifically made for Switzerland (Swisstopo 2024a).

For the places of death, a total of 1006 addresses had to be geocoded out of which 690 were automatically geocoded with the help of the Geocoder. After this was done, 16 of these entries had to be manually corrected, as they were geocoded outside of the city of Zurich. There were two reasons for why this happened:

- The original street changed its name and there is now a street with the former name in one of the neighbourhoods that were not part of the city of Zurich back then (e.g. the Dietzingerstrasse used to be called Friedheimstrasse, while nowadays there is a Friedheimstrasse in Oerlikon).
- An address was not found in Zurich, but a similar address was found outside of Zurich (e.g. nowadays the exact address *Forchstrasse 134, Zürich* does not exist anymore, but there is a *Forchstrasse 134, Egg bei Zürich*).

The rest had to be added manually. The first step of the manual processing was achieved with the help of Google Maps and the old city map from 1913. If unknown, the approximate location of the street was searched on Google Maps and then the exact location of the street was looked up on the old city map, as it contains the house numbers of each building. The exact coordinate was then extracted from the old city map in QGIS. With this process, 278 addresses were found and geocoded. They were not geocoded by the geocoder due to several reasons:

- The input address was not found by the geocoder (193 cases). This was either because some house numbers disappeared over time or because the input address was not in the correct format for the geocoder.
- The location was only a description and not an address (26 cases).
- The street name was spelled differently (15 cases). This was either due to transcribing errors while digitizing the death registry or because the address used to be spelled differently.
- The exact location was not found (44 cases). This was the case when the street was found, but the exact street number was not, either due to a mistake while transcribing the addresses, changes that happened between the date of the entry (1909 – 1911) and the creation of the map (1913) or other unknown reasons. In these cases, an approximate location was picked, based on street numbers close to the missing street number.

A further 31 addresses required additional research. This was either due to streets that ceased to exist, streets that changed their names or specific buildings, like the *Kantonales Säuglingsheim* or the *Schweizerische Pflegerinnenschule*. For the former cases, the website alt-zueri.ch was a useful tool (Dürst n. d.), as it contains all the streets of Zurich with information about their old names. This made it possible to locate the exact address on the old city map. For the latter, the buildings were looked up online, as all of these buildings had a medical usage they were all found on a website of the University of Zurich about medical history in Zurich with a corresponding address (Wolff et al. n. d.).

In the end, all but five entries were successfully geocoded. These five cases were all deaths during transport, either by tram or train or during transport to a hospital. As this only concerned five entries it was decided not to geocode them.

For the place of residence, 409 out of 1908 entries were not geocoded. This was due to two reasons:

- The place of residence was unknown. This was the case in 36 entries.
- The place of residence was located outside of the city of Zurich and therefore it was not deemed as relevant for the thesis. This was the case in 373 entries.

In a further 969 entries, the place of residence was equal to the place of death. Therefore only 530 entries had to be geocoded. 503 out of these 530 were unique addresses that needed to be geocoded. 362 were automatically geocoded by the Geocoder, four of which had to be manually corrected as they were located outside of the city of Zurich. A total of 120 had to be geocoded with the help of Google Maps and the old city map.

- In 89 cases, they were not found by the geocoder.
- In 10 cases the street name was spelled differently.
- In 21 cases the exact location was not found.

A further 21 cases required additional research and were found thanks to the website by Dürst (n. d.).

3.1.3 Weather Data

Weather data for the period in question was taken from IDAWEB by MeteoSchweiz (MeteoSchweiz n.d.a). This contains data about the temperatures, precipitation and sunshine duration, measured at the station in Zurich Fluntern (SMA), which was the only station in Zurich at the time. It is located on the southern slope of the Zürichberg, as can be seen in Figure 33, and it is active since January 1st, 1864 (MeteoSchweiz n.d.f).

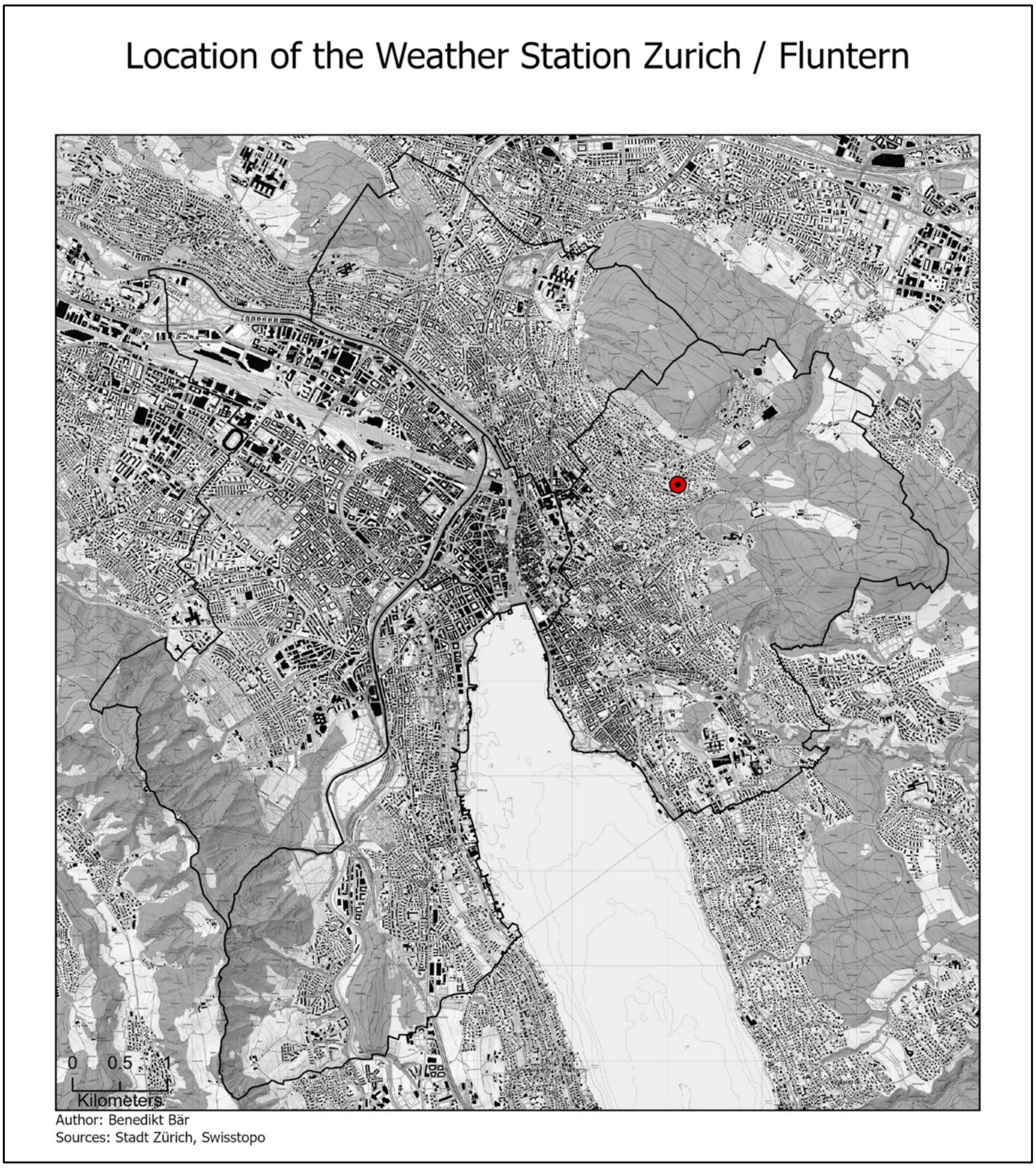


Figure 33: Map showing the position of the weather station Zürich / Fluntern on a modern map of the city of Zurich. As a comparison the historic borders around 1911 were also added to the map.

3.2 Visualisation

3.2.1 Layout

3.2.1.1 Spatial Visualisation

For the general design of maps, (Slocum et al. 2013) list the eight most common map elements. These are:

1. Frame line and neat line
2. Mapped area
3. Inset
4. Title and subtitle
5. Legend
6. Data source

7. Scale
8. Orientation

Slocum et al. (2013) list them in order of the size they should have in the final map. But although these elements are the most common ones, it is important to mention, that not all of them need to be present in every map. As Slocum et al. (2013) further note, it is part of the cartographic design to decide, which elements are needed to fulfill the purpose of the map for the respective target audience. In the next steps I want to go through these elements and explain my implementations or my thoughts why they were not included, respectively.

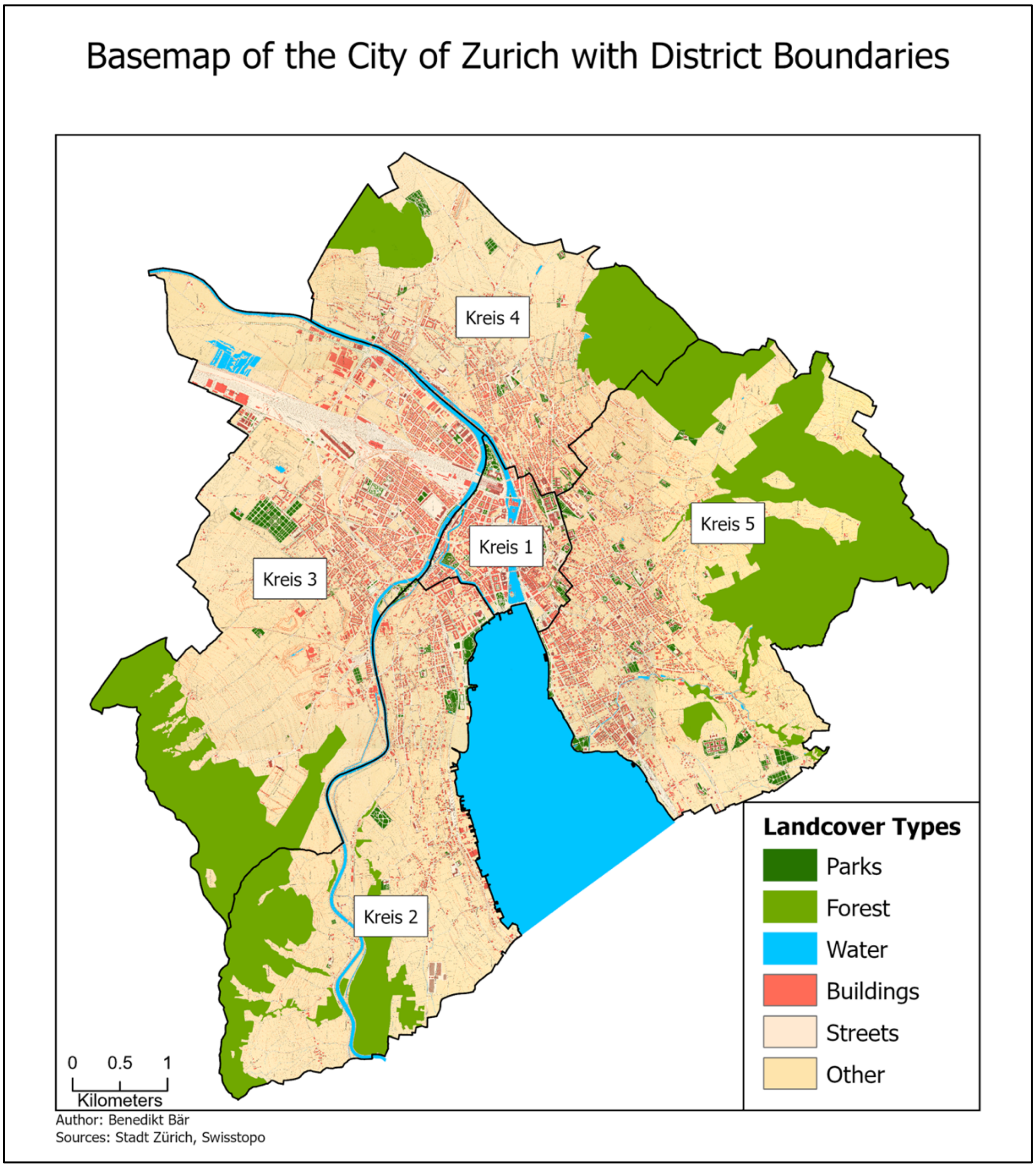


Figure 34: An example of the final map layout used for this thesis.

1. Frame Line and Neat Line

The frame line is the outer boundary of the entire figure. It should enclose all map elements, like a picture frame encloses a picture. The neat line on the other hand encloses the mapped area and visually separates it from other elements, such as the title or the information about the data source (Slocum et al. 2013). Both features are present in the maps used for this thesis. The frame line was defined first to define the outermost extent of all elements. Then the neat line was placed inside and contains both the mapped area and the legend in the final version. It was made sure, that the neat line had a similar side ratio to the bounding box of the city of Zurich at the time, while the frame line was made slightly longer on its vertical axis, compared to the horizontal axis, to make room for the title.

In the first design the frame line was longer in its horizontal axis and the map was placed on the left side, while the legend was placed on the right side. This was changed at a later stage to reduce the amount of white space.

2. Mapped Area

The mapped area should be the most important part of the map. As a general guide Slocum et al. (2013) mentions that the area of interest should be as large as possible, but it should provide enough space for other map elements, and it should not touch the neat line. Additionally, the area of interest should be visually centred in horizontal and vertical direction. The shape of the city of Zurich was quite helpful in this regard, as it automatically left space for other map elements in the corners, after the application of the latter guideline.

The area of interest can either be floating, which mean that surrounding areas are not depicted, or the surrounding areas can be depicted and are cropped by the neat line. Both variants have their advantages. While the floating variant puts more focus on the area of interest, the latter can provide more information about the location (Slocum et al. 2013). For this thesis, this decision was given by the used base map, as the city map from 1913 (Vermessungsamt der Stadt Zürich 1913) is already floating. Only Figure 24 and Figure 33 do use the non-floating variant, as their goal is to show the whole extent of the modern city and therefore depict the modern 1:10’000 raster map (Swisstopo 2024b).

Slocum et al. (2013) further mention the thematic symbols, which represent the map theme and must be present in every map, as well as base information, which provides information not essential to the theme. What base information is included can vary between the maps, but it generally includes the basemap with the district boundaries.

3. Inset

The concept of an inset is nicely described in the following quote:

“An inset is a smaller map included within the context of a larger map.”
– Slocum et al. (2013: 218)

It can either be a zoom in, to focus on a certain area, or a zoom out to show where the area of interest is located. I decided against the use of insets in this thesis. A zoom in does not provide an advantage, as the relevant information on the maps is already visible on the regular zoom level. A zoom out to show the location of the city of Zurich within Switzerland or Europe would have been possible, but I deemed it as not relevant enough for two reasons:

- As this is a geographic thesis looking at the situation in Switzerland, I do expect the target audience to either be geographically interested or to have a connection to Switzerland. Therefore, I do expect the target audience to know at least, where Switzerland is located and the chance is high, that they are also aware of the location of the city of Zurich.
- The exact location of the city of Zurich is not too important for this thesis, which would make a map with a zoom out-inset redundant.

4. Title and Subtitle

Titles should be clear and understandable for the reader, without using too many words. Vital information, such as what it depicts, the location and the year should be included, the subtitle can be used to provide additional information. The title should be the largest text on the map, it should ideally be located on top of the map and it should be horizontally centred if possible (Buckley 2008; Slocum et al. 2013). Most of the maps in this thesis only use a title, subtitles are only used in composite figures.

5. Legend

In the legend the symbols used in the mapped area should be explained, but self-explanatory symbols, as well as symbols not directly related to the theme, can be omitted (Slocum et al. 2013). For this thesis, this means that usually information about the basemap was omitted. In case something is unclear in the basemap, a legend about the landcover types of the basemap was added as can be seen in Figure 31.

As recommended by Slocum et al. (2013) a legend heading is present. It further explains what exactly is shown on the map and shows the unit of measurement when needed.

6. Data Source

Information about the data source and about authorship was added on the bottom left corner, outside of the neat line.

7. Scale

For the scale one has three options: The representative fraction, the verbal scale and the bar scale. The representative fraction is a ratio between the map distance and the distance on earth. For the old city map used in this thesis, it would be 1:2500 and the verbal scale is quite similar, as it basically is a spoken description of how the scale on the map compares to the scale on the earth. But both do have the same disadvantage: If the size of the map is changed, they are no longer accurate (Slocum et al. 2013).

Therefore, this thesis uses a bar scale, which visually shows what distance on the map and due to this, it stays valid, even if the size of the figure is changed. For this thesis a relatively simple scale bar is used, showing the distance one kilometre on the map.

8. Orientation

Orientation is usually shown with a north arrow. But as the northerly orientation used for this thesis is the norm nowadays, a north arrow would be redundant and therefore it was left away (Slocum et al. 2013).

3.2.1.2 Temporal Visualization

Although the temporal visualization uses charts, bar, line and column charts to be exact, I roughly followed the same guidance as for the maps. They have a neat line, which includes the chart itself and a frame line which includes the entire plot. Instead of the mapped area, the chart forms the centrepiece of the figure. The title is the largest text on the figure, followed by the axis titles, which are not present on the maps.

3.2.2 Visualization Choices

3.2.2.1 Colour

One important aspect of Geovisualization is to make sure, that the maps can be read and are understandable for most people of the target audience. For this purpose, it is important to make sure that the figures are colourblind safe, meaning that they can be read by people with a colour blindness (Slocum et al. 2013). For this purpose, colour schemes were either taken from the website colorbrewer2.org, with the option "colorblind safe" ticked or they were manually checked with the tool Color Oracle (Brewer et al. 2013; Jenny and Kelso 2018). An exception is the historic city map, which is not fully colourblind safe. As it is a historic map the colours were left as they were originally. But as this only counts for the base map, this should not limit the ability of understanding the theme of the map.

3.2.2.2 Dot Maps

One of the simplest methods to show the distribution of point features is a dot map, as it is often used in health geography (Shaweno et al. 2018; Soetens et al. 2017) and as such they are used on various occasions in this thesis. In the case of Figure 52 and Figure 53 they are used to offer simple overview, displaying all the cases coloured by years, which offers a first impression about which areas are much affected. In Figure 59 and Figure 60 the dots are additionally coloured according to their distance from a greenspace or a water area. Showing this as a dot map, gives the possibility to show which neighbourhoods are farther away from a greenspace or a water area, while at the same time showing the places where the deaths occurred, which makes it easier to find possible a possible correlation. In this case the dots are coloured in a single hue graduate colour scheme.

One problem of dot maps is that they depict every location as one dot. If multiple deaths occurred at the same location, this is not accurately depicted.

3.2.2.3 Kernel Density Estimation

To overcome the limitations of simple dot maps, a kernel density estimation, which does not show the exact location of individual cases, but instead depicts the density of cases per a specific area (Gibin et al. 2007). For this thesis Kernel Density estimations were used to show the number cases per square kilometre. For this purpose, a single hue graduate colour scheme was used, where the colour for the lowest value of 0 was transparent.

