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Environmental inequality in Austria: How equally is the air pollution burden spread in Styria?*

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** Master thesis written at the Institute of Social Ecology, Master's Program in Social and Human Ecology. This work was supervised by Dipl.-Ing. Dr. Willi Haas.*

Abstract

This thesis aims to contribute to the emerging EJ discourse in Austria by assessing environmental inequalities caused by air pollution. Thereby, data availability was directive to define a geographical area. Thus, Styria was chosen since modelled air pollution data is available in a high resolution. The thesis addresses the question, *if air pollutants affect different social groups of residents of the Austrian federal state of Styria equally*? This study breaks new ground as it assesses environmental inequalities on a small scale through the juxtaposition of modelled air pollution and socio-economic data across the area. One of the key findings indicates that in Styrian urban areas residents with low income are the most air pollution burdened groups. Thereby, PM_{10} exposure levels are above the WHO threshold level and NO_2 levels are below. The distribution of air pollution affecting income groups in urban areas is not linear. On the one hand the intermediate income groups are least exposed. On the other hand, the highest income group carry higher air pollution burden than intermediate income groups, and the lowest income groups carry the highest burden. It is suggested that gentrification of inner city areas could be decisive for this. The second key finding concerns the positive correlation of critical PM_{10} and NO_2 exposure above the WHO threshold levels with migration background. Outcomes show that in all Styrian areas the share of Styrian residents born in countries with low socio-economic-status being exposed to critical levels is higher than the share of residents born in Austria or countries with high socio-economic-status. However, the level of critical exposure differs depending on population density, whereby urban areas are most affected. The findings concerning highest educational attainment in association with air pollution exposure show for critical PM_{10} exposure reverse and for critical NO_2 exposure only weak evidence of environmental inequalities. Income distribution seems to be the most important explanatory factor of the observed environmental inequalities, albeit it is assumed that the place of origin is likewise decisive. It is hoped that this thesis gives further incentives to detect blind spots regarding Environmental Justice in Austria and to conduct more research in order to understand the underlying mechanisms. In this way, adequate social-ecological policy responses to overcome the observed inequalities can be enhanced.

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1. Introduction

Since the industrial revolution economic development, population growth and an increasing societal resource endowment has driven the social metabolism to an unprecedented extent (Mayer, Haas, and Wiedenhofer 2017). Socio-metabolic outputs like air pollution emitted from combustion engines put human and non-human beings at risk. Emissions are not just disappearing but rather changing the living environment and dispersing within the biosphere (Sieferle 2003). This emission problem in form of environmental pollution is not equally shared in societies. Inequalities can arise on the one hand by uneven distribution of benefits like access to resources or favourable living environments or on the other hand by uneven burden sharing of environmental pollution and degradation as well as adverse impacts of climate change (Martinez-Alier et al. 2014).

To face these inequalities, the United Nations Sustainable Development Goals (SDGs) aims for a healthy life and wellbeing for all. To this end targets are set for a substantial reduction of the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination till the year 2030. Additionally, the goals of equal access to clean water and sanitation, clean energy and sufficient food amongst others refer strongly to a reduction of inequalities arising through environmental pollution (Inter-Agency and Expert Group on SDG Indicators 2016).

Further, there has been a critical framework to understand and reduce the unequal distribution of environmental pollution in various spatial and political contexts referring to as Environmental Justice (Walker 2012). For the first time the term of Environmental Justice (EJ) evolved during various protests from civil-society in the US against the disproportionate environmental pollution in predominantly Black, Hispanic or Indigenous communities in the 1980s (Martinez-Alier et al. 2014). Since then, hundreds of scientific reports indicate that “people of colour” and the low-income population do suffer from greater environmental harm than white and well-off communities (Bullard 1990; Bryant and Mohai 1992; Lerner 2010). But even though EJ became firmly established in US laws and regulations recent scientific findings still resemble the outset of the 1980s, where people of colour and low-income communities facing disproportionate environmental burdens (Bullard et al. 2008).

The European debate on EJ or furthermore the crossing of environmental and social perspectives is still at its beginning. There is a growing scientific interest in the European context as current research questions EJ on different spatial scales, ranging from local to national, EU and global level. Thereby, different environmental dimensions as air pollution, noise pollution, siting of polluting facilities, quality of the living environment, changes in climate and natural hazard risk and access to resources are assessed. The findings indicate multiple forms of inequalities (de Schutter et al. 2017). But in comparison to the US the outcomes in the European context are not always clear and the intertwining of the involved dimensions and mechanisms are only incomprehensively understood (de Schutter et al. 2017).

Even though the data situation in Austria is not too bad (de Schutter et al. 2017) there is only very little research related to EJ in Austria. Recent research examining the patterns of unequal distributed air pollution around industrial facilities in total Austria found mixed results (Glatter-Götz 2016). Thereby, the method at hand attempts to find answers rather indirectly via the proximity to industrial facilities emitting these pollutants than directly via observed pollution levels. Concerning Vienna, the capital of Austria, the method fails to give answers if environmental inequalities exist. Whereas the analysis of the remaining parts of Austria show a different picture: People who live close to industrial facilities are more likely to be unemployed, have lower education levels and are twice as likely to be migrants (Glatter-Götz 2016).

With regards to the complexity of the matter this master thesis adds on these results implementing a method using air pollution data assessed via dispersion models on a small spatial scale covering the state of Styria. It is expected that this change of perspective will bring a more detailed picture of the distribution of environmental inequalities in Austria.

