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Air quality and children's well-being in an urban context: The influence of green climate adaptive measures on urban air qualities and children's health and well-being

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Abstract

Air pollution and green climate adaptive measures gain importance among urban planners, as extreme weather events and the (air) quality of the urban areas become one of the key topics for a healthy urban society, for especially children. Children are often seen as the most vulnerable group in society, therefore children's needs must be integrated into the planing process of urban areas. This study researches the effects of green climate adaptive measures in urban areas with its main focus on the impact of green climate adaptive measures on the air quality and how children can profit most from those green areas. It is looked at how children can profit in their physical health and mental health as well as how their well-being correlates with the availability of green spaces. A mixed method approach has been performed to get insights from all angle. First a qualitative analysis has been applied followed by a case specific GIS analysis for the city of Groningen.

The main findings are that there is a clear ration between green climate adaptive measures and air quality and more over that there is a clear relationship between children's physical and mental health as well as an improved general well-being can be found.

Based on the results urban green climate adaptive measures, especially in areas close to schools, kindergartens, need to increasingly promoted by planners as well as incentives to support green climate adaptive measures need to be implemented by governmental organizations. In addition the results illustrate that Groningen already takes action, with regard to climate adaptive measures and their positive influences.

Key words

Air Pollution, Green climate adaptive measures, child inclusive spatial planning, well-being of children, urban green space, green urban planning

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1. Introduction

1.1 Background

The world is urbanizing, developing and industrializing at rapid speeds. Alongside the industrial developments, the world's population is growing and will be urbanized up to 70% by 2050. This growth and development will have profound impacts on sustainability, human welfare, land use and children's health (Ahern, 2011). This process of urbanization and industrialization is accompanied by many positive influences/effects on the one side but, however, also by negative effects such as air pollution (Brimblecombe, 2012). Clean air can be seen as a substantial part of designing sustainable and healthy cities. Since it is known that air pollution, even to a very small extent, can increase mortality and the likeliness of respiratory and cardiovascular diseases, air pollution reduction measures are essential and must be continuously implemented (Brunekreef and Holgate, 2002). Especially children are the ones suffering most from bad air quality and thus need to be protected extensively (Vanos, 2015). The societal as well as the academic relevance of this research is supported by Kinney (2008), explaining the correlation between climate change and air pollution and how the interplay between air pollution and climate change affects human health. Additionally, Mohai et. al., (2011, p.853) state: „Exposing children to environmental pollutants during important times of physiological development can lead to long-lasting health problems, dysfunction, and disease." However, in addition to the severe health impact of air pollution on young children and school children, a considerable mental impact can be found. Children growing up or studying in air polluted areas tend to have lower school attendance rates as well as lower educational performances (Mohai, Kweon, Lee and Ard, 2011). Even though each European country and even some cities developed certain restrictions and guidelines on air quality standards, these are often not met (Standards - Air Quality - Environment - European Commission, 2021). The regulatory framework, however, only sets threshold values for certain air polluting substances, but does not offer guidance on how cities can physically improve air quality. Cities not sticking to the set limits and regulations concerning air quality often do not have to fear severe consequences. In order to promote measures improving air quality, a clear connection between green climate adaptive measures and the reduction of polluted air can be important as cities will have to adapt to impacts caused by climate change.

Groningen is located at a very interesting geological location surrounded by some industrial areas and business parks, highly used roads within and around the city. Furthermore the city offers housing, schools, kindergartens etc. to families with young children while lacking green spaces in the inner city.

1.2 Research Problem

Air pollution in urban areas is still a major issue which can have big impacts on people's physical and mental health. However, especially children suffer the most from bad air qualities (Vanos, 2015). There is evidence that air pollution can harm children's wellbeing and health to a considerable extent. However, little research has been conducted on how green climate adaptive measures contribute towards improvements of the air quality in close proximity to schools, kindergartens and playgrounds. This research paper investigates to what extent green climate adaptive measures can improve the air quality of places made for children of the age group 1 to 12 years. The direct impact of the air quality on children's health as well as the indirect impact, if for

example lower traffic densities, on children's wellbeing play a major role. This research paper aims at providing policy as well as spatial solutions for cities in order to be able to improve the air quality, and therewith children's health and well-being, while adapting to the rapid climatic changes.

Acknowledging the described research problem, the following research questions arise:

How can green climate adaptive measures improve the air quality of urban areas, in close proximity to schools, kindergartens and playgrounds and thereby directly improve children's health but also indirectly enhance children's well-being?

Sub-questions:

- What direct health effects and indirect influence on the well-being of children do green climate adaptive measures have?
- Which green climate adaptive measures to improve the air quality in urban areas are most effective at enhancing children's health and well-being?
- How can green climate adaptive and air enhancing measures be spatially integrated and implemented to enhance children's wellbeing?

- Which green climate adaptive measures to improve the air quality in urban areas are discussed in current literature?
- To what extent can green climate adaptive measures improve air quality in cities?

1.3 Outline

To successfully answer the research question, in a first step an extensive literature review will be conducted. This aims at defining the concepts of green climate adaptive measures and assessing the influence of air pollution in cities, especially on places such as schools, kindergartens and playgrounds. The next step of this research is to define and elaborate those concepts and identify which indicators are present and how they influence each other.

In a second step, scientific and grey literature as well as policy documents about the city of Groningen need to be consulted in order to work with those background information. The city of Groningen has been chosen because it is a very well developed city, offers surrounding business parks in proximity to the city and provides a very interesting geology. In addition, Groningen has been selected as it provides many educational buildings and areas within the city, while lacking green (climate adaptive) spaces in the inner city. This offers room for spatial and institutional improvements. In order to get a better understanding, the zoning plans and as well as the development goals of the city (in terms of green climate adaptive measures and air quality) will be explained, described and analyzed. Additionally, the concept of green climate adaptive measures will be further researched and analyzed and especially focus on the impacts of polluted air on

children's health and well-being. In order to answer the research questions, different strategies to collect information and data will be applied. To analyze air pollution patterns and investigate if schools, kindergartens and playgrounds are affected by severe air pollution, ArcGIS will be used. Additionally, scientific papers on the existence and execution of policy instruments will be consulted. Furthermore, it will be assessed if vulnerable areas such as schools etc. are explicitly considered and protected.

2. Theoretical Framework

2.1 General outline

Cities need to adapt and find solutions in order to be resilient and well prepared for more frequently occurring extreme weather events (Gray, 2007) such as extreme storms, rainfalls or heat. This study aims at discovering the influence of green climate adaptive measures on polluted air in cities, especially looking at places such as schools, kindergartens and playgrounds. The research is looking for solutions to improve the air quality of places frequently used by children (in the age between 1 and 12 years) and therewith enhance children's health and well-being. As explained by van Loon (2011) this offer and ability of green (play) spaces can also lead to an increased physical activity and therewith significantly improve children's well-being as well as their physical and mental health conditions.

Among scientists there is much evidence and knowledge about climate change and its effects and how this can influence weather conditions. However, there is not yet any possibility to exactly forecast how and at which speed climate change will evolve and where the major impacts will be (Gray, 2007).