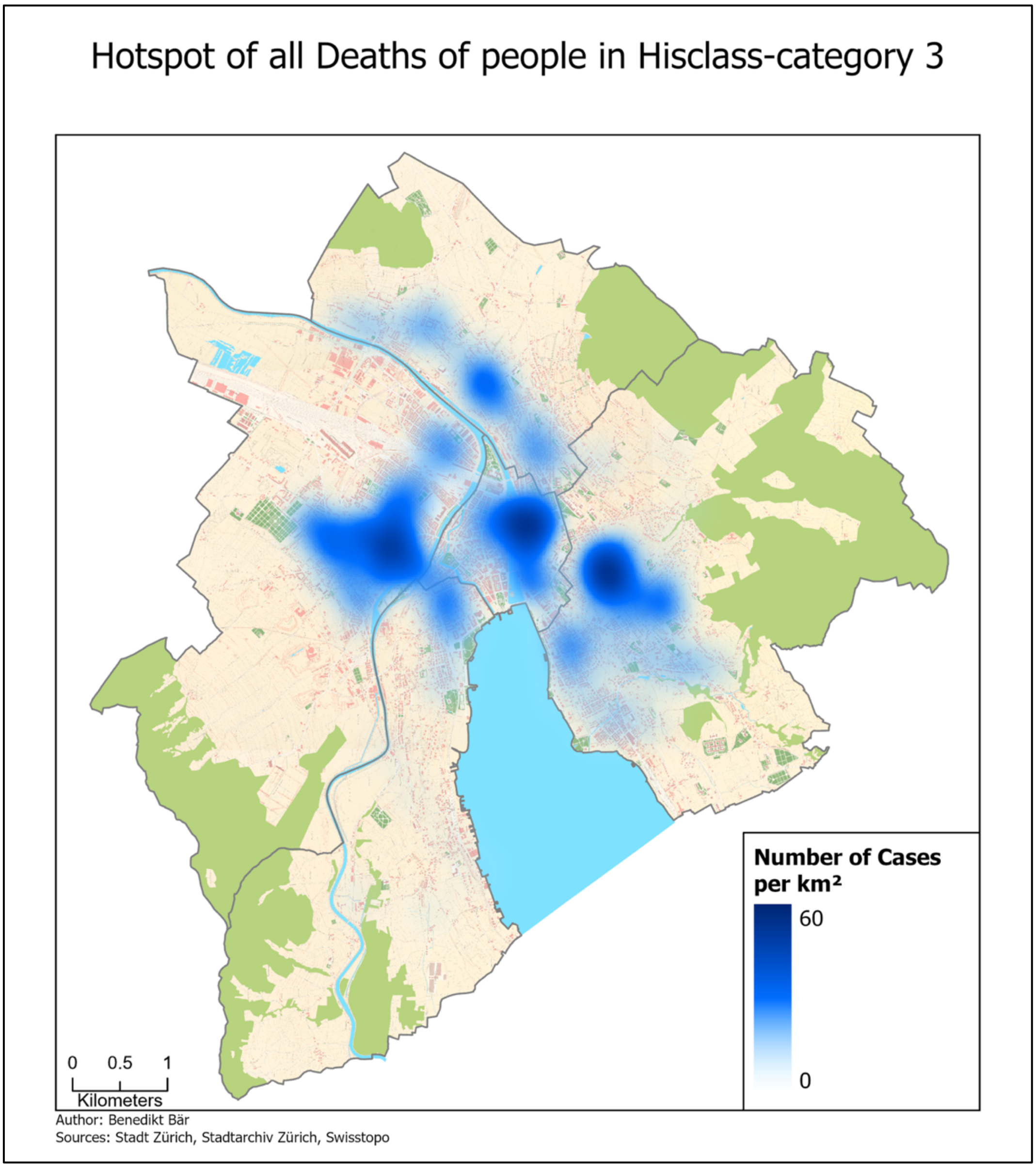


Figure 35: An example of a map created with kernel density estimation, showing nicely where hotspots are located.

3.2.2.4 Choropleth Maps

One of the most used map types is the choropleth map, where usually administrative units, such as countries, states, cantons or, in the case of this thesis, districts are coloured based on a given variable (Slocum et al. 2013). But they do also have disadvantages. As they are based on administrative units, they are susceptible to the MAUP (modifiable area unit problem), which means that, results can differ depending on the unit used (Wong 2009). Because of this, this thesis only uses choropleth maps, if the data is only available on a district level and if comparing the districts is the goal of the map.

Next it is also important to note, that the data for choropleth maps should be normalized, to make sure that differently sized administrative units are comparable (Slocum et al. 2013). Therefore, Figure 25 shows the populations density instead of the total population, Figure 26 and Figure 56 show the average rent price and Figure 61 and Figure 62 show a percentage of the total district area.

As the level of measurements for the values of the choropleth maps is a ratio scale, a single hue, sequential colour scheme was used (Brewer 1994).

Furthermore, the water areas were placed on top of the choropleth map and the colours were set slightly transparent so that the base map can still be seen below.

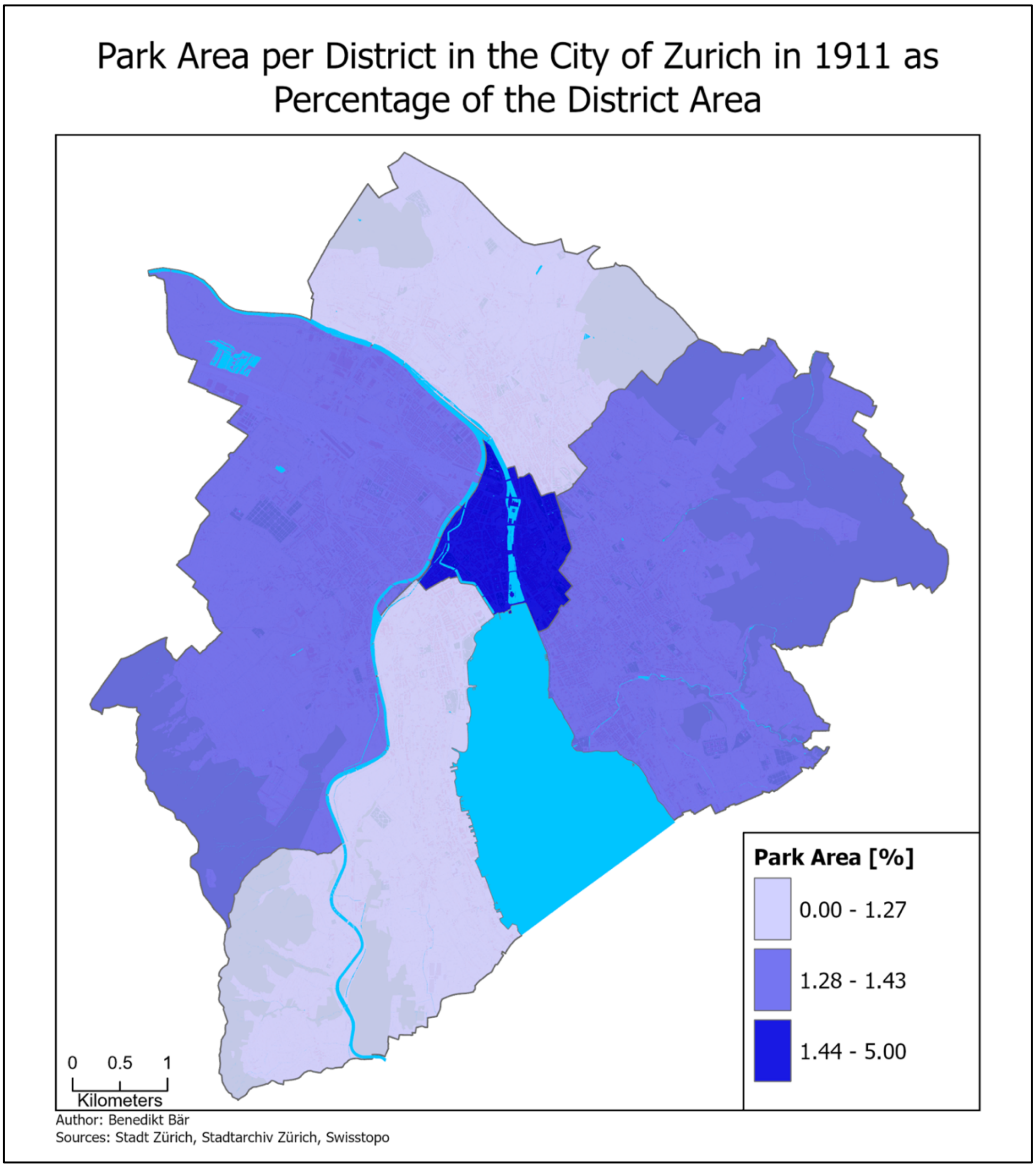


Figure 36: An Example of a choropleth map. The districts are slightly transparent, and the water areas are placed on top.

4 Results

In this chapter we will look at the results of this thesis, which will be split into two parts. The first part will provide results that are comparable to previous medical and historical studies on heatwaves. I will present the statistical analysis of the thesis, looking at how the year of 1911 compares to the two previous years. Returning to the original research questions the first part therefore aims to answer questions like:

- What groups of people were especially affected by the heatwave?
- Which causes of death did increase during the heatwave?

Furthermore, it will also show how cases changed throughout the summer months. Is there an increase in deaths during warmest part of the time of interest?

In the second part I will present the results of the geographic analysis, to bring a new perspective into the historical heatwave research. This part aims to answer the following of the original research questions:

- Were there specific areas of the city that were more affected?
- Did the proximity to greenspaces or water areas have an influence?

4.1 Temporal Analysis

Diving into the temporal analysis, I'd like to start with the total number of deaths during the three summers. The dataset includes a total of 1908 entries, distributed across three summers. The data shows a consistent increase in the numbers during the period of interest. The number of deaths increased from 591 in 1909 to 700 in 1911, with an especially sharp increase occurring between 1910 and 1911.

However, as shown in Figure 27, there has been a consistent population growth in Zurich during the time of interest. An increase in the number of deaths could also be explained by the population growth. To make sure this was not the case, I calculated the death rates for each year. The number of deaths was divided by the number of inhabitants during the respective year, and this was then multiplied by 100 to get a percentage, resulting in Figure 37. It can be seen here as well that there has been a slight increase between 1909 and 1910 and a bigger increase between 1910 and 1911. For a better comparison of the rates a statistical comparison of the two rates was performed (MedCalc Software Ltd. n.d.), of which the results can be seen in Table 4. The statistical test by MedCalc Software Ltd. is based on the Chi^2-test and was developed for the comparison of two rates in the medical field. This test was used to calculate the p-value of the rate difference.

This test has shown that the rate increase between 1909 and 1910 is clearly insignificant, while the increase between 1910 and 1911 is also not significant, but a lot closer to the threshold of 0.05. However, there is a significant increase when looking at the change between 1909 and 1911.

However, the effect size, Cohen's h to be more precise, was also calculated. Cohen's h is a method to calculate the effect size for differences between proportions, using the formula $(2 \times \sin^{-1}\sqrt{P1}) - (2 \times \sin^{-1}\sqrt{P2})$ (Cohen 1988). For this thesis P1 and P2 were defined as the death rate of the respective year. Cohen (1988) proposed that an h of 0.2 equals a small effect, an h of 0.5 equals a medium effect and an h of 0.8 equals a large effect. The numbers calculated for this thesis are way below even a small effect, as it can be seen in Table 4, and therefore the effect is negligible.

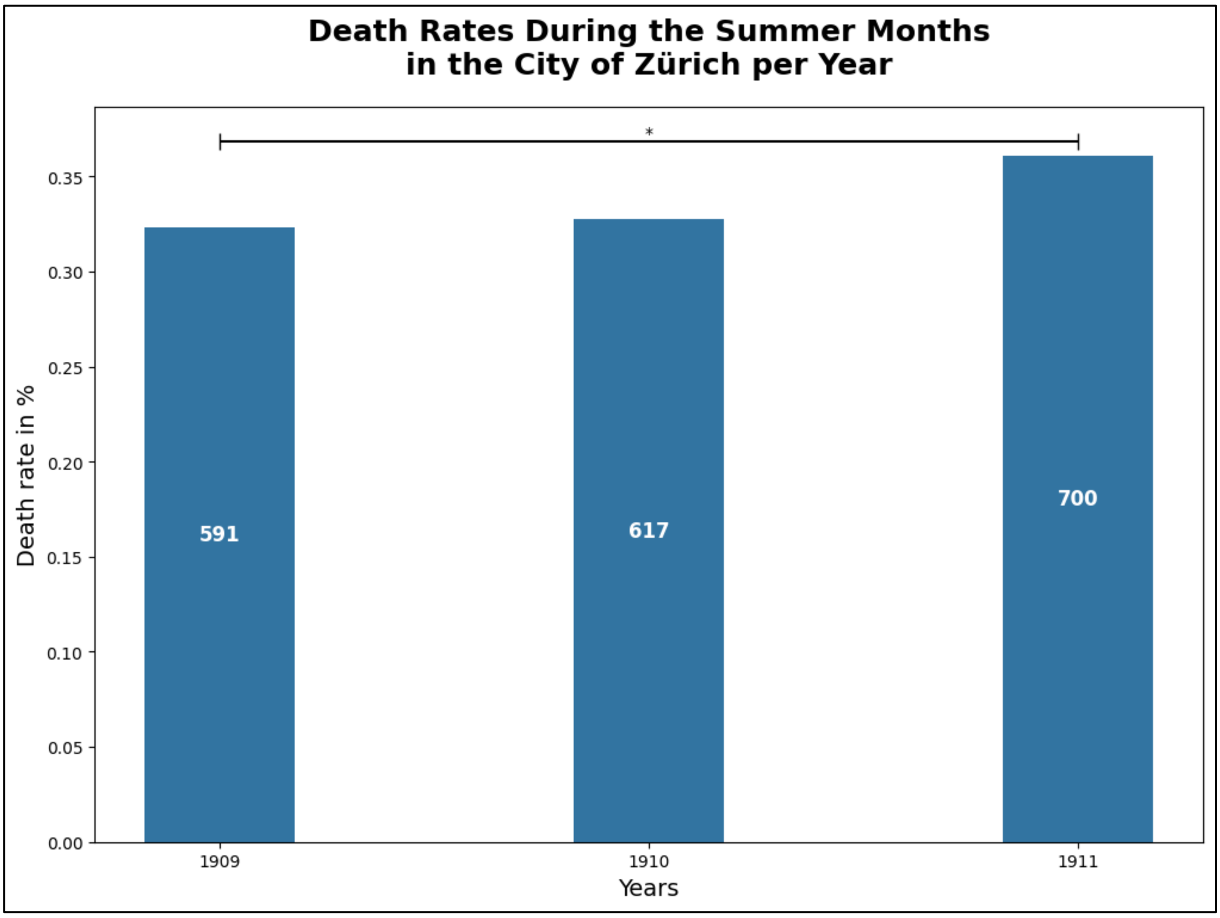


Figure 37: Death rate during the three summers, looking at how many percent of the population passed away during each summer. Also here the increase between 1910 and 1911 is visible. The numbers inside the pillars show the total number of deaths per summer.

Table 4: Table showing the results of the rate comparison.

Years	Death rate difference [%]	P-value from rate comparison test	Cohen's h (Effect Size)
1909 to 1910	0.0040	0.8304	0.0007
1910 to 1911	0.0337	0.0760	0.0058
1909 to 1911	0.0377	0.0482	0.0065

In the further analysis, the number of deaths and death rates were examined by age group. The total numbers of the three years are compared in Figure 38. Where the year 1911 exceeds the number of deaths in the previous in most age groups. This is particularly noticeable among the infants, children below the age of one, and for the group of 20- to

49-year-olds. Only for the group of 50- to 69-year-olds the numbers in 1911 are smaller than in both previous years. Looking at stillbirths and the people over the age of 80 1910 seems to be the outlier, as it is having a lower death rate, than the years of 1909 and 1911.

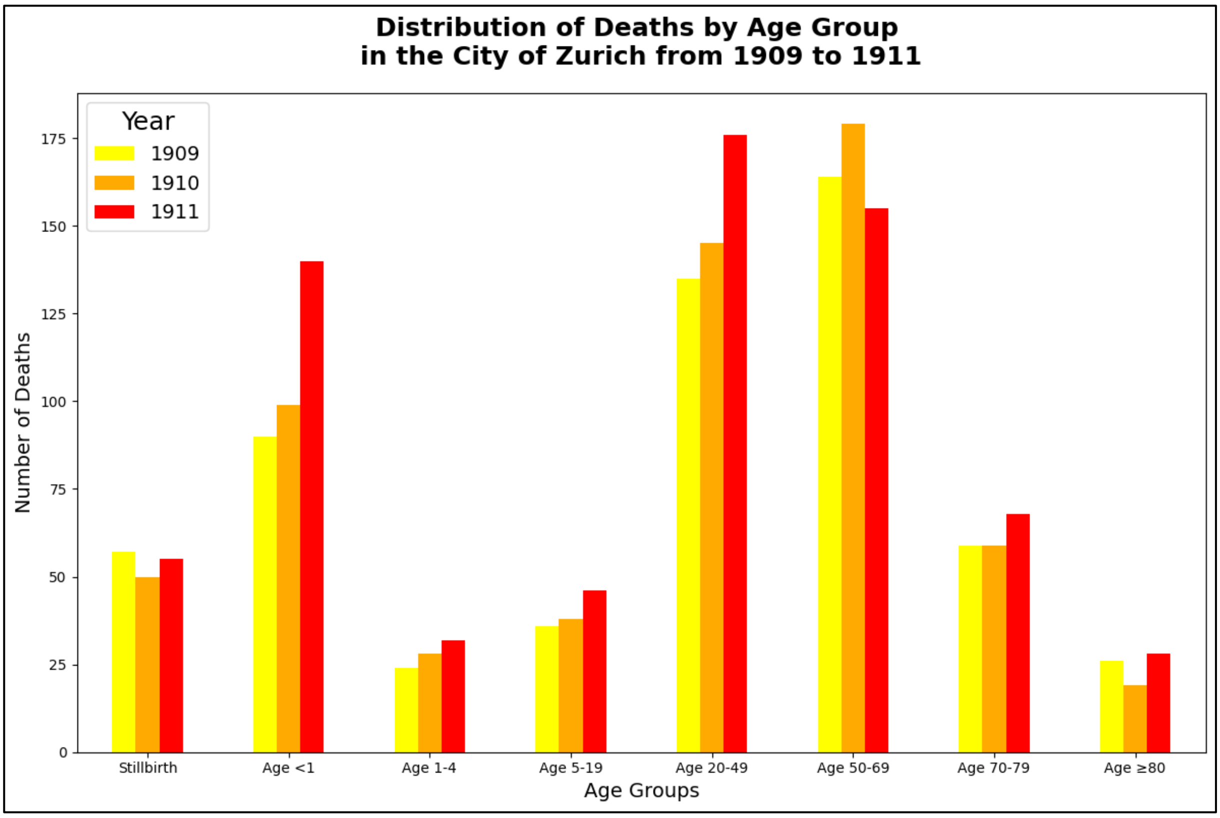


Figure 38: Distribution of deaths by age group in the city of Zurich from 1909 to 1911. Especially notable is the increase the deaths of children below the age of one.

In Figure 39 the comparison is made by looking at the death rate among each age group. It shows that the death rate is especially high among infants, while the other age groups were clearly below one percent. It is important to note that the population data by age group was only available for the year 1910. In case a shift in the age distribution occurred, this would not be depicted in Figure 39, although it is unlikely that such a shift occurred.

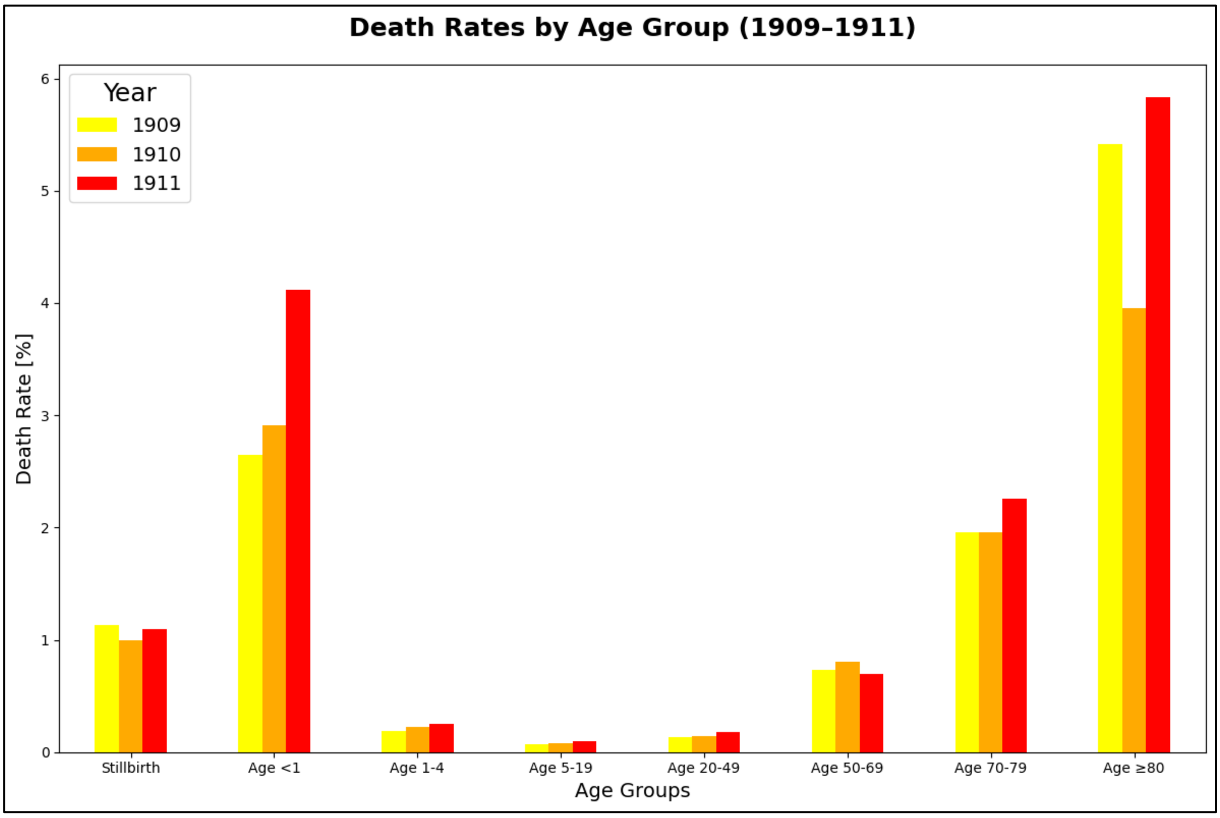


Figure 39: Distribution of deaths by age group when looking at the death rates.

