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Geovisualization of Swiss Birth Weights at the Beginning of the 20th Century

GEO 511 Master's Thesis

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Analysis and Comparison of Data from Maternity Hospitals in Basel and Lausanne

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Abstract

Changes in newborn body size and shape reflect changes in the health and well-being of a particular population (Cole, 2003). For that reason, anthropometric historians have studied birth weight as a reflection of female living standards since the 1990s (Ward, 2016). The archives of Basel and Lausanne possess interesting data sets related to birth weight for the time period between 1912 and 1921. This Master's thesis visualizes data from two maternity hospitals in Basel and Lausanne at the beginning of the 20th century. Using a geovisualization approach, the spatial distribution of birth weights as well as other anthropometric variables (e.g., maternal height) are visualized. In addition, the two following analyses are conducted: 1) measuring significant local clusters of low and high birth weights; 2) elaborating on the relationship between polluting factories and birth weight measures. The result suggests that Basel had higher birth weight scores and a lower prevalence of low birth weight compared to Lausanne. The observed pattern could be explained by Basel's social and economic advantage due to its chemical industry as well as social policies (Floris et al., 2016). However, cultural differences could also be evident, which have been preserved in health-related parameters until today (Faeh et al., 2010; Faeh et al., 2009). Furthermore, the results indicate that the socioeconomic small-scale structures were more visible in Basel. Significant high birth weight clusters, taller and older mothers tended to occur in wealthier districts. In contrast, significant low birth weight clusters, smaller and younger mothers, stillbirths and low birth weights were more likely to be found in poorer districts. These findings are in line with previous studies, which identified similar patterns between anthropometric variables (Ericson et al., 1989; Fraser et al., 1995; Subramanian et al., 2009). As the current data set of Lausanne has not been fully transcribed, improvements on the data set could lead to similar socioeconomic patterns. Regarding the relationship between polluting factories and stillbirths/ low birth weights a positive association could be observed for both cities. Even though the results were not significant, this does not necessarily mean that polluting factories had no effect on the number of stillbirths/low birth weights. While this thesis can make a valuable contribution approach, more research in this field is needed to better understand the underlying patterns related to newborn body size.

Keywords: Biological Standard of Living, Switzerland between 1912 and 1921, Historical Birth Weights, Geovisualization and Analysis, Geographic Information System (GIS), Anthropometry

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List of Abbrevations

SNSF	Swiss National Science Foundation
WHO	World Health Organization
OECD	Organization for Economic Co-operation and Development
FOAD	Fetal Origins of Adult Disease
GDP	Gross Domestic Product
SEP	Socioeconomic Position
API	Application Programming Interface
OR	Odd Ratio
CI	Confidence Interval
GWR	Geographically Weighted Regression

1 Introduction

1.1 Motivation

As part of a project funded by the *Swiss National Science Foundation* (SNSF) my supervisor Kaspar Staub and his research team are investigating how the health status of newborns in Lausanne has developed between 1905 and 1925 in the context of World War I and the Spanish flu (Swiss National Science Foundation, n.d.,b). This Master's thesis is embedded in this ongoing project and addresses research questions in the field of geovisualization. Compared with the previous Basel-Bern SNSF project (Swiss National Science Foundation, n.d.,a) as well as similar international research initiatives, the new Lausanne project will be a significant advancement in terms of both data quality and methodology. Furthermore, the subjects covered are highly relevant in times of the Covid-19 outbreak. Because of the long-term negative outcomes associated with reduced neonatal health in general (D. Barker, 1990), it is valuable to evaluate these high quality Swiss data from the beginning of the 20th century in greater depth.

In Switzerland, the maternity hospitals in Basel and in Lausanne recorded detailed information about mothers, newborns and childbirths at the beginning of the 20th century. There are two data sets that are essential for this Master's thesis, namely the data set of Basel (covering years from 1912 to 1920) and the data set of Lausanne (covering years from 1917 to 1921). The data sets show a high quality and a broad coverage of other anthropometric factors, which allows a wide range of spatial analyses and geovisualizations.

Changes in newborn body size and shape reflect changes in the health and well-being of a particular population (Cole, 2003). For that reason, anthropometric historians have studied birth weight as a reflection of female living standards since the 1990s (Ward, 2016). When considering newborns, birth weight is a useful anthropometric measure as it offers insight into maternal and population health more generally (Ward, 2016, p.627). Identifying factors that impede normal development and growth are crucial to improve neonatal health in general (World Health Organization, 1995). It is estimated that non-genetic maternal (e.g., nutritional status, health condition) and environmental factors (e.g., altitude, pollution) account for 60-70% of the variation in birth weight

(Bogin, 1999, pp.58-63). Therefore, birth weight is a more direct measure of the biological standard of living at the time of measurement (WHO Working Group, 1986, pp.930-932).

The average birth weight varies in today's world. Wealthy Western countries are characterized by the highest average birth weights (3,250 to 3,500g) (Donahue et al., 2010). In contrast, the lowest values are found in the poorest regions, such as South Asia (2,600 to 2,700g) (Metgud et al., 2012). As malnutrition and food insecurities are still a major issue today (Unicef et al., 2022), 828 million people were facing hunger in 2021 (Unicef et al., 2022, p.13). Climate change, conflicts around the world as well as the corona pandemic have massively exacerbated the situation in many countries (Unicef et al., 2022). In this context, children and pregnant women are particularly vulnerable. A pregnant woman's nutritional and health status has an impact on her unborn child (Ward, 2016). A newborns health is still a cause for concern, because neonatal conditions are associated with long-term negative health outcomes (D. Barker, 1990; Burstein et al., 2019).

1.2 Research Gap

In anthropometric history [1], spatial studies are less common until today. Applying spatial modelling and geovisualization would be a novelty, as it is applied for the first time to historical birth weights. The data of the maternity hospitals in Lausanne and Basel show remarkable potential for spatial visualizations and spatial analysis and thus allow conclusions about relationships between anthropometric variables and small scale spatial structures. The identification of geographic clusters can lead to a clear added value. For example, in the cities of Lausanne and Geneva cold and hot spots of excess weights have been identified (Guessous et al., 2014; Joost et al., 2018; Joost et al., 2016). Further, spatial clusters of today's height and obesity levels of Swiss conscripts have been revealed in the studies of Panczak et al. (2017) and Panczak et al. (2016). Spatial patterns can increase the explanatory power of models, as it has been shown for modern birth weights in Switzerland and Africa (Ngwira, 2019; Skrivankova et al., 2019).

[1] Anthropometric history can be defined as the study of human height and weight to quantify changes in the standard of living during the last 200 years (Komlos, 1992).

1.3 Research Aim and Research Questions

In light of the identified research desideratum, the following research question should be addressed:

How can the historical data set of Basel (1912-1920) and Lausanne (1917-1921) be processed, visualized and analyzed using the example of birth weight as an indicator of the biological standard of living?

The aim and the objectives of the paper at hand are therefore to prepare, to visualize and to analyse the data. This leads to three objectives as well as four corresponding sub research questions.

Objective 1: Data Preparation (addressed in Chapter 3.1.2)

> **1.1:** How can the data set of Lausanne be geocoded?

Objective 2: Data Visualization (addressed in Chapter 4.1 and Chapter 4.3)

> **2.1:** What spatial pattern do birth weights and other anthropometric measures show in Basel and Lausanne?

Objective 3: Data Analysis (addressed in Chapter 4.2 and Chapter 4.4)

> **3.1:** What is the relationship between a negative birth weight measure (stillbirth, low birth weight) and a negative point of interest (factory) in Basel and Lausanne?
>
> **3.2:** To what extent are there spatial clusters of birth weights in Basel and Lausanne?

The following section briefly describes the objectives and the corresponding sub-questions. Figure 1 gives an overview about the objectives of this thesis.

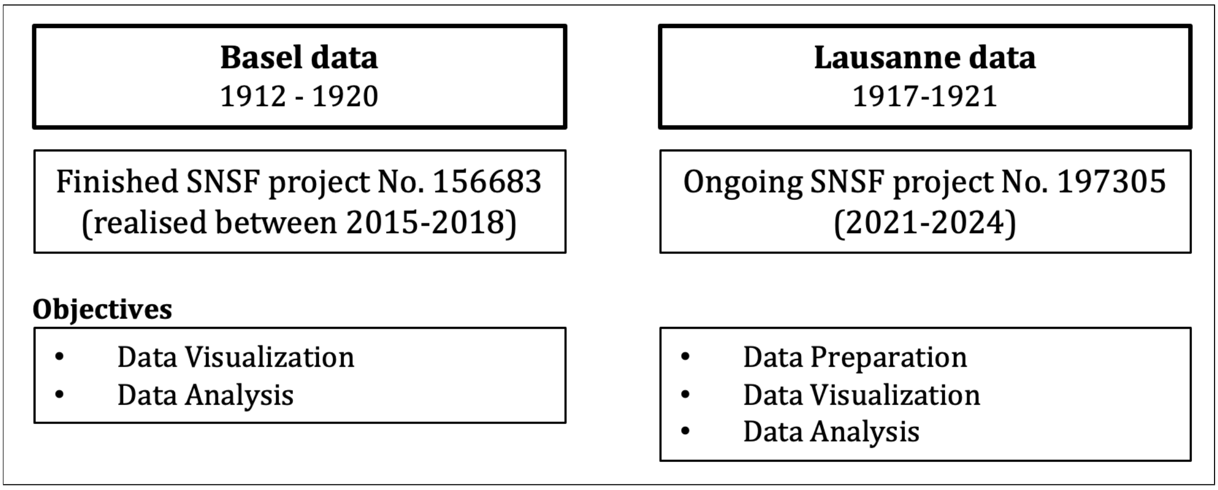

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Figure 1: Overview of objectives

As a first objective, the data set of Lausanne needs to be processed. The place of residence is recorded for each mother, which gave birth in the maternity hospital. The address of the mother can be transformed into coordinates to display it on a map (see Chapter 3.1.2). The Basel data must not be processed, as it has already been geolocated in the previous Basel-Bern SNSF project (Swiss National Science Foundation, n.d.,a). This project was carried out between 2015 and 2018 and have shown that World War I had a negative impact on mothers and their newborns in Basel and in Bern, although Switzerland was not directly involved (Butie et al., 2020; Floris et al., 2016; Floris et al., 2021a, 2021b). Regarding geovisualization and spatial analysis, the possibilities are not yet exhausted. For that reason, the Basel data set is also used for data visualization and data analysis.

As a second objective, the processed data will be visualized in maps. Average birth weights are visualized accordingly in maps at point and district level in Chapter 4.1.2 and 4.3.2. Several maps are created to show the temporal development of low birth weight infants at point level in Chapter 4.1.3 and 4.3.3. The data set contains a large number of anthropometric variables, with stillbirths, maternal age, height, and placental weight visualized in choropleth maps in Chapter 4.1.4 and 4.3.4.

As a third objective, a buffer analysis will be conducted to visualize the relationship between low birth weights and stillbirths and selected points of interest. Larger factories are chosen as points of interest due to their negative environmental impact. In addition, a logistic regression is carried out in Chapter 4.2.1 and 4.4.1 to calculate the relationship between these variables. A cluster analysis (using Getis-Ord Gi statistics) is performed in Chapter 4.2.2 and 4.4.2 to investigate if there are significant local clusters in relation to birth weights.

A discussion and a conclusion complete the thesis and place the objectives in a larger context. Thereby, the results of both cities are compared with each other in Chapter 5.1 . Lastly, limitations are elaborated in Chapter 5.2. A conclusion briefly summarizes the thesis and gives an outlook for possible future research in Chapter 6.

2 Theoretical Background

2.1 Birth Weights from Today's Perspective

2.1.1 Importance and Determinants of Neonatal Health

To study fetal growth, anthropometric parameters of newborns are considered (World Health Organization, 1995, p.130). These anthropometric parameters serve as an indirect research method to record body size (World Health Organization, 1995, p.1). The most common anthropometric parameters are birth weight, body length, head circumference and the Rohrer's Ponderal Index, which is a combination of birth weight and body length (World Health Organization, 1995, p.7). These parameters allow conclusions about the intrauterine environment, maternal nutritional status and socioeconomic living standards (Ward, 2016). It further allows predictions of the newborns postnatal health as well as long term health outcomes (D. Barker, 1990) (see Chapter 2.1.2). Birth weight provides a useful anthropometric measure as it offers insight into maternal and population health more generally (Ward, 2016, p.627).

The factors that influence neonatal health are diverse. Important determinants are the fetal genetics, the environment (e.g., distance above sea level), the pregnancy itself as well as the health, the socioeconomic and nutritional status of the mother (Ward, 2016, pp.624-625). However, it is estimated that non-genetic maternal and environmental factors account for 60-70% of the variation in birth weight (Bogin, 1999, pp.58-63). As these two factors account for most of the variation in birth weight and are therefore of decisive importance, several studies have already analysed the influence on birth weight.

Regarding non-genetic maternal effects, Dorélien (2019) investigated the influence of intrauterine exposure to influenza and could observe a negative effect on premature births and thus also on birth weight. Susser and Stein (1994) have further shown that maternal nutritional levels, especially third trimester exposure to malnutrition negatively affect fetal growth. Triggered by food shortages, short-term changes in birth weight are very common. Among the best known are the fluctuations that occur during unrest such as wars. During severe local famines at the height of the siege of Leningrad (1941–1943) during World War II, the average birth weight dropped dramatically and newborns weighed 500 to 600 grams less than average (Antonov, 1947). Average birth weights dropped significantly too during the "Hunger Winter" of 1944–1945 in the Netherlands (Stein et al., 1975). Also during World War I birth weights dropped significantly during the years 1918–1919 in Basel (Floris et al., 2016). The study emphasized on the importance of relief measures, as only birth weights from the middle *socioeconomic position* (SEP) decreased during 1917 and 1919. While low SEP families received support in form of relief measures, and high SEP families could still pay for high prices, middle SEP families neither received relief measures nor could they keep up with prices (Floris et al., 2016).

Concerning environmental determinants, Zamudio et al. (2007) examined the effect of altitude on birth weights. They concluded that fetal growth is reduced among mothers that are living in high elevations. Juárez (2011, pp.106-107) found seasonal patterns in birth weights, with the highest means values observed in winter and lowest mean values in summer. However, the relationship between birth weight and climate remains still unclear. Dadvand et al. (2013) and Hystad et al. (2014) pointed out the negative effect of noise and air pollution on birth weight, just as the benefits of having access to urban green spaces.

2.1.2 Negative Aspects of Low Birth Weight

The *World Health Organization* (WHO) has defined low birth weight as less than 2,500 grams (World Health Organization, 1992). This threshold has been set to identify newborns with a higher risk of infant mortality and morbidity (United Nations Children's Fund and World Health Organization, 2004, p.2). Based on epidemiological research newborns with low birth weight are 20 times more likely to die than heavier babies (Kramer, 1987). Low birth weight gets linked with preterm delivery or poor growth during pregnancy and it contributes to a number of poor health outcomes that are more common in developing countries (United Nations Children's Fund and World Health Organization, 2004). Looking at trends in average global rates of low birth weight, the percentage decreased from 17 % to 15 % between 1980 and 2012 (World Health Organization, 1980, 2012). These declines happened almost completely in developing countries (OECD, 2013). In *Organisation for Economic Co-operation and Development*

(OECD) countries, low birth weight rates have increased over this period, especially in Japan. The reasons include the increasing use of fertility treatments, the increasing use of medical interventions during childbirth, such as induction of labour and caesarean section and the increasing age of mothers (OECD, 2013, p.38). In Switzerland, the low birth weight rate is about 6% (United Nations Children's Fund and World Health Organization, 2004, p.17). Female newborns tend to be lighter than male newborns. Therefore, female newborns are likely to be over representative in a low birth weight population (United Nations Children's Fund and World Health Organization, 2004).

The *fetal origins of adult disease* (FOAD) hypothesis posits that fetal conditions may have long-lasting and possibly hidden health effects (Almond & Currie, 2011, p.154). Although David Barker wasn't the first to hypothesize health effects of fetal conditions (as for example Forsdahl (1977)), his name is nearly synonymous as it was popularized as the "Barker's hypothesis" (Calkins & Devaskar, 2011, p.158). The FOAD hypothesis holds that low birth weight is associated with future adult disease (D. Barker, 1990). Although low birth weight remains a major public health problem (Paneth, 1995), excessive birth weight ($>$ 4,000 or $>$ 4.500 g) is neither favorable and poses risks to the mother and the newborn child (Newton et al., 2017). However, the threshold of excessive birth weight is not precise and not as significant as the one from low birth weight infants. For that reason, birth weight is classified in Table 1 into low and normal birth weight.

Table 1: Birth weight classification

Classification	**Range**
Low birth weight	$<$ 2,500 grams
Normal birth weight	$\geq$ 2,500 grams

2.2 Birth Weights from an Anthropometric Historical Perspective

2.2.1 Body Dimensions as an Indicator for Well-Being

There is a consensus that well-being consist of various elements such as access to material goods and services, inequality, political freedom, health, or education (Steckel, 2008, p.1). Economists usually focus on the material aspects of well-being such as real wages or *Gross Domestic Product* (GDP) per capita (van Zanden et al., 2014, p.24). Although these material measures are crucial for understanding living standards in the present and in the past, they have several limitations as they cannot capture health aspects or gender inequalities (Steckel, 1995, p.2). Alternative parameters such as average adult height, life expectancy, mortality rates and morbidity are used as measures to include health-related aspects of living standards (van Zanden et al., 2014, pp.27-28).

As an alternative indicator for living-standards, the height of adults has been increasing more or less linearly since the middle of the 19^{th} century (Cole, 2003, p.165), which mirrors economic improvement of the biological standard of living (van Zanden et al., 2014). The relationship between average adult height and socioeconomic conditions at the time of birth assumes that with increasing real income per capita, the availability of food is better in qualitative and quantitative terms, which leads to an increase in average adult height (Komlos, 1992). This is particularly important for the first years of childhood and during adolescence (Bogin, 1999). Normal growth requires high quality and regular food intake, moderate physical activity and adequate disease environment (van Zanden et al., 2014, pp.119-120). However, there are two prominent examples which do not hold this relationship: the Ante-Bellum Puzzle in the USA (Komlos, 2008, p.106) and the Early Industrial Growth Puzzle in Europe (Steckel, 1995, p.1930). They describe the paradox of increasing industrial development but decreasing body height during early stages of the industrial revolution. Possible reasons for this phenomenon have been identified by researchers as changes in income distribution, relative price effects, urbanization and disease burden (Steckel, 1995, p.1930).

2.2.2 History of Birth Weights Research

The systematic weighing and measuring of newborns date back to the 19th century and largely took place in maternity hospitals (Tanner, 1981). By 1850, it was a common practice in some leading maternity hospitals in North America and Western Europe, resulting from simple curiosity to real concern for neonatal health and mortality (Tanner, 1981). However, the larger significance of fetal size remained largely unexplored until the second half of the 19th century, when researchers began to recognize diagnostic insights from the physical dimensions of newborns (Ward, 2016). They placed birth weight as an index of fetal maturity and routine weighing as a way to monitor the health of the newborn (Odier, 1868). At about the same time, systematic research began to identify factors associated with differences in size at birth as for example the age of the mother (Duncan, 1864). By the end of the 19th century, measuring and weighing newborns had become standard practice in maternity hospitals as well as in private obstetric care in most countries of the Western world. Birth weight was considered as the most important index of fetal maturity and an important reference point for future physical development (Ward, 2016).

In the 1980s and 1990s a number of studies were carried out in different countries based on maternity hospital data (Goldin & Margo, 1989; Rosenberg, 1988; Ward, 2016). World War I has been studied by several researchers (Floris et al., 2016; Peller & Bass, 1924), in which they examined the role of exogenous factors in intrauterine development in the context of war and post-war conditions. There is no consensus in the literature on how height at birth and height development at other ages are related. For example, it is not clear whether birth size was stable or increasing in the first half of the 20th century. There are some studies that show that birth size was stable during the first half of the 20th century (Schneider, 2017), and others that show an increase in birth weight (Solth & Abt, 1951). However, researchers have found that birth weight has been relatively stable over the last 150 years (Cole, 2003; Schneider, 2017).

2.3 Switzerland at the Beginning of the 20th Century

2.3.1 Historical Context

During the 19th century, Switzerland transformed into an increasingly industrialized and urbanized state (Halbeisen et al., 2017). At the end of the 19th century, Switzerland was among the wealthiest countries in Europe based on GDP (Maddison, 2006). In general, mortality rates decreased due to changes in water supply and waste water systems (Floris & Staub, 2019). Life expectancy at birth increased between 1880 and 1910, where males had an upward shift from 41 to 51 years and females from 43 to 54 years (Eidgenössisches Statistisches Amt, 1935). The population in the city of Lausanne (located in the French-speaking region) doubled from about 34,000 to ca. 68,000 between 1890 and 1920. Basel (located in the German-speaking region) had already about 70,000 inhabitants by 1890. Until 1920, the population increased to 136,000 inhabitants (Floris & Staub, 2019).

Although Switzerland was not directly involved in World War I, it was still affected by it. The dependence on imported food and raw materials led to a shortage of supplies in the interior of the country. In 1918, one sixth of the population was dependent on relief measures. In the cities, even a quarter of the population was dependent on aid (Fuhrer et al., 2015). A social crisis could not be prevented which led to a nationwide strike (*Generalstreik*) (Gautschi, 1955). The situation was exacerbated by the Spanish flu, where two million people were affected in Switzerland. Between July 1918 and June 1919 24,500 people died from the consequences of the flu in Switzerland (Sonderegger, 2017).

2.3.2 Factory Branches Contributing to Environmental Pollution

With the exception of odor emissions from certain trades (e.g., tanneries [2]), air and water pollution were not an issue in the Swiss agricultural society. Cases of industrial air pollution have been recorded sporadically on the basis of court cases. For a long time the toxicity of industrial pollutants was underestimated. For example, in the middle of the 19th century, the chemical company *Geigy* in Basel discharged waste products high in arsenic directly into the Rhine River. In relation to birth weight, such events have

[2] A tannery process animal skins into leather (Dubler, 2012).

a negative effect on birth weight. For example, Dadvand et al. (2013) have shown the negative effects of air pollution on birth weights.