Green climate adaptive measures are and can be defined as physically implemented measures reducing the effects caused by climate change, focussing on measures like green roofs, green (play) spaces or other plants such as trees, bushes and smaller vegetation. As researched and discussed by Markevych et al. (2017) green spaces are assumed to be beneficial for the mental as well as the physical health of the ones living within the city, it is seemingly not yet clear on how to design those and how to transform them into useful policy guidelines.

Recent studies show that the air quality, especially in developing countries, can often be classified as poor. Additionally, the same studies show that even within Europe, air quality standards, set by either the European Union (EU), a European country or the World Health Organization (WHO), are often not met and consequently cause major health and environmental issues (Pascal et al., 2013). However, certain aspects and relationships remain unclear or even unknown. Implementation strategies or policy instruments, on a local level, regarding air quality are often not in place or not functioning very well, as a result the implementation of physical measures on the improvement of air quality is often difficult and time-consuming. Looking at recently conducted scientific literature and studies about implementation strategies or policy instruments, this specific rubric/ research area is still developing , especially over the past one or two decades. Most scientific research has been conducted many years ago, thus it is unclear how valid and relevant they are in 2021. Furthermore there is little knowledge if places visited frequently by children (e.g. schools, kindergartens and playgrounds) are particularly protected against air pollution and if there are any guidelines to do so. The influence of green climate adaptive measures on climatic changes are already researched well and are still being investigated (Voskamp and Van de Ven, 2015). However, the degree to which those green climate adaptive measures influence not only the resistance against extreme rainfall and heat but also contribute to a reduction of polluted air is not fully clear and evident.

When looking at the methods that have been used in relevant studies, papers and scientific articles, it is clearly visible that there are multiple options and there is not one best theory or method. Many studies and research is built upon a literature review and the use of secondary data, as it is much more difficult to obtain qualitatively and scientifically valuable primary data (Rabianski, 2003).

2.1 Green climate adaptive measures

The research area of green climate adaptive measures is constantly developing and growing. Green climate adaptive measures include many physical actions but also policy guidelines or interventions. Physical measures could for instance be the implementation of green areas in order to improve the absorption of water, increase natural cooling and improve the air quality within the city. This additionally can have a positive effect on residents, especially children, living close by (Nielsen and Hansen, 2007). Other methods would be the implementation of e.g. green roofs, water retention areas or even water collection tanks to withstand heavy rain showers and storms.

2.2 Child inclusive spatial planning

The domain of child inclusive spatial planning is developing and gaining importance among planners over the last decades. However, child inclusive spatial planning is still often only briefly considered in decision making processes about urban design developments. Main elements such as making green (play) spaces well accessible is often only superficially included in urban design processes (Haider, 2007). Even though the need for child- and family-friendly (green) spaces within cities is rising, municipalities and planners often often don't have high incentives by e.g. regulatory frameworks given by the municipal or national government (Krishnamurthy, 2019). Child inclusive spatial planning thus needs legal regulatory frameworks and policies to gain influence in the planning domain.

2.3 Air pollution

Air pollution can be seen as an often hardly visible but possibly life threatening danger. Air pollution consists of chemicals or particles which can have serious health effects to the human body, especially to children's health, as well as they can have tremendous impact on nature and thus important ecosystems (Bernstein et al., 2004). It is important to distinguish between polluted air caused by natural events, such as volcanic eruption, wildfires or drying bog, and pollution caused by humans through motorized vehicles, agriculture, coal power plants or other industrial plants and activities (AR5 Climate Change 2014: Mitigation of Climate Change — IPCC, 2021). However, there are different types of air pollution such as smog, toxic pollution or the production of so-called greenhouse gases. Some of the most harmful greenhouse gases are methane, nitrous oxide and carbon dioxide, mainly produced through burning fossil (fuels) such as coal and oil (Global Greenhouse Gas Emissions Data | US EPA, 2021).

2.4 Conceptual model

The graphs above illustrate the relationship between the different variables, factors and how they interact. The dotted lines show the external influences that can not be changed/ influenced directly and form the biggest uncertainty. The other variables can be influenced through policies and

physical intervention/ physical measures. Spatial Design, Location and Policies interact with each other as the three variables are in need of green climate adaptive measures and in return are influenced by the degree of functionality or success of those measures. The other three factors (children's needs, age groups and parental situation) influence green climate and air adaptive measures in such a way that they build the basis on which e.g. spatial design and policies are developed. All those factors form the basis for an adoption plan regarding physical measures and policy guidelines. Those eventually lead to improved air quality and therewith increase children's wellbeing and physical health.

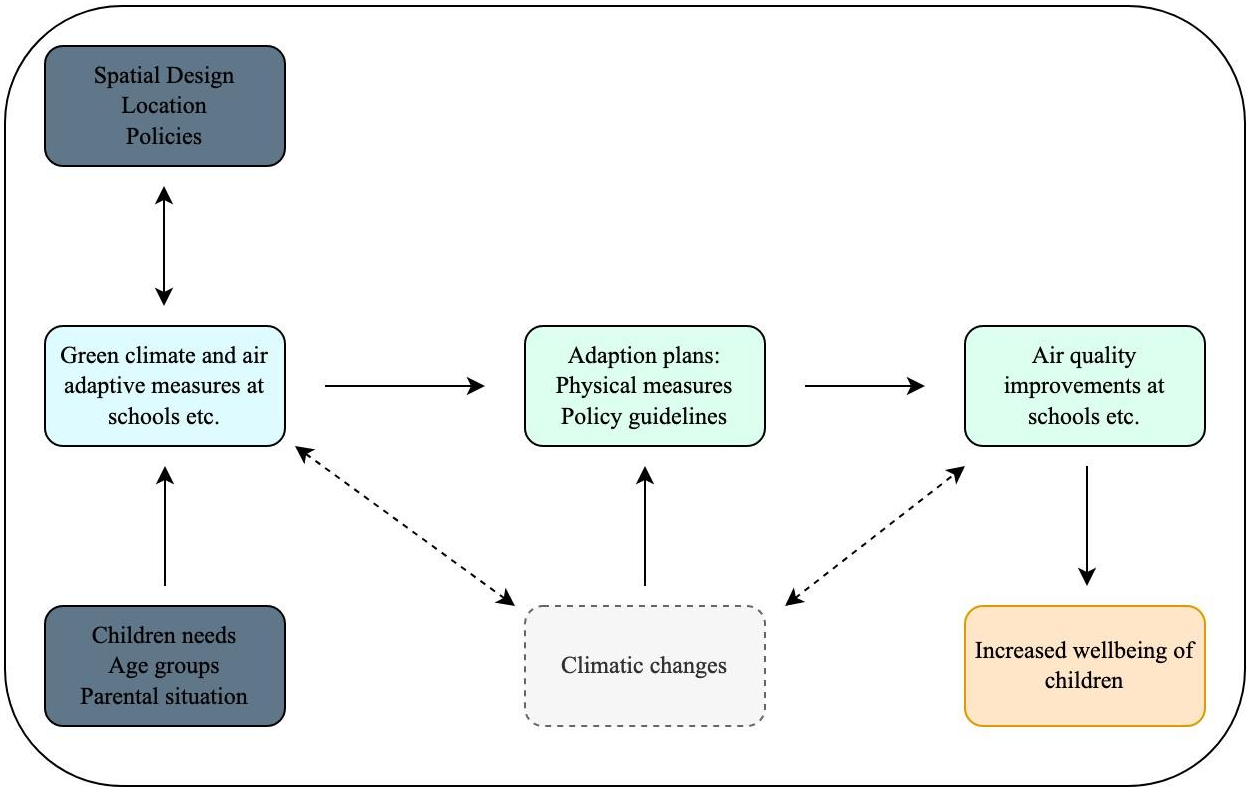

Figure 1. Conceptual model

2.5 Hypotheses

Following the main research question and its following sub-questions the below listed hypotheses have been developed and are based on the theoretical framework. The hypotheses belong to the specific case of Groningen as well as to the more general findings of this research.