Now it is interesting to look at the temporal distribution of cases throughout the summer months and comparing them to the temperature. First let's have a look at the number of deaths in Zurich. Figure 40 shows the ten-day-average throughout the three years. As it can be seen there is a noticeable peak from mid-July until the end of August. When comparing this to the weather situation explained in chapter 2.4 it is noticeable that this corresponds with the warmest period of the heatwave. This is also illustrated in Figure 41. To check if there is a connection between the two variables, a regression was used. The temperature was used as the independent variable and the number of deaths per day as dependent variable. To check whether there may have been a lag between the temperature rising and the deaths, the regression was calculated with a 0-, 1-, 2- and 3-day lag respectively.

The results of the regression can be seen in Table 5. The results show that it is not significant ($p>0.05$) without a lag, but there is a significant connection between the temperature and the number of deaths, if a lag is implemented, although the effect is rather small, as it can be seen in the respective r^2-value. r^2 values between 0.01 and 0.09 are generally interpreted as having a small effect. The results show the strongest statistical relationship in the regression with a two-day lag, as a p-value of 0.009 is clearly below 0.05. The two-day lag is also shown to have the largest effect at 0.075.

In contrast the regressions for the years 1909 and 1910 do not show a significant relationship between temperature and the number of deaths.

Furthermore, I also calculated the regression for days where the heatwave threshold of 28.02°C, as per the definition by the WMO, is surpassed. Which ended up being the best fitting model. With a p-value of 0.0002 it is highly significant, and the r^2-value is 0.142 which means a moderate effect.

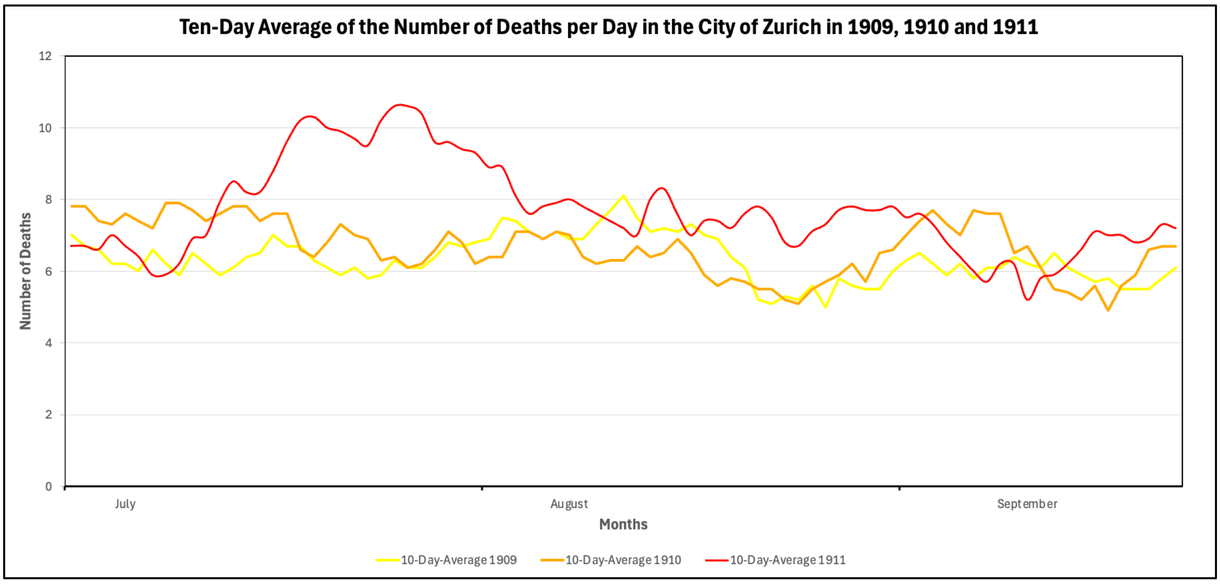


Figure 40: Ten-day average of the number of deaths per day in the city of Zurich throughout the summer months of the three years.

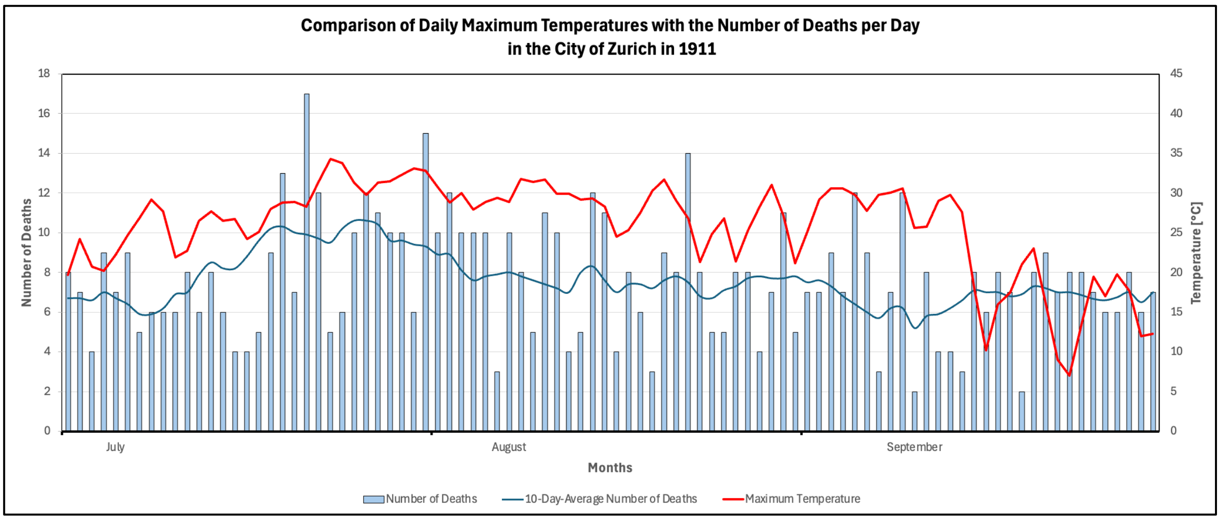


Figure 41: Comparison of the daily maximum temperature with the number of deaths per day (Data source: MeteoSchweiz n.d.a).

Table 5: Results of the regression between the number of cases per day and the daily maximum temperature in 1911.

	0-day lag	1-day lag	2-day lag	3-day lag
r^2	0.033	0.048	0.075	0.052
p-value	0.083	0.037	0.009	0.032

But how does this look like, when looking at specific causes? For this I first looked at the causes which had the biggest increase in 1911 compared to the two previous years. Figure 42 pictures the causes of death that were deemed most likely to increase during a heatwave at the start of this thesis and among those it's mainly the number of individuals who died from acute gastrointestinal diseases who had a notable increase, as the share of deaths almost doubled in 1911 compared to the two years prior. Similarly, the share of drownings also doubled.

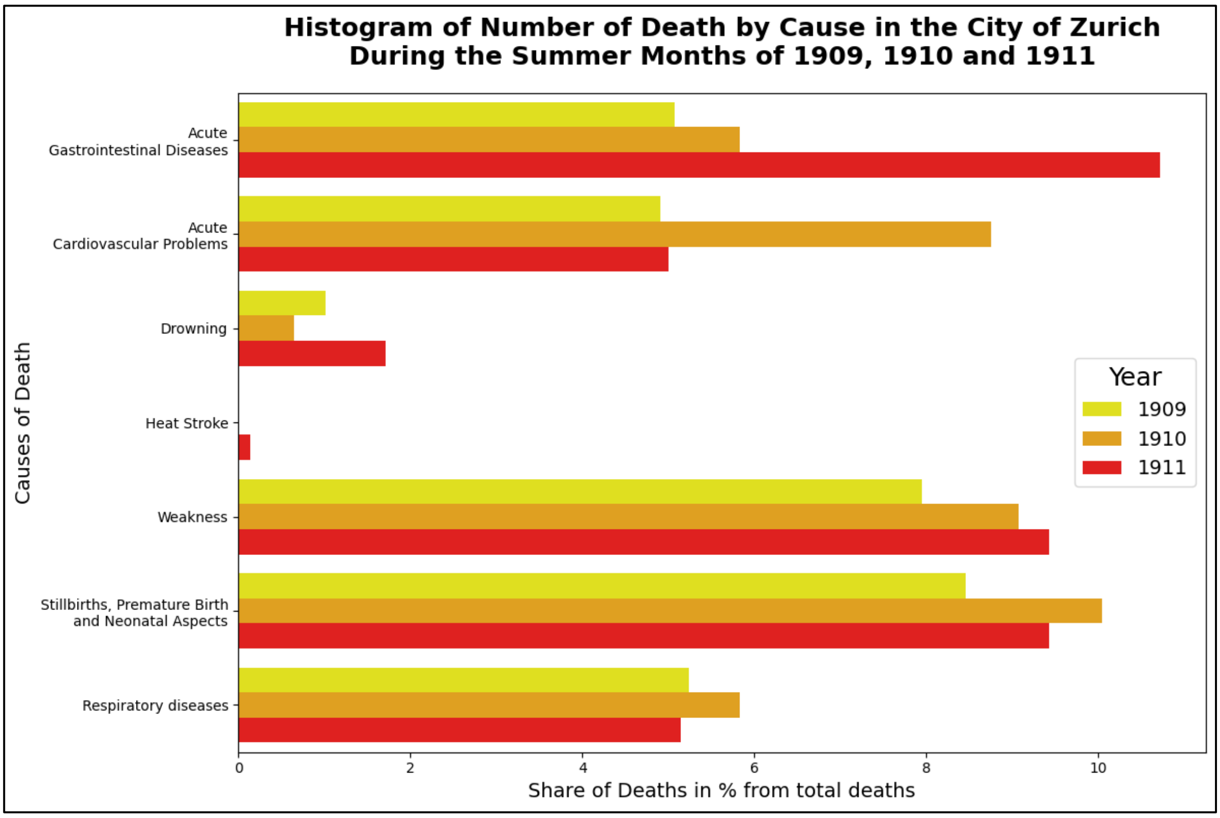


Figure 42: Share of the number of cases by cause of death in the City uf Zurich.

For both drowning and gastrointestinal diseases an increase during the major heat period at the end of July is clearly visible (Figure 43 and Figure 44). For the gastrointestinal diseases the number remained higher than in the two previous years throughout the summer until late September. Regarding the drownings it must be said that the sample size is fairly small. Throughout the three years only 22 drownings happened, 12 of them in 1911. Most of this 12 occurred during the major heat period.

In addition to these two, a peak during the heatwave of 1911 can also be seen among other causes, such as respiratory diseases (Figure 45) or cardiovascular diseases (Figure 46), though these peaks were less prominent.

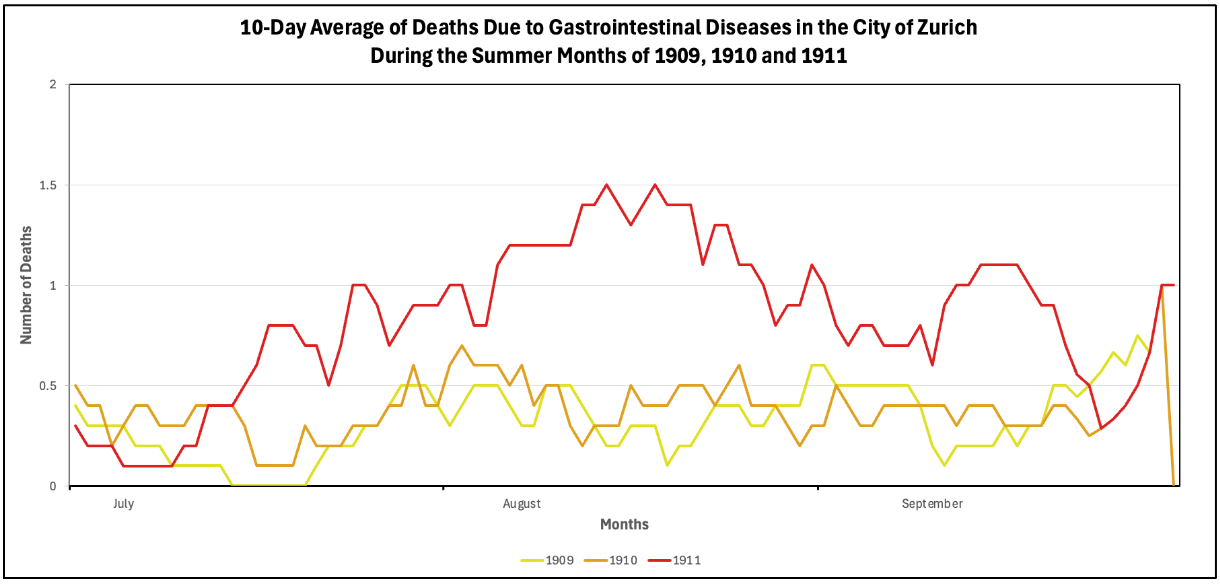


Figure 43: 10-day average of deaths due to gastrointestinal diseases throughout the summer months.

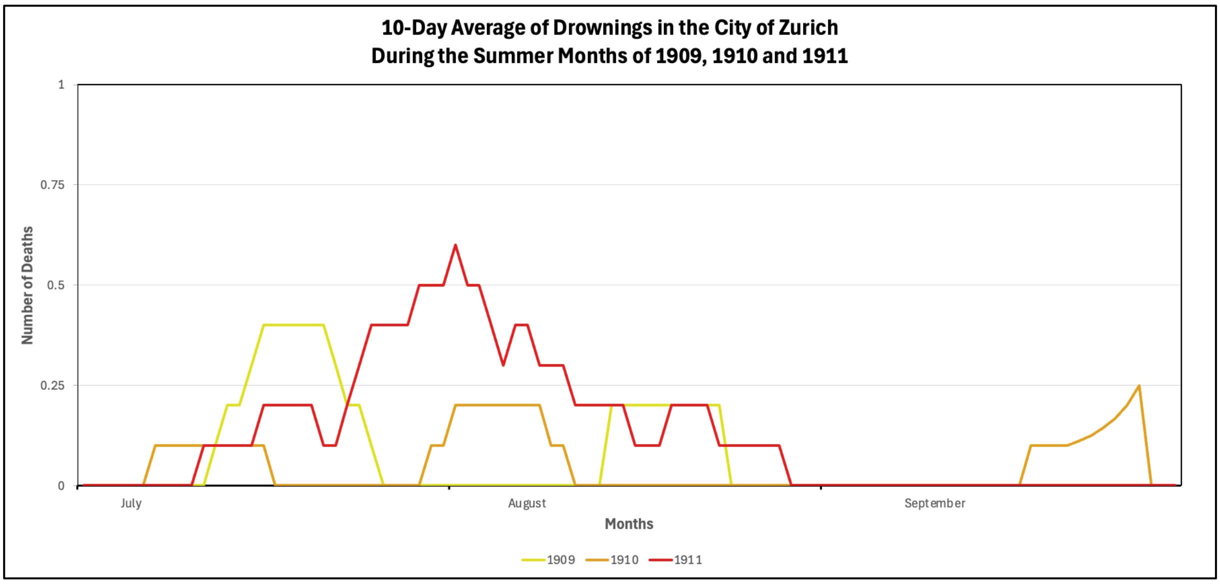


Figure 44: 10-day-average of deaths due to gastrointestinal diseases throughout the summer months.

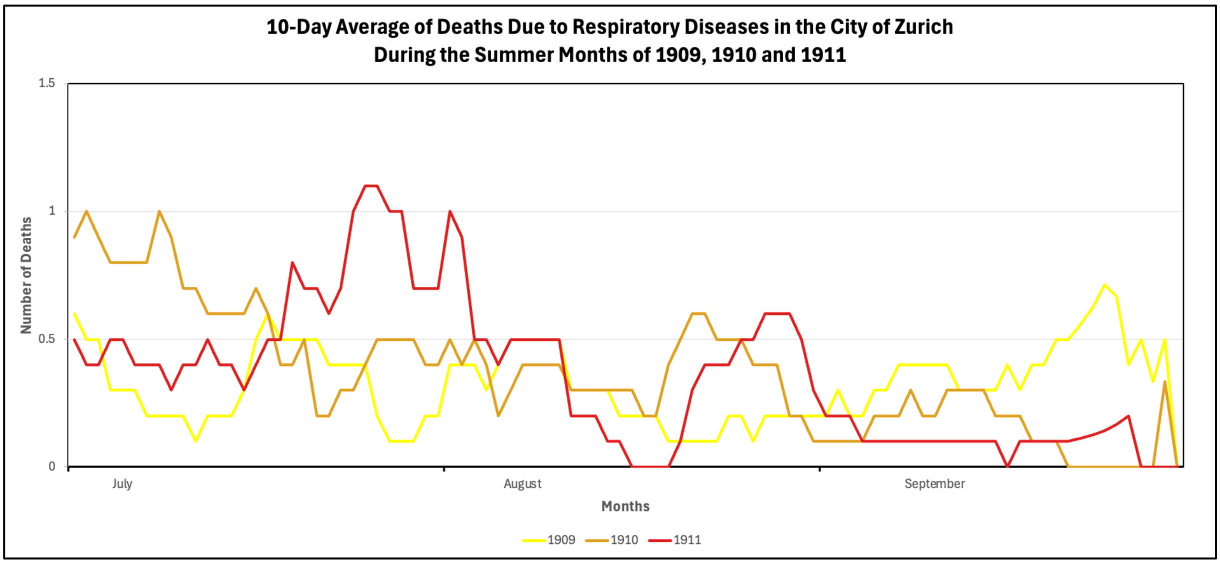


Figure 45: 10-day average of deaths due to respiratory diseases throughout the summer months.

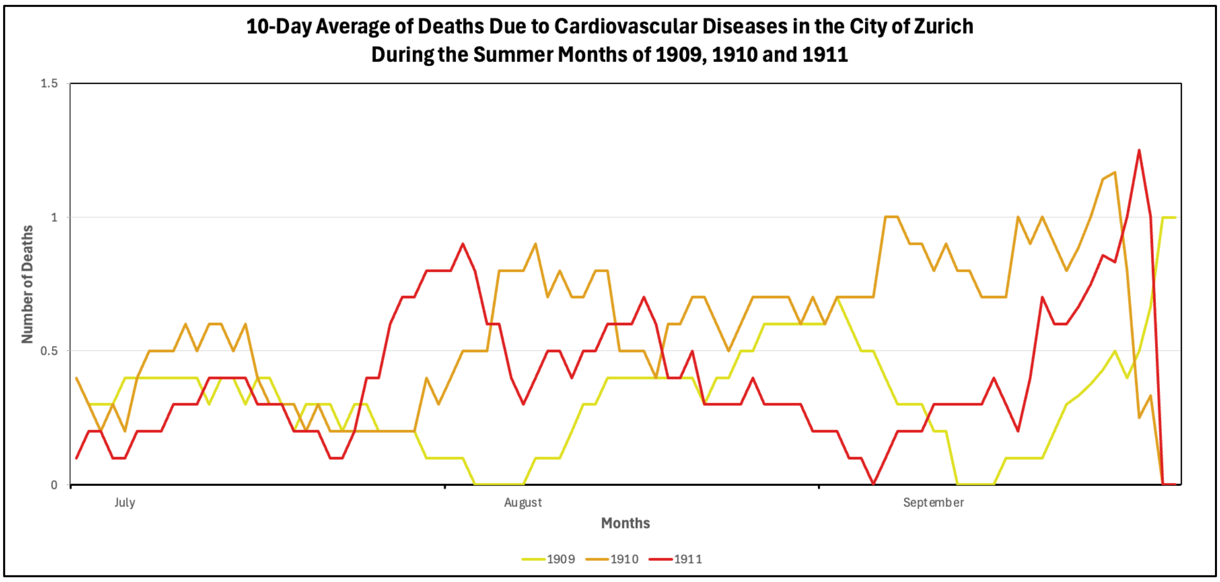


Figure 46: 10-day average of deaths due to cardiovascular diseases throughout the summer months.

Then there is also the Hisclass-Classification, which helps to look at the social standing of the deceased. The data indicates that most individuals who passed away during the three-year period were classified in class 2, with 365 cases in 1909, 354 in 1910 and 395 in 1911. Followed by class 1 with 156 in 1909, 173 in 1910 and 183 in 1911. This can be attributed to the fact that many women are classified into Class 2, due to working as housewives. In both classes, the year 1911 has the highest number of deaths, though the difference is only minor, especially among Class 1. It is interesting to note that the largest increase in 1911 was observed in Class 3, where the number increased from 65 in 1909 and 79 in 1910 to 115 in 1911. Class 3 contains the upper-class population.