Policy adjustments did not take place until the 1930s, when the pollution of water bodies decreased due to the increased recycling of waste materials (Walter et al., 2014). Since the 1960s, systematic measurements of air pollution took place. Since 1910, the Federal Office for the Environment, Forests and Landscape extrapolated air quality from statistics and measured emission factors for Switzerland. The measurement data shows that between 1910 and 1950 emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2) and volatile organic compounds (VOC) remained at about the same level (Walter et al., 2014).

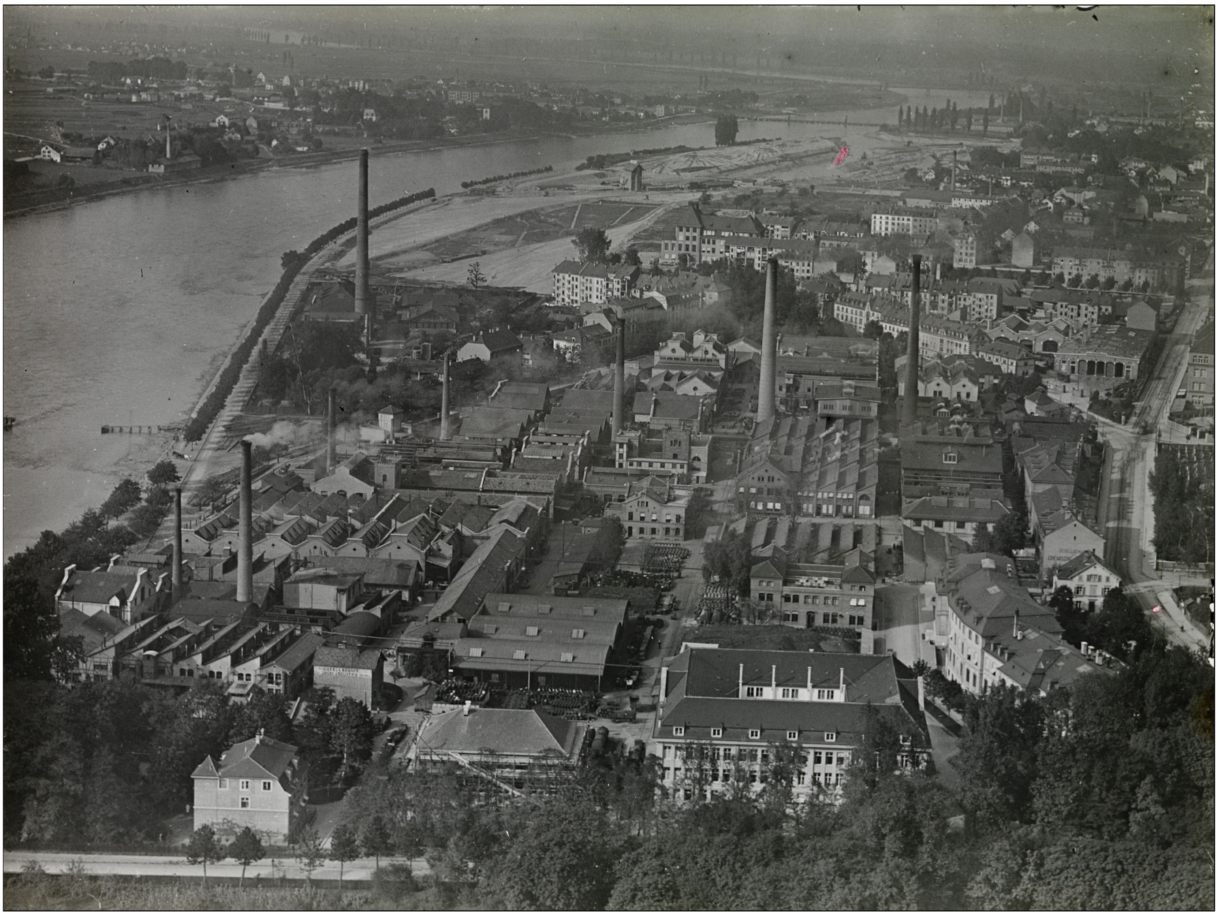
The following section describes the main factory branches which contributed to air and water pollution at the beginning of the 20^{th} century in Switzerland.

Tannery Tanneries were placed along rivers and streams because of their need for water. Due to water pollution and odor nuisance, tanneries were preferably located on the periphery of cities or in suburbs. During the First World War, the tannery recovered as a "key industry of the war economy" (Dubler, 2012).

Textile Industry The textile industry includes those industries that process textile raw materials. The process includes stages from washing to bleaching and dyeing. Toxic waste, such as bleaching, dyeing and washing processes, were disposed of via water (Dubler, 2014).

Cardboard Industry The paper or cardboard factories processed textile wastes into fibers in a stamping mill. During this process, the textile waste was subjected to a rotting process, whereby toxic waste was produced (Tschudin, 2010).

Chemical Industry in Basel Mainly represented in Basel, the modern chemical industry had its origins in the production of artificial dyes and the synthesis of natural dyes. The tar produced during the coking of hard coal for iron and steel production became the source of those chemicals which formed the basis of the "tar dye industry". The Rhine River facilitated the disposal of toxic waste (Hansen, 2007). Basel offered several advantages as a location: With the local silk and Alsatian *Indiennes* [3] industries , there was a favorable sales market. Switzerland had no patent legislation until 1907, and Basel companies were able to copy products, unlike their foreign competitors. Basel had good railway connections for procuring raw materials from Germany and France (Hansen, 2007). Figure 2 shows the location of the chemical company *Ciba* in 1920 in Basel. The large industrial area gives an impression of that time.



Source: Mittelholzer (1920)

Figure 2: Ciba A.G. in *Kleinbasel*, 1920

2.3.3 Socioeconomic Spatial Structures in Basel and Lausanne

The Rhine River divides the city of Basel into the two territories *Kleinbasel* and *Grossbasel*, with *Kleinbasel* lying to the northeast of the Rhine River. Based on Kanton Basel-Stadt (1921, p.12) the city of Basel can be divided into four residential districts, namely business, prosperity, middle class and working districts (see Figure 3). The business districts connects the old towns of *Grossbasel* and *Kleinbasel*. In general, wealthier districts are

[3] Indiennes are printed and painted cotton fabrics from India (Hansen, 2007).

within *Grossbasel*, south-western of Rhine River. In contrast, the poorer areas (e.g., the working districts) are located in *Kleinbasel*, north-eastern of the Rhine River.

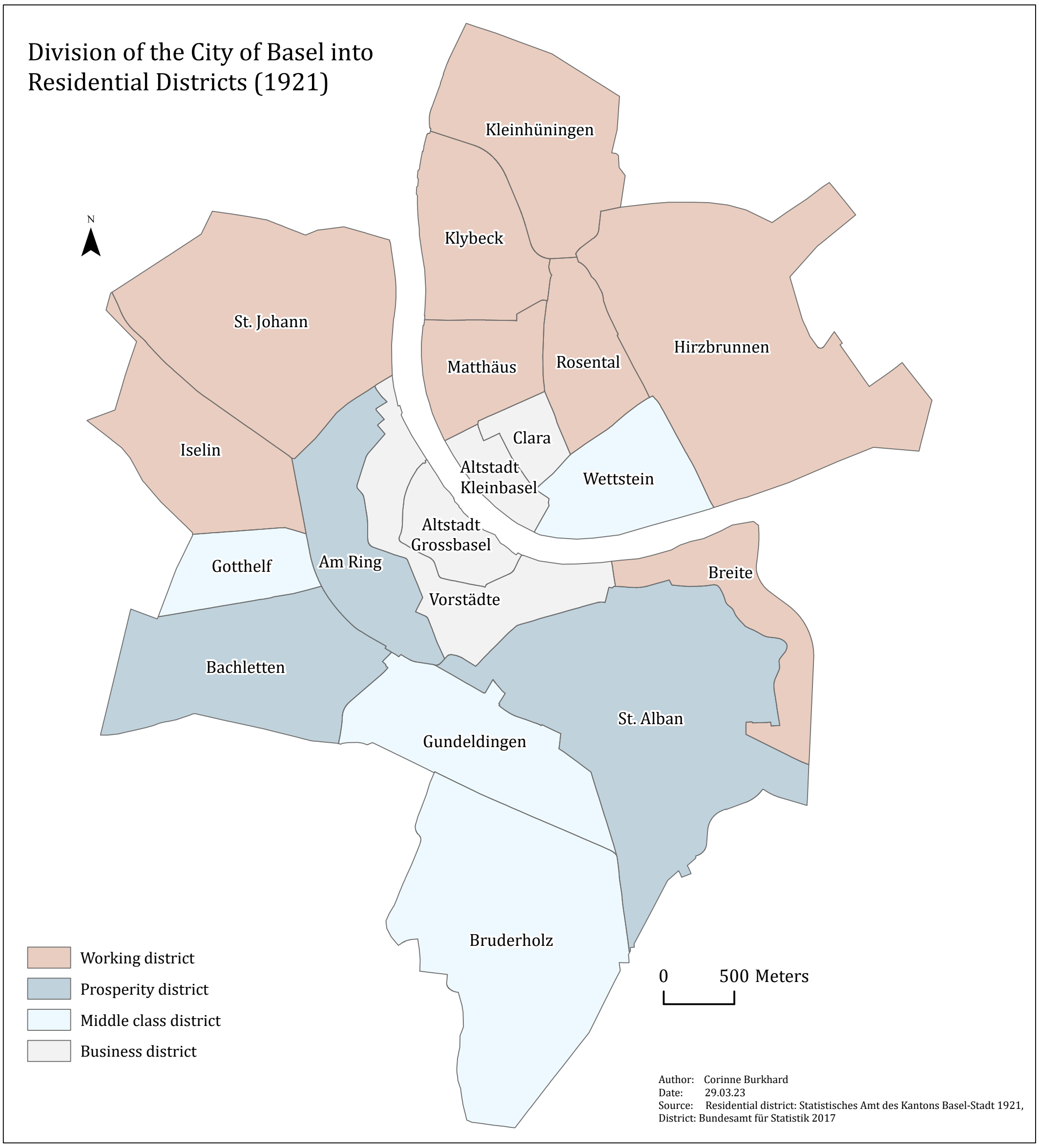


Figure 3: District categories in Basel 1921

Lausanne is located on the shore of Lake Geneva. There is no official classification of districts in Lausanne for the time period around 1920. However, a study by Roh (1990) on income, wealth and taxes in Lausanne provides a representation of the geographical distribution of these three elements for the year 1987. It shows that the wealthiest taxpayers are mainly distributed in the south-eastern, eastern and north-eastern districts of the city. The west of the city is characterized by poorer people.

2.3.4 Maternity Hospital in Basel and Lausanne

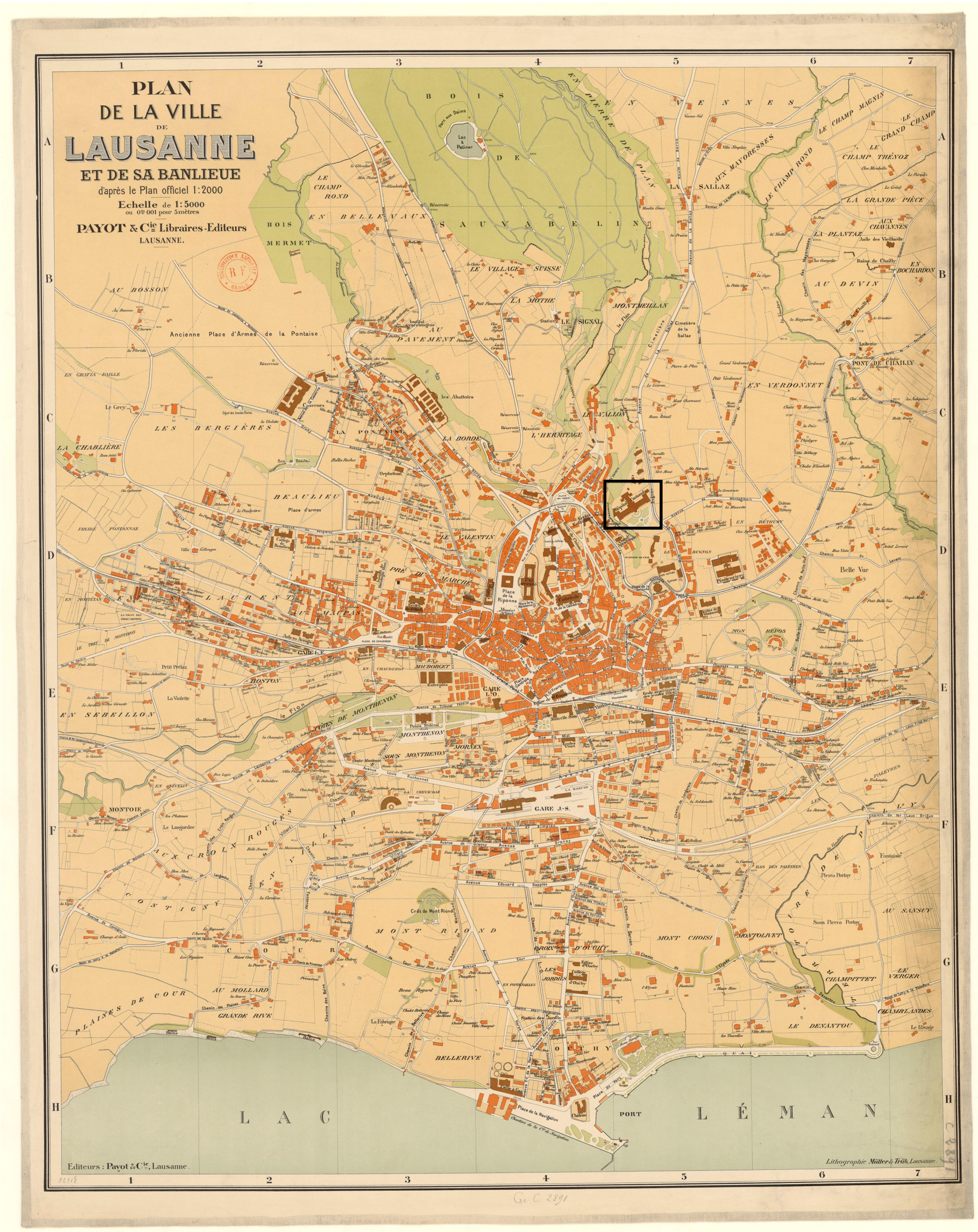
The maternity hospital (*Frauenspital*) in Basel is located in a prosperity district called *Am Ring* in *Grossbasel* (see black square in Figure 4).

Source: Baudepartement des Kantons Basel-Stadt (1905)

Figure 4: Basel at 1905 – location of the maternity hospital

Since 1888 detailed data on each birth have been recorded in the maternity hospital (Staatsarchiv des Kantons Basel-Stadt, 1888–1939). Each birth record spreads up to four pages and contains information about the mother, her child and the childbirth. Unfortunately, only 1/3 of the initial control books were kept in the archives. An increasing number of childbirths were given in the maternity hospital in Basel. From 1912 to 1920, between 51% and 64% of all births and more than 90% of all hospital births were given in the maternity hospital (Floris et al., 2016, p.12). During the war, the percentage share of hospital births increased (Floris et al., 2016, p.11).

In Lausanne, the obstetrics department was initially situated in a pavilion next to the cantonal hospital. The cantonal hospital was located north, marked by a black rectangle (see Figure 5).



Source: Müller and Trüb (1910)

Figure 5: Lausanne at 1910 – location of the cantonal hospital

In 1916, the obstetrical department got its own large building, which was the maternity hospital (Fuschetto, 2017). Since 1902, detailed data on each childbirth has been recorded (Archives cantonales vaudoises, 1902–1948). Each record spreads over six pages. In Lausanne, the whole series of register books has been kept. An overall increasing number of births in the city took place in this maternity hospital. As this data is part of the current SNSF-project, a detailed analysis of the percentage of births which took place in the maternity hospital is not yet finished. One estimates similar values as for Basel, ranging from 40 to 60% of births given in the maternity hospital.

3 Methods

3.1 Data and Data Preparation

3.1.1 Data Set of Basel (1912-1920)

The Basel data contains 3,707 entries, with 2,595 addresses geolocated in the previous SNSF project. Therefore, the data set already has x and y coordinates for each address. In the SNSF project, the addresses were standardized according to Salvisberg (1999). The geolocation process of the addresses was made through the database of the land registry and survey office of the canton of Basel city (https://www.gva.bs.ch/). The data set covers the years between 1912 and 1920. For each childbirth record the variables listed in Table 2 were transcribed, showing the variable name, a short description and an example.

Table 2: Transcribed variables of Basel data

Variable	Description	Example
First and last name	free text	Marie Mahler
Place of residence	free text	Sustenstrasse 2
Occupation	free text	Hausfrau
Date of birth of the mother	date	22.01.1891
Age at first menarche	in years	14
Height	in cm	165
Body shape type	categories	kräftig
Nutritional status	categories	gut
Date of the childbirth	date	11.01.1916
Parity of child	continuous number	2
Sex of the child	categorical	1
Maturation status of the child	categorical	1
Last menstruation	date	20.08.1914
Gestational age	in weeks	39
Birth weight (at birth, fifth, release)	in grams	3010
Length of the child	in cm	45
Placenta weight	in grams	400
Singleton or twin birth	continuous number	1
Vital status of the child	categorical	1

Source: Staatsarchiv des Kantons Basel-Stadt (1888–1939)

Twin births (n=67), stillbirths (n=76) and points located in the northeastern districts (*Riehen*, *Bettingen*) (n=51) were excluded. In total, 2,401 data points were used for the geovisualization.

3.1.2 Data Set of Lausanne (1917-1921)

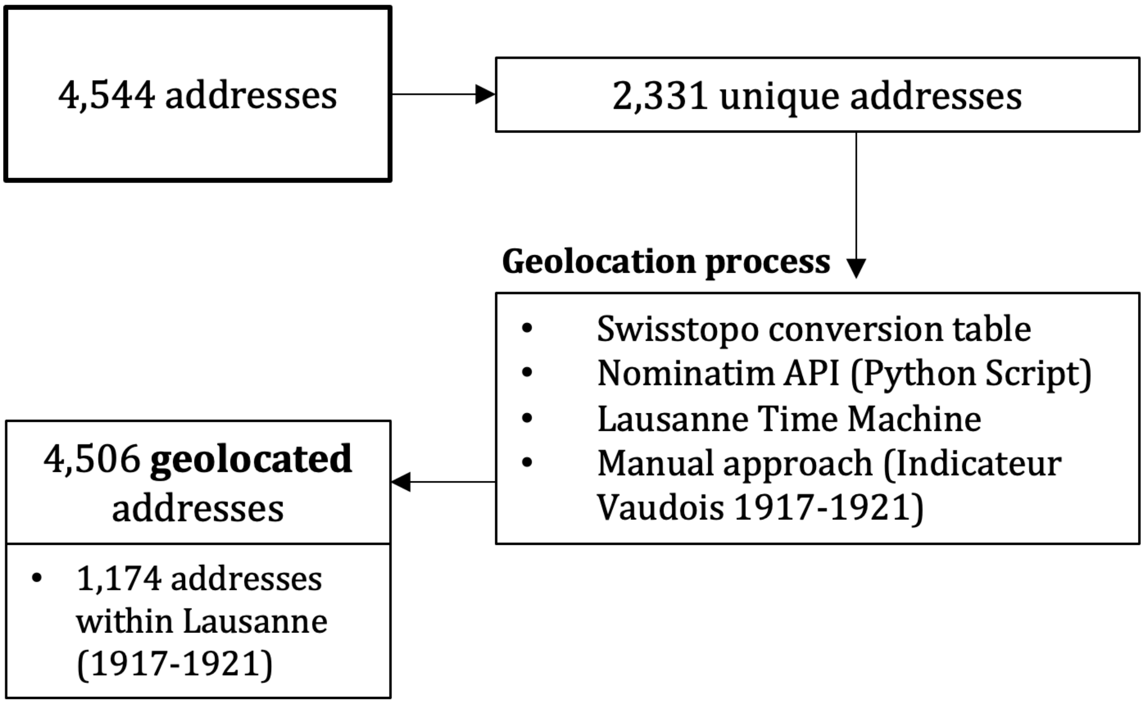
The data set of Lausanne includes 4,544 entries and covers the years between 1917 to 1921. The variables listed in 3.1.1 were transcribed for Lausanne too. The data set of Lausanne is of slightly higher quality than the data set of Basel. Among others, the medical history and maternal history are described much more precisely (see Table 3).

Table 3: Transcribed variables of Lausanne data

Variable	Description	Example
First and last name	free text	Lea Chapuis
Place of residence	free text	Avenue de Leman 75
Occupation	free text	menagere
Civil status	free text	mariee
Religion	free text	catholic
Age of the mother	date	25
Age at first menarche	in years	14
Height	in cm	165
Body shape type	categories	normal
Nutritional status	categories	bon
Date of the childbirth	date	11.01.1916
Parity of child	continuous number	2
Sex of the child	categorical	1
Maturation status of the child	categorical	1
Last menstruation	date	20.08.1914
Gestational age	in weeks	39
Birth weight	in grams	3010
Weight at fifth day	in grams	2900
Weight at release	in grams	3000
Length of the child	in cm	45
Previous births	free text	1912 1st pregnancy 2970g
Syphillis	categorical	yes
TB	categorical	no
Gonorrhoea	categorical	no
Flu	categorical	no
Three pelvic measurements	categorical	0
Child's head circumference	in cm	32
Waist circumference	number	84
Placenta weight	in grams	350
Placenta diameter	in cm	17x15
Feeding	free text	maternal
Home birth	categorical	0

Source: Archives cantonales vaudoises (1902–1948)

Geolocation of the Addresses To display the data on a map, the Lausanne data set must be geolocated. As a spatial information, the transcription contains the residential addresses of the mothers, which can be used. Figure 6 summarizes the procedure that was carried out to geolocate the addresses.



Source: own Figure

Figure 6: Geolocation process

In a first step, duplicates were removed from the data set to obtain unique addresses. The 2,331 unique addresses were standardized in a specific format (Street, Number, City) and some entries were randomly compared with the old historical street register from Lausanne from 1918 (Canton de Vaud, 1918) and with the mapping platform of the Swiss Confederation (https://map.geo.admin.ch/) to get a first overview of the addresses. In a next step, the excel conversion table of the Swiss Confederation (geo.admin.ch – Geoportal des Bundes, 2019) was used to automatically extract the coordinates. Through this process, about 70% of the unique addresses could be assigned a geocoordinate.