- More green climate adaptive measures reduce air pollution.
- The improved air quality through green climate adaptive measures has a positive effect on children’s health and physical activity.
- Green climate adaptive measures have a positive effect on children’s well-being.
- Green climate adaptive measures increase resistance to extreme climate events such as heavy rains or heat.

3. Methodology

In this paragraph the used methods and the types of data used will be discussed. To successfully answer the research question and its supporting sub-questions multiple methods will be applied. This mixed methods approach has been chosen to ensure the validity of all gathered and analyzed data, as it provides the researcher with information from many different angles. The research questions, sub-questions and the associated methods and data types can be found in the table and the data analysis scheme below.

Research question	**Methods used**	**Data type**
How can green climate adaptive measures* improve the air quality of urban areas, in close proximity to schools, kindergartens and playgrounds and thereby directly improve children's health but also indirectly enhance children's well-being?	Results of the sub-questions	Qualitative & Quantitative
Sub-questions	**Methods used**	**Data type**
1. Which green climate adaptive measures to improve the air quality in urban areas are discussed in current literature?	• Literatur Review (Academic papers, journals & Book) Qualitative analysis (Mayring)	Qualitative
2. To what extent can green climate adaptive measures improve air quality in cities?	• Literatur Review Qualitative analysis (Mayring) • GIS analysis	Qualitative Quantitative
3.What direct health effects and indirect influence on the well-being of children do green climate adaptive measures have?	• Literatur Review (Academic papers, journals & Book) Qualitative analysis (Mayring)	Qualitative
4. Which green climate adaptive measures to improve the air quality in urban areas are most effective at enhancing children's health and wellbeing?	• Literatur Review • GIS analysis Qualitative analysis (Mayring)	Qualitative Quantitative
5. How can green climate adaptive and air enhancing measures be spatially integrated and implemented to enhance children's wellbeing?	• Literatur Review • GIS analysis Qualitative analysis (Mayring) • Data provided by subquestions 1,2,3,4 & 5	Qualitative Quantitative

Table 1: Research questions & methods used

3.1 Mixed method

This research is based on a case study, which in this case is the city of Groningen. This choice is based on different considerations and methodological thoughts, such as which method is most suitable in answering the main research questions and its sub-questions. Considering different methods, a qualitative approach analyzing for example solely the air quality values at different educational locations would also be possible, however, this can be covered using a GIS air quality map. In addition an interview would have a beneficial value, but could not be taken into consideration due to the late switch of locations and the COVID-19 situation. A case study is ideal in providing deep insights and in-depth understanding of phenomena, the actors involved and how they interact. The advantage of a case study is that a case study can provide very specific insights and allows access to realistic and real life information and data. Even though the process of using and generalizing the collected data can be very difficult, such specific information can be very valuable as it can help to describe, explain and predict phenomena at a very local and individual level. The exact data analysis scheme can be seen in figure 2.

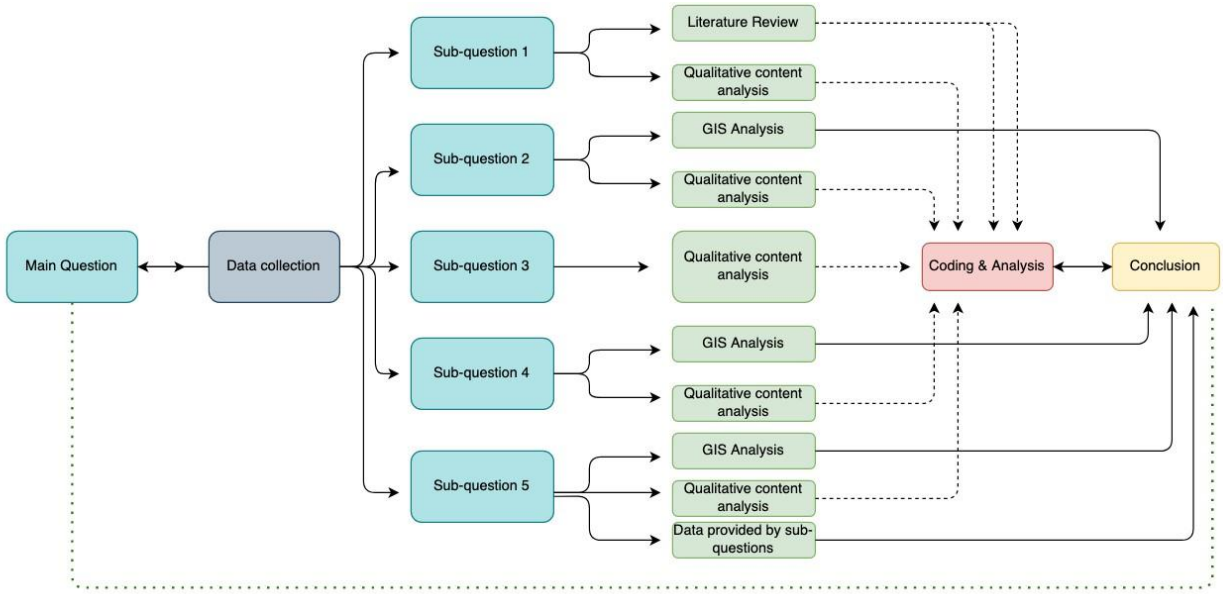

Figure 2. Data analysis scheme

3.2 Data collection

The research includes qualitative as well as quantitative data. Those datasets and information will be conducted mainly through secondary data and to a smaller extent also through primary data.

Other sources will be academic literature such as academic journals, papers, books, grey literature and policy documents. In order to point the research in one direction, different key terms have been selected. This will be based on a first test of how convenient and straightforward they are. Furthermore, those key terms will be combined to find relevant literature including multiple key aspects and terms.

3.2.1 Research strategy

The figure below illustrates the research strategy that will be applied. All three steps, literature review, GIS analysis and in depth exploration of selected locations will be executed successively. The results of all three research steps will be explained and illustrated in the chapter discussing overall results and findings.