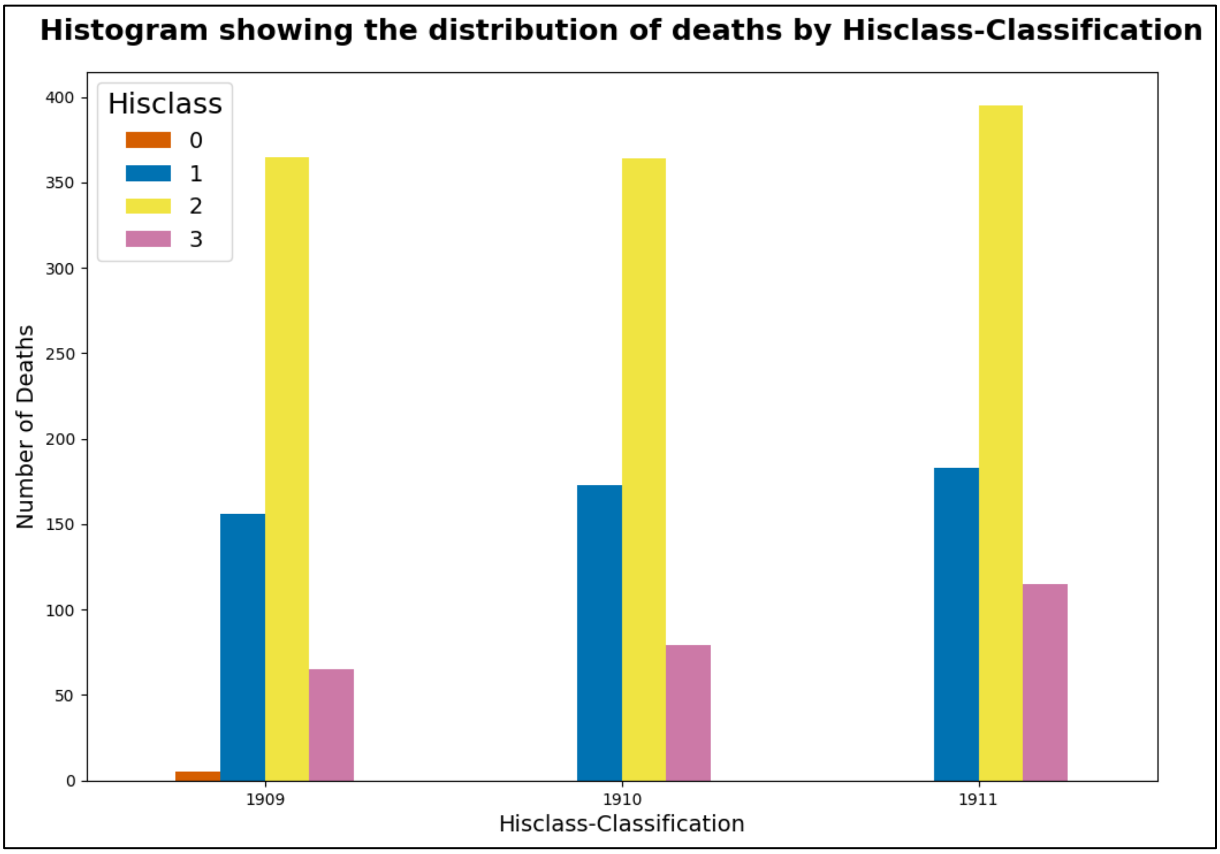


Figure 47: Number of deaths by hisclass-classification and year.

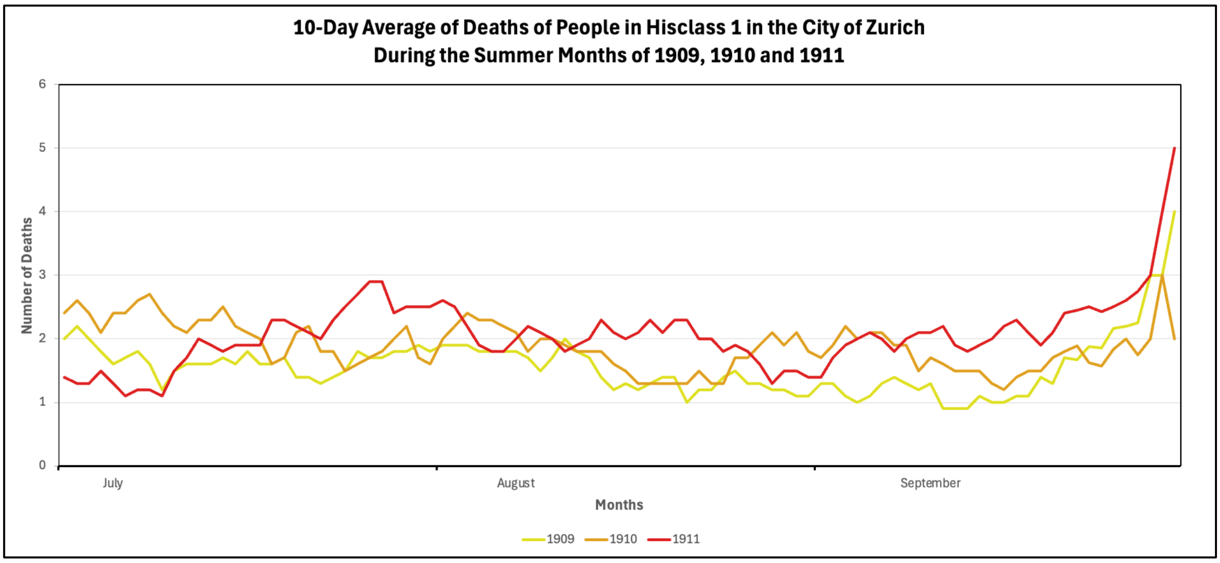


Figure 48: 10-day average of deaths by people classified as hisclass 1.

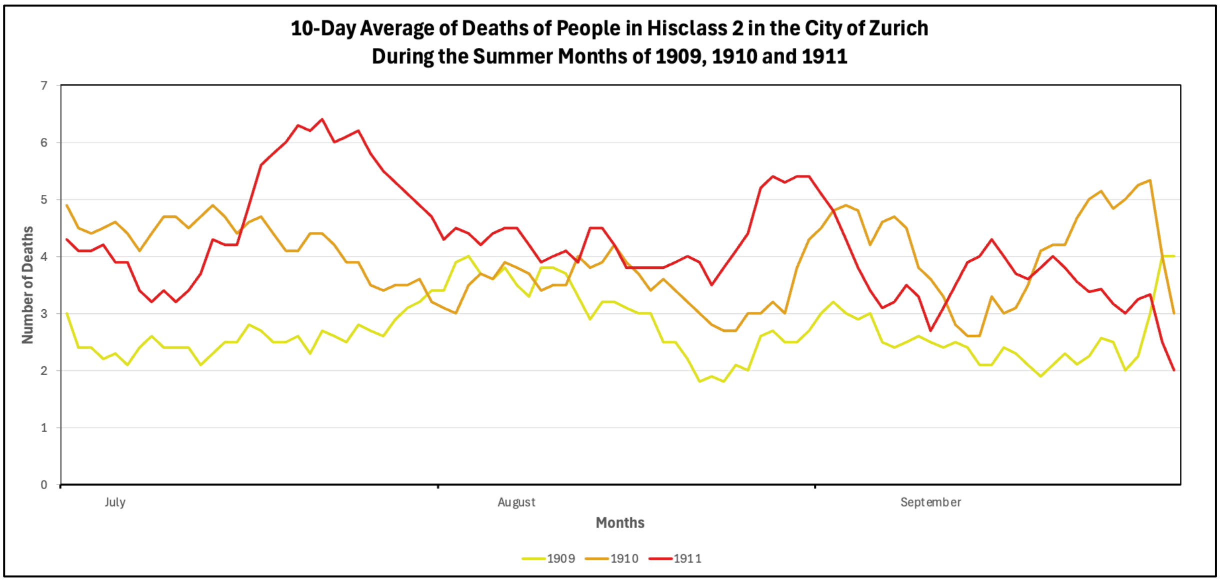


Figure 49: 10-day average of deaths by people classified as hisclass 2.

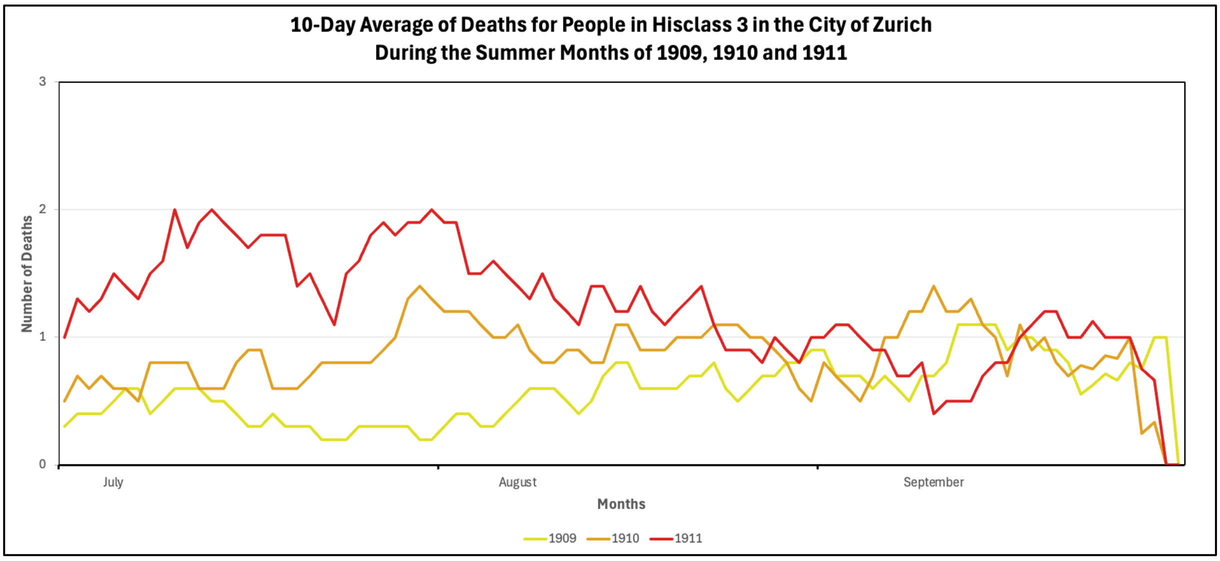


Figure 50: 10-day average of deaths by people classified as hisclass 3.

Lastly there is the sex of the people who passed away and here something interesting can be observed. While in the years 1909 and 1910 slightly more women passed away, it flipped in 1911, when clearly men were more at risk (Figure 51).

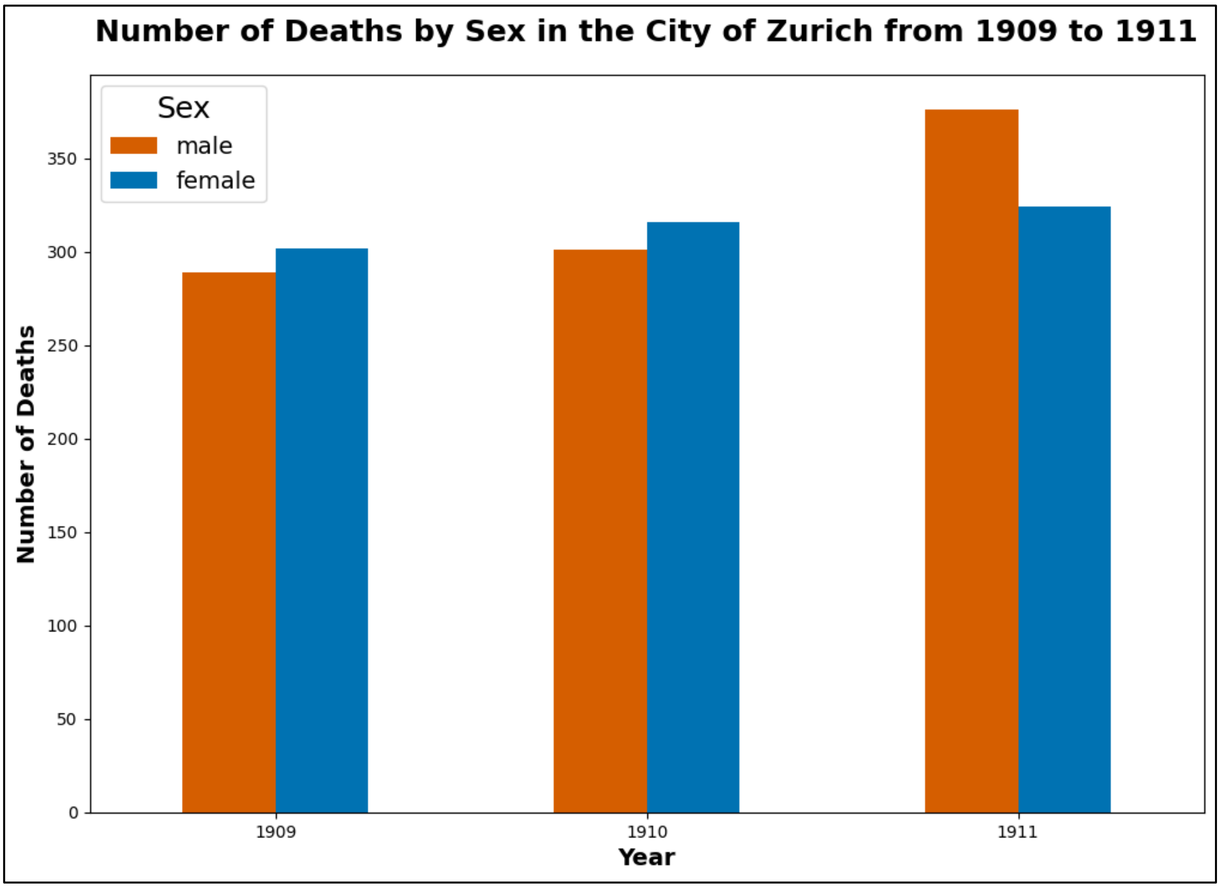


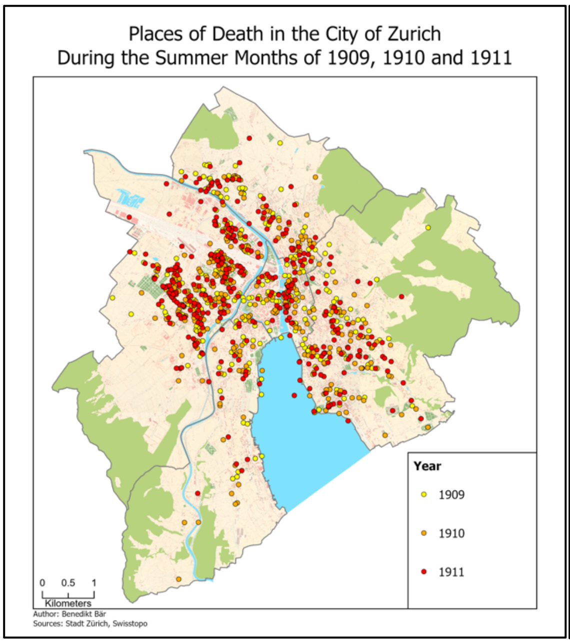
Figure 51: Number of deaths by sex in the city of Zurich.

This concludes the temporal analysis, and we will now continue by looking at the results of the spatial analysis.

4.2 Spatial Analysis

As a broad overview over the cases within the city of Zurich they first were simply mapped as dots. The maps shown in Figure 52 and Figure 53 display all the cases that happened during the time of interest. Figure 52 shows the places of death during these three years. 1903 cases were successfully mapped. Five cases were not possible to map, as the deaths happened in a moving vehicle and were therefore not possible to pinpoint to a specific location.

In Figure 53 1499 cases were placed on the map. 373 of the deceased had their place of residence outside the City of Zurich and for a further 36 the place of residence was unknown. These maps provide a good first overview over the situation, but for a further analysis more specific maps are required.



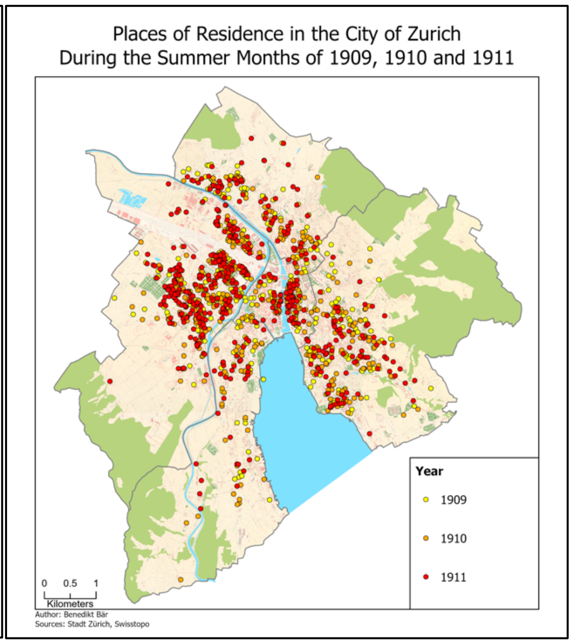


Figure 52 (left) and Figure 53 (right): Maps of all the deaths that happened in the city of Zurich during the three years. Figure 52 shows the place of death, Figure 53 shows the place of residence.

One option is the kernel density estimation (KDE). This type of map does not show the exact location where the deaths happened but will show hotspots, areas where particularly many people die, due to this it gives a better overview how many deaths occurred where and makes it possible to find clusters, where more people passed away during a certain year. This was done for both, the places of death and the places of residence. But when looking at the initial results received for the places of death, it becomes evident that these KDE maps are not too useful. All three maps for the place of death had one single big cluster close to the Hochschulquartier, as can be seen in Figure 54. At the time the Kantonsspital (nowadays Universitätsspital), the Frauenklinik and the Kinderspital were all located in this area, which lead to this massive cluster. In an attempt to get a more useful map for the places of death, an additional hotspot map was created, where the hospitals and clinics were removed from the data.

For this purpose, the dataset was filtered to remove the following places of death from the map:

- Kantonsspital Zürich
- Kantonale Frauenklinik
- Kinderspital
- Kantonales Säuglingsheim
- Kranken- und Diakonissenanstalt Neumünster
- Krankenheim Rehalp
- Schweizerische Anstalt für Epileptische
- Theodosianum

This process reduced the number of cases to 1185.

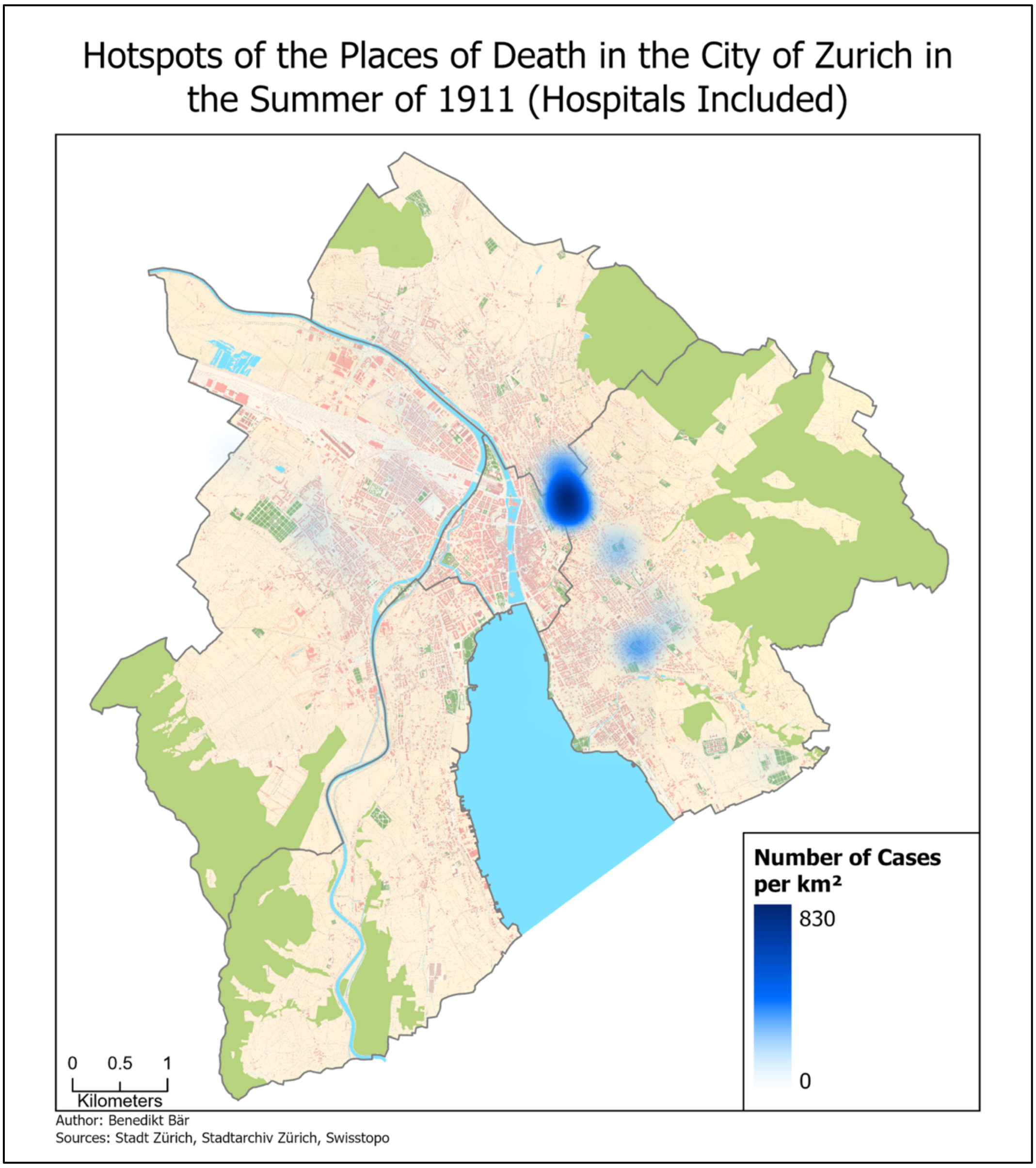


Figure 54: Hotspot map of the places of death. There is one big cluster in the Hochschulquartier.