1.1. The Research Question

This thesis' goal is to find out whether environmental inequality exists in the state of Styria. The main share of European environmental inequality research was conducted by assessing the spatial distribution of air pollution (de Schutter et al. 2017). Following this perspective this master thesis focuses on possible inequalities concerning the spatial distribution of air pollution. The master thesis attempts to answer the question*, if air pollutants affect different social groups of residents of the Austrian federal state of Styria equally?* In order to elucidate any associations between the burden of air pollution on different socio-economic groups the spatial distribution of air pollution, assessed via dispersion models, were juxtaposed with the spatial distribution of income groups, highest educational attainment and migration background.

As outcomes of the European environmental inequality research indicate, it can be hypothesized that less wealthy and less educated people as well as those with a migration background are more likely to live in areas with higher air pollution exposure.

1.2. Design of the Thesis

The introduction contains a brief description of the actual Environmental Justice (EJ) paradigm focusing on the importance of further environmental inequality research in Austria. Following from that, the research question and associated hypothesis are defined. *Chapter 2* discussed the differences as well as similarities of the EJ conceptual framework, EJ historical evolution, EJ methods and EJ outcomes in the US and in the European context. Furthermore, *chapter 2* highlights the state of the art of environmental inequality research caused by air pollution. In *chapter 3,* the research of this master thesis is contextualized in the actual Environmental Justice Framework. Additionally, the evolution of EJ spatial methods analysing the burden of air pollution are described. Thereby, the method using spatial distribution of air pollution, assessed via dispersion models, which was applied in this master thesis are highlighted. *Chapter 3* also describes the spatially explicit data used to examine the distribution of environmental burden in Styria. To analyse this distribution first the datasets of air pollutants, socio-economic characteristics have to be georeferenced. In the next step, a comprehensive description of the statistical and spatial analysis is provided. Before outlining the findings of research in *chapter 5* relevant indicators of Styria are shown in *chapter 4.* Thereby, hotspots of environmental exposure and features of social susceptibility are specified. In *chapter 5,* the associations between income and air pollution, education and air pollution and migration background and air pollution are elucidated to find evidence of environmental inequality in Styria. In *chapter 6,* the findings are discussed by relating them to outcomes of recent EJ research dealing with the burden of air pollution exposure. Those study were conducted in the US and in the European context by analysing the spatial distribution of modelled air pollution. The findings of this research are contextualized with the current situation in Styria to delineate possible explanations of the found evidence of environmental inequalities. In this thesis a rather new methodological approach to assess environmental inequalities was applied and *chapter 6* discusses the strengths and limitations of this method. *Chapter 7* contains the conclusion in which the key points of this thesis and an outlook for potential EJ research in Austria are highlighted.

2. The Environmental Justice Framework

In general terms Environmental Justice refers to a simultaneous involvement of social and environmental dimensions (de Schutter et al. 2017). Since the founding of the term in the 1980s several EJ concepts emphasize different aspects. The Environmental Protection Agency (EPA) of the US federal government introduces the following definition:

"Environmental Justice is the fair treatment and meaningful involvement of all people regardless of race, colour, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies. EPA has this goal for all communities and persons across this nation. It will be achieved when everyone enjoys the same degree of protection from environmental and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn and work." (EPA 2017)

This definition on one hand emphasizes the distribution of environmental goods and environmental bads among different social groups and the fairness or equity of this distribution and is known in the EJ context as distributional justice (Laurent 2010). On the other hand it highlights the fairness of access to environmental decision making processes known in the EJ context as procedural justice (Schlosberg 2009). From the onset, distributional and procedural justice have been present in the work of most researchers defining EJ but there has been a call from some scholars to widen the EJ approach (Glatter-GERO_ITEM . Agyeman and Evans (2004) are one example as they widened the EJ approach by introducing the term "Just Sustainability". This term links EJ to the sustainability discourse, as it includes a broader concern about environmental quality and human equality at all scales. Just Sustainability is not only about distributing environmental risks equally but also about preventing their emergence in the first place. Agyeman demands the integration of EJ into sustainable development policy at international level. (Agyeman and Evans 2004) This thesis adds on this perspective by acknowledging that the Sustainable Development Goals by the United Nations have implicitly included the principles of EJ as they aim for a healthy life and well-being for all. To this end targets are set for a substantial reduction of the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination till the year 2030 and the reduction of inequality in more general terms. Additionally, the goals of equal access to clean water and sanitation, clean energy and sufficient food amongst others refer strongly to the EJ discourse (Inter-Agency and Expert Group on SDG Indicators 2016).

Especially, in the European context there has been a reflection about the theoretical framing of EJ. It has been stated that the theoretical framing of EJ is problematic as the question of justice strongly depends on the dominating social and political normative value system (Siedl 2016). Till now, there is neither scientific work nor government documents, which define the meaning of just distribution of the environmental goods and bads in practical terms (Siedl

2016). Therefore, the current definition of the term EJ involves the danger to be used by various disciplines, politicians and citizen who interpret the term of justice according to their own values and convictions (Been 1993).

To solve this problem recent research uses the term of EJ as theoretical framing to determine how things ought to be (de Schutter et al. 2017). EJ in this master thesis is defined as

"a process towards a healthy living environment where all stakeholders participate and learn about the mechanisms and structures that produce social differentiation in environmental terms, and develop and adopt social-ecological responses that enhance the fulfilment of fundamental needs within, and take responsibility for environmental limits." (de Schutter et al. 2017)

In order to promote this EJ process the term of environmental inequality is used to describe how things are. Environmental inequality refers to the unequal distribution of environmental risks and hazards, access to environmental goods and services among societal groups. It is closely connected to growing social inequalities in income, wealth, living conditions and access to public institutions and can be measured and described empirically (de Schutter et al. 2017).