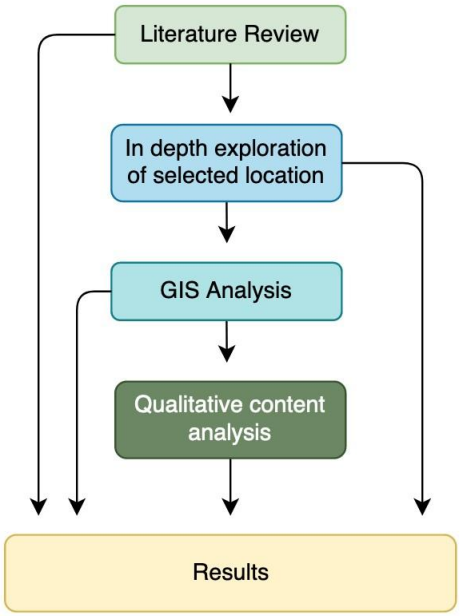

Figure 3: Research strategy step by step

3.2.2 Literature review

In order to answer the research question and sub-question, an academic literature review has been performed. The literature review suitable key search terms such as green climate adaptive measures, child inclusive spatial planning, climate change, air pollution, sources of air pollution, health effects of air pollution on children, spatial adaptation to polluted air and policy guidelines for air pollution. The used academic literature has been searched and accused via search engines such as SmartCar or Google Scholar.

3.2.3 Background of datasets

During this research multiple datasets will be used and analyzed. Groningen can be seen as a suitable location, as educational buildings such as schools or kindergartens are located in the inner city and are surrounded by streets and often sealed ground. The inner city thus provides room for improvements regarding green climate adaptive measures, especially in close proximity to schools, kindergartens and playgrounds. There are different datasets provided by the city of Groningen, including data on air pollution measurements within the city, locations of vulnerable locations (schools, kindergartens, playgrounds), highest polluted areas, information about green spaces and much more relevant data. This is very important as the data provided by the city can be seen as a credible source and thus provide a high validity and accuracy. However, this depends on how up to

date the data is, how detailed the datasets are and to what extent they give access to non-employees. This needs to be checked carefully.

Variables that have been analyzed:

- Main pollutants
- Location of main pollutants
- Geological and climatic conditions
- Vulnerable locations for children (schools, kindergartens, playgrounds)
- Health effects of polluted air towards children
- Green climate measures and their contribution to clean air
- Current policies and guidelines in place
- Spatial outcomes of green climate adaptive measures
- Policies implemented to reduce air pollution and increase children's well being and health

In order to substantiate the provided variables, a closer look at the research area, the literature review and the research background can be taken. This will better illustrate the relationship between the variables/ cases and how they contribute towards answering the sub-questions and most importantly answering the main research question. These variables will be very influential when deciding on the key search terms for the literature review, when choosing specific attributes during the GIS analysis or, if possible, while designing a questionnaire or survey. The variables contribute to answering the research question(s) in such a way, as they are implicitly included in the research questions, that the analysis of those variables will provide the necessary informations and data

3.2.4 Qualitative content analysis (Mayring)

To answer the research question and its sub-questions a qualitative content analysis has been chosen and performed. In detail, the qualitative content analysis approach developed by Mayring (2000) has been used as a guideline. Mayring developed a deductive approach as well as an inductive approach of analyzing qualitative data. The deductive analysis approach requires an in beforehand developed clear coding scheme/ guideline. The inductive analysis approach allows the creation of the codes during the process of content analysis (see appendix 8.3). Due to the higher flexibility the inductive approach has been chosen for this study. The created codes can be modified at a later stage to ensure the overlap between the codes is not too large, the content of the different codes can thus not be too similar. The used codes, such as "Influence of green measures“,“Green measures effects on children's well-being“ or “spatial measures to improve children's well-being" have been grouped in subcategories. After reviewing 30 to 40% of the data/ literature a revision of the created codes has been executed to be able to check the reliability and quality of the codes. The codes contain the material in a compressed and abstracted form. This allows to set the material/

codes in relation to each other and draw conclusions. The entire analyzed content has been carefully checked regarding its relevance and validity.

3.2.5 GIS analysis

The GIS analysis will be performed due to multiple useful aspects. With the support of a GIS analysis spatial patterns of spatial schemes of areas affected most by air pollution can be identified and analyzed. QGIS has been used as the analysis tool is freely accessible, provides many helpful features and offers a user friendly interface. During the process of analyzing the data, datasets will be imported to QGIS where certain attributes, provided by the dataset, can be selected, analyzed and illustrated. A flow chart with the detailed steps of the analysis will be developed after the literature review has been completed.

3.6 Ethical considerations

Considering ethical aspects, it is important to bear in mind that those necessarily need to be addressed in this methodology section. When using secondary data, the researcher needs to be aware that the information has been collected by someone else and for another purpose (Clifford et al., 2016). The questions asked might not have been exactly the ones that the researcher would have used for example. In addition, there should be an awareness that secondary data are often strongly spatially referenced. When conducting an interview or survey, it is important to ask the respondents if his/ her answers can be anonymously published.

4 Results

This chapter presents the results of the qualitative content analysis as well as the outcomes of the GIS analysis. The chapter follows the theoretical framework and answers the sub questions successively.

4.1 Quantitative content analysis

In this section the qualitative outcomes of the qualitative content analysis will be presented. The findings cover more general outcomes about the researched topics as well as specific case related outcomes for Groningen.

4.1.1 State of research - green climate adaptive measures discussed in current literature

Climate adaptation is gaining importance and awareness in urban planning and the planning field in general. Accordingly green climate adaptive measures, the value of ecosystems within urban areas and its improvements to the residents quality of life (Kabisch, 2015). Current literature partly shows that through green climate mitigation and adaptation strategies (e.g. reduction of emissions or cooling temperatures through changes in the built environment) health co-benefits may occur. In addition, the existence of a relationship between green space exposure of children and their behavioral and emotional difficulties is consistently expected (Vanaken and Danckaerts, 2018).

Vanaken and Danckaerts (2018) connect those issues especially to inattention problems and hyperactivity. As climate change leads to more frequent and extreme weather events, heavy rainfall and urban heat island can be counteracted with green climate adaptive measures (Harlan and Ruddell, 2011). Harlan and Ruddell (2011) furthermore explain excess morbidity and mortality caused by polluted air and heat waves will be a main challenge facing cities world wide, this is also undermined by Nieuwenhuijsen et al., 2018). However, as stated by Kabisch (2015) the awareness of municipalities, regarding benefits of green climate adaptive measures, often remains low. Govindarajulu (2014) explains that municipalities and planning institutions around the globe additionally still often lack understanding on how to use green spaces for climate adaptation and recreational or educational areas at the same time. Current literature nevertheless discusses many approaches of how green climate adaptive measures can have a positive impact on both, air quality as well as mental and physical well-being and health. Berardi, Ghaffarian Hosseini and Ghaffarian Hoseini (2021) for example clearly show the positive effects of green roofs, such as improving air qualities, reducing noise pollution, mitigation of urban heat island effects as well as ecological preservation. However, most research is being conducted with reference to adults. McCracken, Allen and Gow, (2021) state that research about the relation between green spaces and children's health is relatively rare.