Figure 55 compares the hotspots of the places of death, with the hospitals excluded, to the places of residence. In general, the maps based on the place of death and the maps based on the place of residence look fairly similar with regard to the distribution. They mainly differ in the density, as the maps for the place of residence contain more cases, they tend to have a higher density per km^2. This suggests that most people who did not pass away in a hospital died at home or close to their home and due this it was decided to focus mainly on the place of residence for this thesis.

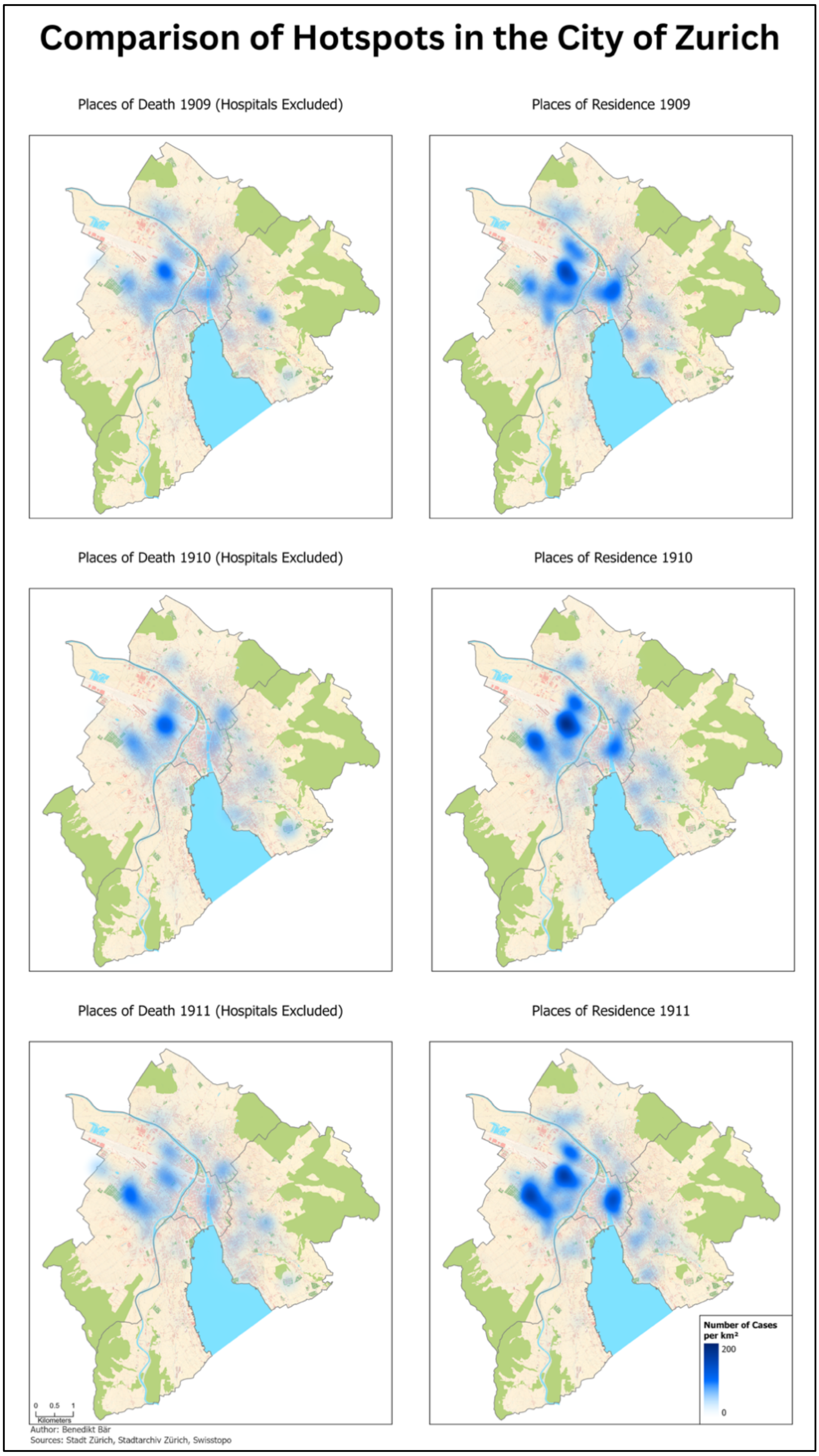


Figure 55: Comparison of the hotspot-maps for the places of death (with the hospitals excluded) and the places of residence.

A different type of map can be seen in Figure 56. It shows the change of cases over time per district and compares them to the average rent price per district. The rent price acts here as a simple method to infer the socio-economic situation in each district. It does present similar findings to the kernel density maps. The deathrate is the highest in district

3. Interesting is also, that while there can be seen an increase in the death rate in 1911 in the districts 3 and 4, the districts with the lowest rent prices. This is not the case in districts 2 and 5, where the highest death rate was in 1910. In district 1 there was also an increase in the death rate from 1910 to 1911, but here the highest death rate occurred in 1909.

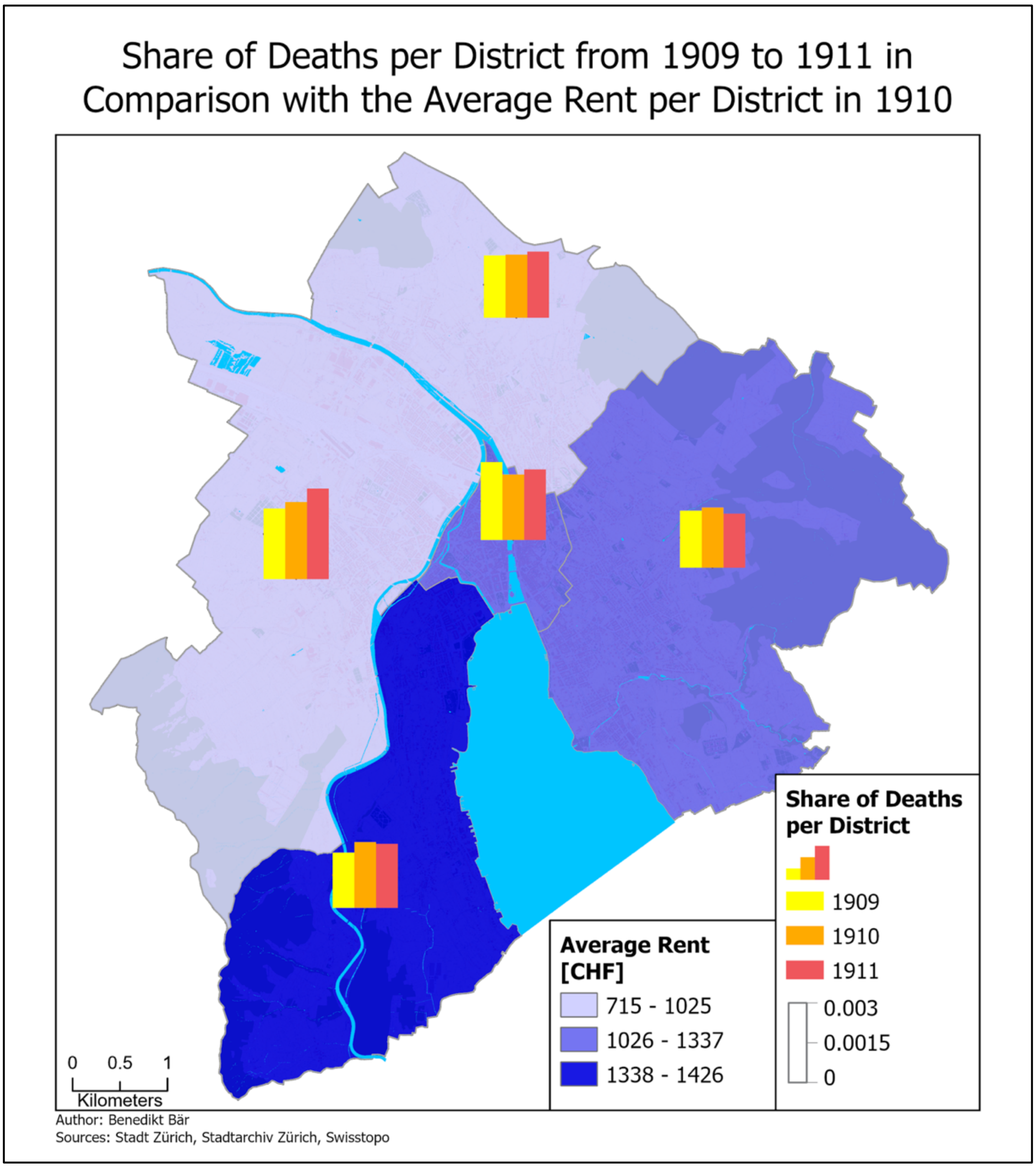


Figure 56: Yearly deaths by district in comparison to the average rent prices. The death rates increase in 1911 in the districts with the lowest average rent prices, while no such change can be seen in the higher rent districts.

Another way to depict the socio-economic status throughout the city, is the hisclass classification, though this data is only available for the people who died during the three summers. Figure 57 depicts this. For hisclass 1 there are clear hotspots in district 3 and one in the Niederdorf in district 1. In general, they look quite similar to the hotspots that can be seen in Figure 55, which depicts the hotspots where most people died.

Hiclass 2 has hotspots in similar loacations, but there are more hotspots throughout the city. Regarding Hisclass 3, the upper-class population, the only thing that can be said when looking at Figure 57, is, that there are generally less people who died in this category. Due to this I also created the map in Figure 58, which depicts the same data, but with a different value range, so that the hotspots are better visible, despite having less cases than the other two categories. This way it is visible that parts look similar to the other two categories. There are also hotspots in district 1 and in district 3. But when looking closely it can be noticed that the hotspot in district 3 is in Wiedikon, close to the river Sihl, and with that it differs from the hotspot in category 1, suggesting that this might have been an upper-class area of the district. Furthermore, there is a hotspot in the neighborhood of Hottingen, which is not present in the other categories.

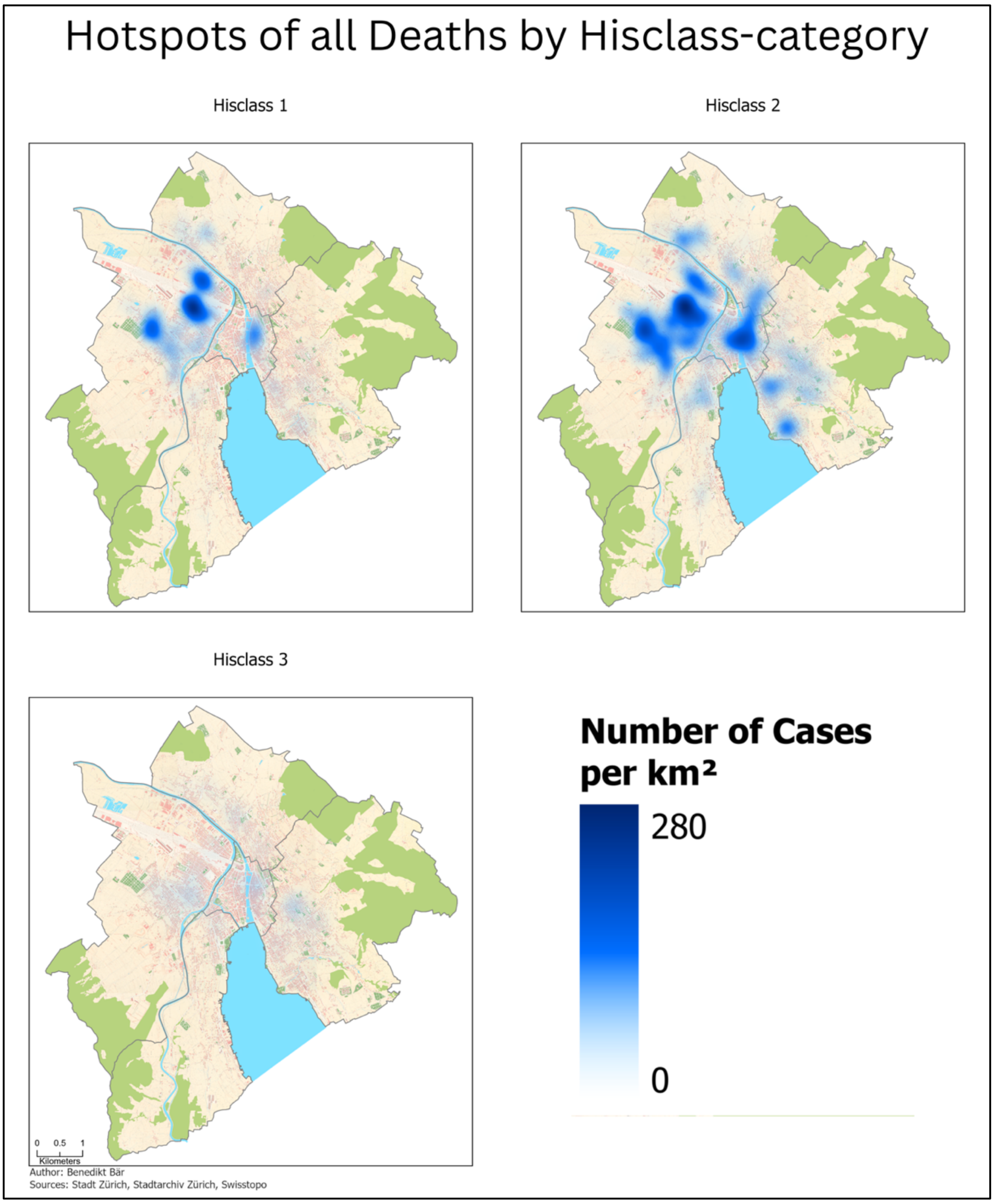


Figure 57: Hotspots by Hisclass-category in the city of Zurich from 1909 to 1911.

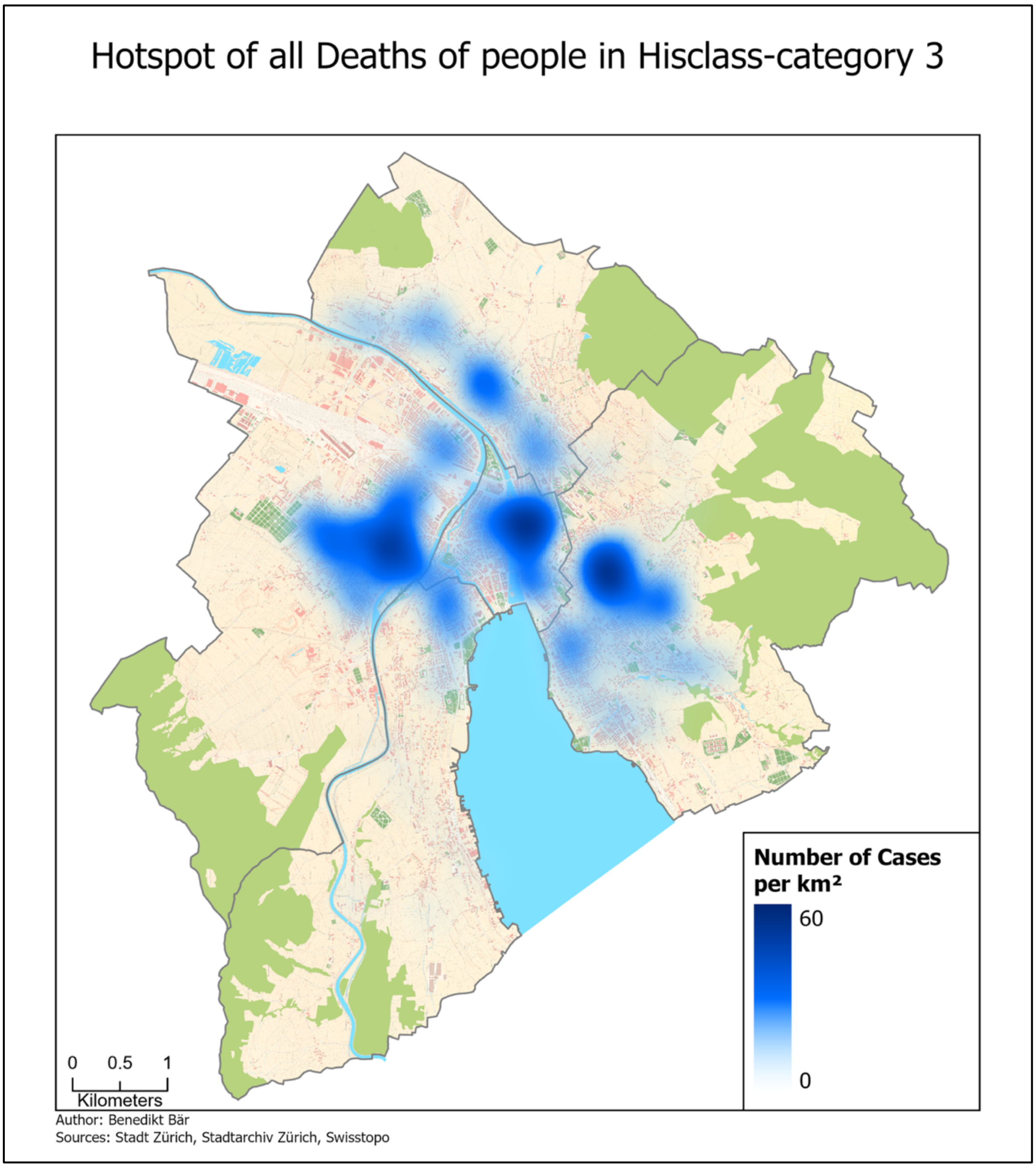
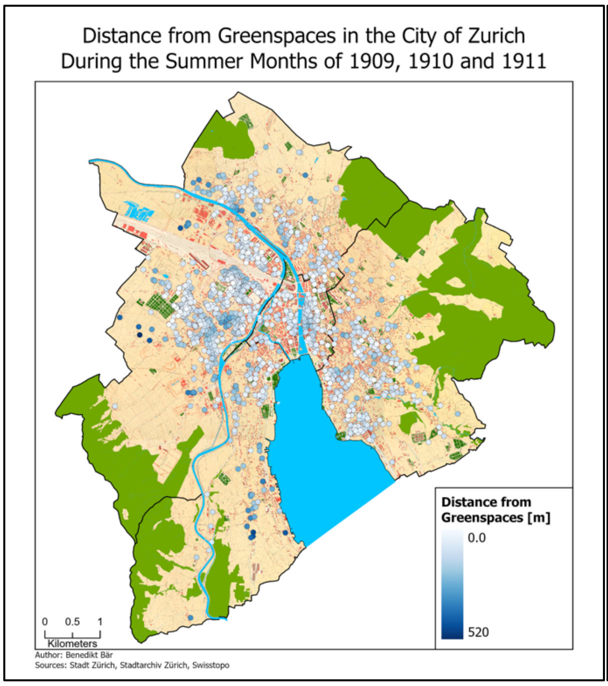


Figure 58: Deaths by people in the hisclass category 3.