In the meantime, Rémi Guillaume Petitpierre [4] was able to increase the percentage of geocoordinates up to 98.2%. He extracted the coordinates with the Nominatim *Applica-*

[4] Rémi Guillaume Petitpierre is a doctoral assistant and student of the doctoral program of digital humanities at EPFL (EPFL, 2020a).

tion Programming Interface (API) from Open Street Map. Further, he linked the data with the Lausanne Time Machine [5] to geolocate streets that no longer exist.

A manual approach was chosen for the remaining 2% of the addresses that could not be geolocated so far. These addresses were looked up in the address book collections of the city of Lausanne from 1917 to 1921 (Canton de Vaud, 1917, 1918, 1919, 1920, 1921) and coordinates were assigned via the mapping platform of the Swiss Confederation (https://map.geo. admin.ch/). For streets that not longer exist, the old city map of Lausanne (Müller & Trüb, 1910) (see Figure 5) was used to identify the location of old street names and addresses. These locations were then georeferenced. The precision could be lifted up to 99.3%.

In addition, 425 women could not be located with a precise address within Lausanne. Instead, they had only *Lausanne* as a place of residence. First, the respective names of these mothers were looked up in the address book collections of the city of Lausanne between 1917 to 1921 (Canton de Vaud, 1917, 1918, 1919, 1920, 1921), where the street based address could be extracted. However, as this approach was time consuming, a student assistant had to be hired to extract these addresses in the state archives of Lausanne. Unfortunately, due to time constraints of this Master's thesis, it was not possible to include these additional addresses into the further visualization and analysis.

In total, 4,506 addresses could be geolocated. Entries were randomly selected for verification, as it was not possible to check every entry. 1,599 coordinates are located in the urban area of Lausanne. However, it should be noted that 425 Lausanne entries must be subtracted as these could only be located at the municipality level.

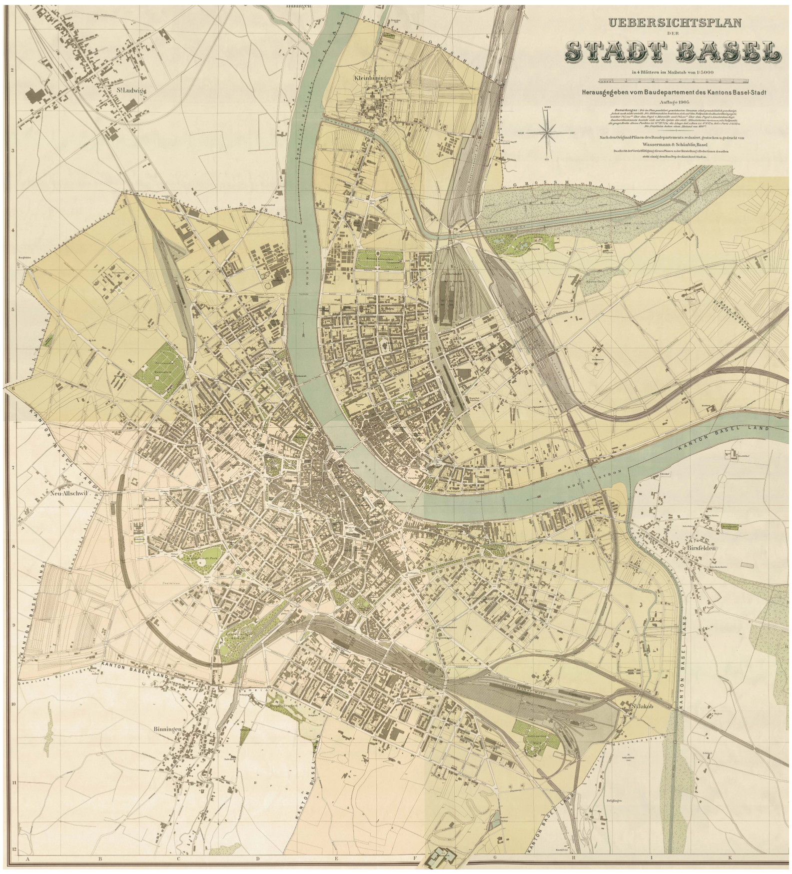
Therefore, 1,174 locations could be placed within Lausanne having a specific street based address. As twin births were not transcribed from the archive, only stillbirths (n=45) were excluded from data set. For Lausanne, 1,129 data points were used for visualization.

[5] The Lausanne Time Machine initiative aims to bring together past, current and future research concerning the Lausanne region. This project unifies different stakeholders, such as research institutions, city administration, heritage institutions, to promote digital projects around heritage. It is part of the international Time Machine project (EPFL, 2023).

3.1.3 Selecting Meaningful Basemaps

As the data is from the beginning of the 20th century, a historical basemap is used for visualizing the data. A basemap provides geographical context to the map. Among others, it can show place names, rivers, buildings, streets and green spaces (Esri, n.d.)

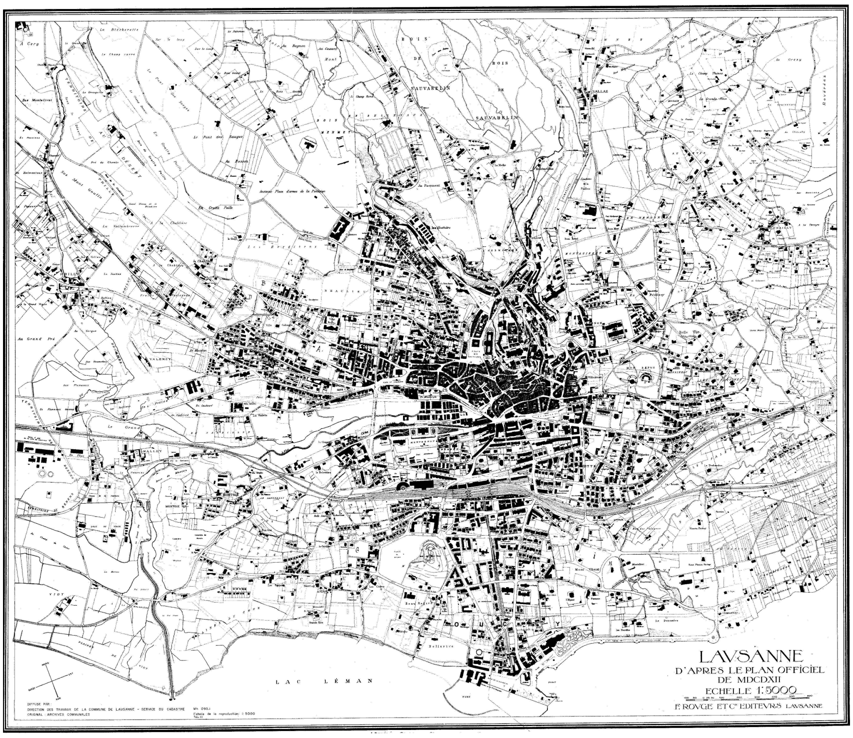
The basemap for the city of Basel was purchased from the geodata shop of the canton Basel city (Geodaten Kanton Basel-Stadt, n.d.). The historical maps were downloaded and the general map of Basel of 1905 was selected (Baudepartement des Kantons Basel-Stadt, 1905). The general map of Basel of 1905 was initially created to replace the map produced in 1882, which had become inaccurate due to the many additions and overprints. The 1905 map was produced as an accurate and carefully executed city raster map in 4 sheets (see Figure 7). The resolution is 0.5 metres, the scale is 1:5,000 and it was referenced in the Swiss coordinate reference system CH1903+ LV95 (EPSG:2056) (Baudepartement des Kantons Basel-Stadt, 1905). The original colourful plan was later adjusted to black and white in order to visualize it with other data.



Source: Baudepartement des Kantons Basel-Stadt (1905)

Figure 7: Basemap of Basel (1905)

For Lausanne, the basemap was purchased from the geodata shop of the city of Lausanne (Service du cadastre de la Commune de Lausanne, 2021). The city raster plan from 1912 was chosen with a scale of 1:5,000 in the Swiss coordinate reference system CH1903+ LV95 (EPSG:2056) (see Figure 8). Since the basemap is already in black and white, only minor colour adjustments were made. The Lausanne basemap is rotated for 21.6 degree to the left for a horizontal view.



Source: Service du cadastre de la Commune de Lausanne (2021)

Figure 8: Basemap of Lausanne (1912)

3.1.4 Adding City Districts to the Basemap

In order to spatially aggregate the data, a spatial division is needed. For Basel, the today's city districts were selected because the districts remained unchanged for over 100 years (Statistisches Amt des Kantons Basel-Stadt, n.d). Lausanne has no official residential districts for the time period around 1920. However, to aggregate the data similar as for Basel, the current districts are chosen for Lausanne too. The current city districts for both cities were downloaded from the Federal Office for Statistics of the Swiss Confederation (Bundesamt für Statistik, 2017).

The city of Basel is divided into 19 statistical residential districts. The districts *Riehen* and *Bettingen* are excluded as the basemap does not cover these areas. Lausanne has 18 residential districts, in which the outermost zone (*zones foraines*) in the north of Lausanne gets excluded. Both city districts and their respective district names are visualized in Figure 9.

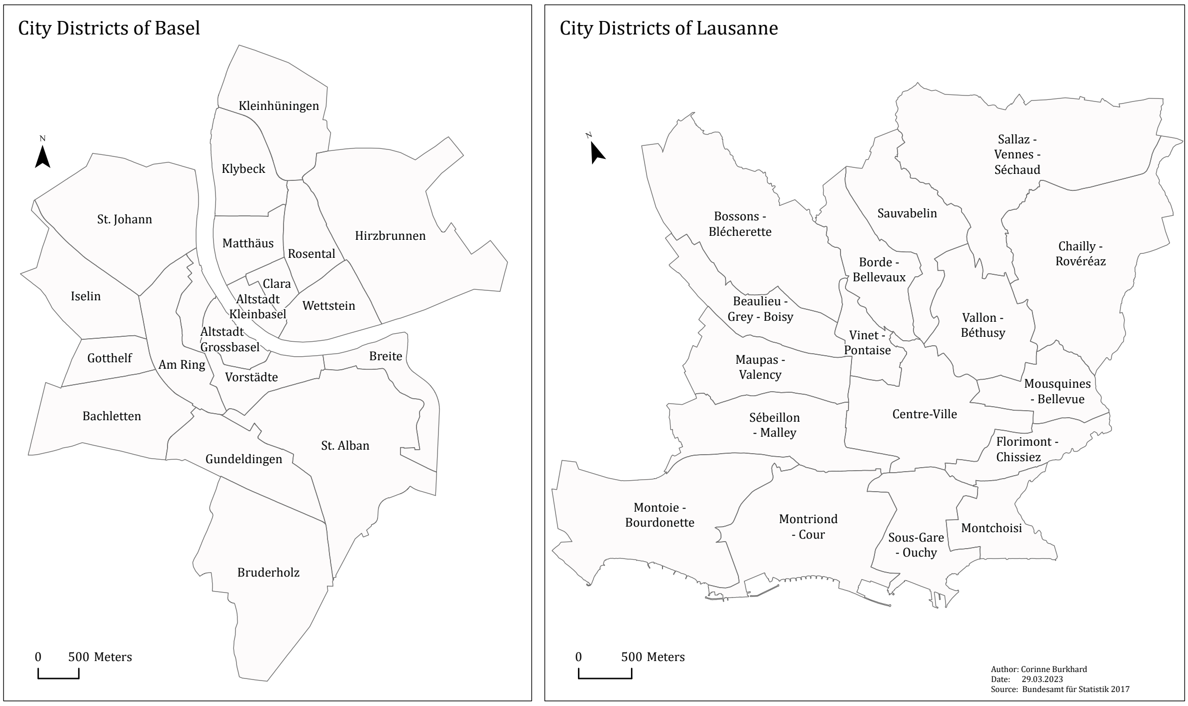


Figure 9: City districts of Basel and Lausanne

3.1.5 Adding Water Bodies to the Basemap

To emphasize the water areas in the basemap, they were included as vector polygons. If necessary, they were drawn based on the basemaps of Basel and Lausanne (Baudepartement des Kantons Basel-Stadt, 1905; Service du cadastre de la Commune de Lausanne, 2021).

The shapefile of the river data set for Basel was downloaded from swisstopo (Bundesamt für Landestopographie swisstopo, n.d). Based on the historical basemap of Basel (Geodaten Kanton Basel-Stadt, n.d.), bigger streams were manually added. Besides the Rhine River, the *Rhein-Rhone Kanal*, the *Wiese Fluss*, the *Birs Fluss* and the *Birsig Fluss* were included as water bodies.

The water body shapefile for Lausanne was downloaded from the Federal Office for Statistics (Bundesamt für Statistik, 2022). Lake Geneva was adjusted to the historical borders of the basemap of Lausanne (Service du cadastre de la Commune de Lausanne, 2021). The river *le Flon* was manually added to the water bodies. Around 1920 *le Flon* flowed directly into Lake Geneva (Service du cadastre de la Commune de Lausanne, 2021).

3.1.6 Factories as Further Points of Interest

A new data set was created consisting of selected points of interest to examine to relationship between locations that may have an influence on the environment and thus on birth weights. Factories were selected as points of interest because of their negative impact on the environment due to air and water pollution.

The factory statistics of Lausanne and Basel from 1929 were consulted in the city archive of Bern (Eidgenössisches Statistisches Amt, 1929). This statistic book recorded, among others things, which factory had how many employees, how much energy was produced by the factory itself, and how much energy was purchased from third parties. For the self-generated energy, a distinction was made between *water*, *steam* and *others* – all measured in horsepower.

The factories were selected based on their category, emission intensity and company size. Besides the categories tannery, chemical, textile and cardboard industry (elaborated in Chapter 2.3.2), the categories millery, brewery and electricity supply were chosen due to their emission intensities. For Basel, 13 factories were selected in the categories textile industry, chemical industry, brewery and electricity supply (see Table 4). For Lausanne, 12 factories were selected in the sectors tannery, textile industry, brewery, cardboard industry and electricty supply (see Table 5).

Table 4: Factories in Basel

S-Nr.	Sector	Factory
85	Tar dyes, fragrances	J.R Geigy A.G. Chemiefabrik
85	Tar dyes, fragrances	Ges. für Chem. Industrie Basel (Ciba)
86	Remedies	Chemische Produkte Sandoz
86	Remedies	F. Hoffmann la Roche A.G.
10	Spinning mill	Industrielle Ges. für Schappe
10	Spinning mill	Industrielle Ges. für Schappe, Rappolts
14	Tape manufacture	DeBary & Co. Seidenfabrik
54	Clean, dye, wash	Chem. Waschanstalt Röthlisberger & Cie
54	Clean, dye, wash	Bruder- Nyfeler Alb.
77	Brewery	Aktienbrauerei
77	Brewery	Brauerei zum Warteck (B. Füglistaller) A.G.
101	Electricity supply	Elektrizitätswerk Basel, (Dolder)
101	Electricity supply	Elektrizitätswerk Basel, (Volta)

Table 5: Factories in Lausanne

S-Nr.	Sector	Factory
52	Furrier	Fourrures Benjamin
52	Furrier	Au Tigre Royal
52	Furrier	Francois Canton
108	Tannery	SA de Tannerie
54	Clean, dye, wash	Blanchisserie Excelsior
54	Clean, dye, wash	Blanchisserie Montriond
54	Clean, dye, wash	Teinturerie Rochat
64	Millery	Grande Meunerie
77	Brewery	Brasserie Beauregard
107	Cardboard	Cartonages SA
107	Cardboard	Marmillon et Cie.
101	Electricity supply	Usine electric Pierre de Plan

The addresses of the factories were looked up in the address books of Lausanne (Canton de Vaud, 1918) and Basel (Kanton Basel-Stadt, 1918). In addition, the Lausanne archives were contacted to identify the addresses of some factories. After having all information, the addresses were geolocated with the mapping platform of the Swiss Confederation (https://map.geo. admin.ch/). The location of the factories are visualized in the Figures 10 and 11. The factories are colored according to their category. It is noticeable that the factories are evenly distributed in the city of Basel. However, for Lausanne the factories are more clustered in the center.
More information about the selected factories can be found in the Appendix (A.1 and A.2).

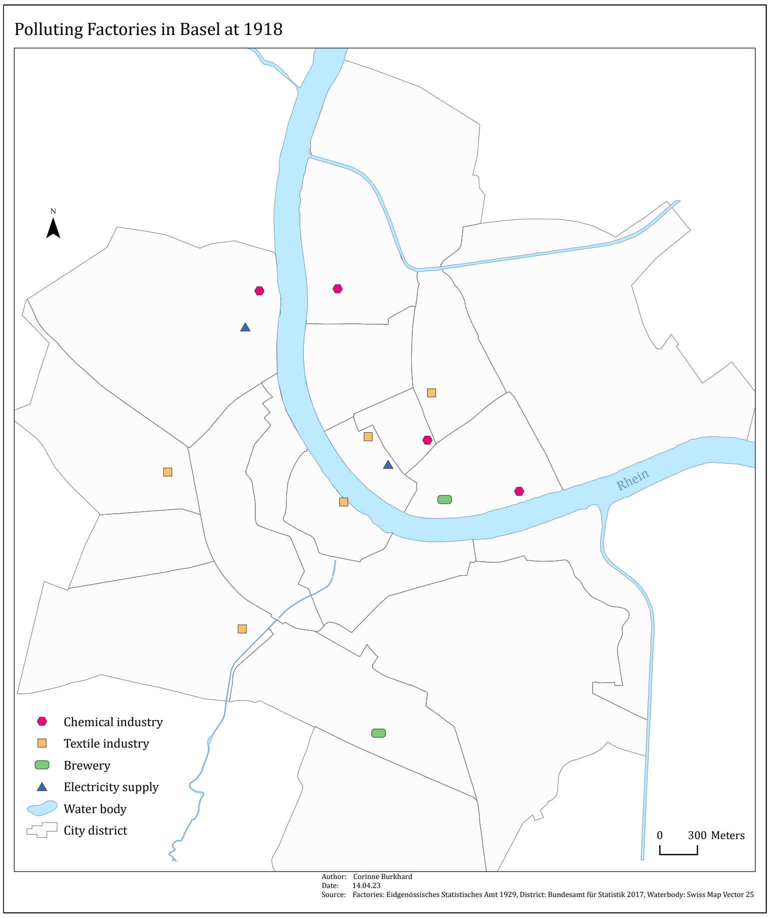


Figure 10: Polluting factories in Basel at 1918

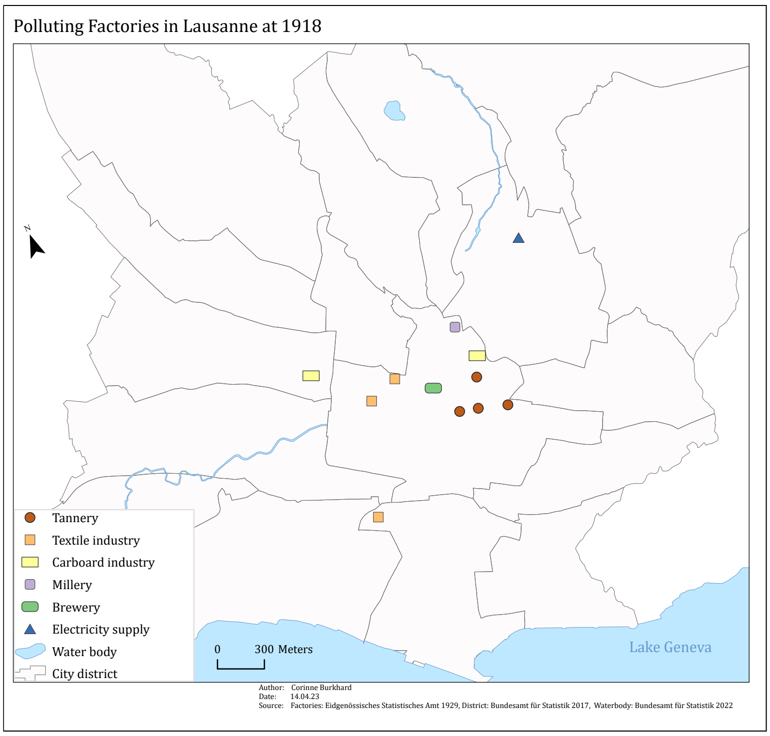


Figure 11: Polluting factories in Lausanne at 1918

3.2 Data Visualization

3.2.1 Choosing a Geovisualization Tool

ArcGIS Pro (version 3.1.0) from Esri Inc. was used to store, modify and visualize the data. All created maps aim to meet the cartographic principles (Slocum et al., 2022). Based on Slocum et al. (2022, p.205) a frame line was drawn around each map to differentiate between the map and the written text more easily. In addition, a neat line was chosen to emphasize on the maps' extent. The map elements (frame line, neat line, mapped area, inset, title, subtitle, legend, data source, scale and orientation) were placed based on their relevance (Slocum et al., 2022, p.204).

3.2.2 Generating Thematic Maps

Dot maps and choropleth maps were chosen to visualize the data (Slocum et al., 2022, p.267ff). Dot maps were used to show the residential addresses of the women which gave birth in the maternity hospital. As several women received the same coordinate, the number of women per residential address was visualized by the size of the dot. In ArcGIS Pro, this was managed with the *Summary Statistics* tool to summarize for each coordinate. Choropleth maps were created for the whole time period at district level to make trends visible showing average birth weights and other average anthropometric measures. In ArcGIS Pro, the data was intersected with the city districts. After that, the tool *Summarize Within* was used to count the points for each district and to calculate the mean value.

3.2.3 Different Methods to Classify Data

When creating maps, data is usually grouped into classes, with a specific color used for each class. This is referred to as classed maps (Slocum et al., 2022, p.83). Most maps created in this thesis are classed maps. Birth weights per place of residence were created as unclassed maps in order to show the range of values.

Two different classification methods were applied for creating classed maps, namely the manual classification and the quantile classification (Slocum et al., 2022, p.87). The manual classification was chosen for maps which have to be comparable over time, as for example visualizing low birth weight infants for each year. The quantile classification has been applied to most data showing birth weights and other anthropometric measures. Quantile classification ranks the values in order and then divides them into groups, with each group having the same number of points. Different names are used depending on the number of classes. When five classes (quantiles) are formed, each group accounts for 20% of the data. When four classes (quartiles) are formed, each group accounts for 25% of the data (Slocum et al., 2022, p.87).