4.1.2 Effects of green climate adaptive measures on children's health and well-being

The influence of green measures in urban areas can be both, direct through physical health and indirect through the offer of e.g. green (play) spaces and therewith influence children's well-being. Throughout the scientific landscape it is evident that a constant level of air pollution can cause serious health effects (Bernstein et al., 2004). Some of the most influential health risks can be seen in the table below. However, the quantity of green spaces is not the main factor for a better health

TABLE III. Possible mechanisms of pollutant-associated adverse health effects

1. PM- or ozone-induced pulmonary inflammation
2. Free radical and oxidative stress generation by transition metals and organic chemical compounds (eg, PAH)
3. Covalent modification of key intracellular proteins (eg, enzymes)
4. Biologic compounds, such as endotoxin and glucans, which induce inflammation and innate immune effects
5. Stimulation of nocioreceptor and autonomic nervous system activity, which regulates heart rate variability and airway reactivity
6. Adjuvant effects in the immune system (eg, DEPs and transition metals enhancing responses to common environmental allergens)
7. Procoagulant activity by ultrafine particles after access to the systemic circulation
8. Suppression of normal defense mechanisms (eg, suppression of alveolar macrophage functions)

PAH, Polyaromatic hydrocarbons.

Table 2: Source, (Bernstein et al., 2004)

related quality of life (McCracken, Allen and Gow, 2021). The qualitative content analysis furthermore clearly illustrates the positive effects of green spaces within the city, as all age groups profit from the use of common green spaces. A survey among school children showed that the vast majority feels healthy and optimistic. However, close to 50% of the children feel stressed on a regular basis, every tenth child feels regularly lonely and every fifth child has a increased chance of mental health issues (Gezondheidsprofiel jeugd 2019 | GGD Groningen, 2021). McCracken, Allen and Gow's (2021) state that the use of green spaces in early childhood and youth can have bigger positive impacts on health and well-being compared to adults. Scientific paper and literature have previously shown that there is a restorative effect on mental and physical health. The use of green spaces can reduce symptoms of stress and anxiety, which is contrary to typical urban areas, which can cause decreased attention and happiness (McCracken, Allen and Gow, 2021). However, green spaces in urban areas, especially playgrounds, schools or kindergartens within close proximity to green spaces, can have positive effects towards the productivity and educational performances (additional information see section 4.1.1) of children (Vanaken and Danckaerts, 2018). Higher television consumption among children increases alongside the distance to the next green (play) space. This also correlates with higher risks of psychological and general health issues, compared to children living nearby green (play) spaces (McCracken, Allen and Gow, 2021). Nielsen and Hansen (2007) complimentary compared the availability and volume of green spaces in residential environments with health. It was found that residents of neighborhoods with abundant green space tended, on average, to enjoy a better health condition and personal development through the additional contact with other children. Green (play) spaces in close proximity to residential areas, schools and kindergartens can have a significant influence on children's well-being and health.

4.1.4 Air quality improvements by green climate adaptive measures (Groningen)

There are numerous green climate adaptive measures which can have huge potential regarding air filtration, cooling through shade and moisture, noise reduction as well as they can increase or save parts of the biodiversity in urban areas (Kabisch, Qureshi and Haase, 2015). Examples of green climate adaptive measures which are also related to air filtering effects are green roofs, vertical greening and different forms of green urban areas in combination with trees and bushes alongside roads. Trees are a good and effective solution to clean polluted air, the overall cleaning effect is , however, small but still relevant. Trees are the most effective at filtering for example PM10 coarse[1], but are less effective regarding other substances (Selmi et al., 2021). However, even pollution values smaller than the critical values set by governmental organizations, can have negative health effects. If a green climate adaptive measure reduces only to a small degree the polluted air, it can still be beneficial (Verslag luchtkwaliteit 2016 Gemeente Groningen, 2021). A mix of different green climate adaptive measures is thus the most effective solution to lower air pollution levels within urban areas. Green roofs do not only provide better air through plants, but can also have positive effects on keeping houses cool during warm periods and regulate the temperature through shading and evapotranspiration (Selmi et al., 2021). Groningen is taking action on green climate

[1] PM10 coarase: a particular matter with a diameter of 10 micrometers or less (smoke, dust, acid, gases and particles emitted by burning fossil fuels etc.) (Titos et al., 2014).

adaptive measures and promotes (mainly through financial support) the implantation of green roofs on already existing buildings, but focuses on green roofs on newly built housing projects (Green roofs - Climate Initiative Groningen, 2021). In addition, the municipality of Groningen is implementing other green climate adaptive measures (see paragraph: 4.1.5) to support the mitigation of extreme weather events such as heavy rainfalls, drought and contribute to a cleaner within the city (Bijlagenboek klimaatbestendig Groningen 2020-2024, 2021).

4.1.5 Spatial implementation of child friendly as well as health and well-being enhancing measures

Children are often identified as being the most vulnerable group within society, therefore planning instruments need to be continuously developed (Vanos, 2021). Scientists are discussing the urgent need for guidelines for planners on the use of green spaces, by using an integrated approach to meet social and ecological standards (Govindarajulu, 2014).However, it is important to integrate the needs and vulnerability of children as they are often still only superficially integrated in the planning process (Vanos, 2021). The municipality of Groningen is taking climatic changes and its consequences into account and are for example planning to provide the streets with more greenery in order to combat extreme weather events and on the other hand create spaces for children to play and socialize or set financial incentives for residents to implement green measures

(Bijlagenboek klimaatbestendig Groningen 2020-2024, 2021). In order to implement green climate adaptive measures and improve the air quality it is vital to first know where the main pollutants are, how the air quality is within the municipal area and then decide on the measures and actions that need to be taken (Verslag luchtkwaliteit 2016 Gemeente Groningen, 2021). The different green measures have different costs and benefits. However, urban green spaces can generally be seen as a cost effective climate adaptive measure while having positive aspects for the local inhabitants (Govindarajulu, 2014). Another tool used by planners, also by the municipality of Groningen, to improve the air quality is to ban cars from certain areas and therewith create free spaces which can then be used to implement green climate adaptive measures (Bernstein et al., 2004). Another approach to make green spaces accessible to all residents would be to create green areas within a 15 minutes walking distance, like planned by the municipality of Groningen

(Bijlagenboek klimaatbestendig Groningen 2020-2024, 2021), as there is evidence that the frequency of visiting green spaces decreases drastically with the distance to the nearest green space (Nielsen and Hansen, 2007).

4.2 GIS analysis Groningen

The GIS analysis shows that the air quality values in Groningen are generally very good. The only areas where higher values of polluted air could be measured are in areas with frequently used roads or in closer proximity to business parks. The air quality throughout Groningen meets the standards

for playgrounds, kindergartens and schools. The map below illustrates the air quality values throughout the city of Groningen (Figure 4). and has been obtained via the website of the municipality of Groningen as no data sets have been freely accessible through the common GIS data websites or the Geodienst.

4.2.1 Nitogen-Dioxide (NO2) concentration map Groningen.

Figure 4, air concentration of NO2 in Groningen city centre. Source: (Luchtkwaliteitskaart inzien | Gemeente Groningen, 2021)

Figure 4 shows the air quality levels in the city centre of Groningen. In this case nitrogen-dioxide (NO2) has been chosen as indicator as NO2 as most other indicator values such as for example particular matter (pm) are much lower within the municipality of Groningen. In addition, NO2 is often used as a general indicator of air quality levels within cities (Moshammer et al., 2020).