Additionally, public health research identifies the exposure to environmental pollution as a major contribution factor as it produces health inequalities (de Schutter et al. 2017). Recent research indicates that low socio-economic status exacerbates the health effects of exposure to environmental pollution in some cases, by making those exposed more susceptible to environmental factors (Briggs, Abellan, and Fecht 2008) . This susceptibility to environmental exposure results by for example the lack of money to afford proper housing. In addition, low-socio-economic status is often closely connected to the lack of access (Landrigan et al. 2017). Especially, the lack of access to education, health care, sanitation services and access to participation in legal and political processes solidifies social and environmental inequalities (Landrigan et al. 2017).

2.1. Differences and similarities: Environmental Justice in the US and in Europe

In 1980, powered by structural inequalities in the US, a national EJ movement evolved from the black civil rights movement (Martinez-Alier et al. 2014). The claim for EJ was driven by various protests from civil-society against the disproportionate incidence of environmental pollution in predominantly Black, Hispanic or Indigenous communities (Martinez-Alier et al. 2014). Till then hundreds of scientific reports indicate that people of colour and low-income population do suffer from greater environmental harm than white and well-off communities (Bullard 1990; Bryant and Mohai 1992; Lerner 2010). The claim for EJ was answered by the US-government in 1994 and EJ now can be considered as a part of federal regulatory authority duties, such as the Environmental Protection Agency (Davies 2006).

Two decades later, the European debate on EJ or furthermore the crossing of environmental and social perspectives is still at its beginning. There are some differences with regards to the inclusion of the civil-society, political framing and research practices in the US and in the European context. As already mentioned, the origin of EJ in the US was forced by activists who were not environmental professionals, but every-day individuals from the communities experiencing environmental degradation (Davies 2006) often fighting through non-violent opposition for their rights. In Europe the early beginning of EJ was framed in an institutional context. In 1998, during the Aarhus Convention the first draft was implemented ensuring the access to information on environmental status, public participation in environmental decision making processes and justice in environmental matters (Laurent 2010), making EJ an European issue. In Europe, in the 1990s, the professional non-profit organisation Friends of the Earth campaigned for EJ by promoting an EJ agenda (Walker 2012). This agenda was developed in close cooperation with the scientific community (Walker 2012). This social composition of driving forces leads to a paradox. Whereas in the US context EJ arguments allow campaigners to strategically slide between the scale of everyday experience and the scale of environmental justice as a central part of federal regulatory authority, there is a lack of public connection to the term EJ in the European context (Davies 2006). The term justice is not expected to be commonly used and understood in European civil-society campaigning despite the fact that certain concepts are used that could be located within an expansive interpretation of EJ (Davies 2006). So the promotion of EJ in the civil society and it´s concepts gaining prominence in policy documents are in Europe rather driven by environmental degradation in combination with well-organised environmental groups (Davies 2006) as opposed to the civil society fighting for their rights. However, arguments were proposed that adopting the language of EJ can 'scale-up' the political voice of campaigners. It addresses the constituencies beyond the immediate geographic vicinity and connects similar campaigns across the globe as well as it establishes a connection to national and internationally organised networks (Towers 2000).

It is assumed that the divergences of US and European EJ civil-society inclusion bases on more general differences (Laurent 2011). The underlying philosophies of public policy in the US, which determines the strategies identifying EJ, traditionally recognizes the universality of natural rights granted to individuals and aims at curbing discriminations faced by them in exercising these rights whereas the continental European countries focus on correcting the social processes that produce situations of inequalities (Laurent 2011).

In both world regions, the emergence of EJ stimulated in-depth empirical investigation of the relationship between the location of environmentally polluting activities and marginalised communities (Laurent 2010). In the US, initially there were reports of strong relationships between racial and economic status and proximity to waste facilities (Laurent 2010). In the past several decades a considerable number of quantitative analyses has been conducted that demonstrates the existence of racial and socioeconomic disparities in the distribution of a wide variety of environmental hazards (Mohai and Saha 2015). But this long research tradition does not imply that EJ matters have been solved yet, as more recent research still resembles the initial findings (Mohai and Saha 2007). The first European surveys followed the US research framework questioning the distributional and procedural dimensions of EJ by asking if polluting industrial facilities reveal social biases in siting patterns (Walker 2012). Ever since, research practice differs in spatial scales, ranging from local, to national, to EU and to a more global level (de Schutter et al. 2017). The main share of research was assembled on a local, often urban, scale (de Schutter et al. 2017). Findings indicate that urbanisation, as it leads to hotspots of high population numbers and coupled environmental burden, is a main driver for areas of ´double blessing´ where people with high social economic status (SES) enjoy high quality environment or ´double burden´ where vulnerable groups are confronted with poor environment (de Schutter et al. 2017). Contemporary research assesses different environmental dimensions. Thereby, the impact of air pollution, noise pollution, quality of the living environment, of climate change and natural hazard risk are questioned (de Schutter et al. 2017). The outcomes show that the UK, Germany, the Netherland, France, Italy and the Czech Republic are affected by multiple environmental inequalities (de Schutter et al. 2017). These environmental inequalities are associated to growing social inequalities, for example in income, wealth, housing, and access to public amenities (de Schutter et al. 2017).

The investigated social groups do differ between US and Europe. European research highlights more the social conditions producing injustices, whereas North-Americans insist on the racial dimension of discriminations and the exclusion from decision-making process (Laurent 2010). But that does not mean that European findings of environmental injustice do not have any racial dimensions (de Schutter et al. 2017).

In contrast to research in the US, the results of European studies show inconsistent patterns (Padilla et al. 2014). It is not possible, even though there is strong evidence, to generalize patterns of environmental inequality in Europe. So, more research is needed to understand the underlying mechanisms.