Advantages of quartile classification are that one can refer to the upper or under 25% of the data, since the class boundaries reflect the range of actual data that fall into each class. Furthermore, the median falls in the middle of the classes with an odd number of classes. A disadvantage, however, is that the quartile classification does not take into account how the data are distributed along the number line. Outliers can be placed with lower magnitudes in the same class (Slocum et al., 2022, p.88).

3.2.4 Choosing Visual Variables

Visual variables describe the perceived differences in map symbols that are used to represent geographical data. Jacques Bertin, a French cartographer, developed the concept of visual variables in 1983, which was later modified by others (Slocum et al., 2022, p.67).

For the maps, the visual variables *size* and *colour (hue, lightness, saturation)* were chosen (Slocum et al., 2022, p.69). The colours were selected with ColorBrewer 2.0 (https://color brewer2.org) to find optimal colours suitable for colour blindness. In addition, the maps were checked with Color Oracle, which is a free color blindness simulator for Windows, Mac and Linux (https://colororacle.org/). Point size was either based on graduated symbols or proportional symbols. Proportional symbols were selected to display unique values. The graduated symbols were chosen for data points which represent classes of data.

Choropleth maps were created with graduated colors using a single hue color scheme to display the course of the data from low to high. To avoid confusion between the two cities, different color schemes were chosen for the average birth weights maps at district level. For Basel, a single hue 4-class purple color scheme was used, whereas for Lausanne a single hue 4-class blue color scheme was chosen (Figure 14 and 22). The same colors were used to show the unclassed data range, where birth weights were visualized on point level showing the residential addresses of the mothers. The outline color of the points is white to emphasize on overlapping points (Figure 13 and 21) .

Dot maps which show if an issue is present (like for example stillbirths or low birth weights) were colored in salient colors to draw attention (Figure 15, 16, 23, 24). Dark red and orange were chosen as prominent colors. Less important points were colored in a transparent color having a grey outline color.

For both cities, the same colors were used to display stillbirths/ low birth weights and anthropometric variables. The range for colorblind friendly colors is small. For this reason, same color schemes were used for the anthropometric variables. In addition, it should help to recognize the maps more easily due to consistent color schemes. The age and the height of the mothers were colored in a 4-class green and in a 4-class purple-red color scheme, respectively. The placental weight was colored in a 4-class orange scheme (Figure 17, 25).

Regarding the buffer analysis, the buffers of the factories were colored with different brown values (lightness), which become radially lighter towards the outside (Figure 18, 26). This is to emphasize the uncertainty of the pollution, as the affected area is not clear.

The hot and cold spots of the cluster analysis were colored accordingly in red and blueish colors to emphasize on high and low values. Points which were not significant where drawn in transparent color having a grey outline color. Different methods were considered to visualize superimposed points, such as marking points with a special symbol with several women per address or adapt the size of the point according to the number of women. Adapting the number of women per residential address seemed to be a reasonable way. The *Summary Statistics* tool was applied two times, for the points which were categorized in a cluster and for the points which were not part of a cluster. The significance of the points were colored in a 4-class brown color scheme (Figure 19, 27).

Table 6 summarizes for all maps created in this thesis, what type of symbology, classification method and color scheme was used.

Table 6: Applied symbology, classification method and color scheme for all maps

Map	Symbology	Class.	Color scheme
Figure 14	grad. colors	quartile	single hue 4-class purple
Figure 13, 21	prop.symbols	unclassed	cont. purple; cont. blue
Figure 22	grad. colors	quartile	single hue 4-class blue
Figure 15, 23	grad. symbols	manual	orange, white
Figure 16, 24	prop. symbols	unclassed	dark red
Figure 17, 25	grad. colors	quartile	single hue 4-class green
Figure 17, 25	grad. colors	quartile	multi hue 4-class purple-red
Figure 17, 25	grad. colors	quartile	single hue 4-class orange
Figure 14, 17, 22, 25	grad. symbols	quartile	grey
Figure 18, 26	buffers		brown (lightness)
Figure 19, 27	prop. symbols		red, blue, white
Figure 19, 27	grad. colors		single hue 4-class brown

3.3 Data Analysis

3.3.1 The Buffer Analysis Technique

The buffer analysis was performed with ArcGIS Pro and R. Since air moves radially in space, the euclidean distance between the points of interest and the places of residence of the women were calculated. For the air distribution, wind direction is also an important factor. However, in the absence of data on this parameter, wind directions were not considered. Also, water pipelines and water bodies were not considered because such data are partly not available and too many assumptions would have to be made.

With the *Buffer* function in ArcGIS Pro, a radius of 200 meter for Basel and a radius of 100 meter was chosen for Lausanne. A buffer radius of 200 meters was set for Basel, as the factories were more equally distributed over the city as for Lausanne. Basel was also home to factories with higher emissions that could impact a larger environment. In Lausanne, the factories were rather clustered in the center. For this reason, a larger radius could not be selected without overlapping the buffers.

The data was intersected with the buffers to determine which points were within a buffer. Before the data set was intersected with the buffers, two additional columns were added to categorize low birth weight and stillbirth into binary variables. After intersecting, a column was added to capture if the point is within a buffer or not. Finally, the intersected table could be joined to the original data set. This table was exported in a comma-separated value format (.csv) to use it further in R.

To test the association between the outcome variable (low birth weight, stillbirth) and the exposure variable (within distance to a factory) a logistic regression model was used. The variables maternal age, year, gestational age, parity, maternal height, sex, stillbirth were set as control variables. The outcome variables were binary coded. A basic code was generated by Katarina Matthes [6] and Kaspar Staub, where they cleaned both data sets and created the logistic regression model. This code was used as a basis to run it on the data sets in R. The code is added in the Appendix (see A.3).

3.3.2 The Cluster Analysis Technique

The open source software *GeoDa* (Anselin & McCann, 2009) was used to determine where clusters of high and low birth weights occurred in the cities of Basel and Lausanne. Stillbirths were excluded from the data set. For Basel, 2,401 points and for Lausanne, 1,129 points were used for the analysis.

The Getis-Ord-Gi statistic was chosen to measure local clusters [7]. Getis-Ord Gi indicators measure spatial dependence and assess the presence of local clusters in the spatial distribution of a given variable (e.g., birth weight) (Getis & Ord, 1992). Within a given spatial lag, the sum of a single birth weight value is compared proportionally to the sum of individual birth weight values within the entire data set (Getis & Ord, 1992). For both cities, birth weights were analyzed within 1000 m of each individual's place of residence. Statistical significance testing was based on row-standardized weights with a sample of 999 permutations. A Gi cluster map and a Gi significance map were created

[6] Katarina Matthes is a postdoctoral research assistant of the Anthropometrics & Historical Epidemiology group (Universität Zürich, 2023).

[7] The method for the cluster analysis including the tool and the parameter settings were agreed with Stéphane Joost. He is a senior scientist at EPFL. His field of expertise is Geographic Information Science as well as spatial statistics, molecular ecology, landscape and seascape genomics,spatial epidemiology, geomedicine and precision population health (EPFL, 2020b).

in GeoDa. The results were saved to the attribute table and accordingly visualized with ArcGIS Pro.

3.4 Data Publication

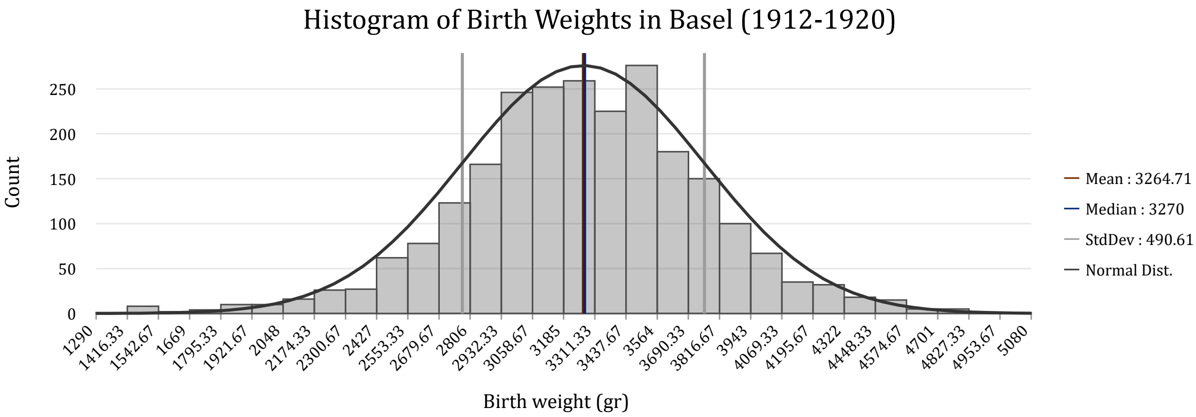
The whole ArcGIS project as well as individual shapefiles (newly created or existing) will be made accessible through the Department of Geography at the University of Zurich. For further information, please contact Dr. Tumasch Reichenbacher (tumasch.reichenbacher@geo.uzh.ch) or PD Dr. Kaspar Staub (kaspar.staub@iem.uzh.ch).

4 Results

4.1 Data Visualization for Basel

4.1.1 Descriptive Statistics of Birth Weights

A short descriptive statistic was carried out with ArcGIS Pro using the function *charts* to examine the distribution of the variable birth weight (see Figure 12). The values of birth weights are almost normally distributed having a kurtosis of 3.9 and a skewness of -0.197. Skewness is a measure of symmetry, whereas kurtosis says something about if the data is heavy-tailed or light tailed (Universität Zürich, 2022). The data is nearly symmetrical having a few outliers at the lower end. Looking at the measures of central tendency, the mean value lies by 3264,7 grams having a standard deviation of 490,6 grams. The median is 3270 grams. The minimum and maximum value are 1,290 and 5,080 grams respectively.



Source: own Figure

Figure 12: Histogram of birth weights in Basel (1912-1920)

4.1.2 Spatial Distribution of Average Birth Weights

Since the data are spatially referenced, the addresses of the mothers and the corresponding birth weight of the newborn can be visualized in a map. Figure 13 shows the georeferenced residential addresses of the mothers, which gave birth at the maternity hospital in Basel. The points are colored according to the respective birth weight in a purple unclassed color ramp. If several women had the exact same coordinate, the point size is adjusted and the average birth weight value is visualized. The number of points range from 1 to 7 mothers per residential address. The average birth weight per residential address ranges from 1,420 grams to 4,850 grams. The points are equally distributed over the city with more dense areas in some parts. There are some parts where no points occur. The point pattern is difficult to describe due to the large sample size and the small differences of the saturated color. By zooming in, differences of lower and higher birth weights can be seen.

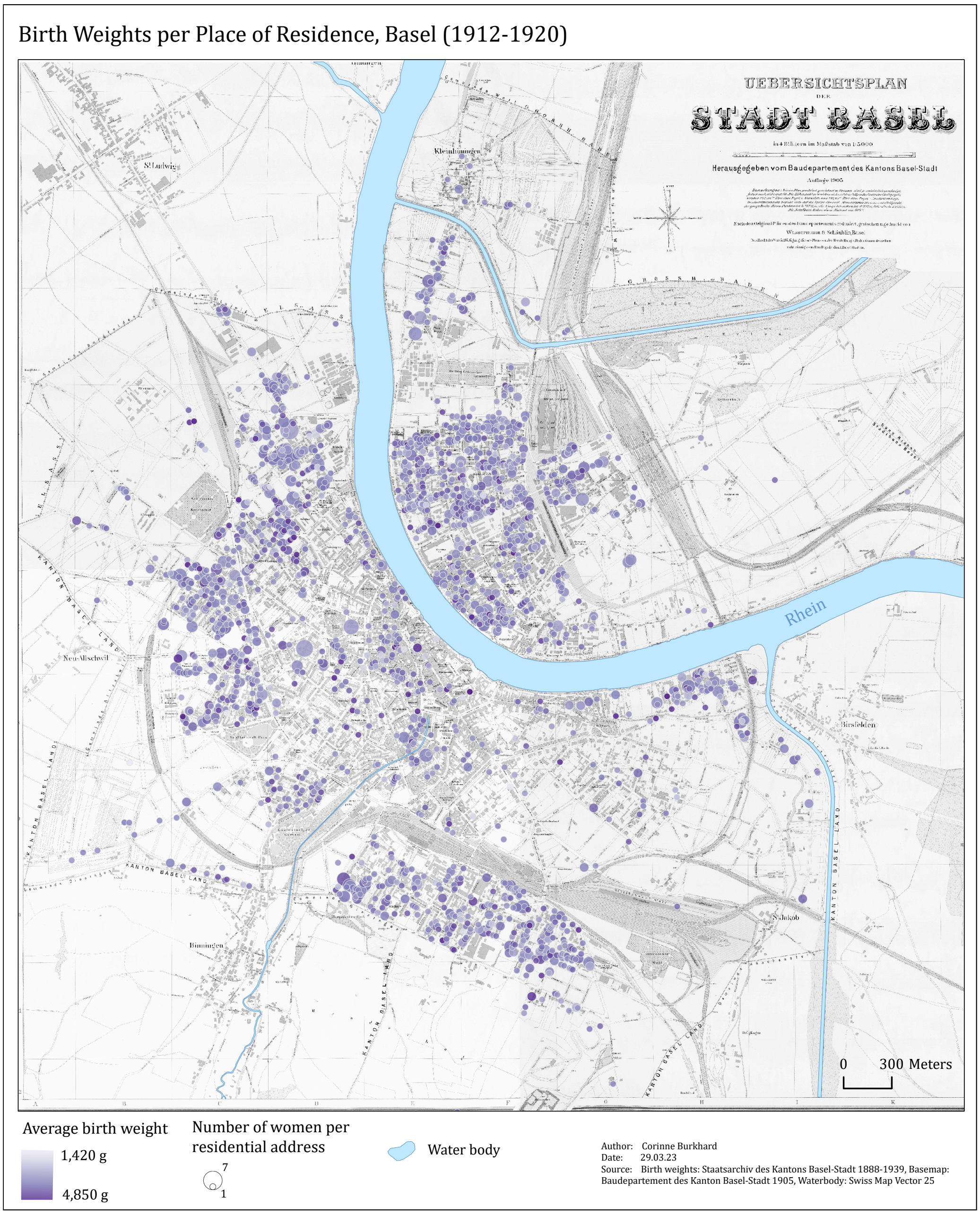


Figure 13: Birth weights per place of residence, Basel (1912-1920)

In a further step, the data is visualized on district level to solve the above-mentioned problem of interpreting the point pattern. By summarizing the data points on district level, trends can be revealed. Figure 14 shows the aggregated average birth weight values on district level. Average birth weight ranges from 3,118 grams to 3,362 grams having a difference of 244 grams. Not all districts include the same amount of points. The values range from 5 to 409 points. Classified into quartiles, the under 25% of the data varies between 5 and 58 points (e.g., districts: *Kleinhüningen*, *Hirzbrunnen*, *Wettstein*, *St.Alban*, *Bruderholz*). Higher average birth weights can be seen in the southwest of Basel involving the districts *Gotthelf*, *Bachletten* and *am Ring*. Particularly noteworthy is the *Matthäus* district, north of the Rhine River, which has a large sample size and the smallest average birth weight class.

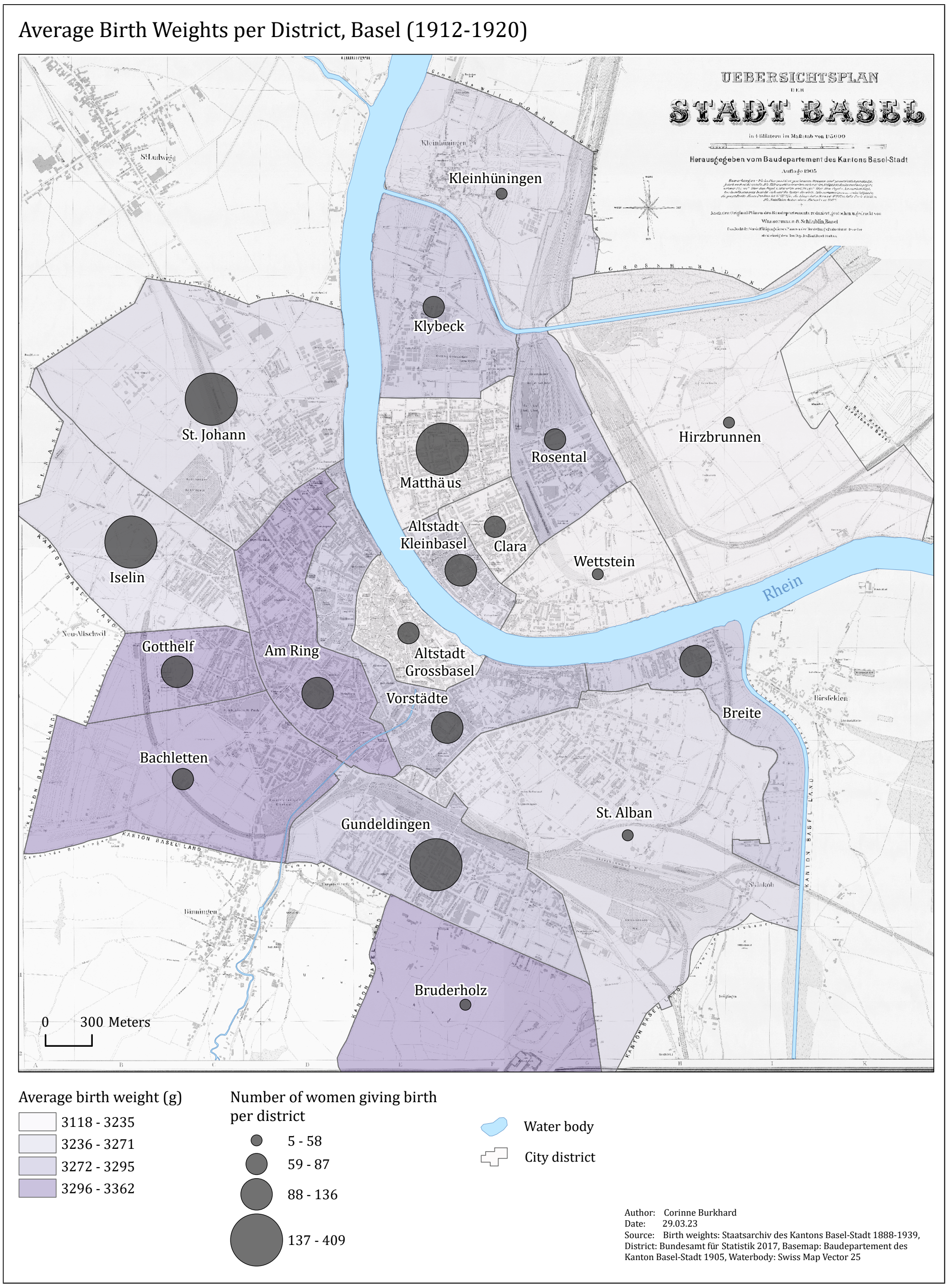


Figure 14: Average birth weights per district, Basel (1912-1920)

The spatial pattern of average birth weights seems to be similar to the division of Basel into residential districts (see Figure 3). Higher average birth weights are more likely to occur in prosperity and middle-class districts (e.g., *Bachletten* district). In contrast, lower average birth weights tend to occur in working-class districts (e.g., *Matthäus* district).

4.1.3 Spatiotemporal Distribution of Low Birth Weights

After presenting average birth weight on point and district level, the spatiotemporal distribution of low birth weights is examined in more detail. Low birth weights (newborns with less than 2,500 g) are considered as this threshold is decisive in literature (United Nations Children's Fund and World Health Organization, 2004).

Figure 15 shows the distribution of low birth weights for each year. The years 1912 and 1913 are shown together because the sample size of those years are comparatively small to the other years. On average, the maps shows 300 points per year, ranging from 254 to 339 points. The legend indicates that the size of the dots relates to the number of women who had the same georeferenced residential address. The color of the dot indicates whether the birth weight is low (orange) or normal (white). The prevalence of low birth weight is noted for each year and shows how many underweight infants were born in each year relative to the total sample of births.

Considering the low birth weight prevalence, it is noticeable that the years 1912/1913, 1914, 1918 and 1919 are having the largest relative share of low birth weights with values between 6.8% and 8.1%. In 1915, 1916 and 1920 the low birth weight prevalence was under 4.0%. Particularly noteworthy is the sudden increase of low birth weight prevalence between the years 1917 and 1918, and the decrease between the years 1914 and 1915 as well as between 1919 and 1920. The difference between these years is more than 2 percentage points.

Taking the spatial pattern into account, the distribution seems random at first. No clear pattern emerges for 1912/1913, 1914, and 1920, as low birth weights occur throughout the city. However, looking closer at the years 1915 to 1919, there is a difference between north and south of Basel. Low birth weights seem to occur more likely in working-class districts (*Matthäus*) and less in prosperity districts (*Bachletten*) .