A further interesting aspect to look at is the distance to greenspaces and water areas. For these categories, two different methods were used. First, the causes were mapped showing the Euclidean distance from each point to the closest greenspace or water area respectively. For Figure 59, the greenspaces, here defined as parks and forest areas, are quite evenly distributed throughout the city. The statistics show that 75% of cases are within 130.416 meters of a greenspace, the mean distance of all point is around 102 meters and the maximum distance from a greenspace is 517.89 meters. As a consequence, there is also no big difference in the mean distance from year to year. They vary between 100.98 meters in 1910 and 104.61 meters in 1911.

The water areas in Figure 51 show a different picture. Only 25% are within 137.617 meters from a water area, the mean distance is around 276 meters, and the maximum distance is at 876.39 meters. Looking at the changes between the years there is also a more notable increase when compared to the green spaces. While the mean distance to a water area in 1909 was at 264.78 meters, it rose to 285.03 in 1911. In 1910 it was at 278.58. Especially notable is the area east of the Sihlfeld cemetery, which was among the longest distance to a water area.



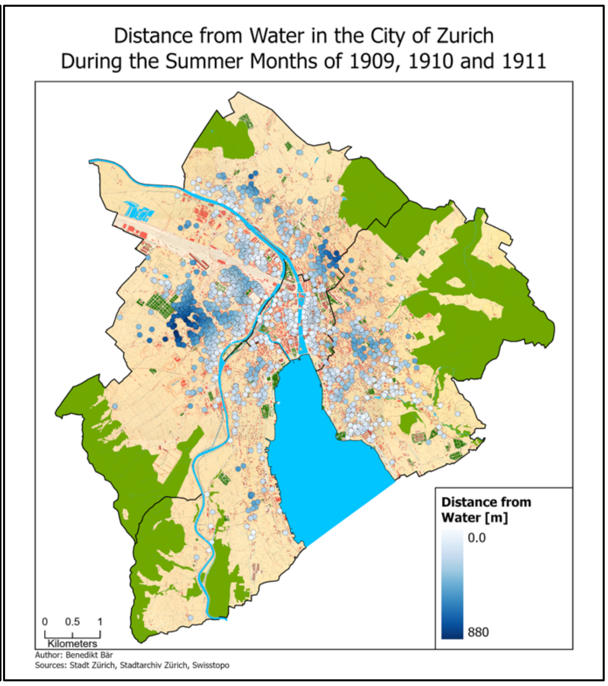


Figure 59 (left) and Figure 60 (right): Figure 59 shows the distance from greenspaces for each case in the city of Zurich. Figure 60 shows the distance from water for each case in the city of Zurich.

The second method was by calculating the share of recreational areas per district. For the greenspaces only the parks were considered, as most forested areas are on the outskirts of the city, quite far away from the majority of cases. With forests included districts 3 and 4 would have a large percentage of greenspaces, despite a notable distance between the populations centres and the forests.

After calculating the share of greenspaces, it can be seen in Figure 61, that there is a higher park density in districts 3 and 5, with the highest density in district 1, while districts 2 and 4 have the lowest park density.

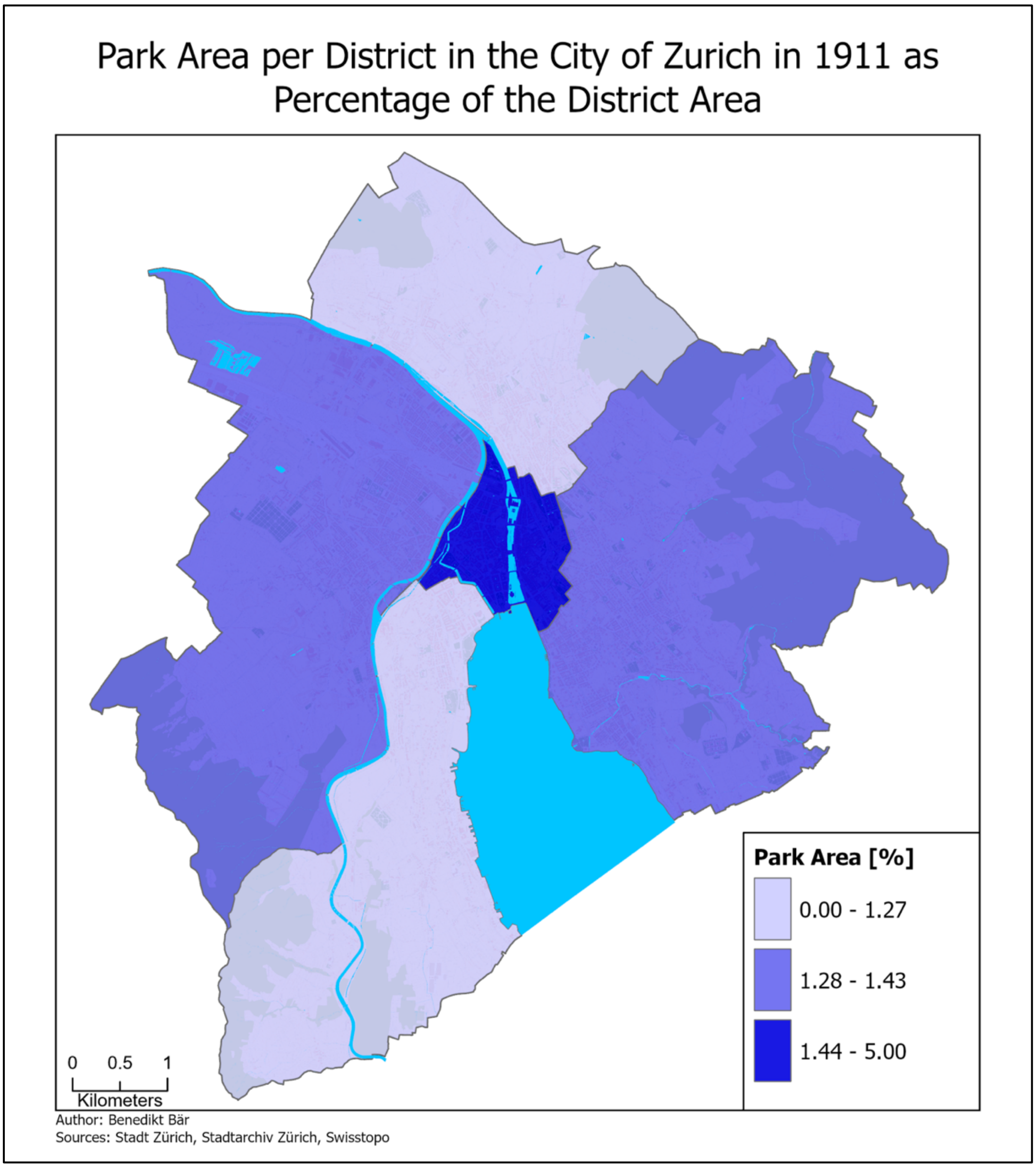


Figure 61: Park area per District in the City of Zurich. District 2 has the lowest coverage with 0.9%, districts 3, 4 and 5 are all between 1.27 and 1.44%, district 1 has a coverage of 4.95 %.

For water areas, as shown in Figure 62, the clearly highest density is in district 2 with 26.38%, followed by districts 1 and 5 with 15.04% and 13.61%, respectively. Then there is a clear gap to district 3 with 2.72% and district 4 with 1.09%.

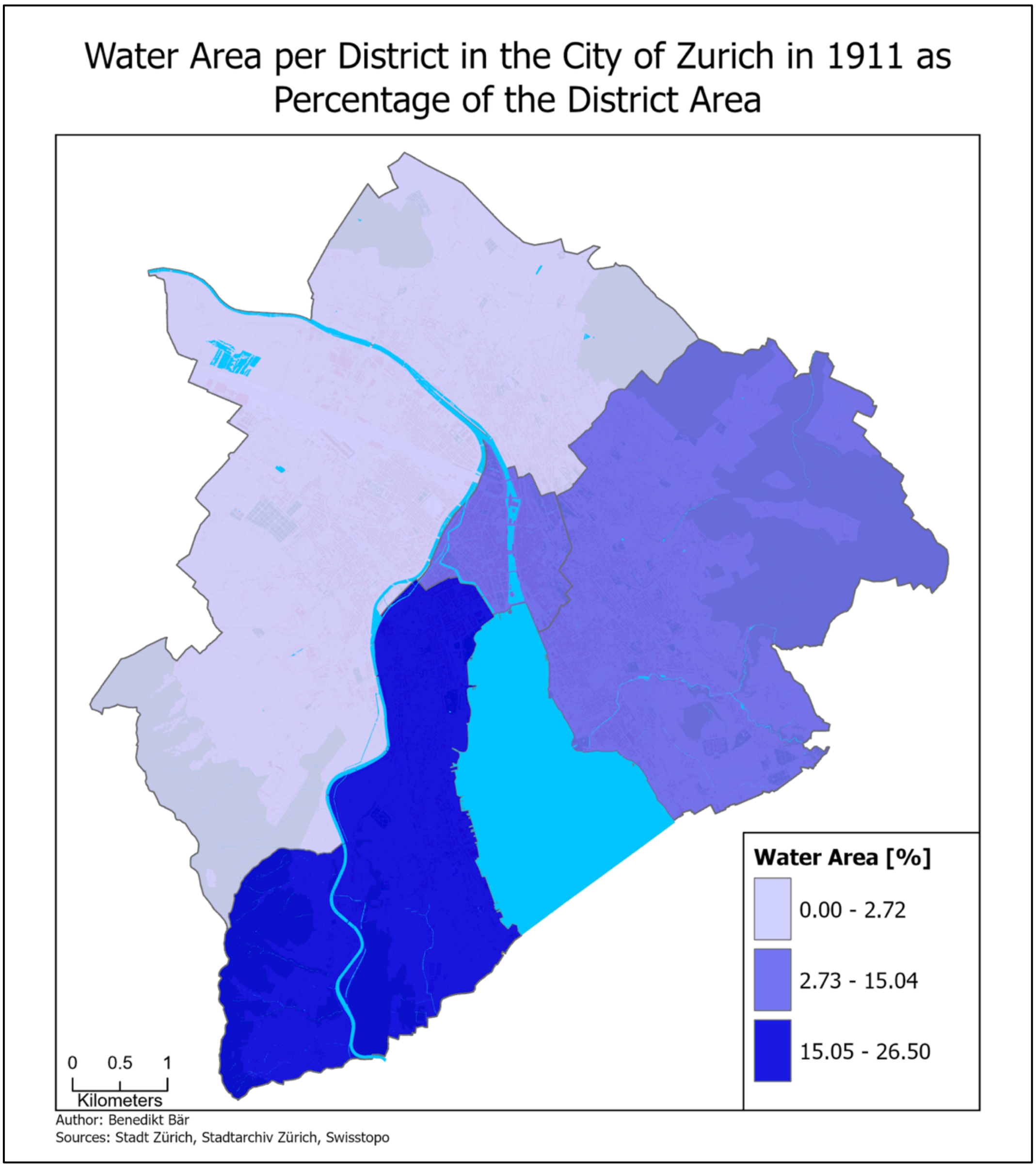


Figure 62: Water area per district in the City of Zurich.

Now the hotspot analysis previously done for all causes, can also be done for each cause specifically, as can be seen in the following figures. For 1909 and 1910 (Figure 63 and Figure 64) it again can be noticed, that most causes do have a hotspot in district three, just south of the train tracks, as it was also noticed in Figure 55. This Hotspot is generally also visible in 1911 (Figure 65).

As it could be seen in Figure 42, deaths due to weakness and stillbirths used to be the most common causes of death in 1909 and 1910, which is also visible when looking at the hotspot maps for the respective years. Meanwhile, this has changed completely in 1911. While deaths due to weakness and stillbirths remained relatively stable, deaths due to gastrointestinal diseases have peaked that year, with major hotspots east of the Sihlfeld cemetery and in the Industriequartier between the railway lines and the Limmat.

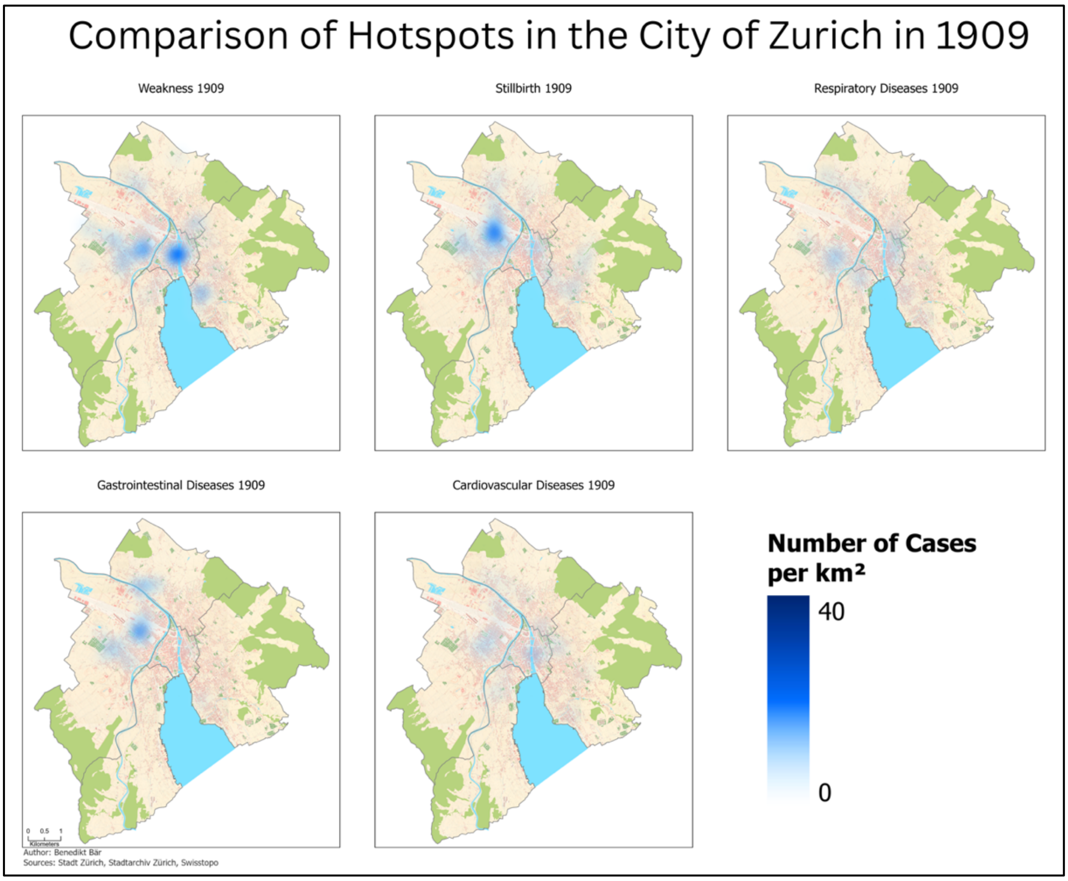


Figure 63: Comparison of hotspots by cause based on the place of residence in 1909.

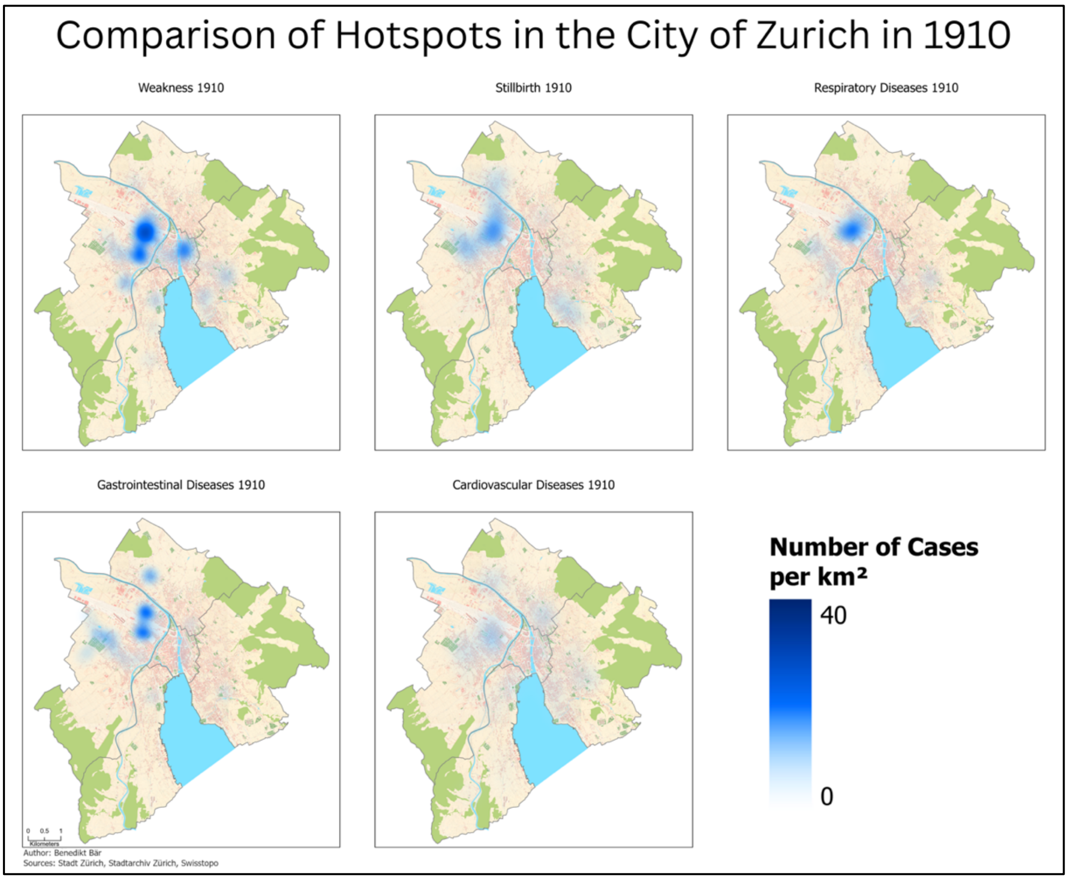


Figure 64: Comparison of hotspots by cause based on the place of residence in 1910.

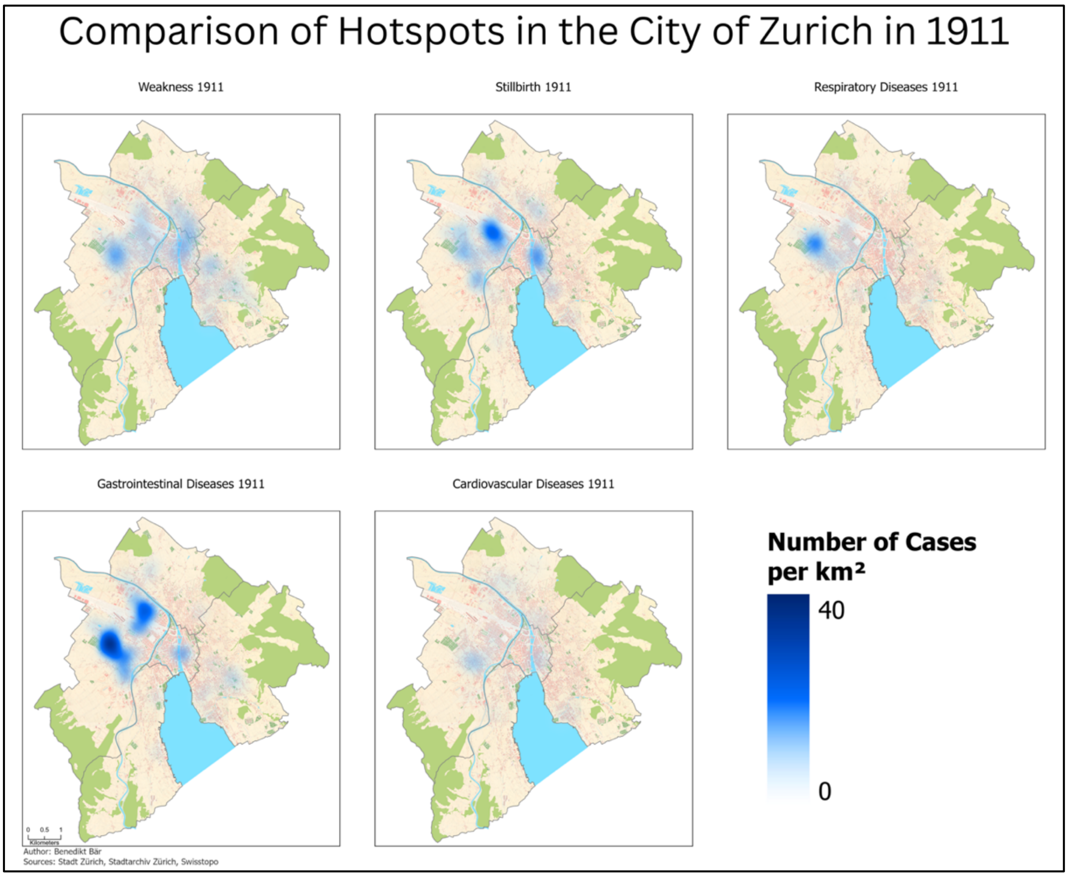


Figure 65: Comparison of hotspots by cause based on the place of residence in 1911.