2.2. Environmental inequality caused by air pollution

The currently prevalent, linear, to-make-use-dispose economic paradigm can be identified as main driver of an increasing ambient air, soil, and chemical pollution (Landrigan et al. 2017). Even though there are still gaps in knowledge about the health impact though pollution, air pollution is attributed to heart diseases and strokes and is in Europe the most common reason for premature death followed by lung diseases and lung cancer (European Environment Agency 2017). The WHO defines air pollution as

"contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide. Outdoor and indoor air pollution cause respiratory and other diseases, which can be fatal" (WHO 2018a).

Recent EJ research indicates that exposure to pollutants can lead to injustice and inequality in all countries regardless of income level. Especially, poor and marginalised groups are exposed disproportionately to air pollution and air pollution-related diseases. To understand this complex relationship of environmental inequality, it is important to note that poverty does not only mean the lack of money but furthermore it includes the lack of access. Especially, access to education, health care, sanitation services and access to participation in legal and political processes. (Landrigan et al. 2017)

In the US and in Europe, air pollution is acknowledged as priority environmental risk (Clark, Millet, and Marshall 2014; Landrigan et al. 2017). North-American EJ studies that deal with the social distribution of air pollution exposure differ in spatial scale, pollutants of interest, geographic location, and methodology implemented. The general findings show patterns in which disadvantaged communities experience a higher burden of air pollution than more privileged (Gray, Edwards, and Miranda 2013). In the European context environmental inequality caused by air pollution is the most frequently examined environmental dimension in EJ research but the outcomes show mixed results (de Schutter et al. 2017) which will be discussed in the following.

On the macro level Richardson et al. (2013) explored EU-wide unequal exposure of potential health-damaging levels of particular matter (PM_{10}). The findings show mixed results in Eastern and Western Europe. In Eastern Europe the lowest income regions are predominantly exposed to the highest PM_{10} levels whereas in Western Europe high income areas are likewise exposed to high PM_{10} levels. Areas with intermediate income levels experience the lowest exposure to air pollution in the EU-wide context (Richardson et al. 2013). Richardson et al. (2013) conclude that there is evidence of environmental inequalities in Eastern Europe, but not in Western Europe.

At the meso-level, the UK is leading in nation- wide environmental inequality research related to air pollution, followed by France, the Netherlands, Germany, Czech Republic, Italy, Austria and Switzerland (de Schutter et al. 2017). In 2003 Mitchell and Dorling published the first nation-wide study exploring the connection between nitrogen dioxide (NO_2) exposure and demographic census data at ward level in England, Wales and Scotland. Their findings show that the poorest communities in the UK are the most NO_2 exposed ones, whereby they do emit the least (Mitchell and Dorling 2003). It is suggested that there are different patterns of environmental exposure in urban and rural areas. In general, EJ research indicates that air pollution levels in urban areas are higher than in rural areas (de Schutter et al. 2017). Wheeler and Ben-Shlomo (2005) suggest that the conception of rural areas is not uniform, since rural households consist of either wealthier commuter population living next to conurbation and main roads or poorer population in more remote areas. Both relations do not provoke double burden or double blessing in rural areas. Evidence of environmental inequalities in urban areas is more controversy. On one hand Wheeler and Ben-Shlomo (2005) show that in urban areas lower social class households are the most affected social group. On the other hand Richardson et al. (2013) show that in urban centres high income areas are likewise highly polluted. Looking for an explanation of high air pollution exposure in high income areas Fecht et al. (2015) suggest that gentrification of inner city areas could be decisive. It is assumed that people of high social classes tend to tolerate high levels of air pollution in order to enjoy a multitude of benefits associated with inner city living (Fecht et al. 2015). Urban centres are social conurbations where affluent and poor people live close to each other. It is suggested that more affluent households live for example in rear buildings affected by high air pollution exposure and low-income households live in the front-facing building being even higher affected by air pollution exposure as traffic is directly passing by. Additionally, there are differences between low-income, marginalised groups and more affluent people in the access to coping strategies . It is hypothesized that more affluent people affected by high air pollution exposure can protect themselves better by, for example, investing in improved housing conditions. It is assumed that they have better access to education or health care and sanitation services to learn about the risks of air pollution or to keep track on their health conditions. Additionally, they can participate in legal and political processes to improve their living conditions. Whereby, low-income groups are more susceptible by environmental exposure by the lack of these coping strategies. These divergent outcomes in urban centres are again documented in a study comparing on a neighbourhood scale the exposure to PM_{10} and NO_2 and population characteristics at a national, regional and city level in England and the Netherlands (Fecht et al. 2015). In France a study investigating the spatial and temporal relationship between ambient NO_2 concentrations and socioeconomic data in four French metropolitan areas during two different time periods likewise found mixed results (Padilla et al. 2014).

The comparison of environmental inequality through the same methods and scale between England and Netherland, as it was done by Fecht et al 2015, in both countries revealed links between air pollution and deprivation as well as links between air pollution and ethnic minorities. In particular, the exposure to NO_2 differs in England and the Netherlands. The percentage of children and elderly exposed to NO_2 in Dutch cities is much lower than in US cities. This brings in another aspect of environmental inequality in the European context. Both countries are of comparable wealth, but historically their political systems differ. England is known for its market oriented and libertarian approach, whereby the social structure in the Netherlands is more egalitarian (Fecht et al. 2015). It is assumed that the Netherlands egalitarian approach by fighting inequality lead to lower exposure levels of children and elderly than in England. Environmental inequalities affecting elderly and children in England are explained by today´s housing stock which bases on the still present traditional class system (Fecht et al. 2015).

At the micro-level the UK, Germany, France, Italy, Spain, the Czech Republic and Sweden carried out research in urban areas with heterogeneous results (de Schutter u. a. 2017).