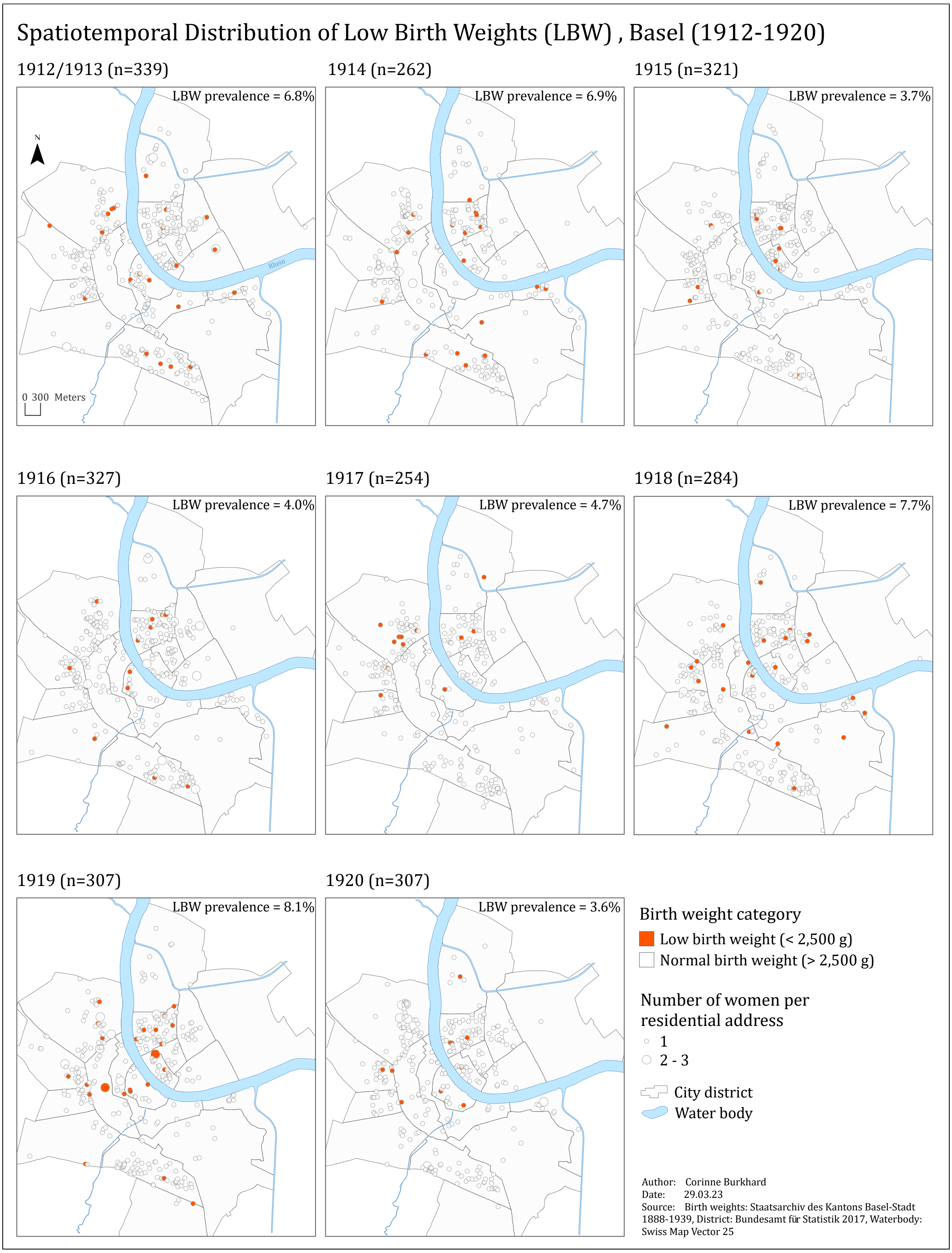


Figure 15: Spatiotemporal distribution of low birth weights, Basel (1912-1920)

4.1.4 Spatial Distribution of Stillbirths, Age, Height and Placental Weights

Of the variety of anthropometric variables, which were captured in Table 2, four are chosen to be visualized: 1) stillbirth, 2) age of the mother 3) height of the mother and 4) placental weight. In the following, these four anthropometric indicators are briefly explained in terms of why they were selected.

Selection of Variables:

A stillbirth is the worst result of a complication during pregnancy or at birth in which the fetus did not survive. A stillbirth can indicate poor (socioeconomic) conditions (Floris et al., 2016).

In terms of maternal age, there are studies that show that teenage mothers are more likely to give birth to preterm and low birth weight infants (Fraser et al., 1995). However, there could be other factors, such as racial and socioeconomic differences, which may confound such results (Fraser et al., 1995).

Regarding adult height, the parameter is an important determinant which influences size at birth. Studies have shown stronger effects for maternal than paternal height (Subramanian et al., 2009). Rochow et al. (2018) observed a correlation between a mother's height and her child's birth weight, where 1 cm height accounted for a 17 gram increase in birth weight. From an anthropometric perspective, the height of adults has been increasing more or less linearly since the middle of the 19th century (Cole, 2003, p.165). This mirrors the economic improvement of the biological standard of living (van Zanden et al., 2014).

Placental weight is a proxy for placental efficiency and plays a decisive role for fetal growth (Galofré-Vilà & Harris, 2021). Scholars found a pattern, in which birth weights and placental weight were both at their lowest in 1918/1919 during World War I (Butie et al., 2020). However, Galofré-Vilà and Harris (2021) found that placental size may expand to compensate maternal malnutrition. This results suggest that placental weight can be seen as an adaptive response. Nevertheless, they are not cost-free. Too low or too high placental weights are associated with early life mortality (D. J. Barker & Clark, 1997; Galofré-Vilà & Harris, 2021).

Stillbirth As a first anthropometric measure, stillbirths are visualized in dark red color in Figure 16. The red dots are showing the places of residence of the mothers, which had a stillbirth at the maternity hospital. The size of the dot shows the number of women per residential address, which had a stillbirth. In total, 76 stillbirths occurred between 1912 and 1920 in the maternity hospital in Basel. Considering the spatial pattern of stillbirths, the points are not randomly distributed. A pattern emerges that more points occur in the north and the northwest of Basel. Most stillbirths occurred in the districts *Matthäus*, *Rosental* and *St.Johann*, which were working-class neighborhoods at the time.

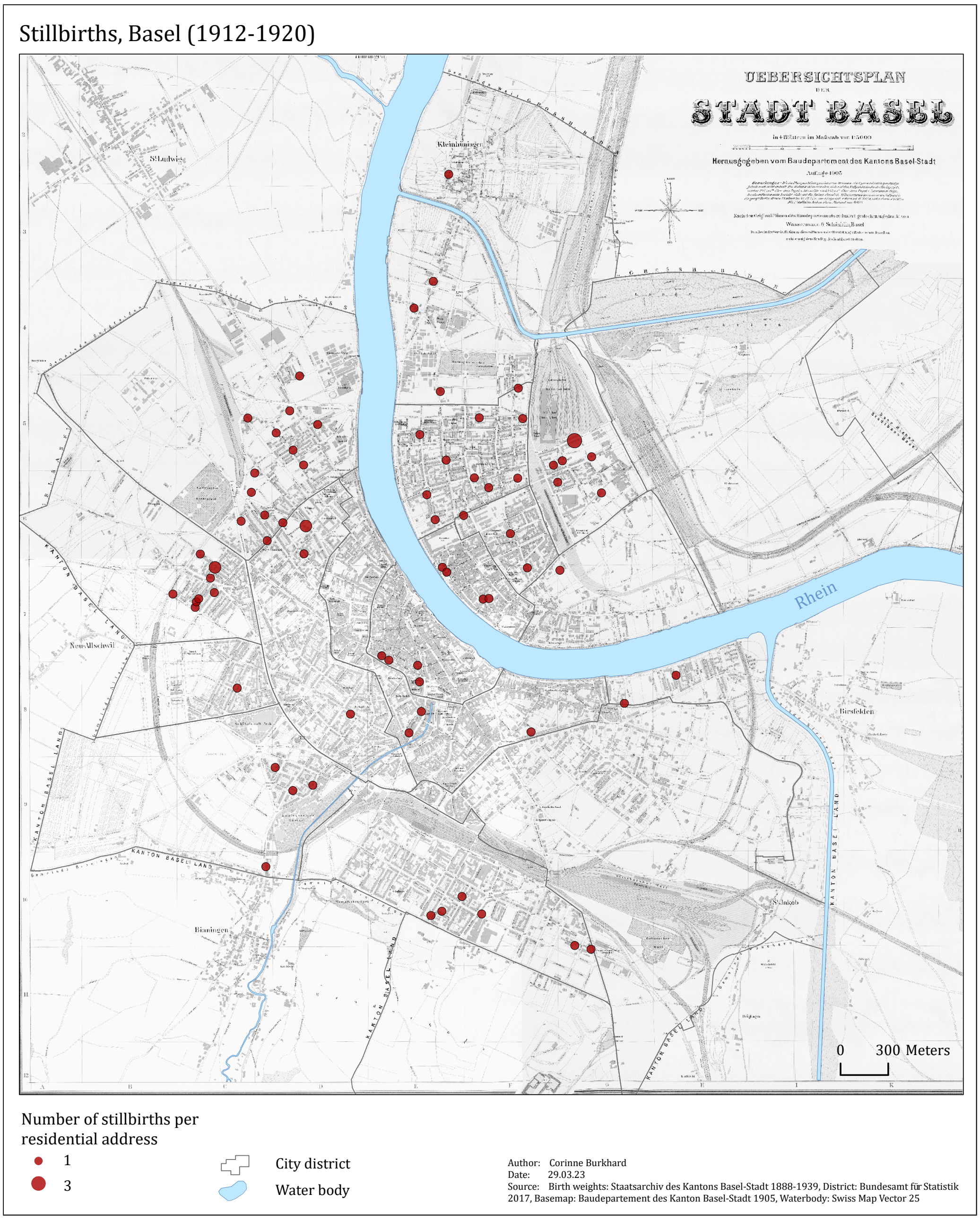


Figure 16: Stillbirths, Basel (1912-1920)

Age, Height and Placental Weight The three anthropometric measures age, height and placental weight of the mothers are visualized in Figure 17. To compare the spatial pattern more easily with birth weights, the average birth weight map from Chapter 4.1.2 is added as a fourth map bottom right of Figure 17. All maps are classified based on quartiles. The size of the circle indicates the number of women, which lived in that district and gave birth in the maternity hospital. The color of the district shows average values of the respective anthropometric measure calculated for each district.

The top left of Figure 17 shows the average age of the mothers in years calculated for each district. Values ranges from 22.4 to 30.1 years. The southwest of Basel has the highest average age, with the districts *Iselin*, *Gotthelf*, *Am Ring* and *Gundeldingen* having the highest values. Younger mothers can be identified in northern districts, such as *St.Johann*, *Klybeck*, *Kleinhüningen*, *Hirzbrunnen* as well as in the center of Basel (*Altstadt Kleinbasel*).

A similar pattern emerges when looking at the top right of Figure 17, indicating the average height in centimeters of the mothers calculated for each district. Here, values range between 154.7 cm and 159.3 cm. Taller women are identified in southwest of Basel in the districts *Gotthelf*, *Bachletten* and *Gundeldingen*.

The bottom left of Figure 17 visualizes average placental weight. Average placental weights vary between 621 grams to 678 grams. No clear spatial pattern is visible. Highest placental weights occur in the working class districts *Hirzbrunnen* and *Rosental* as well as in the prosperity districts *Am Ring* and *Bruderholz*.

Average age and average height seem to have a similar pattern compared to average birth weights. This indicates that taller and older mothers had heavier newborns in wealthier districts. In contrast, smaller and younger mothers located in working-class districts had less heavy newborns.

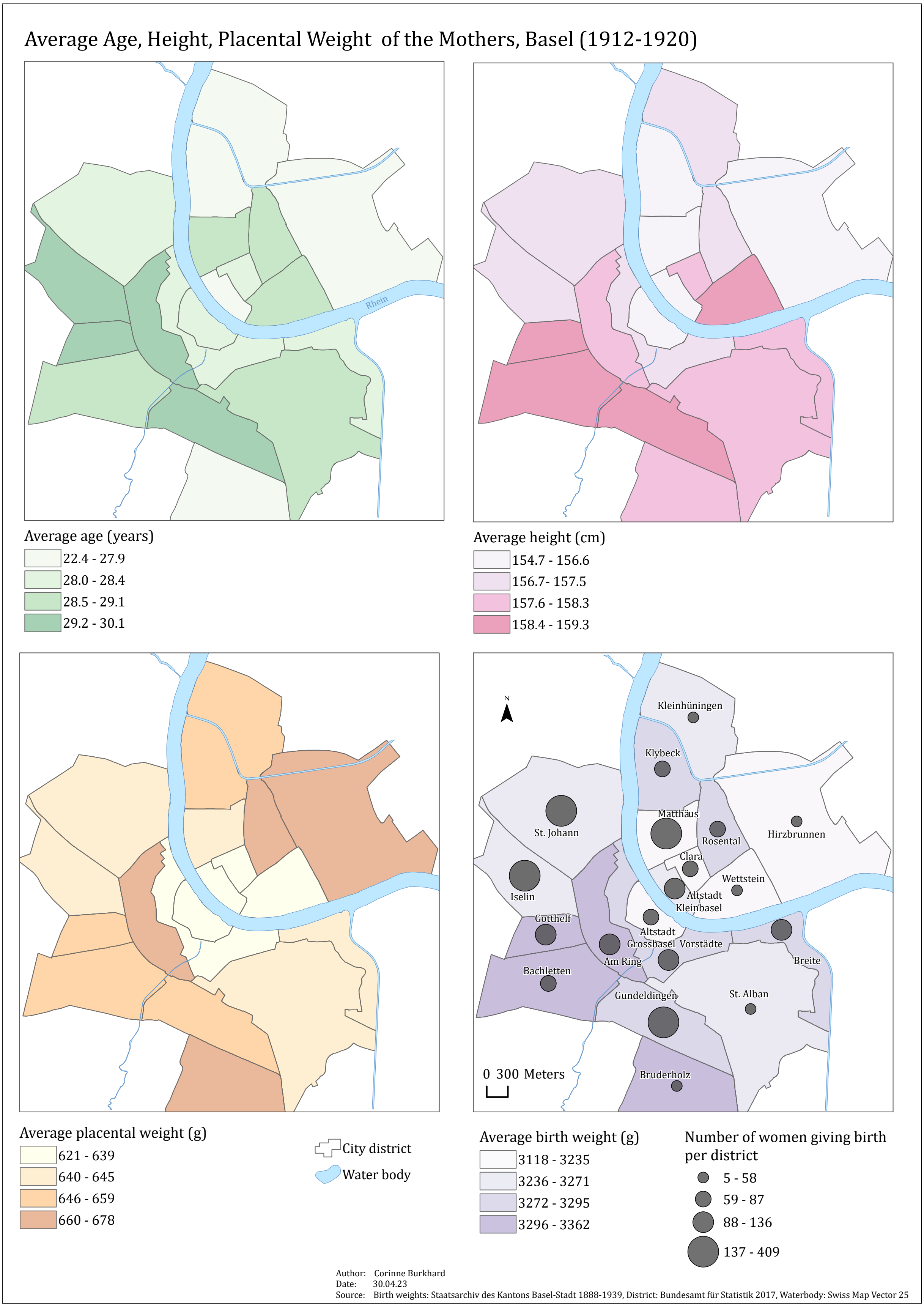


Figure 17: Average age, height and placental weight of the mothers, Basel (1912-1920)

4.1.5 Summary

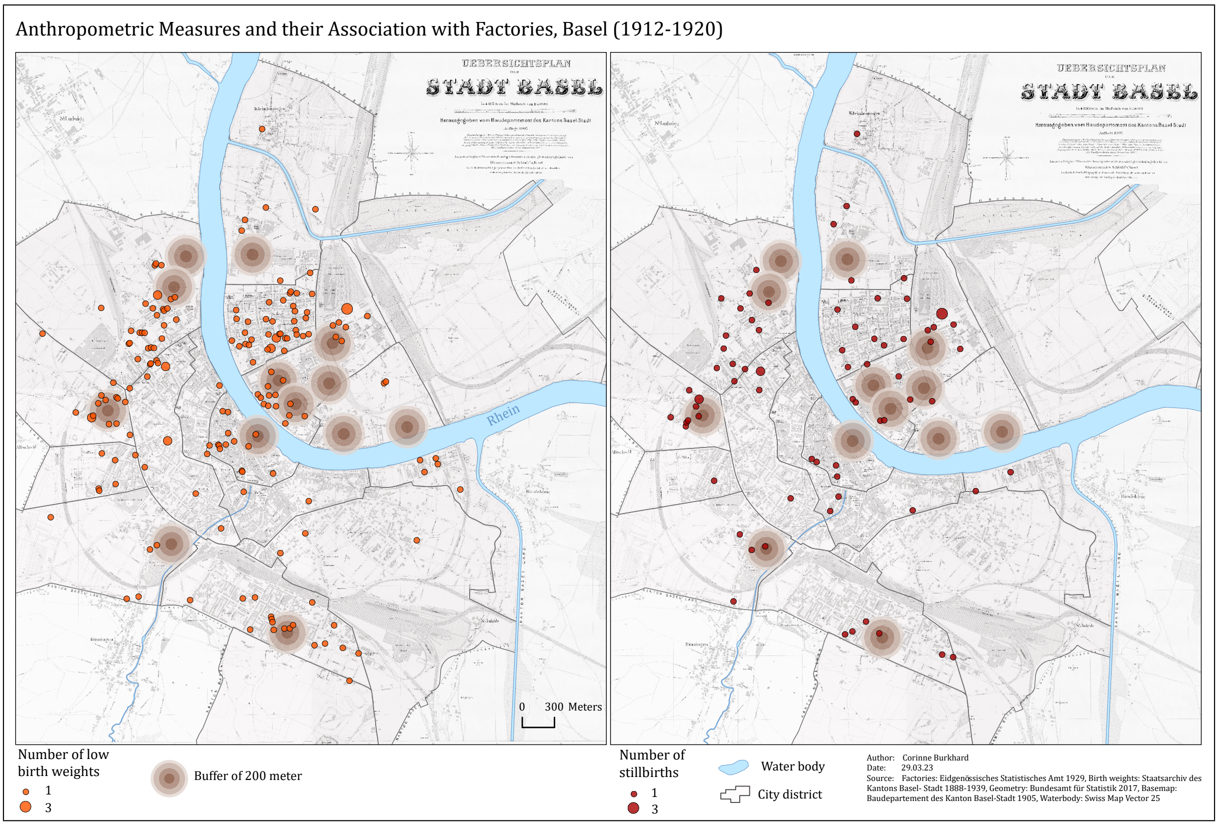
The presented maps for Basel highlighted various aspects of birth weight and other anthropometric data. In wealthier districts, women who gave birth were generally older, taller and had higher birth weights. In contrast, in poorer districts, women who gave birth were generally younger, smaller and had lower birth weights. Further, low birth weights and stillbirths seemed to occur more likely in working-class districts. No clear pattern could be observed for the anthropometric measure placental weight.

4.2 Data Analysis for Basel

So far, the spatial pattern of different anthropometric variables has been presented and elaborated. In a next step, the data will be analyzed with regard to the relationship between polluting factories and birth weight, as well as significant clustering of birth weight.

4.2.1 Buffer Analysis: How Factories Are Related to Birth Weight Measures

Figure 18 visualizes how birth weight measures are related to the created buffers around each factory. The factories were more prevalent in the north of Basel, where relatively more low birth weights and a higher rate of stillbirths could also be observed. To test whether the association is significant, a logistic regression is carried out. The logistic regression calculates the association between all outcome and exposure variables, not just within the occurrence of stillbirths or low birth weights. For illustrative purposes, the other data points (including normal birth weights ($>$ 2,500 g)) were not visualized to minimize overloading.



Note: low birth weights left and stillbirths right

Figure 18: Anthropometric measures and their association with factories, Basel (1912-1920)

Logistic regression results for both models are reported in the *odd ratio* (OR) and the *confidence interval* (CI) for each cofactor. OR compares the relative probability between the occurrence of an outcome variable (e.g., low birth weight or stillbirth) and a given exposure variable (e.g., within buffer of a factory). An OR greater 1 indicates that the outcome is more likely to happen. Vice versa, an OR smaller than 1 indicates that the outcome is less likely to happen. An OR of 1 shows no association between the outcome and the exposure variable (Szumilas, 2010). Table 7 summarizes the classification of the OR results.

Table 7: OR classification

OR = 1	No association between exposure and outcome variable
OR > 1	Outcome is more likely to happen given the exposure variable
OR < 1	Outcome is less likely to happen given the exposure variable

Source: Szumilas (2010)

The 95% CI estimates the precision of the OR. A large CI indicates low precision of the OR, while a small CI indicates a high precision of the OR. No statistical significance can be stated when the CI includes the value 1 (Szumilas, 2010).

Table 8 presents the results of the logistic regression. The OR for the factor *Factory* is 1.76 having a 95% CI between 0.84 and 3.68 for the outcome stillbirth. This means that the exposure of being near a factory is associated with a 1.76 times higher odd of the outcome having a stillbirth. The association is slightly positive. However the 95% CI is too large and includes the value 1.0 to be statistical significant.

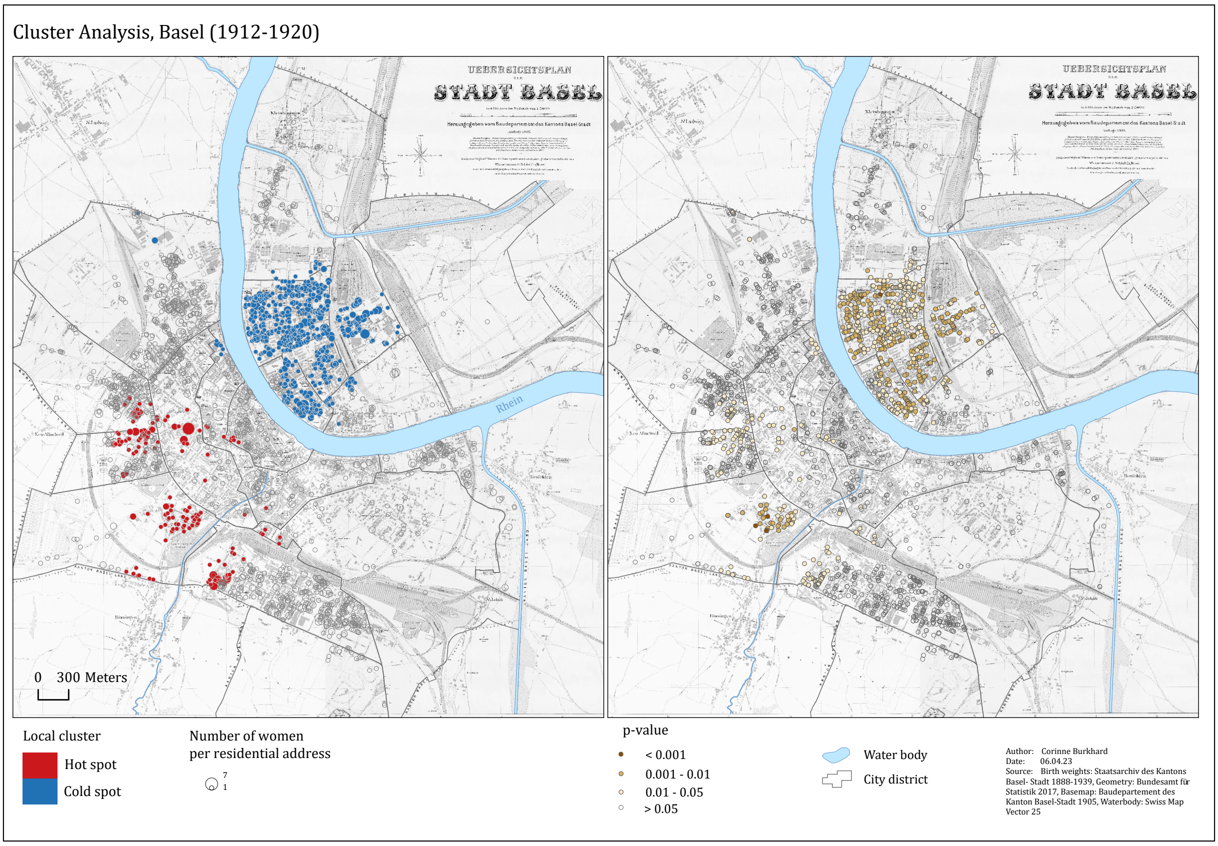
Similar for low birth weights, the cofactor *Factory* has an OR of 1.24 and a 95% CI between 0.75 and 2.04. Here, the association is slightly positive too. However, the result is not significant as well.