4.2.3 Education and leisure areas

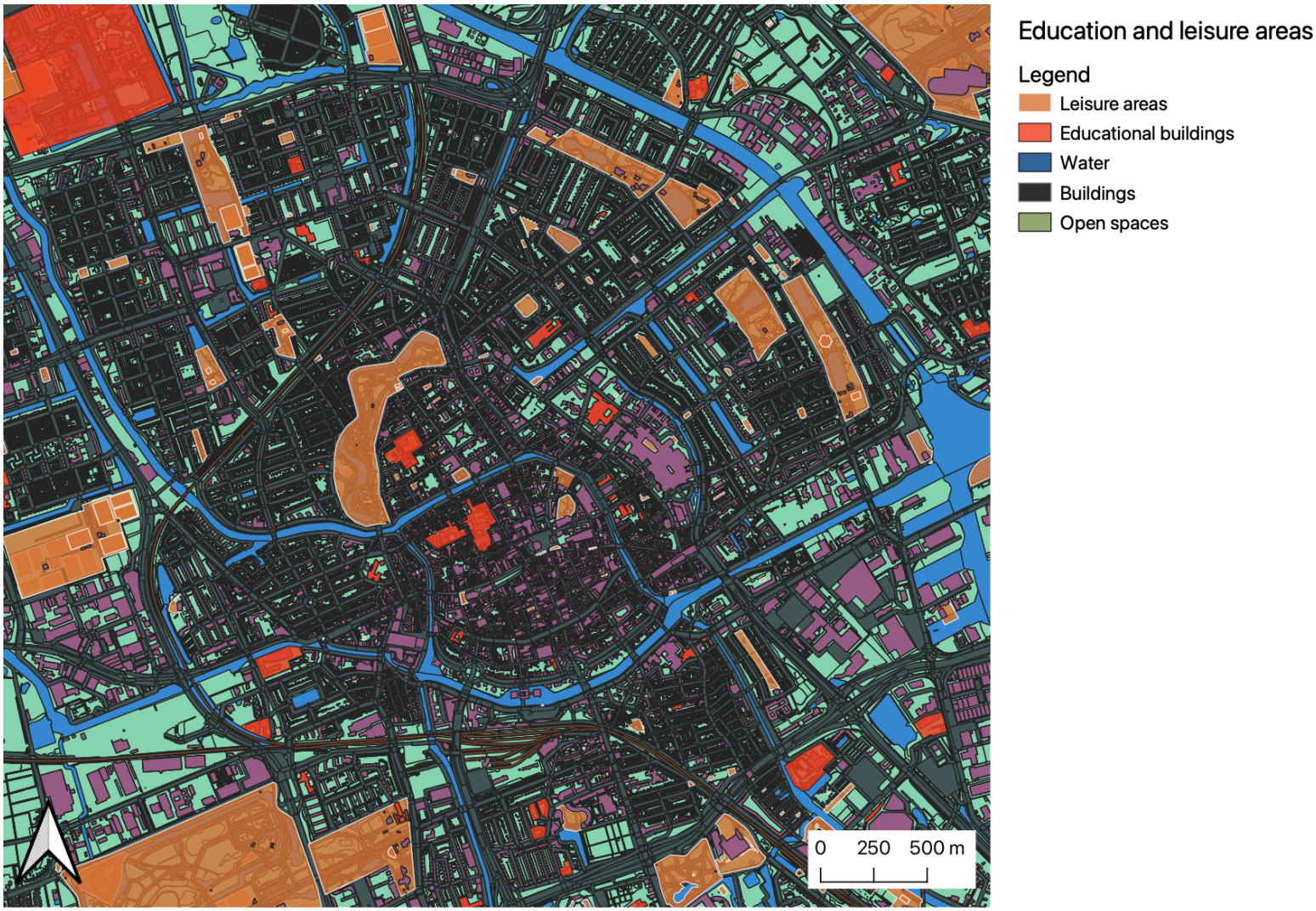

Figure 5: Educational and leisure areas

Figure 5, shows in orange, all areas labeled as leisure areas and in red illustrates all educational buildings such as schools and kindergartens. Many of the leisure areas could potentially be used as both, leisure areas and urban green (play) spaces, as well as they can serve the goal of climate adaptation. However, some would have to be physically changed and rebuilt to, for example, take up more water.

4.2.3 Opportunity Map

The Opportunity map shows suitable locations for urban green (play) spaces in combination with green climate adaptive measures, see appendix 8.1 for more detailed information. To identify

suitable locations, a 5m buffer has been applied to all roads (all traffic related paths), train lines and waterways. This leaves all spaces open (green) that