5 Discussion

One of the first steps of this thesis, was the manual digitization and geocoding of historic data, as it was described in the methods of this thesis. This made it possible to analyse the data, both temporally and geographically. After all the results were presented in chapter 4, it is now time to compare these results to the literature and to answer the research question set at the beginning of this thesis.

The main research question was:

What impact did the 1911 heatwave have on the mortality within the city of Zurich and how was it influenced by the geographic conditions?

To help answering this question four additional questions were formulated, which I will now go through one by one, starting with the questions relevant for the temporal analysis.

5.1 Temporal Analysis

The first question was:

1. **What groups of people were especially affected by the heatwave?**

Prior research has shown, that there tends to be an increase of deaths during heatwaves. (Gasparrini et al. 2012) states that one percent of all deaths during summer months can be attributed to high temperatures and multiple such as (Arbuthnott and Hajat 2017; Gasparrini et al. 2012; Heudorf and Meyer 2005; Luschkova et al. 2021) state an increased risk for older people.

Looking more specifically at the heatwave in 1911, previous research done in France, Germany and the Dutch province of Limburg also discovered a high mortality among infants, which is less often mentioned in research about contemporary heatwaves (Abt 1911; Rollet 2010; Rutten 2012; Vögele 2010; Xu et al. 2014).

Data from Zurich generally shows that there has been a slight increase in 1911, as the numbers have gone up from 591 deaths in the summer of 1909 and 617 deaths in the summer of 1910, to 700 deaths in 1911. Although only the difference between 1909 and 1911 was found to be significant when comparing the rates and the effect size was found to be quite small. While a larger sample size might cause the result to be more significant, the small effect size shows, that the impact of the heatwave on the death counts of the entire summer in the city of Zurich was only minor.

However, daily mortality data reveal a slightly different picture. The regression analysis has shown a significant relationship between the temperature and the number of deaths two days later. A similar regression analysis for the years 1909 and 1910 revealed that this was not the case in these years, which does suggest that the increased temperatures in 1911 had an impact on the daily mortality. This is additionally reinforced when analysing the influence of only the days exceeding the heatwave threshold of 28.02°C was surpassed. Surpassing this threshold resulted in a highly significant regression with a moderate effect size. As this threshold was only surpassed on three and two days respectively in 1909 and 1910, while it was surpassed on 42 days in 1911, this suggests that especially days where this threshold was reached had an impact on the death rate, though there was a two-day lag between the respective heat days and rising death count. This lag is also confirmed by other research, as Koppe (2003) stated that the temporal lag between a peak in temperature and the mortality is between zero and three days.

Regarding the age groups especially affected by the heatwave, the thesis can confirm, that especially the number of infant deaths increased during the heatwave. Compared to 1910 there was also a notable increase in deaths among the elderly, but compared to 1909 this increase was not as notable. It is possible that there was another reason for an increased mortality among the elderly in 1909, but this reason was not part of this thesis.

This leads us to my third question:

2. **Which causes of death did increase during the heatwave?**

Gasparini et al. (2012) wrote in their paper that they discovered an increase in deaths during heat periods no matter the cause, but they mentioned cardiovascular diseases to be the main cause of death and respiratory diseases to be the cause with the steepest increase during periods of high temperatures. Looking at 1911, Rollet (2010), Rutten (2012) and Vögele (2010) all mention gastro-intestinal diseases. Unlike the observations made by Gasparini et al. (2012) a general increase in deaths, no matter the cause is not visible in the data from Zurich, but this can be caused by the fact, that the dataset from Zurich was considerably smaller, than the dataset used by Gasparini et al. (2012), which covered 2’285’519 deaths during a period of 13 years. The data from Zurich mainly shows an increase of gastrointestinal diseases and drownings, as well as a small increase for deaths due to weakness. For the other causes that were looked at, there is no visible trend towards an increase, when looking at the entire three months period. Although, once again it looks a little different when looking at the daily numbers. Apart from peaks for gastrointestinal diseases and drownings, also other causes, such as respiratory diseases, cardiovascular diseases and deaths due to weakness do show a peak during the warmest period of 1911, at the end of July, which suggests a possible causation.

5.2 Spatial Analysis

3. **Were there areas that were more affected?**

As pointed out before, the spatial analysis of historic heatwave data was found to be a research gap and therefore there is a limited amount of available literature on this topic. The literature suggests that this may differ depending on the country or region (Arbuthnott and Hajat 2017), though often members of a lower socio-economic groups are at a greater risk, as for example afro-american people in the US, as described by Schwartz (2005). In Zurich this greater risk of people in a lower socio-economic group is clearly visible. Various statistics, such as the average taxable assets per district (Table 3), the average rent by district (Figure 56) and also the distribution of deaths by hisclass (Figure 57), show that most of the lower class areas of the city of Zurich were located in district 3, especially in the neighbourhoods of Aussersihl and Wiedikon. As seen in Figure 56, this is also the district with the biggest increase in 1911, compared to the two previous years. Meanwhile the share of deaths in the upper-class neighbourhoods of district 2 and district 5 stayed roughly equal or was even lower than in 1909 and 1910.

An important factor when looking at the socio-economic status is the hisclass-classification, even though it comes with several limitations. When looking at these results, there are a few things that seem surprising. All the categories have a slightly increased number of deaths during the year 1911 and all categories do show a peak in the number of deaths in late July of 1911. Interestingly, category 3, containing the highest socio-economic groups, showed the largest increase in deaths in 1911. This might look surprising at first, but can possibly be explained by the generally lower number of deaths in this category, which makes it more susceptible to changes. Furthermore, category 3 is the category with the highest share of males. This is particularly interesting because, contrary to the findings of Arbuthnott and Hajat (2017), who found that in modern-day UK, women were at greater risk during heatwaves, the data from Zurich in 1911 suggests that at the time the male population was at a greater risk of dying during the heatwave, which therefore could be a reason for the sharp increase in deaths in category 3. Then there is also the high number of deaths in category 2, which can be explained by the fact, that women working as housewives, were all grouped into this category, in lack of a better option. Lastly, as seen in Figure 58, a notable part of people in category 3 who died lived in the generally lower-class district 3. This could have several reasons. On one hand, as mentioned before, it is possible, that most of them lived in a wealthier part of this district, but this is not possible to derive from the data available, as this would require more detailed socio-economic data. On the other hand, it is also possible that just living in district 3, no matter the category, meant a higher risk of dying and lastly there is always the question about the accuracy of the hisclass-classification.

And with that, I will lead over to the last question:

4. **Did the proximity to greenspaces or water areas have an influence?**

For green spaces this question can be answered with no. There is no area with a notable lack of greenspaces, as they seem to be quite equally distributed throughout the city. Additionally, district 3, with its especially high death count, has one of the highest shares of park areas as a percentage of district area. But for water areas, there is a possible connection. First, district 1, the district with the highest percentage of water area, had the lowest number of deaths, while district 3 had a low percentage of water areas. Additionally, one of the areas most affected by the heatwave, east of the Sihlfeld Cemetery, happens to be clearly farthest away from a water area.

5.3 Limitations

For this thesis several limitations must be considered.

The digitisation process was the first step. First, all the handwritten entries were photographed, and then they were transcribed manually into a spreadsheet. This alone caused several possible errors. The handwriting was sometimes hard to decipher, and some of the photographs were of poor image quality. These issues may have led to misreadings.

Fortunately, the death registry was a fairly complete dataset. Thirty-six people had an unknown place of residence, seventeen of whom were recorded in 1909. Nine had an unknown cause of death, two had no information about their profession, and two had no date of birth. This number should not have a significant impact on the results, especially in terms of place of residence, as it can be assumed that most of these people did not officially live in the city of Zurich. In this regard, it cannot be guaranteed that no errors were made when these entries were originally written. Deaths were recorded in the registry when reported by a family member, doctor, hospital or police, and it is possible that mistakes were made during this process. In fact, it is certain that such mistakes happened, as a few entries had corrections added later.

Another step in the digitisation process was geocoding. One of the main problems here was the changes to the city's street network. This involved researching streets that no longer existed, manually finding house numbers that no longer existed, matching rough descriptions of places to suitable locations, and correcting addresses that the geocoder had mistakenly placed outside the 1911 city boundaries. In some cases, it was not possible to find the exact address, so an approximate location had to be found instead. All of the above were a cause of potential errors. Furthermore, while addresses that were incorrectly placed outside the city of Zurich were corrected manually, it is still possible that the geocoder incorrectly placed some addresses within the city limits. For the scope of this thesis, it was not feasible to manually check the accuracy of every single location. To mitigate this risk, random samples throughout the city were checked. Although these samples were all placed at approximately the correct location, it cannot be guaranteed that this is the case for every single location.

To keep it simpler, at the start of the thesis it was decided to focus on seven causes of death that were deemed most likely to increase during a heatwave. These causes were: acute gastroenterological diseases, acute problems with the cardiovascular system, drowning, heat strokes, stillbirths and pre-natal births, respiratory diseases, deaths due to weakness and other deaths. To get a more detailed picture of the situation, it would be required to focus on other causes as well.

Furthermore, there is the base map, which is not fully colorblindsafe. The visual contrast from water surfaces, forests and parks were increased, as they are of special interest for the thesis, but other than that I decided to keep the historical coloration.

Notable is also the MAUP (modifiable areal unit problem), which occurs when data is aggregated into larger areal units (Wong 2009), such as the five districts In the case of the city of Zurich. Due to this, information could be lost that would be relevant for an analysis. Additionally, it does not always make sense to use data from the entire district. Due to this, the forests were excluded from the calculation of the greenspace area per district, as they are large areas usually quite far away from the urban population centres.

Connected to this is in general a lack of higher resolution data in certain areas. One example would be that there was only one weather station in Zurich at the time. More stations or other weather records could have allowed a more detailed picture on the weather situation in different parts of the city. Another, more limiting, aspect of this is the lack of socio-economic and demographic data. There is some data that could be used on a district level, which makes it possible to compare the districts, but it does not allow a more detailed picture of the situation inside a certain district.

Luckily for this thesis, there was a census in 1910, which means that there is more data available compared to other years at the time, like population by district or average rent by district. But this also means that certain data were only available for the year 1910 and not for the other years.

Furthermore, there is also the question about the accuracy of the hisclass classification, which provides the option to class the deceased based on their profession. While it is a helpful classification, it has some drawbacks. First, not all professions clearly belong to one class. While it is still possible that a person was part of a lower, or higher, socio-economic class, than they were grouped into by their profession. Secondly, there is the problem with women and children. At the time a lot of women were housewives and children usually do not have a profession. For housewives the decision was made to put all of them into category 2, while the children were classified by the profession of their father, or in some cases their mother.

Additionally, hisclass only helped categorizing the deceased people and as mentioned before, there is no really detailed data about the socio-economic situation. This means that it was not possible to check how the situation was compared to other people in the same socio-economic group. While we do know, in which class most people passed away, whether there was a higher share of deaths in one of the social classes.

Lastly it is also to mark, that three years is a rather small sample of years. While this short period can provide a general idea of how the heatwave affected the population in Zurich in 1911, the inclusion of more years prior to 1909 or after 1911 would certainly provide a more stable image of how regular years, meaning years without a heatwave, compared to 1911.

6 Conclusion and Outlook

This Thesis looked at the year 1911, during which an, at the time, notable heatwave occurred. What is nowadays, due to the ongoing climate change, more normal, was exceptional at the time, as it was described as one of the warmest, driest and brightest summers ever recorded (Billwiller 1911).

This thesis wanted to look at the consequences of this historic heatwave on the population of the city of Zurich. On one hand to check whether findings from previous studies on this heatwave can be found in Switzerland as well, on the other hand to look at this from a geographical perspective, with the use of GIS.

To achieve this the death registry of the city of Zurich during the summer months of 1909, 1910 and 1911 was digitized and each address in this dataset was geocoded to allow it being analyzed.

Findings from previous studies have been confirmed. Also, in Zurich an increase in deaths, especially among infants, was observed. With the main cause being gastrointestinal diseases, most likely caused by milk that has gone bad due to the high temperatures (Vögele 2010). However, the increase in deaths in 1911 in comparison to 1910 was not found to be statistically significant, but there was a statistical significance when comparing it to the summer of 1909.

Further analysis on how the situation evolved over the summer months, has shown that there is a statistically significant regression between high temperatures and the daily number of deaths. The regression analysis has found that there usually is a peak in the number of deaths two days after a peak in temperature.

Regarding the geographic analysis, most deaths occurred in the working-class districts, mainly in district 3 in the neighbourhoods of Wiedikon, Aussersihl and Industriequartier. As this study was limited by a lack of socio-economic data of the alive population, it could be interesting for future work to look at this with more detailed socio-economic data, if such data is available.

While proximity green spaces did not seem to affect the number of cases, this thesis was able to find a possible correlation between the proximity to water and the number of deaths in a neighbourhood, but this does require future research, as this thesis only managed to detect a correlation and not to proof causation.

Additional research could also investigate whether different types of greenspaces and water areas have a different impact. As this thesis treated all kinds of greenspaces and water areas the same way, it could be interesting to see if it makes a difference, whether it’s a forest, a park or just a tree.

Furthermore, future research could include more years or compare the situation in Zurich to the situation in other places in Switzerland, to get a more stable and detailed picture about the consequences of this heatwave in Zurich and Switzerland.

Lastly, it could be interesting to make comparisons to more recent heatwaves. What did change between then and now and how did these changes affect the death counts?