Table 8: Logistic regression results for Basel

	Stillbirth		Low birth weight	
Cofactor	**OR**	**CI**	**OR**	**CI**
Factory yes (ref: no)	1.76	0.84 – 3.68	1.24	0.75 – 2.04
Year of birth	0.87	0.76 – 1.00	1.06	0.97 – 1.16
Age of mother	1.03	0.97 – 1.10	1.01	0.96 – 1.05
Gestational age	0.74	0.69 – 0.80	0.74	0.69 – 0.79
Parity	1.05	0.89 – 1.24	0.92	0.80 – 1.05
Height of mother	0.96	0.92 – 1.01	0.95	0.92 – 0.99
Sex male (ref: female)	1.11	0.58 – 2.10	0.80	0.54 – 1.19
Stillbirth yes (ref: no)			8.89	4.04 – 19.56

4.2.2 Cluster Analysis: Detecting Low and High Birth Weights

Figure 19 presents the results for the cluster analysis. The Gi cluster map on the left indicates whether there are high or low birth weight clusters. A hot spot is a statistically significant accumulation of high values (colored in red). A cold spot is a statistically significant cluster of low values (colored in blue) (Getis & Ord, 1992). All sampling points which are not significant are colored in transparent color. The map on the right shows the Gi significance map.



Note: Gi cluster map left and Gi significance map right

Figure 19: Cluster analysis, Basel (1912-1920)

Significant high and low clusters are clearly separated in Basel with p-values between 0.001 and 0.05. Cold spots are located in the working districts *Matthäus*, *Rosental* and the business districts *Clara, Altstadt Kleinbasel*. Hot spots are visible in prosperity and middle-class districts in *Grossbasel*. The hot spots are more distributed over the place, whereas cold spots are spatially closer to each other. Comparing the cluster result with the average birth weights, the pattern seems to match with lower and higher average birth weights at district level.

4.2.3 Summary

Regarding the exploratory approach of the buffer analysis, results indicate that a negative outcome may be more likely when a mother lived near a factory. The OR for low birth weight is 1.24 (95% CI: 0.75, 2.04), while the OR for stillbirth is 1.76 (95% CI: 0.84, 3.68). The positive trend is evident when controlling for cofactors. However, the results are not significant.

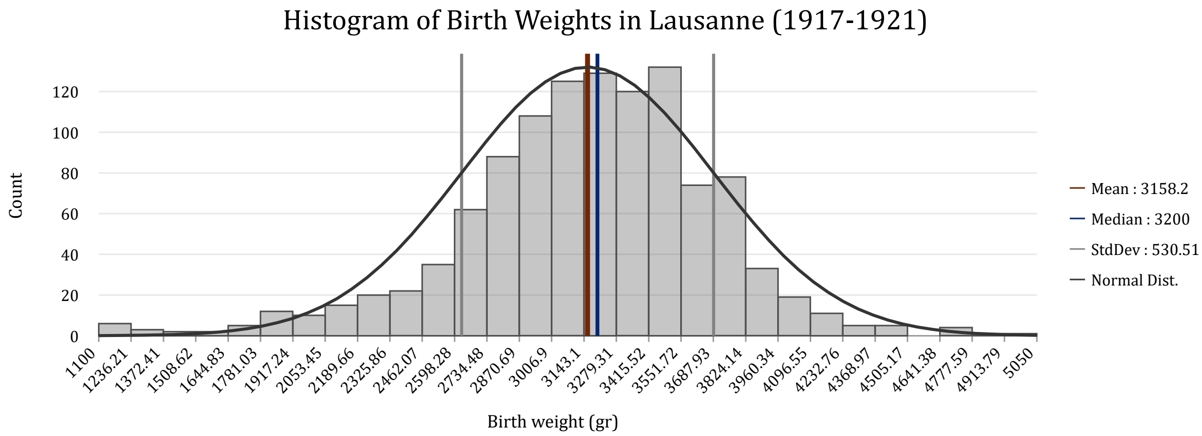
The cluster analysis reveals hot and cold spots. These findings are in line with the patterns about average birth weights. Hot spots are located in wealthier districts, southwest of Basel, whereas cold spots are located in working-class districts, north of the Rhine River.

4.3 Data Visualization for Lausanne

The same structure and proceeding is applied to the results for Lausanne. First, the variable birth weight and the anthropometric measures stillbirth, age, height and placental weight are visualized. Second, the buffer and the cluster analysis will be presented.

4.3.1 Descriptive Statistics of Birth Weights

The values of birth weights are nearly normally distributed having a kurtosis [8] and a skewness [9] of 4.45 and -0.57 (see Figure 20). The data is nearly symmetrical having a few outliers at the lower end. Looking at the measures of central tendency, the mean value lies by 3,158.2 grams having a standard deviation of 530.5 grams. The median is 3,200 grams. The minimum and maximum value are 1,129 and 5,050 grams respectively.



Source: own Figure

Figure 20: Histogram of birth weights in Lausanne (1917-1921)

4.3.2 Spatial Distribution of Average Birth Weights

Figure 21 visualizes the georeferenced residential addresses of the mothers, which gave birth at the maternity hospital in Lausanne. Similar to Basel, the points are colored according to the respective birth weight in a blueish unclassed color ramp. The number of points range from 1 to 34 per residential address, which means that 1 to 34 women had the same georeferenced residential address and gave birth at the maternity hospital in Lausanne between 1917 and 1921. The average birth weight per residential address

[8] Measure of outliers (heavy-tailed or light tailed) (Universität Zürich, 2022).
[9] Measure of symmetry (Universität Zürich, 2022).

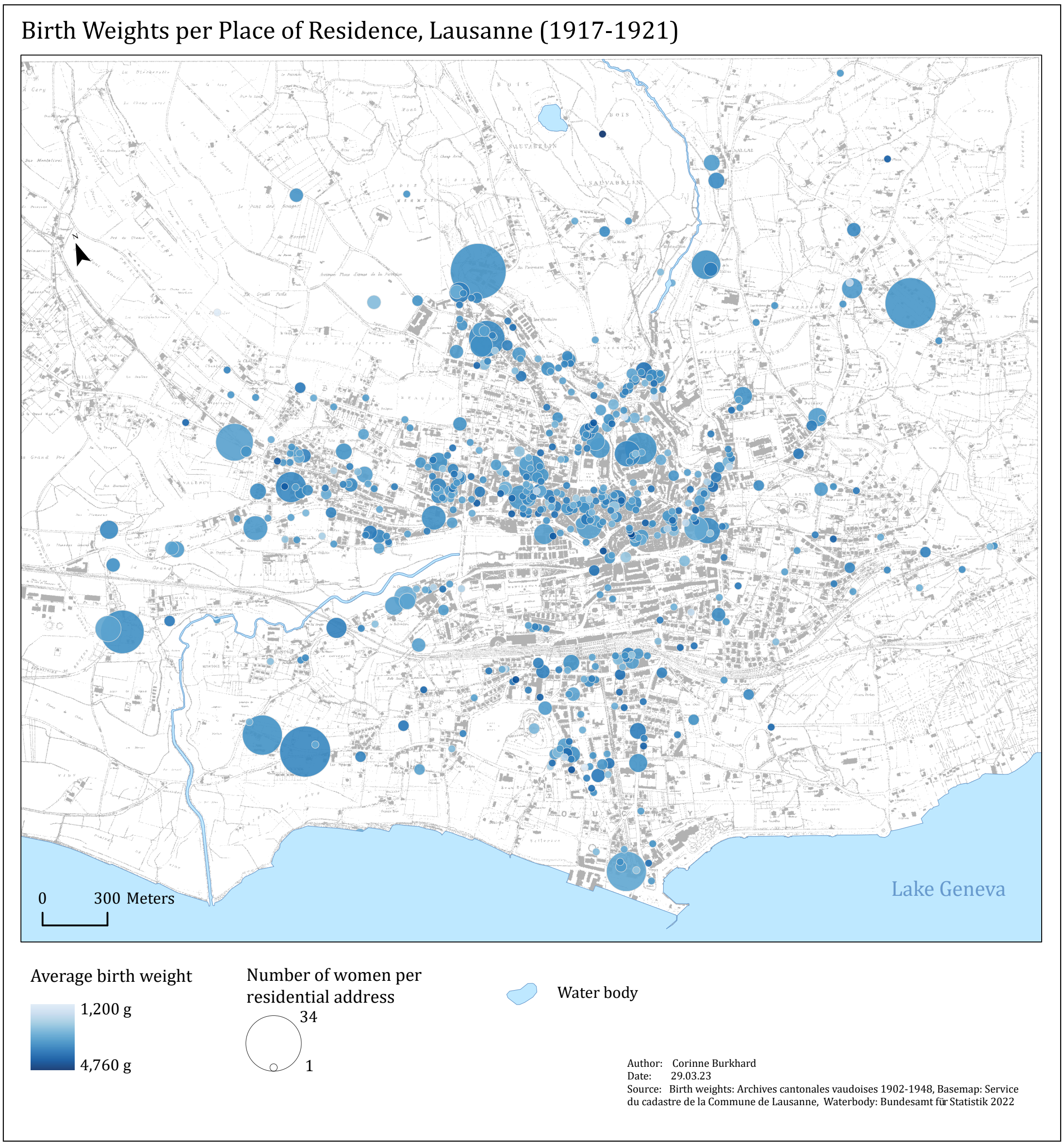


Figure 21: Birth weights per place of residence, Lausanne (1917-1921)

ranges from 1,200 grams to 4,760 grams. The points are not equally distributed over the city. The center of Lausanne has a cluster of points with some bigger data points at the periphery. Looking at the spatial pattern of the points, lower birth weights can be observed in the center of Lausanne. In addition, a group with lower birth weight can be seen at Lake Geneva.

On district level, aggregated average birth weight values are visualized in Figure 22. Average birth weight ranges from 2,882 grams to 3,547 grams having a difference of 665 grams. Considering the sample size, the values range from 3 to 337 points. Divided into quartiles, the lower 50% of the data range from 3 to 42 points. The eastern and northeastern districts have the smallest sample size. Higher average birth weights are more likely to occur in the east and north of Lausanne involving the districts *Sallaz-Vennes-Séchaud*, *Florimont-Chissiez* and *Montchoisi*. Particularly noteworthy are the districts *Centre-Ville*, *Maupas-Valency*, *Sébeillon-Malley* and the *Sous-Gare-Ouchy*, which have the largest sample size and the smallest average birth weight values.

Higher average birth weights are more likely to be observed in the east, northeast and south of Lausanne. These findings are in line with the patterns about spatial socioeconomic structures described by Roh (1990) (see Chapter 2.3.3), whereas wealthier districts are located northeast, east and southeast of Lausanne. However, the sample size is quite small for peripheral districts.

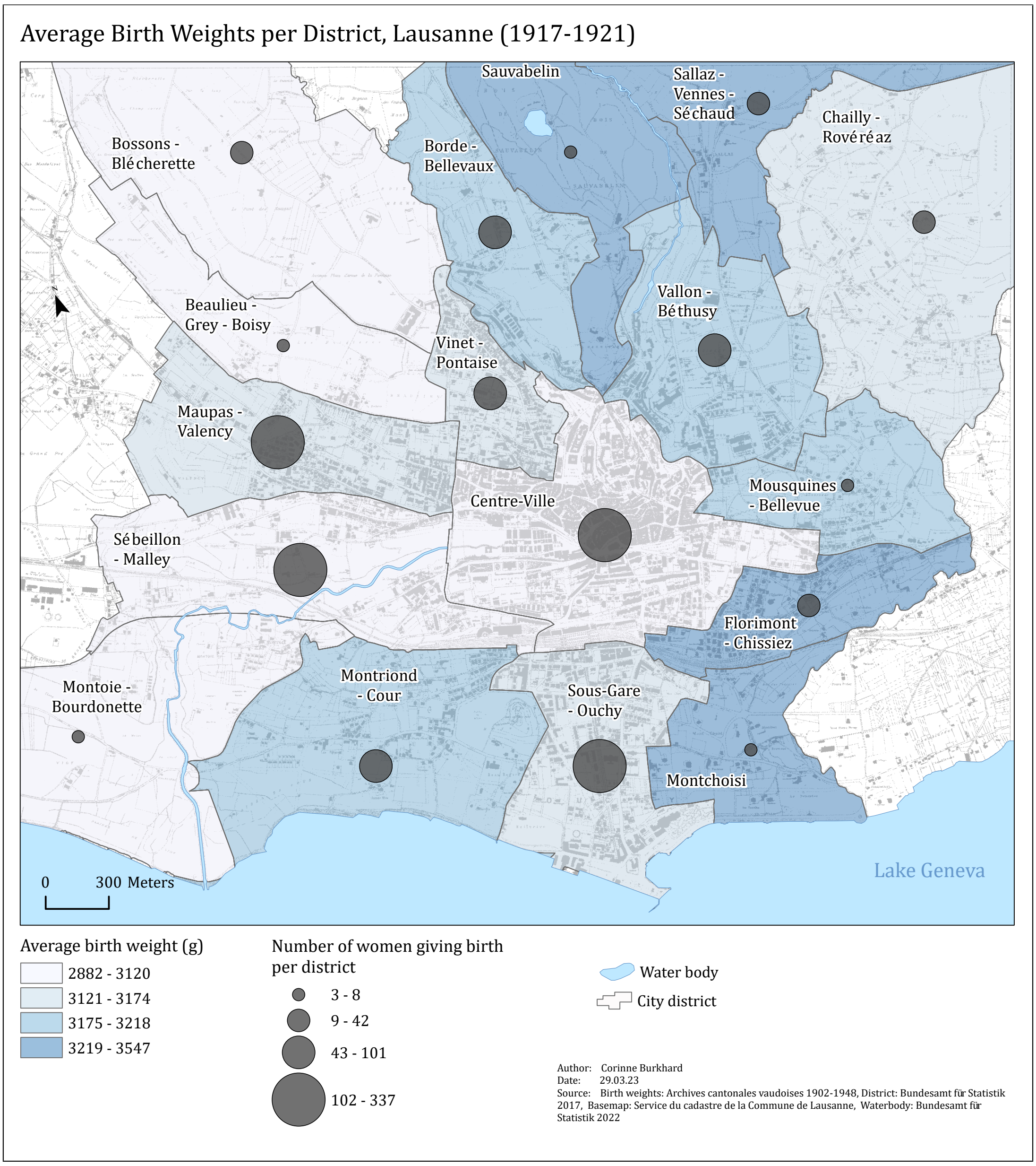


Figure 22: Average birth weights per district, Lausanne (1917-1921)

4.3.3 Spatiotemporal Distribution of Low Birth Weights

The spatiotemporal distribution of low birth weights per year are visualized in Figure 23. On average the maps show 230 points per year, ranging from 172 to 294 points. The legend indicates that the size of the dot relates to the number of women who had the same georeferenced residential address, and the color of the dot indicates whether the birth weight is low (orange) or normal (white). The prevalence of low birth weight is noted for each year and shows how many underweight infants were born each year relative to the total sample.

Considering the low birth weight rate, it is noticeable that all years are having a low birth weight prevalence above 7.2%. In the years between 1918 and 1920, the prevalence of low birth weight was as high as over 9%, up to 10.2% in 1920. Noteworthy is the sudden increase between the year 1917 and 1918 of 2.7 percentage points and the sudden decrease between the year 1920 and 1921 of 2.8 percentage points.

Taking the spatial pattern into account, most low birth weights are prevalent in the center of Lausanne. The center has the most data points in general. Low birth weights are more likely to occur in central and western districts.

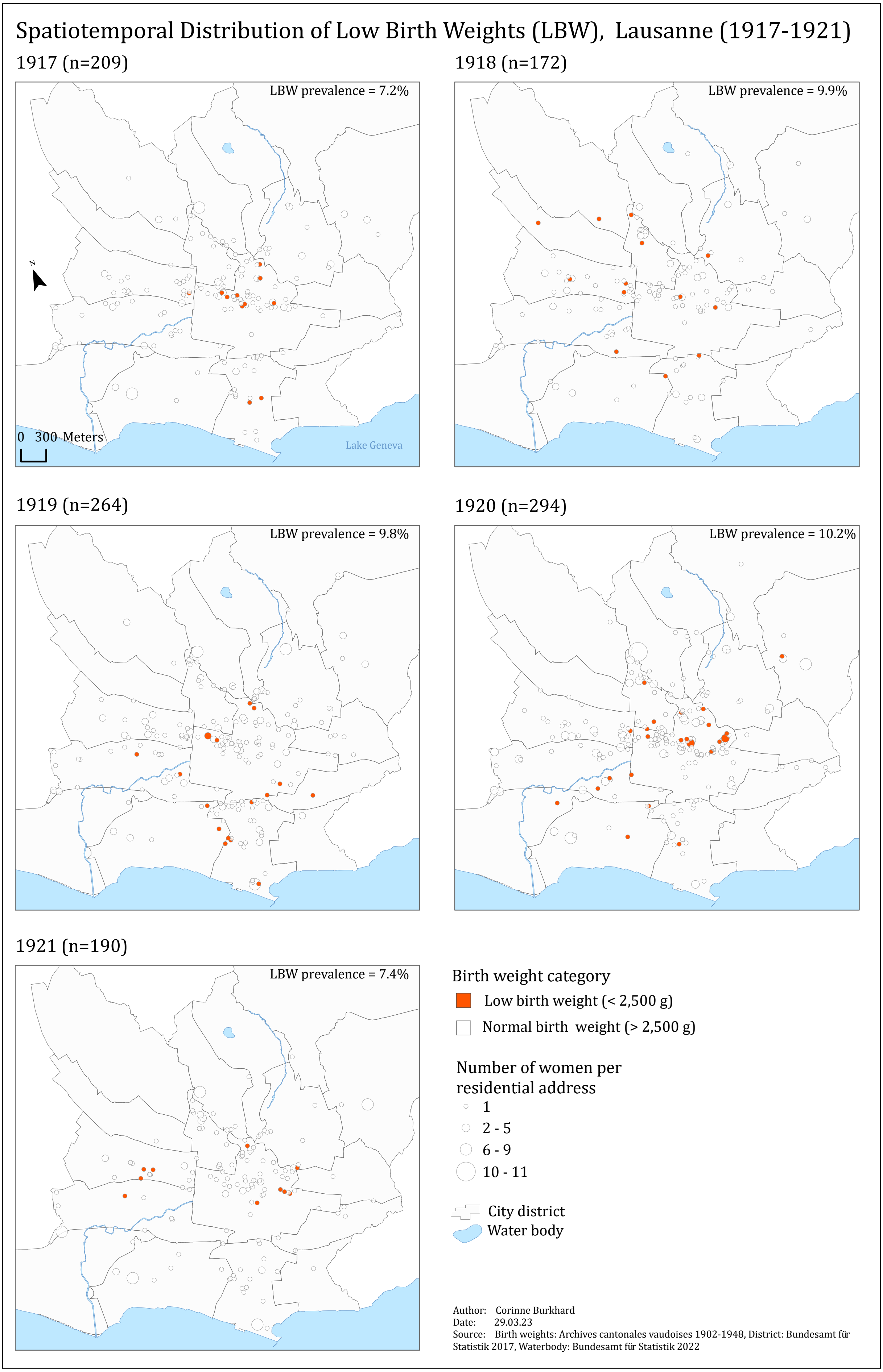


Figure 23: Spatiotemporal distribution of low birth weights, Lausanne (1917-1921)

4.3.4 Spatial Distribution of Stillbirths, Age, Height and Placental Weights

Stillbirth Figure 24 visualizes the spatial distribution of stillbirths in Lausanne. The red dots show the georeferenced places of residence of the mothers, which had a stillbirth at the maternity hospital in Lausanne. The size of the dot shows the number of women per residential address, which had a stillbirth. Up to 2 stillbirths occurred per residential address. In total, 45 stillbirths occurred between 1917 and 1921 in the maternity hospital in Lausanne. Looking at the spatial pattern of stillbirths, it appears that more points are found in the center of Lausanne. Stillbirths seem to occur randomly in peripheral districts.