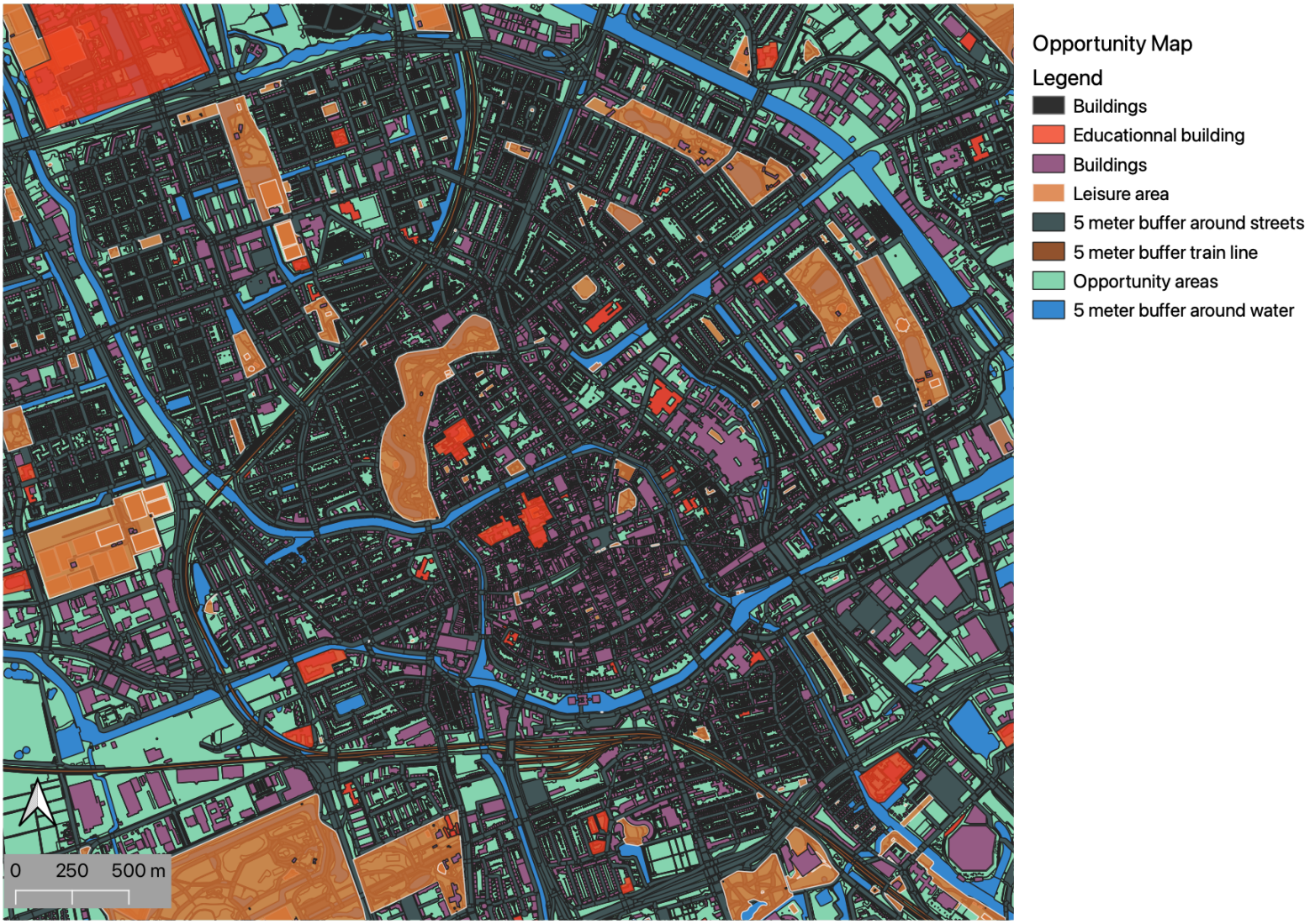

Figure 6, opportunity map Groningen

potentially can be changed thus being used for green climate adaptive measures. However, not all green locations are 100% suitable, all potential locations need a special adaptation plan. Furthermore, some locations can not be changed dramatically due to its current use. Generally schools and kindergartens located further outside of the city provide better access to green spaces compared to those located in the inner city. The educational buildings located close to roads, are mostly the ones with the highest air pollution levels. However, the air quality layer could not be imported to QGIS, it is thus not possible to rank educational buildings following air quality levels.

5. Conclusion

This chapter will discuss and answer the main research question of this study: *How can green climate adaptive measures improve the air quality of urban areas, in close proximity to schools, kindergartens and playgrounds and thereby directly improve children's health but also indirectly enhance children's well-being?* The research question was formulated to give insights to what extent green climate adaptive measures can influence the air quality in urban areas, to investigate how and what influence green spaces (can) have on their physical and mental health as well as children's well-being. As the world is urbanizing and industrializing at rapid speeds, this provides issues and challenges such as air pollution or lack of green (play) spaces in urban areas. This can have, especially for children, severe health and well-being impacts. The research question and its sub questions aimed at providing answers to identify the most useful green climate adaptive measures for children, their needs and quality improvements.

Therefore the first step is to look at general solutions and answers to the proposed questions, while looking at a second step for a solution in the city of Groningen. Groningen has comparably great air quality values and is some steps ahead of other cities, when it comes to the implementation of green climate adaptive measures. However, the analyzed (GIS) data shows that especially the inner city leaves room for spatial improvements such as e.g. the implementation of green roofs, green facades or green water retention areas while offering new green (play) spaces at the same time. The research is based on a mixed method approach to provide insights from different angles. There is evidence among scientists that bad air quality and the lack of green spaces in urban areas can cause severe (mental) health problems to residents, especially towards children. However, most research on air pollution, the need of green spaces in urban areas for health reasons is discussed with regards to adults and only little research regarding the influence on children can be found.

With regard to the suitable green climate adaptive measures, it becomes clear that there is not one correct solution for air quality improvements. To combat air pollution an interplay between multiple green climate adaptive measures such as e.g. green roofs, trees alongside roads and more diverse green urban areas are necessary.

The spatial implementation of such green climate adaptive measures needs to gain awareness among planners around the globe, as often too little attention is paid. Based on the results urban green spaces need to be increasingly promoted by planners as well as incentives to support green climate adaptive measures need to be provided by governmental organizations.

An interplay of green climate adaptive measures can improve urban air quality levels, while simultaneously providing green spaces for children, which ideally can improve children's health and well-being through physical activity and interaction with other children and provide opportunities for schools to be used as a biodiverse green "classroom". A general improvement would be to define conditions for green play spaces and locations for schools and kindergartens, with regards to air quality and the availability of green space, which need to be met when they are newly built and closely monitored over time. When conditions are implemented alongside with a compulsory qualitative and quantitative increased implementation of new green (play) spaces/ green climate adaptive measures for cities, those measures can demonstrate their effects. In addition the

results illustrate that Groningen already takes action with regard to climate adaptive measures and shows their positive influences - nevertheless there is room for improvements. This can also be used as a generalized outcome as this can be applied for many cities nationwide and around the globe. The data linked to the conclusion allows the generalization, that green climate adaptive measures in relation to children's health and well-being can have a huge potential and positive impact Critically can be seen that only one researcher has conducted the data which can potentially cause a subjective influence in the coding process.

Future research needs to be conducted on the exact interplay between green areas and its influence on children's well-being and health as most recent papers are based on the health and well-being of adults.

6. Reflection

This chapter reflects on the research strategy and suggests further research opportunities.

6.1 Limitations

An interview with the municipality of Groningen would have been highly beneficial, but was due to the pandemic situation and the switch op the case study location not possible. In addition a limiting factor is the absence of a freely accessible dataset on air quality levels in Groningen. Children's well-being and health improvements are very hard to measure without medical expertise, this forms a limiting factor to this research. Consequently only non subject specific indicators will be included. However, if the air quality in places used by children very frequently, such as schools, playgrounds and kindergartens, can be improved significantly through green climate adaptive measures, this will allow for the assumption that, based on previously conducted research such as Cavanagh, Zawar-Reza and Wilson (2009), these measures will increase children's health and well-being.

An interview with planners of the municipality of Groningen would have been very beneficial to gather case specific insights/ data regarding climate adaptations plans and role of child inclusive spatial planning.

Another limitation is, that only less scientific literature about Groningen and its strategy of dealing with green climate adaptive measures, air pollution and children's needs of green spaces is available. Most documents are policy guidelines and adaptation plans for the future. It was difficult to measure and analyze the actual outcomes of those documents as there is little documentation available to what extent they will be implemented. Some policy documents were only available in dutch, which could have caused some inaccuracies.

As this research has been conducted and executed by one researcher, the wishful thinking bias might have an influence on the results. The results as well as the chosen methodology have to be reflected critically. The results are closely related to the theories and concepts used and are in the bigger picture in line with the expectations. However, the methodology could have been applied

differently, as the outcomes are more general and broad and only partially very specific and case related.