In general, there has been only little research addressing EJ in Austria (de Schutter et al. 2017). In 2008, in the Austrian cities Graz, Villach, Vienna, St. Pölten and Klagenfurt a study commissioned by the Austrian Federal Environmental Agency measured the impact of indoor air pollution on the health of kids in all-day schools (Hohenblum et al. 2008). The outcomes indicate a demand for action by improving the ambient air quality, by for example a reduced-traffic area around the schools (Hohenblum et al. 2008).

The first research addressing EJ caused by air pollution was conducted in a master thesis of the Institute of Social Ecology in Vienna targeting the question “Environmental Justice: How equally is the pollution burden spread in Austria?” (Glatter-Götz 2016). It was the first study in Austria that examined the patterns of the unequal distribution of pollution around industrial facilities by applying the distance-based approach. Around all industrial facilities in Austria, which were registered in the E-PRTR Register in 2013, 1km and 3km buffers were drawn, to analyse the socio-economic composition inside these buffers compared to areas beyond. The outcomes were mixed. Whereas in Vienna there was no evidence for environmental inequality in the remaining parts of Austria people who live close by industrial facilities are more often unemployed, have lower education levels and are twice as likely to be migrants (Glatter-Götz 2016).

3. Methods and Data

3.1. The Environmental Justice Framework

As the EJ conceptualization becomes more diverse, the approaches to evaluate environmental inequality became likewise more heterogenic. In response to this growing complexity of matter de Schutter et al. (2017) developed an EJ framework to provide a standardized tool for stakeholders seeking to reveal environmental exposure and its social impacts to make environmental regulations and social practices more sensitive to human needs:

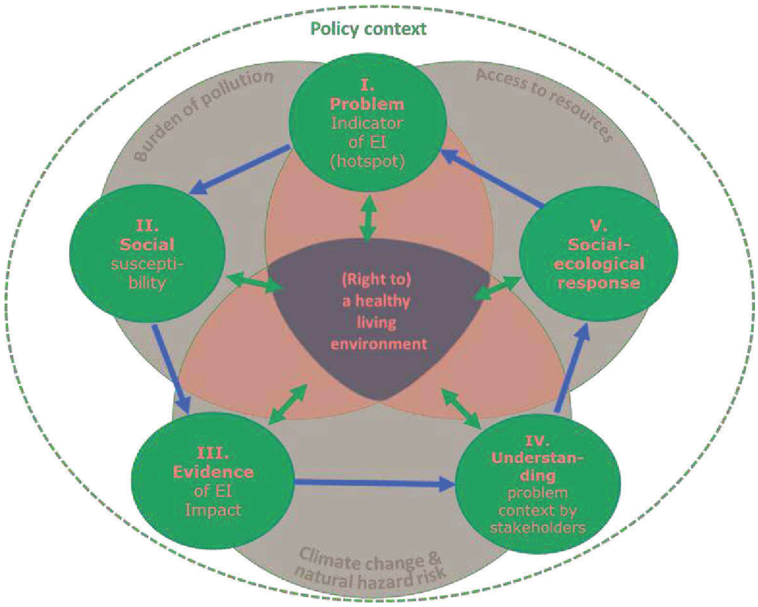

Figure 1 Environmental Justice Framework (de Schutter et al.)

In order to aim the EJ process towards a healthy living environment where all stakeholders participate and learn about the mechanisms and structures that produce social differentiation in environmental terms (de Schutter et al. 2017), the first step of the EJ framework, as shown in **Figure 1**, suggests a **problem indication.** Thereby, **hotspots of environmental exposure** in the explicit living environment are identified. Hotspots of environmental exposure are traditional assessed by air pollution hazards emitted by industrial facilities (Mohai and Saha 2006). More recent, EJ researchers evaluate hotspots of environmental exposure though the spatially dispersion of modelled air pollution data (de Schutter et al. 2017). In the second step, **features of social susceptibility** are assessed. Social susceptibility is measured by for example, the socio-economic status, as education, migration, and quality of the living environment (de Schutter et al. 2017). Especially, the relation between exposure and health are crucial by dealing with social susceptibility (de Schutter et al. 2017). Step one and two together combines to the **burden of pollution.** Thereby, a statistical juxtaposition of environmental hotspots to features of social susceptibility is conducted to find weather double burden or double blessing. Are those burden and blessing not equally shared in society step three, **evidence of environmental inequality,** is accomplished. Step four promotes an **understanding** of the circumstances leading to those environmental inequalities. The stakeholders are charged to find causal relations leading to environmental inequality so they can take up their responsibilities. Finally, step five includes the social-ecological responses. This step is accomplished when drivers of environmental inequalities are sufficiently understood and acknowledged so stakeholders can take up their **responsibilities** by identifying creative solutions. (de Schutter et al. 2017)

3.2. Spatial Methods

Spatial methods developed by the first EJ scientific researchers build the core of EJ methodology (Glatter-Götz 2016). Until now, the most frequently employed methodology is the assessment of the proximity of hazardous sites to nearby populations by applying the unit-hazard coincidence method (Mohai and Saha 2007). This approach involves the selection of pre-defined geographic units determining which subset of the units is coincident with the hazard referring to as host units and which isn't referring to as non-host units, and then comparing the demographic characteristics of the two sets (Mohai and Saha 2007). Implicit in this approach are two assumptions: First, that the adverse impacts tend to be concentrated within close proximity of the hazards, and second, that populations living within the host units are located closer to the hazard under investigation than populations living in the non-host units (Mohai and Saha 2007). As the EJ researchers Mohai and Saha hypothesize these assumptions are not always true (Mohai and Saha 2006). Thereupon, Mohai and Saha (2007) introduced the distance-based methods, such as the 50% areal containment and areal apportionment methods. Thereby, the precise geographic locations of hazardous sites are taken into account by drawing circular buffer zones around them. Then the socio-economic characteristics are allocated to these buffer zones. In order to find any differences of the socio-economic distribution the characteristics inside the buffer zones are compared to the characteristics outside the buffer zones. (Mohai and Saha 2006)