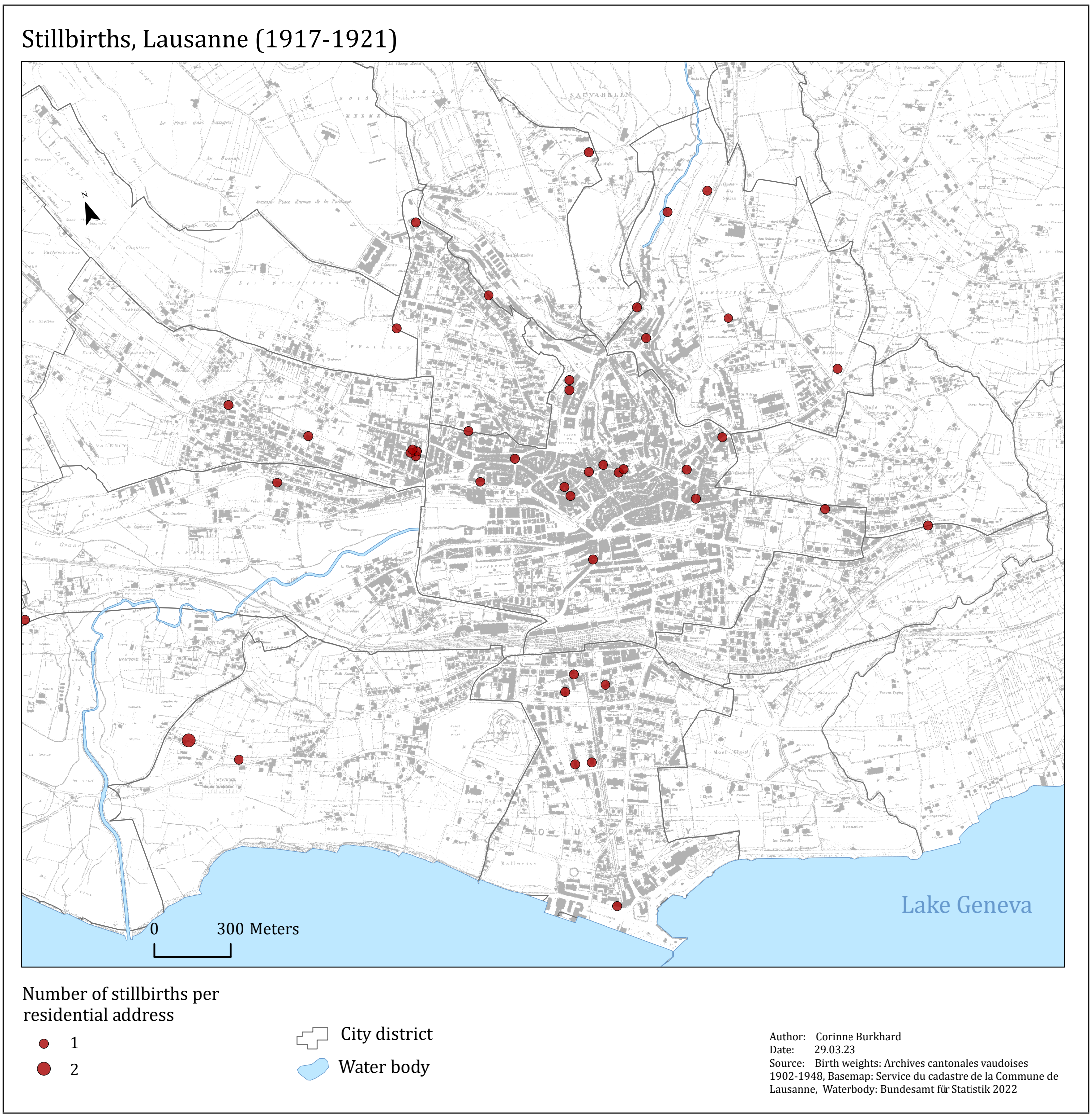


Figure 24: Stillbirths, Lausanne (1917-1921)

Age, Height and Placental Weight of the Mothers Figure 25 visualizes the age, height and placental weight of the mothers for each district. As a fourth map bottom right of Figure 25, the average birth weights are included to compare the results easier.

The top left of Figure 25 shows the average age of the mothers in years calculated for each district. Values range from 25.8 to 33.0 years. Most districts have average values between 25.8 to 28.4 years. There are some peripheral western districts with the highest mean values between 29.1 to 33 years.

Considering the top right of Figure 25, the average height per district is visualized. The pattern seems to be different from the average ages. Average height varies between 151.8 and 163.3 centimeter. Districts on Lake Geneva as well as districts above the center of Lausanne have higher average heights of the mothers.

The bottom left of Figure 25 shows average placental weight in grams. Values varies between 467 to 687 grams. The pattern seems again somehow random and no clear tendencies are visible. Some peripheral districts in the east and northwest of the city have the highest average placental weight. However, the sample size is very small in these districts.

The anthropometric parameters of age, height and placental weight show a different pattern compared to the average birth weight. For individual districts, there could be a correlation between the parameters, but a spatial tendency is not evident.

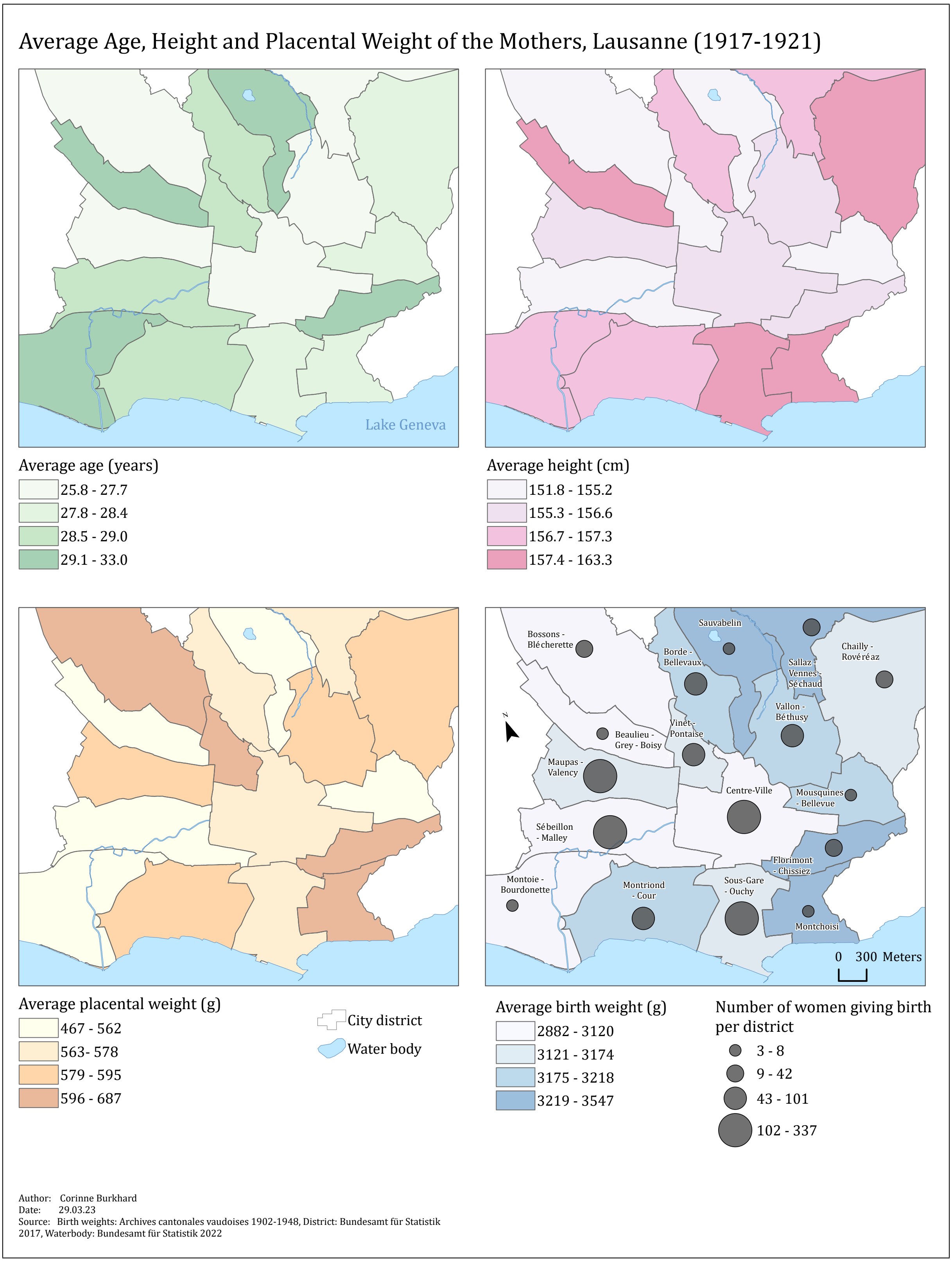


Figure 25: Average age, height and placental weight of the mothers, Lausanne (1917-1921)

4.3.5 Summary

In summary, the average birth weight at district level tends to be higher in the east of Lausanne. These findings are in line with the patterns about spatial socioeconomic structures described by Roh (1990) (see Chapter 2.3.3), whereas wealthier districts are located northeast, east and southeast of Lausanne. In terms of maternal age, the spatial pattern indicates a separation between west and east, with older mothers in the western districts of Lausanne. Furthermore, taller mothers are more likely to be observed north and south of Lausanne. Low birth weights appear to be more common in the central and western districts of Lausanne. Stillbirths occurred randomly without showing a clear pattern. No consistent pattern was observed in placental weight either. In general, the sample size is very small for peripheral districts. No spatial association between the anthropometric variables maternal age, height, placental weight, stillbirth and socioeconomic districts can be observed.

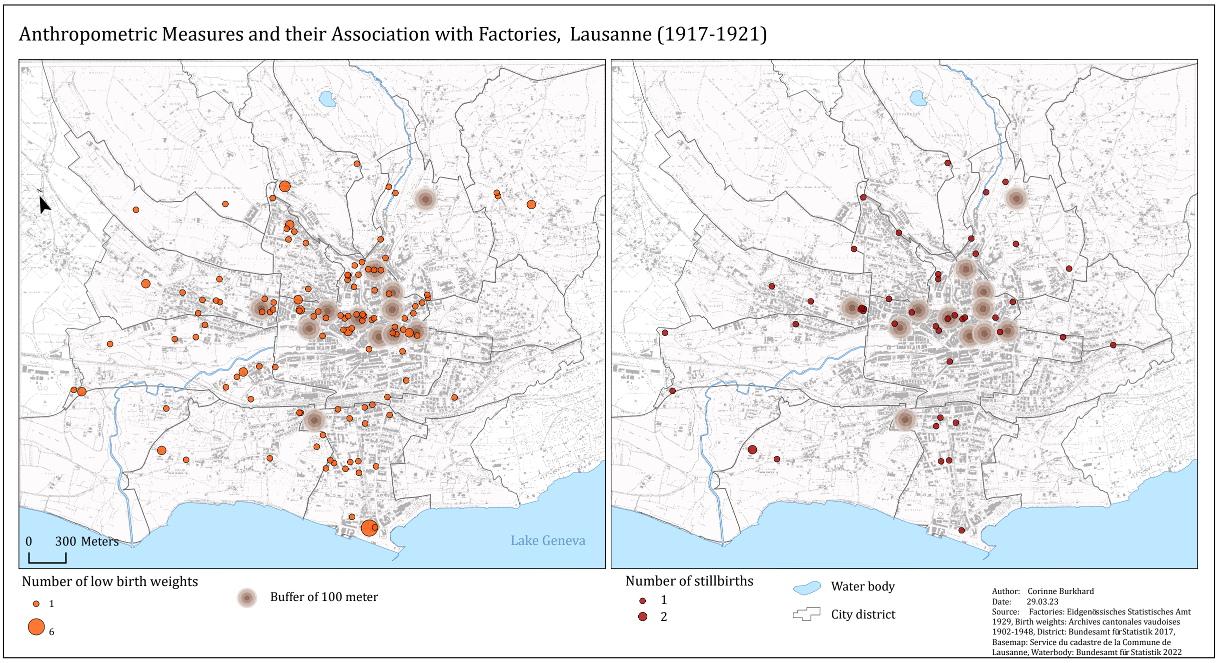
4.4 Data Analysis for Lausanne

So far, the spatial pattern of different anthropometric variables has been presented and elaborated. In a next step, the data will be analyzed in relation to the relationship between polluting factories and birth weight, as well as significant clustering of birth weights in Lausanne.

4.4.1 Buffer Analysis: How Factories Are Related to Birth Weight Measures

Figure 26 visualizes how birth weight measures are related to the created buffers around each factory. The factories were more prevalent in the center of Lausanne, where relatively lower birth weights and a higher rate of stillbirths could also be observed.

To test whether the association is significant, a logistic regression is carried out. The logistic regression calculates the association between all outcome and exposure variables, not just within the occurrence of stillbirths or low birth weights. For illustrative purposes, the other data points (including normal birth weights ($>$ 2,500 g)) were not visualized to minimize overloading.



Note: low birth weights left and stillbirths right

Figure 26: Anthropometric measures and their association with factories, Lausanne (1917-1921)

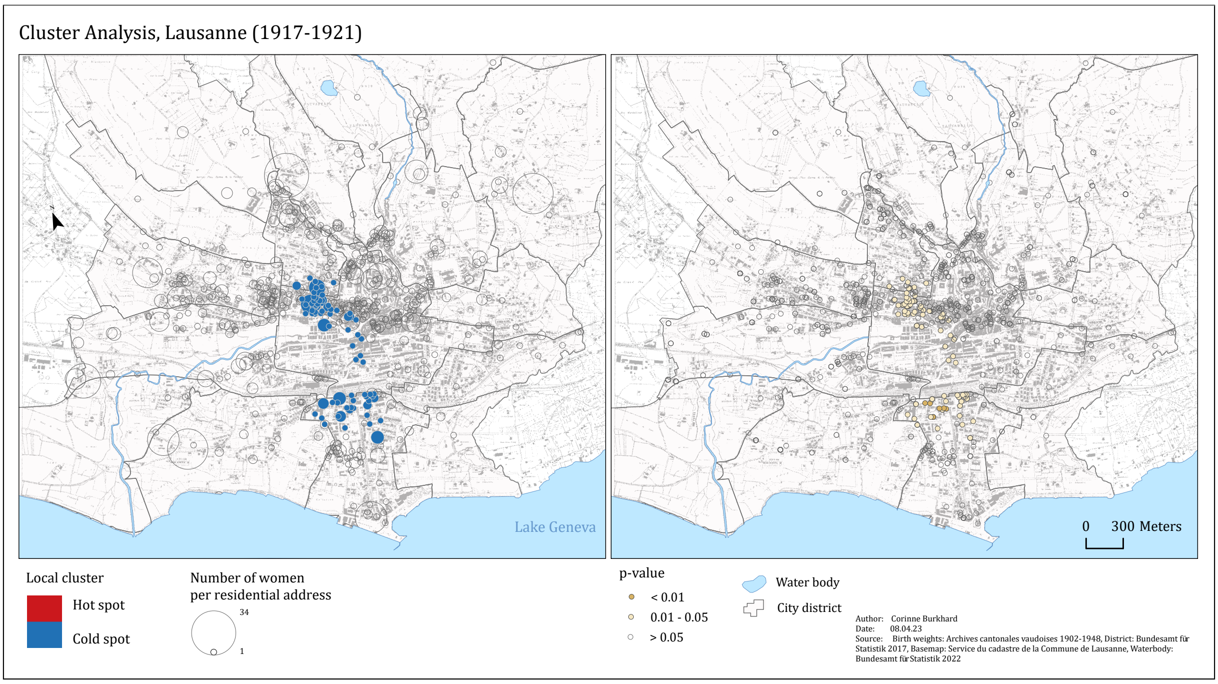
Considering the logistic regression result of Table 9 the OR for the cofactor *Factory* is 2.06 having a 95% CI between 0.89 to 4.79. The exposure of being near a factory is associated with a 2.06 times higher odd of the outcome having a stillbirth. Since the 95% CI spans the value 1.0 and is large, there is no statistical significance. Although the association is low, it shows a positive trend. Similar for low birth weights, the OR is 1.24 and the 95% CI is between 0.70 to 2.19. This means that the association is again slightly positive, but also not significant.

Table 9: Logistic regression results for Lausanne

	Stillbirth		Low birth weight	
Cofactor	**OR**	**CI**	**OR**	**CI**
Factory yes (ref: no)	2.06	0.89 – 4.79	1.24	0.70 – 2.19
Year of birth	1.00	0.76 – 1.31	1.04	0.88 – 1.22
Age of mother	1.05	0.98 – 1.13	1.03	0.98 – 1.08
Gestational age	0.84	0.78 – 0.91	0.70	0.65 – 0.75
Parity	0.99	0.82 – 1.20	0.99	0.87 – 1.12
Height of mother	0.94	0.90 – 0.99	0.97	0.94 – 1.00
Sex male (ref: female)	1.70	0.79 – 3.69	0.78	0.50 – 1.23
Stillbirth yes (ref: no)			5.00	1.96 – 12.76

4.4.2 Cluster Analysis: Detecting Low and High Birth Weights

Figure 27 presents the results for the cluster analysis. The Gi cluster map on the left indicates whether there are high or low birth weight clusters. The Gi significance map on the right indicates how statistically significant each point is.



Note: Gi cluster map left and Gi significance map right

Figure 27: Cluster analysis, Lausanne (1917-1921)

The Gi cluster map shows only cold spots with p-values between 0.01 and 0.05. There are no hot spots in Lausanne. The clusters of low birth weights are located in the center of Lausanne and southern near the Lake. Comparing the cold spots with average birth weights on city district level, the cold spots seem to be in line with lower birth weight at district level.

4.4.3 Summary

Regarding the exploratory approach of the buffer analysis, the results indicate that a negative outcome may be more likely when a mother lived near a factory. The OR for low birth weight is 1.24 (95% CI: 0.70, 2.19), while the OR for stillbirth is 2.06 (95% CI: 0.89, 4.79). The positive trend is evident when controlling for cofactors. However, the results are not significant. The cluster analysis reveals cold spots in the center of Lausanne (*Centre-Ville, Sous-Gare Ouchy*). No hot spots can be identified for Lausanne.

5 Discussion

5.1 Comparing the Results of Basel and Lausanne

In this chapter, the individual results of Basel and Lausanne are compared and discussed in a broader context.

Both cities show similarities with regard to the spatiotemporal distribution of low birth weights ($< 2,500$ g). The results indicate an increase of low birth weights between 2 and 3 percentage points for both cities between the years 1918 and 1920. In Basel, the increase was present for the time period between 1918 and 1919, while for Lausanne the increase was observed between the years 1918 and 1920. The results may be caused due to the presence of the Spanish Flu (1918-1920). The Spanish Flu affected two million people in Switzerland and thus represents the greatest demographic catastrophe in Switzerland in the 20^{th} century. In Switzerland, 24,500 people died between July 1918 and June 1919 from the consequences of the flu (Sonderegger, 2017).

In addition, the results for both cities suggest that a negative birth weight outcome (stillbirth or low birth weight infant) was more likely if the mother lived near a factory since factories caused environmental pollution. The effect was slightly stronger for Lausanne. However, the results were not significant. Nevertheless, this is in line with other studies, which have shown a negative association between air pollution and birth weight. For example, Dadvand et al. (2013) showed that low birth weight was positively associated with a 10 $\mu g/m^3$ increase in PM10 [10] (OR = 1.03; 95% CI: 1.01, 1.05) and PM2.5 (OR = 1.10; 95% CI: 1.03, 1.18), both adjusted for maternal socioeconomic status.

Although similar results were prevalent for both cities regarding the association between low birth weight/stillbirth and factories, the cities did not include the same factory branches. In Basel, the chemical industry was strongly prevalent, while in Lausanne tanneries and cardboard industries were more prominent (see Figure 10 and 11). However, both cities had factories from the textile, brewery and power supply industries. In addition, the reported emissions for each factory varied greatly. In general, Basel

[10] Particulate matter PM10 and PM2.5 are less than 10 thousandths and 2.5 thousandths of a millimeter in diameter, respectively, and can enter and damage the lungs, the lymphatic system and the bloodstream (BAFU, 2021).

had factories with higher emissions, while Lausanne had factories with lower emissions.

Furthermore, studies pointed out the relationship between systematic differences in birth weights and socioeconomic status. The social status of the mother is highly correlated with the weight of the newborn (Ward, 2016). As average birth weight varies in today's world, wealthy Western countries are characterized by the highest average birth weights (3,250 to 3,500g) (Donahue et al., 2010). In contrast, the lowest values are found in the poorest regions such as South Asia (2,600 to 2,700g) (Metgud et al., 2012). Even in countries with low levels of social inequality, differences regarding birth weight can be stated between privileged and underprivileged mothers. For example, a study in Sweden, where social inequalities have long been very low, indicated that singleton newborns of underprivileged mothers weighed 155 grams less than those of privileged mothers (Ericson et al., 1989). A similar pattern could be observed for the results of Basel and Lausanne, where differences regarding socioeconomic districts and birth weights were visible. The spatial relationship was more evident in Basel (see Figure 3, 14, 19). In wealthier districts, southwestern of Rhine River, birth weight was generally higher. Furthermore, low birth weights were more likely to occur in poorer districts in the territory *Kleinbasel*, northeast of Rhine River. These findings are in line with the results of the cluster analysis. Cold spots occurred in working class districts (*Matthäus*), whereas hot spots were identified in prosperity districts (*Gundeldingen*, *Bachletten*). As Ward (2016) points out, the relationship between birth weight and SEP is not causal. Members of the upper class in most societies have social and economic advantages that affect their health and well-being directly. Socioeconomic status is merely indicative of other factors (Ward, 2016).

Regarding the anthropometric measures, results indicate for Basel that taller mothers had heavier babies. Maternal height is an important determinant of neonatal size at birth. Mendelian randomization studies have supported the hypothesis that higher maternal height is causally associated with higher offspring birth weight (Warrington et al., 2019). For Lausanne, the expected pattern was not visible.

In addition, results show that younger mothers had a tendency to have newborns with lower birth weight. In Basel, lower birth weight and younger mothers occurred in working districts in the territory *Kleinbasel*. Studies showed similar results between maternal age and birth weight (Fraser et al., 1995). Lausanne showed no association between maternal age and birth weights.

Moreover, average placental values were smaller in Lausanne than in Basel. As the data was classified into quartiles, the under 50% of the data varied between 467 grams and 578 grams in Lausanne (see Figure 25). In contrast, the under 50% of the data varied between 621 grams and 645 grams in Basel (see Figure 17). For some districts in Basel (e.g., working district *Rosental*) as well as for Lausanne (e.g., western district *Bossons-Blécherette*), lower birth weights were prevalent with higher placental weight. This could support the findings of Galofré-Vilà and Harris (2021), in which placental size may expand to compensate maternal malnutrition and that placental weight can be seen as an adaptive response. However, average placental weight seems not consistent on small scale level. There are examples (e.g., the prosperity district in Basel *Am Ring* or the eastern district in Lausanne *Florimont-Chissiez*) that showed the opposite according to the study of Butie et al. (2020), where placental and birth weights correlated during World War I.

There is a difference between the cities of Basel and Lausanne regarding average birth weights. Measures of central tendencies showed for Lausanne that the mean value was lower by 106.5 grams, the median value lower by 70 grams and the minimum value lower by 161 grams. Lower mean birth weights were also found when summarizing on district level (see Figure 22). In addition, Lausanne had a higher low birth weight prevalence than Basel (see Figure 23). The relative proportion was almost twice as high in Lausanne (7% vs. 4%).