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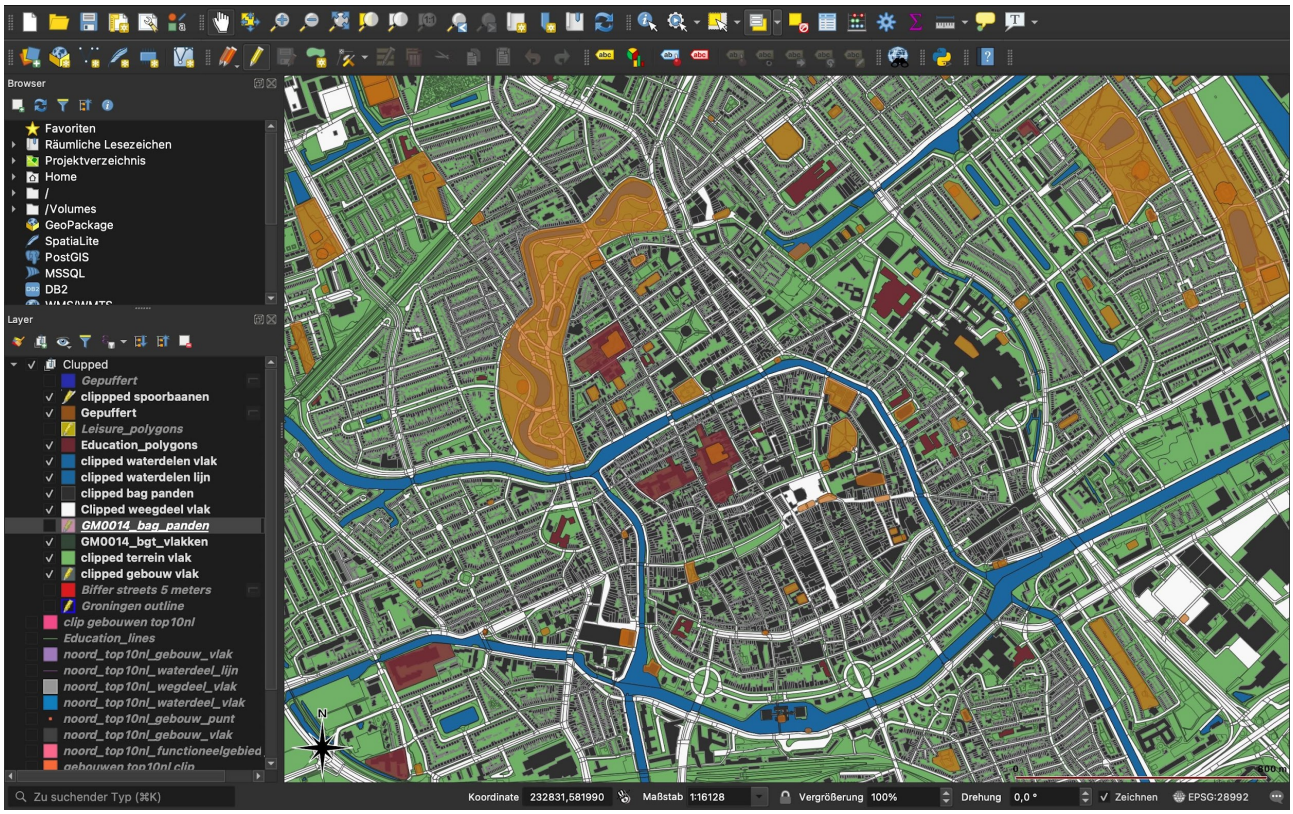
8. Appendix

Appendix 8.1 - Explantation of GIS analysis execution

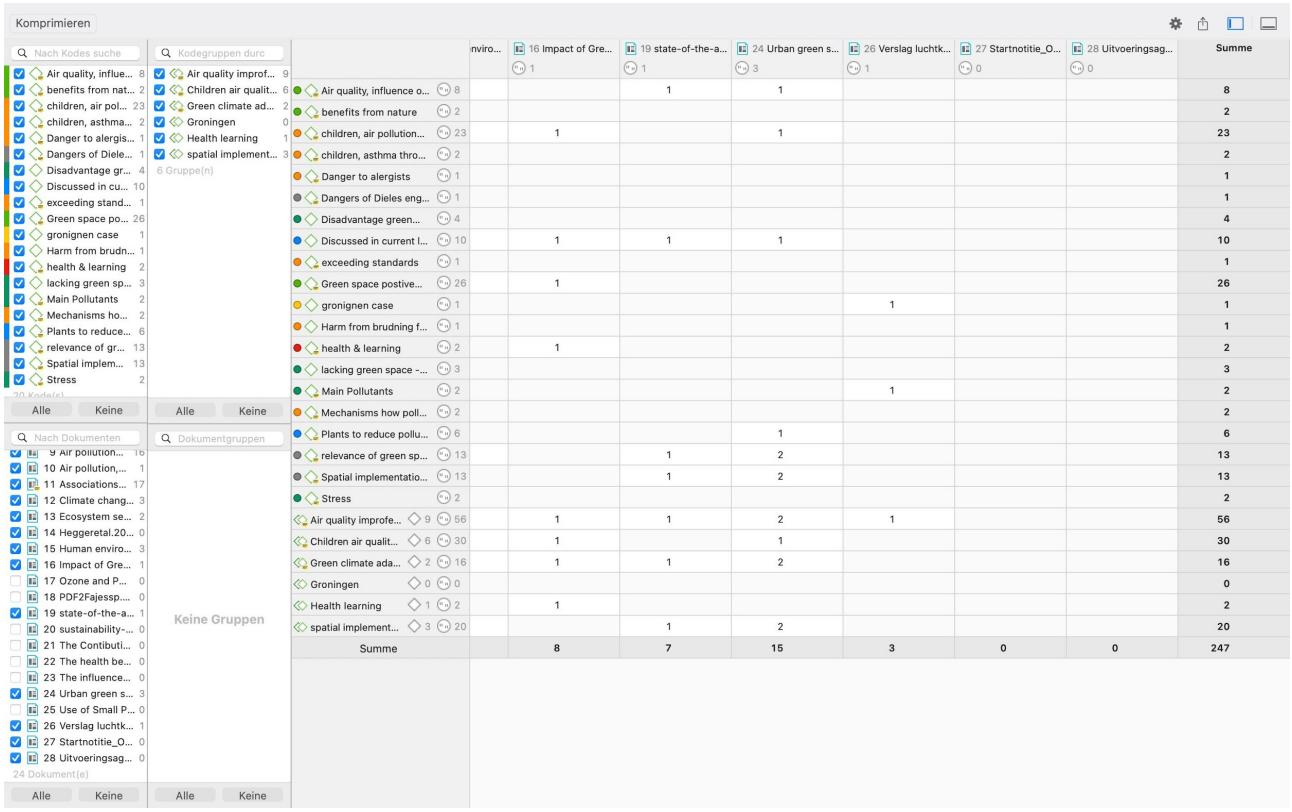
The GIS analysis is based on data provided by the Geodienst Groningen, the municipality of Groningen and national websites for geo data such as PDOK viewer. As a start all data sets were added to QGIS and were transformed into the right format and coordinate system. As a second step I clipped the different layers, so they excluded data from outside the city of Groningen. As streets are the areas with the highest pollution values, I created a buffer of 5 meters around streets, waterways, train tracks and therefore excluded those areas from being suitable locations. I then separated „grassland" from the layer „bgt_vlakken" to exclude for example forests and agricultural fields. Grassland can also be seen as agricultural land, however, it can often be transformed into either built areas (schools and kindergartens) or be transformed into green areas used by children.

The opportunity map shows suitable locations for urban green (play) spaces/ spaces where green climate adaptive measures can be implemented. All white areas have a distance of 5m to the orange area (buildings, streets, waterways and other infrastructure). The white areas are green spaces (mainly grassland with some bushes and only little trees) suitable for green climate adaptive measures.

Appendix 8.2 - Screenshot of GIS analysis process



Appendix 8.3 - Coding process in Atlas.ti



The screenshot of the coding process at an early stage