More recent there is a growing body of EJ research assessing environmental inequality caused by air pollution through small scale dispersion assessments (Hajat, Hsia, and OCSL_CITATION. These publications involve collected data about the volumes and toxicities of various air emissions, timing of emission releases, stack heights, wind directions and speeds, and other factors to estimate geographic dispersion and deposition models. Socioeconomic characteristics are allocated to those modelled air pollution data in order to determine those who are most likely to live where pollution and toxicity levels are concentrated. (Mohai and Saha 2007) The application of air pollution dispersion models overcomes the simplified assumption of the unit-hazard coincidence and the distance-based method that air pollution is evenly distributed around emitting facilities. Furthermore, the analysis is not limited to point sources of emissions but can also depict diffuse sources such as traffic (Glatter-Götz 2016).

As this master thesis questions the burden of modelled air pollution in Styria, the Environmental Justice Framework (**Figure 1**) is applied in order to find evidence of environmental inequality. On that account modelled air pollution data, assessed by small-scale dispersion models, are juxtaposed to spatial social-economic and social-demographic characteristics.

3.3. Data

Two types of spatial data are needed to examine air pollution burden in Styria: modelled air pollution data, respectively ambient particular matter (PM_{10}) and nitrogen dioxide (NO_2) and data concerning socio-economic characteristics, respectively income, education and migration background.

3.3.1. Air pollution data

Till now, Styria is the only federal state in Austria measuring ambient air pollution and calculating dispersion models on a small scale. No other Austrian state provides area wide dispersion models on such a small scale.

The first data set concerning air pollution contains the annual average of particular matter (PM_{10}) in $\mu g/m^3$ computed and shown in a dispersion model on a 10*10m grid unit in 2010 for total Styria. This data set was provided for free by Mag. Ingrid Payer and Mag. Dr. Dietmar Öttl working in ABT 15 Energy, Housing, Technic department of air quality monitoring in Styria.

PM_{10} are dust fractions consisting of 50% particles with a diameter of 10 µm. Therefore, they are not visible to the naked eye. From a health perspective this small size is very dangerous as these particles can pass the larynx and get deep into the lungs to do serious damage (Umweltbundesamt 2017a).

The second data set concerning air pollution in Styria contains the annual average of nitrogen dioxide (NO_2) in µg/m^3, likewise particular matter, computed and shown in a dispersion model on a 10*10m grid unit in 2010. This data likewise was provided for free by Mag. Ingrid Payer and Mag. Dr. Dietmar Öttl. NO_2 is mainly a product of traffic, as it emerges as a by-product of combustion processes. NO_2 puts exposed people in danger as it reduces the lung functions and is co-responsible for acidification and eutrophication of soils and water bodies (Umweltbundesamt 2017b).

3.3.2. Income

The second type of data applied in this study, was taken from the integrated income and wage statistic 2010, of the Austrian Statistical Office. It gives itemized information about the total income of the Styrian residents. The income is calculated through income tax, wage tax, employee assessment and transfer payment data. The income was calculated by (Statistik Austria 2017):

Income (profit/loss) from agriculture and forestry

+ Income (profit/loss) from self-employment

+ Income (profit/loss) from business

+ adapted gross remuneration from dependent work

+ Income (profit/loss) from capital assets

+ Income (profit/loss) from renting and leasing

+ Income (profit/loss) from other income

+ sum of transfer payments

The sum of transfer payments includes all payments reported by the Federal Ministry of Finance or payments managed by the Austrian Federal Computing Centre GmbH on behalf of the Ministry. So the sum of transfer payments is calculated by

Unemployment benefits

+ calamity assistance

+ family aid

+ sickness benefits and benefits during the period of maternity protection

+ payments according to the Austrian Insolvency Payments Act

+ other aids

There are some limitations with regards to the integrated income and wage statistics. The sum of transfer payments does not included child-care money, needs-based minimum benefits, residential and study grants and all aids paid by the Austrian federal states. In terms of total income, it is important to note that calculating income taxes the income from agriculture and forestry and income from capital assets is disproportionately underrepresented. This is because the generalization of small farmers and final taxation through the capital gains tax have not been reported in the income tax declarations (Statistik Austria 2017). The integrated income and wage statistic is usually not available on a spatial scale. As the spatial scale is crucial for this assessment, the Austrian Statistical Office provided 250m, 500m and 1000m regional statistical grid units for total Styria by assigning the income data to ZIP codes. As there are strict data protections rules for providing data in spatial units, the threshold for reporting associated numbers are a minimum of four residents within a regional grid unit.

3.3.3. Education and migration background

To be able to describe environmental inequalities from a perspective other than income the characteristics education and migration background, are introduced. The datasets were taken from the Austrian census of 2011, as they are not available in the year of 2010. It is assumed that within one year there was no fundamental change with regards to education and migration background spatial distribution. Both characteristics were provided in 250m*250m regional grid units for the entire federal state of Styria. In contrast to the data set of the integrated income and wage statistic, where every grid unit contains information of the annual average income per capita, those datasets include information about the quantity of residents counted for every characterization inside every grid unit. Again, the strict data protections rules of the Austrian Statistical Office come into importance as the threshold for reporting associated numbers are a minimum of four residents within a regional grid unit.