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Appendix

Python Code

Some of the graphics and calculations were made with python and the respective code can be seen below. Other graphics were created with Excel or ArcGIS Pro.

```
import seaborn as sns
import pandas
import geopandas
import matplotlib.pyplot as plt
import math
import statsmodels.api as statmod
```

```
zh_kreise = geopandas.read_file("/Users/benedikt/OneDrive - Universität Zürich UZH/Masterarbeit/Stadtkreise1911/Stadtkreis_1911_withdata.shp")
Station_Fluntern =
geopandas.read_file("/Users/benedikt/Library/CloudStorage/OneDrive-UniversitätZürichUZH/Masterarbeit/WETTERSTATION/Fluntern.shp")
Wohnorte = geopandas.read_file("/Users/benedikt/OneDrive - Universität Zürich UZH/Masterarbeit/wohnundsterborte/Wohnort.shp")
Sterbeorte = geopandas.read_file("/Users/benedikt/OneDrive - Universität Zürich UZH/Masterarbeit/wohnundsterborte/Sterbeort.shp")
Stadt = geopandas.read_file("/Users/benedikt/OneDrive - Universität Zürich UZH/Masterarbeit/Stadtkreise1911/Zurich_Boundary.shp")
data_csv = pandas.read_csv("/Users/benedikt/OneDrive - Universität Zürich UZH/Masterarbeit/Sterberegister_csv9.csv", sep=";")
bev_agegroup = pandas.read_csv("/Users/benedikt/OneDrive - Universität Zürich UZH/Masterarbeit/Bev_Altersgruppen.csv", sep=";")
distances = pandas.read_csv("/Users/benedikt/Library/CloudStorage/OneDrive-UniversitätZürichUZH/Masterarbeit/Wohnort_Distances_v2.csv", sep=";")
greenwater = geopandas.read_file("/Users/benedikt/OneDrive - Universität Zürich UZH/Masterarbeit/greenwater.shp")

inhabs = Stadt[["1909", "1910", "1911"]].values.tolist()[0]

colorblindsave = ["#D55E00", "#0072B2", "#F0E442", "#CC79A7", "#009E73", "#56B4E9", "#E69F00"]
yearcolor = ["#ffff00", "#ffaa01", "#ff0200"]
```

```
years = [1909, 1910, 1911]
age = ["Stillbirth", "Age 0-1", "Age 1-5", "Age 5-20", "Age 20-50", "Age 50-70", "Age 70-80", "Age >80"]
categories = ["Stillbirth", "Age 0-1", "Age 1-5", "Age 5-20", "Age 20-50",
              "Age 50-70", "Age 70-80", "Age >80"]

shares_data = pandas.DataFrame({
    "Age_Group": categories,
    "tot": [data_csv["Altersgruppen"].value_counts()[agegroup] for agegroup in categories]
```

```
})
shares_data["m"] = [data_csv[data_csv["Geschlecht"] ==
"m"]["Altersgruppen"].value_counts()[agegroup]
                       for agegroup in categories]
shares_data["w"] = [data_csv[data_csv["Geschlecht"] ==
"w"]["Altersgruppen"].value_counts()[agegroup]
                       for agegroup in categories]
for year in years:
    filtered_data = data_csv[(data_csv["Year"] == year)]
    shares_data[f"tot{year}"] =
[filtered_data["Altersgruppen"].value_counts()[agegroup] for agegroup in
categories]
    shares_data[f"m{year}"] = [filtered_data[filtered_data["Geschlecht"] ==
"m"]["Altersgruppen"].value_counts()[agegroup]
                       for agegroup in categories]
    shares_data[f"w{year}"] = [filtered_data[filtered_data["Geschlecht"] ==
"w"]["Altersgruppen"].value_counts()[agegroup]
                       for agegroup in categories]

shares_data["share_tot"] = shares_data["tot"] / bev_agegroup["tot"] * 100
shares_data["share_1909"] = shares_data["tot1909"] / bev_agegroup["tot"] * 100
shares_data["share_1910"] = shares_data["tot1910"] / bev_agegroup["tot"] * 100
shares_data["share_1911"] = shares_data["tot1911"] / bev_agegroup["tot"] * 100
shares_data["share_m"] = shares_data["m"] / bev_agegroup["m"] * 100
shares_data["share_w"] = shares_data["w"] / bev_agegroup["w"] * 100
shares_data["share_m_1909"] = shares_data["m1909"] / bev_agegroup["tot"] * 100
shares_data["share_w_1909"] = shares_data["w1909"] / bev_agegroup["tot"] * 100
shares_data["share_m_1910"] = shares_data["m1910"] / bev_agegroup["tot"] * 100
shares_data["share_w_1910"] = shares_data["w1910"] / bev_agegroup["tot"] * 100
shares_data["share_m_1911"] = shares_data["m1911"] / bev_agegroup["tot"] * 100
shares_data["share_w_1911"] = shares_data["w1911"] / bev_agegroup["tot"] * 100

tot_counts = [shares_data["tot1909"].sum(), shares_data["tot1910"].sum(),
shares_data["tot1911"].sum()]
tot_bev = [bev_agegroup["tot"].sum()]

tot_shares = [tot_counts[i] / inhabs[i] * 100 for i in range(3)]
tot_shares_nonprozent = [tot_counts[i] / inhabs[i] for i in range(3)]

deaths_total = data_csv.shape[0]

shares_data.to_csv('shares_data.csv', index=False)
```

```
city = "Zürich"

#choose the years
x_values = [1909, 1910, 1911]
y_values = [Stadt.loc[Stadt["bezeichnun"] == "Zürich", "1909"].values[0],
           Stadt.loc[Stadt["bezeichnun"] == "Zürich", "1910"].values[0],
           Stadt.loc[Stadt["bezeichnun"] == "Zürich", "1911"].values[0]]

plt.figure(figsize=(14, 8))
```

```
ax = sns.barplot(x=x_values, y=tot_shares, width=0.35)
ax.set_title(f"Death Rates During the Summer Months\nin the City of {city} per
Year", fontsize=18, fontweight='bold', pad=20)
ax.set_ylabel("Death rate in %",  fontsize=14)
ax.set_xlabel("Years", fontsize=14)
ax.set_xticklabels(["1909", "1910", "1911"])
custom_texts = ['591', '617', '700']
for i, text in enumerate(custom_texts):
    ax.text(i, tot_shares[i]/2, text, ha='center', va='center', color='white',
fontsize=12, fontweight='bold')
max_value = max(tot_shares)
ax.errorbar(1, max_value * 1.02, xerr=1, color='black', capsize=5)
ax.text(1, max_value * 1.02, '*', ha='center', va='bottom', color='black')
```

```
plt.figure(figsize=(12, 8))
ax = sns.barplot(x=x_values, y=y_values)
ax.set_title(f"Population growth in {city} from 1909 to 1911")
ax.set_ylabel("Number of inhabitants")
ax.set_xlabel("Year")
ax.set_xticklabels(["1909", "1910", "1911"])
```

```
#create empty dictionary
counts_dict = {}

#add up number of males and females per year
for year in years:
    filtered_data = data_csv[(data_csv["Year"] == year)]
    m = (filtered_data["Geschlecht"] == "m").sum()
    w = (filtered_data["Geschlecht"] == "w").sum()

    #store in dictionary
    counts_dict[year] = [m, w]

#create dataframe
gendercount = pandas.DataFrame(counts_dict).T

#name columns
gendercount.columns = ["male", "female"]

#plot
gendercount.plot(kind="bar", figsize=(12,8), color=colorblindsave[:2])
plt.xlabel("Year", fontweight='bold', fontsize=14)
plt.xticks(rotation=0)
plt.ylabel("Number of Deaths", fontweight='bold', fontsize=14)
plt.title("Number of Deaths by Sex in the City of Zurich from 1909 to 1911",
fontsize=18, fontweight='bold', pad=20)
plt.legend(title="Sex", labels=gendercount.columns, loc='upper left', fontsize=14,
title_fontsize=18)
plt.show()
```

```
#create empty dictionary
counts_dict = {}
hisclass = [0, 1, 2, 3]

#add up number of males and females per hisclass
for hisc in hisclass:
    filtered_data = data_csv[(data_csv["Hisclass3_b"] == hisc)]
    m = (filtered_data["Geschlecht"] == "m").sum()
    w = (filtered_data["Geschlecht"] == "w").sum()

    #store in the dictionary
    counts_dict[hisc] = [m, w]

#create dataframe
histclasscount = pandas.DataFrame(counts_dict).T
histclasscount.columns = ["male", "female"]

#plot
histclasscount.plot(kind="bar", figsize=(12,8), color=colorblindsave[:2])
plt.xlabel("Hisclass-Classification", fontweight='bold', fontsize=14)
plt.xticks(rotation=0)
plt.ylabel("Number of Deaths", fontweight='bold', fontsize=14)
plt.title("Distribution of Gender by Hisclass-Classification in the City of
Zurich", fontsize=18, fontweight='bold', pad=20)
plt.legend(title="Sex", labels=histclasscount.columns, loc='upper left',
fontsize=14, title_fontsize=18)
plt.show()
```

```
x_values2 = [1901, 1902, 1903, 1904, 1905, 1906, 1907, 1908, 1909, 1910, 1911]
y_values2 = [150200, 151400, 155800, 161100, 166400, 171200, 176100, 179900,
Stadt.loc[Stadt["bezeichnun"] == "Zürich", "1909"].values[0],
           Stadt.loc[Stadt["bezeichnun"] == "Zürich", "1910"].values[0],
           Stadt.loc[Stadt["bezeichnun"] == "Zürich", "1911"].values[0]]


#set colors
colors = ["#3375a1"] * (len(x_values2) - 1) + ['red']

#plot
plt.figure(figsize=(14, 8))
ax = sns.barplot(x=x_values2, y=y_values2, palette=colors)
ax.set_title(f"Population growth in {city} from 1901 to 1911", fontsize=18,
fontweight='bold', pad=20)
ax.set_ylabel("Number of inhabitants", fontsize=14)
ax.set_xlabel("Year", fontsize=14)
```

```
age_labels = ["Stillbirth", "Age <1", "Age 1-4", "Age 5-19",
              "Age 20-49", "Age 50-69", "Age 70-79", "Age ≥80"]

#create dataframe for totals
totals_df = pandas.DataFrame({
```

```
    "1909": shares_data["tot1909"].values,
    "1910": shares_data["tot1910"].values,
    "1911": shares_data["tot1911"].values
}, index=age_labels)


#create dataframe for shares
shares_df = pandas.DataFrame({
    "1909": shares_data["share_1909"].values,
    "1910": shares_data["share_1910"].values,
    "1911": shares_data["share_1911"].values
}, index=age_labels)

#plot totals
totals_df.plot(kind="bar", figsize=(12, 8), color=yearcolor)
plt.xlabel("Age Groups", fontsize=14)
plt.ylabel("Number of Deaths", fontsize=14)
plt.title("Distribution of Deaths by Age Group in the City of Zurich(1909–1911)",
fontsize=18, fontweight='bold', pad=20)
plt.xticks(rotation=0)
plt.legend(title="Year", loc="upper left",fontsize=14, title_fontsize=18)
plt.tight_layout()
plt.show()

#plot shares
shares_df.plot(kind="bar", figsize=(12, 8), color=yearcolor)
plt.xlabel("Age Groups", fontsize=14)
plt.ylabel("Death Rate [%]", fontsize=14)
plt.title("Death Rates by Age Group (1909–1911)", fontsize=18, fontweight='bold',
pad=20)
plt.xticks(rotation=0)
plt.legend(title="Year", loc="upper left",fontsize=14, title_fontsize=18)
plt.tight_layout()
plt.show()
```

```
p1909 = tot_counts[0] / inhabs[0]
p1910 = tot_counts[1] / inhabs[1]
p1911 = tot_counts[2] / inhabs[2]

#calculate effect sizes (Cohen's h)
print(f"p1909: {p1909}, p1910: {p1910}, p1911: {p1911}")
h0910 = 2 * (math.asin(math.sqrt(p1909)) - math.asin(math.sqrt(p1910)))
print(f"effect size 1909-1910: {h0910}")
h0911 = 2 * (math.asin(math.sqrt(p1909)) - math.asin(math.sqrt(p1911)))
print(f"effect size 1909-1911: {h0911}")
h1011 = 2 * (math.asin(math.sqrt(p1910)) - math.asin(math.sqrt(p1911)))
print(f"effect size 1910-1911: {h1011}")
```

```
all_data = []
columns = ["Akture Magendarmerkrankungen", "Akute Herzkreislaufprobleme",
"Ertrinken",
```

```
                  "Hitzeschlag", "Schwäche", "Totgeburten Frühgeburt und Neonatale
Aspekte", "Atmung"]
used_columns = data_csv[columns]

translations = {
    "Akture Magendarmerkrankungen": "Acute\nGastrointestinal Diseases",
    "Akute Herzkreislaufprobleme": "Acute\nCardiovascular Problems",
    "Ertrinken": "Drowning",
    "Hitzeschlag": "Heat Stroke",
    "Schwäche": "Weakness",
    "Totgeburten Frühgeburt und Neonatale Aspekte": "Stillbirths, Premature
Birth\nand Neonatal Aspects",
    "Atmung": "Respiratory diseases"
}

for year in years:
    filtered_data = data_csv[data_csv["Year"] == year]

    if year == 1909:
        deaths_total = shares_data["tot1909"].sum()
    elif year == 1910:
        deaths_total = shares_data["tot1910"].sum()
    else:
        deaths_total = shares_data["tot1911"].sum()

    used_columns = filtered_data[columns]
    norm_columns = (used_columns.sum() / deaths_total * 100)

    # Prepare data for combined plot
    for col in used_columns.columns:
        all_data.append({
            "Cause": translations[col],
            "Year": year,
            "Share": norm_columns[col]
        })

# Create DataFrame
causes_df = pandas.DataFrame(all_data)

# Create combined plot
plt.figure(figsize=(12, 8))
ax = sns.barplot(data=causes_df, x="Share", y="Cause", hue="Year",
palette=yearcolor)
ax.set_xlabel("Share of Deaths in % from total deaths", fontsize=14)
ax.set_ylabel("Causes of Death", fontsize=14)
ax.set_title("Histogram of Number of Death by Cause in the City of Zurich\nDuring
the Summer Months of 1909, 1910 and 1911", fontsize=18, fontweight='bold', pad=20)
plt.legend(title="Year", bbox_to_anchor=(1.0, 0.5), loc="center right",
fontsize=14, title_fontsize=18)
plt.tight_layout()
plt.show()
```

```
#create empty dict
counts_dict = {}

#count data per hisclass
for year in years:
    filtered_data = data_csv[(data_csv["Year"] == year)]
    count_0 = (filtered_data["Hisclass3_b"] == 0).sum()
    count_1 = (filtered_data["Hisclass3_b"] == 1).sum()
    count_2 = (filtered_data["Hisclass3_b"] == 2).sum()
    count_3 = (filtered_data["Hisclass3_b"] == 3).sum()

    #put data in dictionary
    counts_dict[year] = [count_0, count_1, count_2, count_3]

#create dataframe
histclasscount2 = pandas.DataFrame(counts_dict).T
histclasscount2.columns = [0, 1, 2, 3]

#plot
histclasscount2.plot(kind="bar", figsize=(12,8), color=colorblindsave[:4])
plt.xlabel("Hisclass-Classification", fontsize=14)
plt.xticks(rotation=0)
plt.ylabel("Number of Deaths", fontsize=14)
plt.title("Histogram showing the distribution of deaths by Hisclass-
Classification", fontsize=18, fontweight='bold', pad=20)
plt.legend(title="Hisclass", labels=histclasscount2.columns, loc='upper left',
fontsize=14, title_fontsize=18)
plt.show()
```

```
#calculate statistics for greenwater distances
greenspaces = greenwater["DistGreen"]
print(f"mean: {greenspaces.mean()}")
print(f"std: {greenspaces.std()}")
print(f"min: {greenspaces.min()}")
print(f"max: {greenspaces.max()}")
print(f"median: {greenspaces.median()}")
print(f"0.25: {greenspaces.quantile(0.25)}")
print(f"0.75: {greenspaces.quantile(0.75)}")
print(f"0.1: {greenspaces.quantile(0.1)}")
print(f"0.9: {greenspaces.quantile(0.9)}")
print(f"0.05: {greenspaces.quantile(0.05)}")
print(f"0.95: {greenspaces.quantile(0.95)}")
```

```
#calculate statistics for greenwater distances per year
for year in greenwater["Year"].unique():
    print(year)
    filtered_data = greenwater[greenwater["Year"] == year]
    greenspaces = filtered_data["DistGreen"]
    print(f"mean: {greenspaces.mean()}")
    print(f"std: {greenspaces.std()}")
    print(f"min: {greenspaces.min()}")
```

```
    print(f"max: {greenspaces.max()}")
    print(f"median: {greenspaces.median()}")
    print(f"0.25: {greenspaces.quantile(0.25)}")
    print(f"0.75: {greenspaces.quantile(0.75)}")
    print(f"0.1: {greenspaces.quantile(0.1)}")
    print(f"0.9: {greenspaces.quantile(0.9)}")
    print(f"0.05: {greenspaces.quantile(0.05)}")
    print(f"0.95: {greenspaces.quantile(0.95)}")
```

```
#calculate statistics for greenwater distances per district
for kreis in greenwater["Kreis_Wohn"].unique():
    print(kreis)
    print(year)
    filtered_data = greenwater[greenwater["Kreis_Wohn"] == kreis]
    greenspaces = filtered_data["DistGreen"]
    print(f"mean: {greenspaces.mean()}")
    print(f"std: {greenspaces.std()}")
    print(f"min: {greenspaces.min()}")
    print(f"max: {greenspaces.max()}")
    print(f"median: {greenspaces.median()}")
    print(f"0.25: {greenspaces.quantile(0.25)}")
    print(f"0.75: {greenspaces.quantile(0.75)}")
    print(f"0.1: {greenspaces.quantile(0.1)}")
    print(f"0.9: {greenspaces.quantile(0.9)}")
    print(f"0.05: {greenspaces.quantile(0.05)}")
    print(f"0.95: {greenspaces.quantile(0.95)}")
```

```
#calculate statistics for greenwater distances per year and district
for year in greenwater["Year"].unique():
    print(year)
    for kreis in greenwater["Kreis_Wohn"].unique():
        print(kreis)
        filtered_data = greenwater[(greenwater["Kreis_Wohn"] == kreis) & 
(greenwater["Year"] == year)]
        greenspaces = filtered_data["DistGreen"]
        print(f"mean: {greenspaces.mean()}")
        print(f"std: {greenspaces.std()}")
        print(f"min: {greenspaces.min()}")
        print(f"max: {greenspaces.max()}")
        print(f"median: {greenspaces.median()}")
        print(f"0.25: {greenspaces.quantile(0.25)}")
        print(f"0.75: {greenspaces.quantile(0.75)}")
        print(f"0.1: {greenspaces.quantile(0.1)}")
        print(f"0.9: {greenspaces.quantile(0.9)}")
        print(f"0.05: {greenspaces.quantile(0.05)}")
        print(f"0.95: {greenspaces.quantile(0.95)}")

mean_df = greenwater.pivot_table(index="Kreis_Wohn", columns="Year", 
values="DistGreen", aggfunc="mean")
```

```
#plot mean distances per district and year
print(mean_df)
mean_df.plot(kind="bar", figsize=(10,6))
plt.xlabel("Year")
plt.ylabel("Mean Distance")
plt.title("Mean Distance by Year and Kreis")
plt.legend(title="Kreis")
plt.show()
```

```
#calculate statistics for distance to water areas
waterareas = greenwater["RASTERVALU"]
print(waterareas)
print(f"mean: {waterareas.mean()}")
print(f"std: {waterareas.std()}")
print(f"min: {waterareas.min()}")
print(f"max: {waterareas.max()}")
print(f"median: {waterareas.median()}")
print(f"0.25: {waterareas.quantile(0.25)}")
print(f"0.75: {waterareas.quantile(0.75)}")
print(f"0.1: {waterareas.quantile(0.1)}")
print(f"0.9: {waterareas.quantile(0.9)}")
print(f"0.05: {waterareas.quantile(0.05)}")
print(f"0.95: {waterareas.quantile(0.95)}")
```

```
#calculate statistics for distance from water areas per year
for year in greenwater["Year"].unique():
    print(year)
    filtered_data = greenwater[greenwater["Year"] == year]
    greenspaces = filtered_data["RASTERVALU"]
    print(f"mean: {greenspaces.mean()}")
    print(f"std: {greenspaces.std()}")
    print(f"min: {greenspaces.min()}")
    print(f"max: {greenspaces.max()}")
    print(f"median: {greenspaces.median()}")
    print(f"0.25: {greenspaces.quantile(0.25)}")
    print(f"0.75: {greenspaces.quantile(0.75)}")
    print(f"0.1: {greenspaces.quantile(0.1)}")
    print(f"0.9: {greenspaces.quantile(0.9)}")
    print(f"0.05: {greenspaces.quantile(0.05)}")
    print(f"0.95: {greenspaces.quantile(0.95)}")

mean_df = greenwater.pivot_table(columns="Year", values="RASTERVALU",
aggfunc="mean")
```

```
#calculate statistics for distance from water areas per district
for kreis in greenwater["Kreis_Wohn"].unique():
    print(kreis)
    filtered_data = greenwater[greenwater["Kreis_Wohn"] == kreis]
    greenspaces = filtered_data["RASTERVALU"]
    print(f"mean: {greenspaces.mean()}")
```

```
    print(f"std: {greenspaces.std()}")
    print(f"min: {greenspaces.min()}")
    print(f"max: {greenspaces.max()}")
    print(f"median: {greenspaces.median()}")
    print(f"0.25: {greenspaces.quantile(0.25)}")
    print(f"0.75: {greenspaces.quantile(0.75)}")
    print(f"0.1: {greenspaces.quantile(0.1)}")
    print(f"0.9: {greenspaces.quantile(0.9)}")
    print(f"0.05: {greenspaces.quantile(0.05)}")
    print(f"0.95: {greenspaces.quantile(0.95)}")
```

```
#calculate statistics for distance from water areas per year and district
for year in greenwater["Year"].unique():
    print(year)
    for kreis in greenwater["Kreis_Wohn"].unique():
        print(kreis)
        filtered_data = greenwater[(greenwater["Kreis_Wohn"] == kreis) &
(greenwater["Year"] == year)]
        greenspaces = filtered_data["RASTERVALU"]
        print(f"mean: {greenspaces.mean()}")
        print(f"std: {greenspaces.std()}")
        print(f"min: {greenspaces.min()}")
        print(f"max: {greenspaces.max()}")
        print(f"median: {greenspaces.median()}")
        print(f"0.25: {greenspaces.quantile(0.25)}")
        print(f"0.75: {greenspaces.quantile(0.75)}")
        print(f"0.1: {greenspaces.quantile(0.1)}")
        print(f"0.9: {greenspaces.quantile(0.9)}")
        print(f"0.05: {greenspaces.quantile(0.05)}")
        print(f"0.95: {greenspaces.quantile(0.95)}")

mean_df = greenwater.pivot_table(index="Year", values="RASTERVALU", aggfunc="mean")
```

```
#plot mean distances per year
print(mean_df)
mean_df.plot(kind="bar", figsize=(10,6))
plt.xlabel("Year")
plt.ylabel("Mean Distance")
plt.title("Mean Distance by Year and Kreis")
plt.legend(title="Kreis")
plt.show()
```

```
p1909 = tot_counts[0] / inhabs[0]
p1910 = tot_counts[1] / inhabs[1]
p1911 = tot_counts[2] / inhabs[2]

#calculate effect sizes (Cohen's h)
print(f"p1909: {p1909}, p1910: {p1910}, p1911: {p1911}")
h0910 = 2 * (math.asin(math.sqrt(p1909)) - math.asin(math.sqrt(p1910)))
print(f"effect size 1909-1910: {h0910}")
```

```
h0911 = 2 * (math.asin(math.sqrt(p1909)) - math.asin(math.sqrt(p1911)))
print(f"effect size 1909-1911: {h0911}")
h1011 = 2 * (math.asin(math.sqrt(p1910)) - math.asin(math.sqrt(p1911)))
print(f"effect size 1910-1911: {h1011}")

#calculate regression model for 1911
regression = pandas.read_csv("/Users/benedikt/Library/CloudStorage/OneDrive-UniversitätZürichUZH/Masterarbeit/regression.csv", delimiter=";")

x = regression["maximum11"]
y = regression["deaths 1911"]

x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()

print(model.summary())
```

```
#calculate regression model for 1911 shifted by one day
regression["maximum11shift"] = regression["maximum11"].shift(1)
x= regression["maximum11shift"]
y = regression["deaths 1911"]


x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()


print(model.summary())
```

```
#calculate regression model for 1911 shifted by two days
regression["maximum11shift2"] = regression["maximum11"].shift(2)
x= regression["maximum11shift2"]
y = regression["deaths 1911"]


x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()


print(model.summary())
```

```
#calculate regression model for 1911 shifted by three days
regression["maximum11shift3"] = regression["maximum11"].shift(3)
x= regression["maximum11shift3"]
y = regression["deaths 1911"]


x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()
```

```
print(model.summary())
```

```
#calculate regression model for 1911 shifted by four days
regression["maximum11shift4"] = regression["maximum11"].shift(4)
x= regression["maximum11shift4"]
y = regression["deaths 1911"]


x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()


print(model.summary())
```

```
#calculate regression model only for gastrointestinal diseases in 1911
regression["maximum11magen"] = regression["maximum11"].shift(2)
x= regression["maximum11magen"]
y = regression["magen 1911"]


x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()
```

```
#plot regression model
plt.figure(figsize=(12, 8))
sns.regplot(x="maximum11shift2", y="deaths 1911", data=regression,
scatter_kws={"s": 40}, line_kws={"color": "red"})
plt.title("Regression of Deaths due to Temperature two days prior in Zürich 1911")
plt.xlabel("Maximum Temperature [°C]")
plt.ylabel("Deaths per day")
plt.grid(True)
plt.tight_layout()
plt.show()
```

```
#regression model for 1909
x = regression["maximum09"]
y = regression["deaths 1909"]

x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()

print(model.summary())

#regression model for 1910
x = regression["maximum10"]
y = regression["deaths 1910"]

x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()
```

```
print(model.summary())
```

```
#regression model for 1909 shifted by two days
regression["maximum09shift2"] = regression["maximum09"].shift(2)
x= regression["maximum09shift2"]
y = regression["deaths 1909"]


x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()


print(model.summary())
```

```
#regression model for 1910 shifted by two days
regression["maximum10shift2"] = regression["maximum10"].shift(2)
x= regression["maximum10shift2"]
y = regression["deaths 1910"]


x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()


print(model.summary())
```

```
#regression model for 1911 above a threshold of 28°C
regression["thresholdreached"] = (regression["maximum11"].shift(2) >
28).astype(int)


x= regression["thresholdreached"]
y = regression["deaths 1911"]


x = statmod.add_constant(x)
model = statmod.OLS(y, x, missing="drop").fit()


print(model.summary())
```

Personal Declaration

I hereby declare that this thesis is the result of my own, independent work.

All external sources are explicitly acknowledged in the Thesis.

DeepL translate was used for translations and DeepL write was used to improve the wording of certain paragraphs. ChatGPT was used to help fixing errors in the python code.

Benedikt Bär

Trondheim, 15. August 2025