As a possible explanation Floris et al. (2016) emphasized on the economic and the social advantage that Basel experienced at the beginning of the 20th century. Basel was better prepared to deal with the social consequences than the rest of the country. In 1909, a voluntary cantonal unemployment insurance fund was introduced. In addition, a public health insurance company was established in 1914 (Floris et al., 2016). Nevertheless, like other Swiss cities, Basel suffered from the restricted trade. The chemical industry, in contrast, benefited from the rising demand of the belligerent parties (Floris et al., 2016).

However, there might be general differences with regard to different cultural language regions. Modern studies show that there may be such a systematic difference even for today. For example, Skrivankova et al. (2019) observed that newborns in the French regions were lighter than newborns in the German-speaking region of Switzerland. Results showed that the language region could explain most of the variation in birth weight (62%). The language region is indicative of a wide range of social, behavioral and cultural factors, such as smoking, diet and alcohol consumption of the parents as well as their ancestry (Faeh et al., 2009; Skrivankova et al., 2019). Switzerland in particular, because of its cultural diversity represents an opportunity to study cultural determinants due to same policies and statistical systems (Faeh et al., 2009). Faeh et al. (2009) argues that the French-speaking part of Switzerland thus represents the "French" cultural type, which means a high attachment to a Mediterranean lifestyle, whereas the German-speaking part represents the "German" cultural type with low attachment to a Mediterranean cultural style. Research studies on other health parameters also showed differences between the language regions (Faeh et al., 2009). Although overall mortality was similar, there were significant cause-specific differences between the Swiss regions. In German-speaking Switzerland, deaths due to circulatory diseases were more common. In French-speaking Switzerland, deaths related to alcohol consumption occurred more frequently (Faeh et al., 2009).

Around 1920, there may have been cultural, social and behavioral factors which led to the differences in birth weight. However, there could also have been differences in the health care system itself. The question arises as to whether there were differences in the medical knowledge since German- and French-speaking doctors had probably less knowledge transfer in the 20th century. However, more research is needed to determine whether there are systematic differences regarding historical birth weights between the two language regions.

5.2 Limitations

This Master's thesis and its results are subject to several limitations.

Data Specific Limitations First, there are limitations regarding the data sets. The two data sets from Basel (1912-1920) and Lausanne (1917-1921) do not cover the same time period. Therefore, comparability is possible to a limited extent. The current Lausanne data is not fully transcribed and offers further years to geolocate, analyse and visualize.

Although precision and coverage are very high for both cities, a selection bias might still be present. The percentages of births given in the maternity hospital are very high for Basel (40% to 60%). The number of home births is comparably low (Floris et al., 2016). For Lausanne, about the same percentages are estimated. Compared to other cities, for example Zurich, only 30% to 40% of births were given in the maternity hospital between 1912 and 1920 (Statistisches Amt der Stadt Zürich, 1916, 1925). Furthermore, the data covers births from all socioeconomic positions and includes complicated and problem free childbirths (Floris et al., 2016). It is assumed that there are about 10% temporary addresses in the data set due to the mobile population. Ideally, a method should be developed to adjust for a possible selection bias.

Technical Limitations Second, there are technical limitations regarding the method. The current geolocation is potentially limited for Lausanne, as the points are not distributed evenly throughout the city. Hereby, some peripheral coordinates have up to 34 points. The automated geolocation can process a lot of data and gives the best possible option for a coordinate with the smallest amount of effort. Depending on the scale (e.g., on municipality level), the geolocation can be sufficient. However, improvements in geolocation could be achieved at the small-scale level (e.g., street level).

The sample size is decisive when aggregating points into areal units. Almost all peripheral districts in Lausanne are characterized by a small sample size. Such districts with less than 30 points must be cautiously interpreted, as outliers can have too much influence and can therefore distort results. As the descriptive statistics have shown, both data sets are affected by outliers. For quartile classification, this could be a problem because the method cannot take into account how the data are distributed along the number line. Outliers can be placed in the same class with lower values (Slocum et al., 2022, p.88). When large-scale phenomena are studied, the *modifiable area unit problem* (MAUP) must be considered. MAUP describes a potential spatial challenge when point-based data are aggregated into spatial units, where the choice of units has a major impact on the results (Dark & Bram, 2007). In a sub optimal case MAUP can lead to ecological fallacy [11] (Openshaw, 1984). MAUP is probably less an issue for Basel than for Lausanne. Basel's districts have been stable for over 100 years and the units are based on residential neighborhood type. In Lausanne, the small sample size and the (non-historical) boundaries of the districts could bias the results. Today's districts may not be suitable for the data set, as the points are more likely to occur in the center of Lausanne. Ideally, a different, smaller district geometry should be chosen for Lausanne, which fits the data better.

Regarding the approach of the exploratory analysis of the buffers, the focus was placed on air pollution by using an euclidean distance around each factory. Wind directions were ignored due to the absence of data. Water pollution which was caused by tanneries, textile or cardboard industries was not considered as well. These parameters were not taken into account in order to keep the analysis as concise as possible. Ideally, these pollution pathways will be considered in further analysis.

As a last point, the anthropometric measures regarding geovisualization were not adjusted. For example, birth weight should be controlled for parity as birth weight increases with increased parity (Floris et al., 2016; Magnus et al., 1985). The age of the mother should be controlled with the maternal socioeconomic status (Fraser et al., 1995). To solve this issue, the parameters can be adjusted with control variables in a regression analysis.

[11] Ecological fallacy describes a concept where results based on aggregated areal units are inferred back to individuals within the zone itself (Dark & Bram, 2007).

6 Conclusion and Outlook

In this Master's thesis the research question *How can the historical data set of Basel (1912-1920) and Lausanne (1917-1921) be processed, visualized and analyzed using the example of birth weight as an indicator of the biological standard of living?* was addressed. After processing the data set of Lausanne, both data sets of the cities were geovisualized with ArcGIS Pro. The main focus was placed on birth weights showing average birth weights and low birth weights at point and district level. Furthermore, four anthropometric measures were visualized indicating stillbirths, age, height and placental weight of the mothers. Lastly, a cluster analysis and an exploratory buffer analysis were performed in GeoDa and in R. The cluster analysis was used to test whether there were significant local clusters. The exploratory buffer analysis was performed to test whether there is a association between polluting factories and negative birth weight measures (stillbirths, low birth weight infants).

The results indicate that the underlying socioeconomic pattern in relation to birth weight and other anthropometric measures was more prevalent in Basel. In wealthier districts, women who gave birth were generally older, taller and had higher birth weight infants. In contrast, in poorer districts, women who gave birth were generally younger, smaller and had lower birth weight infants. Furthermore, low birth weights seemed to occur more likely in poorer districts. These findings are in line with previous studies, which identified similar patterns between the anthropometric variables (Ericson et al., 1989; Fraser et al., 1995; Subramanian et al., 2009; Ward, 2016). As the current data set of Lausanne has not been fully transcribed, improvements on the data set may lead to similar results as shown for Basel. Furthermore, a difference between the two cities was observed with Basel showing higher birth weight scores and a lower low birth weight prevalence. There could be several reasons that might explain this pattern. One explanation would be that Basel had social and economic advantages due to social polices and its chemical industry (Floris et al., 2016). Furthermore, cultural differences could also be evident, which have been preserved in health-related parameters until today (Faeh et al., 2010; Faeh et al., 2009). However, more research is needed to explain this observed pattern. Regarding the relationship between polluting factories and stillbirths/ low birth weights a positive association was observed for both cities.

Even though the results were not significant, it does not necessarily mean that polluting factories had no effect on the number of stillbirths/low birth weight infants.

For the first time, spatial visualization and analysis was applied to historical birth weights, which identified small scale socioeconomic differences within Basel itself as well as possible large scale differences between Lausanne and Basel. The thesis was able to contribute to an interdisciplinary field between GI-Science and anthropometric history. Spatial visualization and analysis can reveal patterns that would not otherwise be visible. It can enhance models (Ngwira, 2019; Skrivankova et al., 2019) as it can show for example spatial dependencies. The cluster analysis revealed significant local clusters within wealthier and poorer districts in Basel. More findings can be expected by extending the cluster analysis, for example by using local Moran's I statistics, which identifies dissimilar values (spatial outliers) between local lows and highs (high-low and low-high) (Anselin, 1995). The exploratory approach of the buffer analysis can be extended in various ways, such as choosing only one factory branch to measure the association between exposure and outcome variables more precisely. Moreover, it would be valuable to include positive points of interest, such as green spaces. For example, Hystad et al. (2014) highlighted the benefits of having access to urban green spaces in relation to higher birth weights. Instead of buffers, the method can be fitted using a *geographically weighted regression* (GWR) that accounts for the individual distance between all points (Brunsdon et al., 1998).

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A Appendix

A.1 Factories: Points of Interest for Lausanne

Table A1: Factories: Points of Interest for Lausanne

S-Nr.	Factory(Address)	Employees	Engine power	Water (HP)	Steam (HP)	Other (HP)	Purchased power (HP)
52	Fourrures Benjamin (Av. du Tribunal Fédéral 2)	8	1				1
52	Au Tigre Royal Lausanne (Rue de Bourg 11)	11	1				1
52	Francois Canton (Rue de Bourg 24)	12	1				1
54	Blanchisserie Excelsior (Rue Neuve 9)	7	1				10
54	Blanchisserie Montriond (Chemin du Crêt 3)	7	1				4
54	Teinturerie Rochat (Rue des Terreaux 17)	37	1				10
64	Grande Meunerie (Couvaloup 8)	8	1	25	80		80
101	Usine electric. Pierre de Plan (Ch. de Pierre-de-Plan 6)	21	1		3000		10
77	Brasserie Beauregard (Place de la Palud 19)	40	1		80		111
107	Marmillon et cie Lausanne (Rue du Jura 9)	17	1				12
107	Cartonages SA (Rue St.Martin 21)	30	1				80
108	SA de Tannerie (Rue St.Martin 5)	64	1				200

A.2 Factories: Points of Interest for Basel

Table A2: Factories: Points of Interest for Basel

S-Nr.	Factory(Address)	Employees	Engine power	Water (HP)	Steam (HP)	Other (HP)	Purchased power (HP)
10	Industr. Ges. für Schappe (Isteinerstr. 40)	733	1	700			898
10	Industr. Ges. für Schappe (Rappoltshof 9)	319	1	475			485
14	DeBary & Co. Seidenfabrik (Augustinerg. 1)	284	1	100			100
77	Aktienbrauerei (Dornacherstr. 200)	105	1		200		270
77	Brauerei zum Warteck (Burgweg 7)	125	1		150		350
85	J.R Geigy A.G Chemiefabrik (Riehenring 51)	456	1		100		1496
85	Ges. für Chem. Industrie (Klybeckstr. 141)	1379	1				665
86	Chemische Produkte Sandoz (Fabrikstr. 60)	160	1				259
86	F. Hoffmann la Roche A.G Basel (Grenzacherstr. 184)	297	1				200
54	Waschanstalt Röthlisberger & Cie (Bachlettenstr. 37)	47	1		25		7
54	Bruder- Nyfeler Alb. (Colmarerstr. 38)	27	1				35
101	Elektrizitätswerk Basel (Dolderweg)	7	1		1033		
101	Elektrizitätswerk Basel (Voltastr.)	13	1		14606	1340	5

A.3 Code for Logistic Regression

GEO511: Code for Logistic Regression

Corinne Burkhard

24.03.2023

Contents

This code was mainly generated by Katarina Luise Matthes and Kaspar Staub. The code was adjusted to the data by the author.

Preliminaries

```
library(openxlsx)
library(tidyverse)
library(dplyr)

library(readxl)
options(scipen =999)
```

Basel

```
#Load data
data_basel <- read.csv(file="data/Basel_Daten_2003.csv", header=T, sep=";")
```

Clean dataset

```
#clean dataset
data_basel<- data_basel %>%
  filter(Jahr >= 1912 & Jahr <= 1920) %>%
  filter(K_Mehrlinge ==1) %>%
  rename(birthyear = Jahr,
         birthweight = K_NAeburtsNAewicht_0,
         age_mother =  M_Alter_Quelle,
         GA_weeks = K_Gestationsalter,
         parity = K_Para,
         height = M_Groesse,
         sex =  K_Gschlecht,
         stillbirth = stillbirth_neu) %>%
  mutate(City= "Basel",
         birthweight=replace(birthweight, (birthweight<10 | birthweight>6000), NA),
         parity=replace(parity, (parity==0 | parity >25), NA),
         sex=replace(sex, (sex == " "), NA),
         LBW = cut(birthweight, breaks=c(1, 2500, 6000)),
         LBW = case_when (LBW=="(1,2.5e+03]" ~"1",
                         LBW=="(2.5e+03,6e+03]" ~"0"),
         parity_cat=cut (parity, breaks=c(0,1,2,5,Inf)),
         PTB = case_when (GA_weeks<37 ~"1",
                          GA_weeks>37 | GA_weeks==37 ~"0"),
         sex = case_when (sex=="1" ~"male",
                          sex=="2" ~"female"),
         buffer_200m_poi = case_when (buffer_200m_poi=="0" ~"no",
                                      buffer_200m_poi=="1" ~"yes",),
         sex = as.factor(sex),
         PTB = as.factor(PTB),
         stillbirth = as.factor(stillbirth),
         buffer_200m_poi = as.factor( buffer_200m_poi),
         LBW= as.factor(LBW))%>%
  select(City, birthyear,birthweight, age_mother, GA_weeks, parity, height,
         sex,stillbirth,LBW, parity_cat, PTB,buffer_200m_poi) %>%
  filter(complete.cases(.))
```

Logistic regression

```
#calculate logistic regression

# LBW
mod_lbw_basel <- data.frame(summary(glm(LBW ~  buffer_200m_poi + birthyear
                                        + age_mother + GA_weeks+  parity +
                                          height+sex+stillbirth, data=data_basel,
                                        binomial(link = "logit")))$coefficients)%>%
  mutate(OR = round(exp(Estimate),3),
         CIl = round(exp(Estimate - 1.96*`Std..Error`),3),
         CIu = round(exp(Estimate + 1.96*`Std..Error`),3),
         CI = paste0(CIl, "-", CIu),
         Cofactor=row.names(.),
```

```r
         Cofactor = recode(Cofactor, "buffer_200m_poiyes" = "Industry yes (ref: no)",
                          "birthyear" = "Year of birth",
                          "age_mother" = "Age of mother",
                          "GA_weeks" = "Gestational age",
                          "parity" = "Parity",
                          "height" = "Height of mother",
                          "sexmale" = "Sex male (ref: female)",
                          "stillbirth1" = "Stillbirth yes (ref: no")) %>%
  slice(-1) %>%
  select(Cofactor,OR, CI)

write.xlsx(mod_lbw_basel, "mod_lbw_basel.xlsx", rownames=FALSE, overwrite = TRUE)

# stillbirth
mod_stillbirth_basel <- data.frame(summary(glm(stillbirth ~  buffer_200m_poi
                                               + birthyear + age_mother + GA_weeks+
                                                 parity + height+sex,data=data_basel,
                                               binomial(link = "logit")))$coefficients) %>%
  mutate(OR = round(exp(Estimate),3),
         CIl = round(exp(Estimate - 1.96*`Std..Error`),3),
         CIu = round(exp(Estimate + 1.96*`Std..Error`),3),
         CI = paste0(CIl, "-", CIu),
         Cofactor=row.names(.),
         Cofactor = recode(Cofactor, "buffer_200m_poiyes" = "Industry yes (ref: no)",
                          "birthyear" = "Year of birth",
                          "age_mother" = "Age of mother",
                          "GA_weeks" = "Gestational age",
                          "parity" = "Parity",
                          "height" = "Height of mother",
                          "sexmale" = "Sex male (ref: female)")) %>%
  slice(-1) %>%
  select(Cofactor,OR, CI)

write.xlsx(mod_stillbirth_basel, "mod_stillbirth_basel.xlsx", rownames=FALSE,
           overwrite = TRUE)
```

Results

```r
#Results
mod_stillbirth_basel
```

```
##                                  Cofactor    OR          CI
## buffer_200m_poiyes Industry yes (ref: no) 1.758 0.839-3.682
## birthyear                   Year of birth 0.867 0.756-0.995
## age_mother                  Age of mother 1.029 0.967-1.095
## GA_weeks                  Gestational age 0.740 0.688-0.797
## parity                             Parity 1.047 0.887-1.236
## height                   Height of mother 0.963 0.915-1.012
## sexmale            Sex male (ref: female) 1.106 0.582-2.102
```

```
mod_lbw_basel
```

```
##                                    Cofactor    OR          CI
## buffer_200m_poiyes  Industry yes (ref: no) 1.238  0.75-2.044
## birthyear                    Year of birth 1.061 0.974-1.156
## age_mother                   Age of mother 1.005 0.965-1.046
## GA_weeks                   Gestational age 0.737 0.691-0.787
## parity                              Parity 0.917 0.799-1.054
## height                    Height of mother 0.954 0.923-0.986
## sexmale              Sex male (ref: female) 0.798  0.535-1.19
## stillbirth1         Stillbirth yes (ref: no 8.893 4.044-19.56
```

Lausanne

```
#Load data
data_lausanne <- read.csv(file="data/Lausanne_data_2003.csv", header=T, sep=";")
```

Clean dataset

```
#Clean dataset
data_lausanne <- data_lausanne %>%
  mutate(City="Lausanne",
         LBW = cut(birthweight, breaks=c(1, 2500, 6000)),
         LBW = case_when (LBW=="(1,2.5e+03]" ~"1",
                          LBW=="(2.5e+03,6e+03]" ~"0"),
         parity_cat=cut (parity, breaks=c(0,1,2,5,Inf)),
         PTB = case_when (GA_weeks<37 ~"1",
                          GA_weeks>37 | GA_weeks==37 ~"0"),
         sex = case_when (sex=="0" ~"male",
                          sex=="1" ~"female"),
         buffer_100m_poi = case_when (buffer_100m_poi=="0" ~"no",
                                      buffer_100m_poi=="1" ~"yes",),
         sex = as.factor(sex),
         PTB = as.factor(PTB),
         stillbirth = as.factor(stillbirth),
         buffer_100m_poi = as.factor( buffer_100m_poi),
         LBW= as.factor(LBW),
         height= as.numeric(height),
         GA_weeks = as.numeric(GA_weeks)) %>%
  select(City, birthyear,birthweight, age_mother, GA_weeks, parity, height, sex,
         stillbirth,LBW, parity_cat, PTB,buffer_100m_poi)%>%
  filter(complete.cases(.))
```

Logistic regression

4

```
#Logistic regression

#LBW
mod_lbw_lausanne <- data.frame(summary(glm(LBW ~  buffer_100m_poi + birthyear
                                           + age_mother + GA_weeks+  parity +
                                             height+sex+stillbirth, data=data_lausanne ,
                                           binomial(link = "logit")))$coefficients) %>%
  mutate(OR = round(exp(Estimate),3),
         CIl = round(exp(Estimate - 1.96*`Std..Error`),3),
         CIu = round(exp(Estimate + 1.96*`Std..Error`),3),
         CI = paste0(CIl, "-", CIu),
         Cofactor=row.names(.),
         Cofactor = recode(Cofactor, "buffer_100m_poiyes" = "Industry yes (ref: no)",
                           "birthyear" = "Year of birth",
                           "age_mother" = "Age of mother",
                           "GA_weeks" = "Gestational age",
                           "parity" = "Parity",
                           "height" = "Height of mother",
                           "sexmale" = "Sex male (ref: female)",
                           "stillbirth1" = "Stillbirth yes (ref: no)")) %>%
  slice(-1) %>%
  select(Cofactor,OR, CI)

write.xlsx(mod_lbw_lausanne , "mod_lbw_lausanne.xlsx", rownames=FALSE, overwrite = TRUE)


#LBW

mod_stillbirth_lausanne <- data.frame(summary(glm(stillbirth ~  buffer_100m_poi
                                                  + birthyear + age_mother +
                                                    GA_weeks+  parity + height+sex,
                                                  data=data_lausanne ,
                                                  binomial(link = "logit")))$coefficients) %>%
  mutate(OR = round(exp(Estimate),3),
         CIl = round(exp(Estimate - 1.96*`Std..Error`),3),
         CIu = round(exp(Estimate + 1.96*`Std..Error`),3),
         CI = paste0(CIl, "-", CIu),
         Cofactor=row.names(.),
         Cofactor = recode(Cofactor, "buffer_100m_poiyes" = "Industry yes (ref: no)",
                           "birthyear" = "Year of birth",
                           "age_mother" = "Age of mother",
                           "GA_weeks" = "Gestational age",
                           "parity" = "Parity",
                           "height" = "Height of mother",
                           "sexmale" = "Sex male (ref: female)")) %>%
  slice(-1) %>%
  select(Cofactor,OR, CI)


write.xlsx(mod_stillbirth_lausanne, "mod_stillbirth_lausanne.xlsx", rownames=FALSE,
           overwrite = TRUE)
```

Results

```
#Results
mod_stillbirth_lausanne
```

```
##                                       Cofactor    OR          CI
## buffer_100m_poiyes Industry yes (ref: no) 2.059 0.885-4.791
## birthyear                    Year of birth 0.996  0.757-1.31
## age_mother                   Age of mother 1.052 0.978-1.131
## GA_weeks                   Gestational age 0.843 0.782-0.909
## parity                              Parity 0.991 0.821-1.195
## height                     Height of mother 0.942   0.9-0.986
## sexmale              Sex male (ref: female) 1.704 0.788-3.687
```

```
mod_lbw_lausanne
```

```
##                                        Cofactor    OR           CI
## buffer_100m_poiyes  Industry yes (ref: no) 1.242  0.704-2.189
## birthyear                     Year of birth 1.035  0.875-1.224
## age_mother                    Age of mother 1.027   0.98-1.075
## GA_weeks                    Gestational age 0.698  0.649-0.752
## parity                               Parity 0.987  0.874-1.115
## height                      Height of mother 0.970  0.941-1.001
## sexmale               Sex male (ref: female) 0.781  0.497-1.226
## stillbirth1          Stillbirth yes (ref: no 5.001 1.959-12.763
```

B Personal Declaration

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

Wettingen, April 27, 2023