The data set of education reports the quantity of the highest educational attainment for Styrian residents older than 15 years in every regional grid unit in Styria. As the categories of highest educational attainment are very detailed and these details do not give any further information about inequalities related to education the categories were summarized into four categories according to Vogtenhuber et al. (2016):

1. Compulsory school
2. Apprenticeship
3. Secondary and upper secondary school (Vocational school/Grammar School/ Vocational school with higher educational qualification/College)
4. Institution of higher education (Institution of higher education other than university/ University)

In 2015 the United Nations Economic Commission for Europe (UNECE) defines the term of migration background in their “Recommendation for the 2020 censuses of population and housing” as following: First, all residents born in an foreign country are defined as migrants of the first generation. Second, the children of first generation migrants born in the immigrated country are defined as migrants of the second generation (United Nations Economic Comission for Europe 2015). The data set to assess migration backgrounds in Styria counts the quantity of residents’ according to their birth-country for every regional grid unit. As second generation migrant’s data is not available at the Austrian Statistical Office, the migration background of Styrian residents is only assessed for first generation migrants. In this research the countries of birth are distinguished according their socio-economic status (SES) as it is shown in **Table 1**. It is anticipated that Styrian residents immigrated from countries with low SES are more exposed to discrimination than residents emigrated from counties with high SES.

Table 1 Characteristics of the variable "place of birth divided in low SES birth-countries and high SES birth-countries

Birthplace with low SES	Birthplace with high SES
EU- States (2) includes the states of Rumania and Bulgaria accessioned in 2007	Austria
Former Yugoslavia (without Slovenia)	EU- States (14) includes all 15 EU-States accessioned till 2004 without Austria
Turkey	EU- States (10) includes all EU states accessions till 2006
Asia (without Turkey and Cyprus)	EWR, Swiss, associated small states
Africa	Any other European State
Latin-America	North-America
Stateless	Oceania

3.3.4. Georeferencing

As the research question focuses on inequalities assessed by the spatial distribution of air pollution and social economic and social demographic characteristics all data sets were organized in the regional statistical grid units provided by the Austrian Statistical Office.

As the data sets were provided in different scales a decision on the grid unit size was made. For this purpose, the modified areal unit problem (MAUP) was during spatial analysis considered. MAUP takes into account that different aggregation schemes results in different outcomes (ESRI 2018). As it is demanded to keep the spatial resolution as low as possible to prevent ecological fallacies and a small grid unit sizes enables a better differentiation of polluted areas, the 250m*250m regional grid unit size of the Austrian Statistical Office was chosen.

ArcGIS (Geostatistical Analyst) was used to organize all data sets in a 250m*250m regional grid unit size. Therefore, applying the ArcGIS command Zonal Statistic as Table united the raster attribute table of “PM10 annual average concentration“ and ”NO_2 annual average concentration” and “integrated income and wage statistic”. The resulting tables ordered along the 250m regional statistical grid units were imported into MS Excel. All grid units with missing values were deleted in order to gain a coherent data set. Per command =VLOOKUP the dataset was enriched by the data sets “Residents by birth country” and “Residents by highest educational attainment”.

3.4. Analysis of the data

In order to determine how equally air pollution exposure is distributed among different social groups, spatial socio-economic characteristics of the Styrian residents were allocated to the spatial distribution of air pollution.

Following the EJ framework of Schutter et al. (2017), the first objective was to assess the burden of pollution for every regional grid unit. With ArcGIS an outline map was created to visualize the living environment in Styria. The attributes of this outline map are the topography, the location and the proportional population size of the city Graz and all Styrian towns and all main roads, respectively federal highways, the speedway and the Freeways A2 and A9. In the next step, a descriptive analysis of the air pollution data was conducted. Then with ArcGIS two different kinds of maps were created to elucidate hotspots of air pollution. The approach of mapping air pollution data has the advantage that air pollution hotspots can be assigned to specific regional grid units. The first kind of maps visualizes the continuous dispersion of average annual PM_{10} and NO_2 pollution in Styria. The second kind of maps shows regional grid units where critical levels of air pollutants are measured. In order to create this map, the annual average of NO_2 and PM_{10} exposure was each divided into two groups “non-critical exposure” and “critical exposure” according to the “WHO Air quality guideline” (WHO, 2018b):

Table 2 Annual average PM_{10} and NO_2 exposure divided in "non-critical exposure" and "critical exposure" according to the WHO scheme (WHO 2018b)

	PM_{10}	NO_2
“non-critical exposure”	annual average < 20 µg/m^3	annual average < 40 µg/m^3
“critical exposure”	annual average > = 20 µg/m^3	Annual average > = 40 µg/m^3

The term of “critical exposure” with regards to PM_{10} is attributable to the quantitative relationship between high concentration to PM_{10} exposure and an increased mortality or morbidity (WHO, 2018b). The term “critical exposure” bases on the findings of several epidemiological studies that link symptoms of bronchitis as well as reduced lung function to high NO_2 exposure (WHO, 2018b). Since the introduction of the WHO air pollution guidelines the evidence base for adverse health effects by air pollutants has become broader (WHO 2018b). As a consequence, the WHO started to work towards an update of the Global Air Quality Guidelines. As the updated guidelines had not been published while writing this thesis the current threshold levels are used.

The second aspect to evaluate the burden of pollution is the assessment of social susceptible areas in Styria. The assessment was carried out by a descriptive analysis of the categories income, highest educational attainment and place of birth as described in *chapter 3*.

Recent findings of EJ research indicate that urbanization, leading to hotspots of high population numbers coupled with environmental burden, is a main driver of environmental inequalities (de Schutter et al. 2017). To take this into account a classification of the degrees of urbanization according to the scheme of the European Commission (Eurostat Statistic Explained 2018) was implemented for Styria. The grid units of “Integrated income and wage statistic" and "highest educational attainment" were respectively separated according to the following scheme:

Table 3 Classification of urbanization by Eurostat applied in the data set of the "integrated and wage statistic" in Styria

Degree of Urbanization	Inhabitants per 1*1 km grid units (Eurostat Statistic Explained 2018)	Inhabitants per 250*250 m regional grid unit in Styria
Thinly populated grid units	< 300	< 19
Intermediate populated grid units	Between 300– 1 500	Between 19 - 94
High populated grid units	> 1 500	>94

The result was mapped with ArcGIS. In the following, thinly populated grid units are referred to as rural areas, intermediate populated grid units including towns and suburbs are referred to as suburban areas, whereby high-populated grid units are referred to urban centres.

In order to detect social susceptible areas within Styria the distribution of income was elucidated by a spatial analysis. Thereby, the distribution of three income groups separated into terciles ranging from low to medium to high income was mapped with ArcGIS.

As a final step, the air pollution data and the social-economic and social demographic data were juxtaposed to find double burden or double blessing and evidence of environmental inequality:

To elucidate the association between the burdens of air pollution by different income groups the two metrics of mean PM_{10} and NO_2 exposure were plotted against the deciles of the annual average income. Then the decile graphs were divided according the degrees of urbanization. These graphs were analysed in order to find ´double blessings´ where people with high average annual income enjoy good air quality or ´double burden´ where people with low annual average income are confronted with poor air quality. The statistical significance between the average air pollution levels and the decile income groups was tested with the Spearman´s rank correlation coefficient, which is an adequate measurement for continuous and discrete ordinal variables.

To elucidate any differences of the burden of air pollution in relation to education the spatial characteristics of the highest educational attainments of the Styrian residents were juxtaposed to the spatial exposure levels of air pollutants. Thereby, the air pollution levels were separated in "non-critical exposure" if they did not exceed the WHO threshold levels and "critical exposure" if they exceeded the WHO threshold levels.

To elucidate any differences of the burden of air pollution in relation to migration background the spatial characteristics of birthplace were juxtaposed with the spatial exposure levels of air pollutants. As already mentioned in *chapter 3.3.3* the birthplaces were separated in countries with low SES and countries with high SES. Again, the air pollutants were separated in the categories “non-critical exposure” and “critical exposure” according to the WHO threshold levels.

All steps where accomplished by the usage of MS Excel, IMB SPSS Statistics and ArcGIS.

4. Relevant indicators of Styria

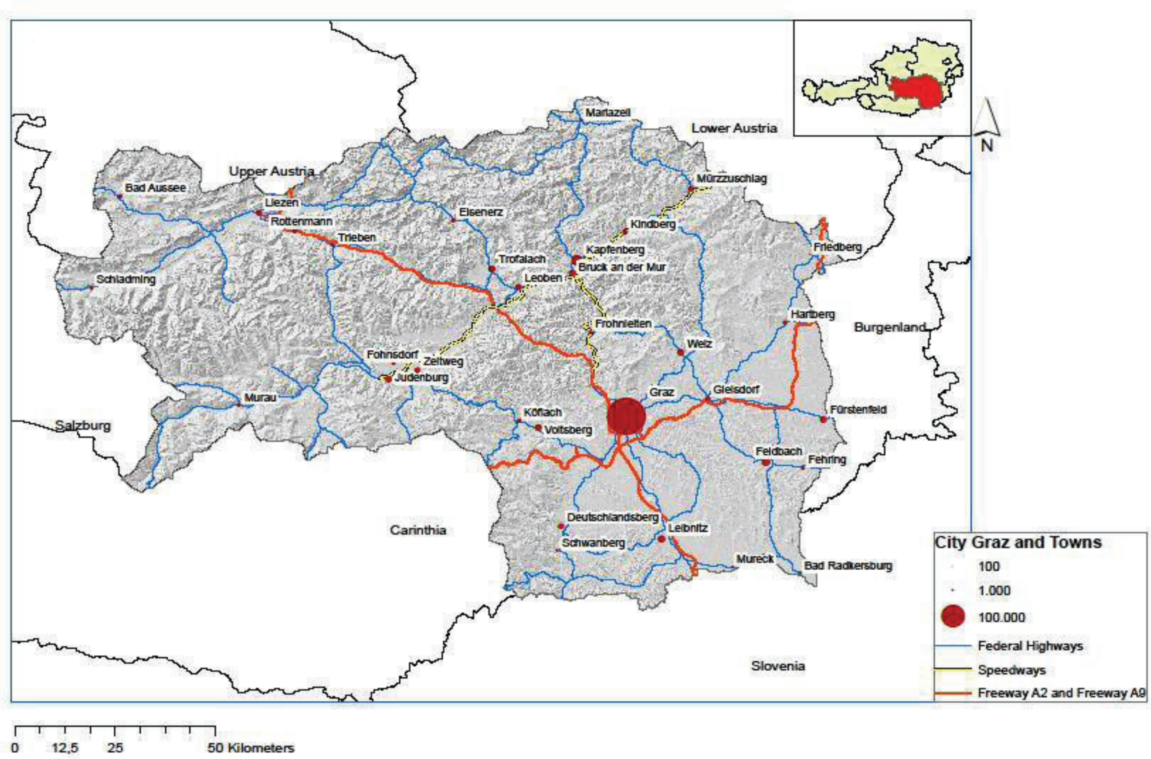

Figure 2 Outline map of Styria: Showing the topography, the location, the proportional population size of Graz and towns and main roads, respectively federal highways, speedways and freeway

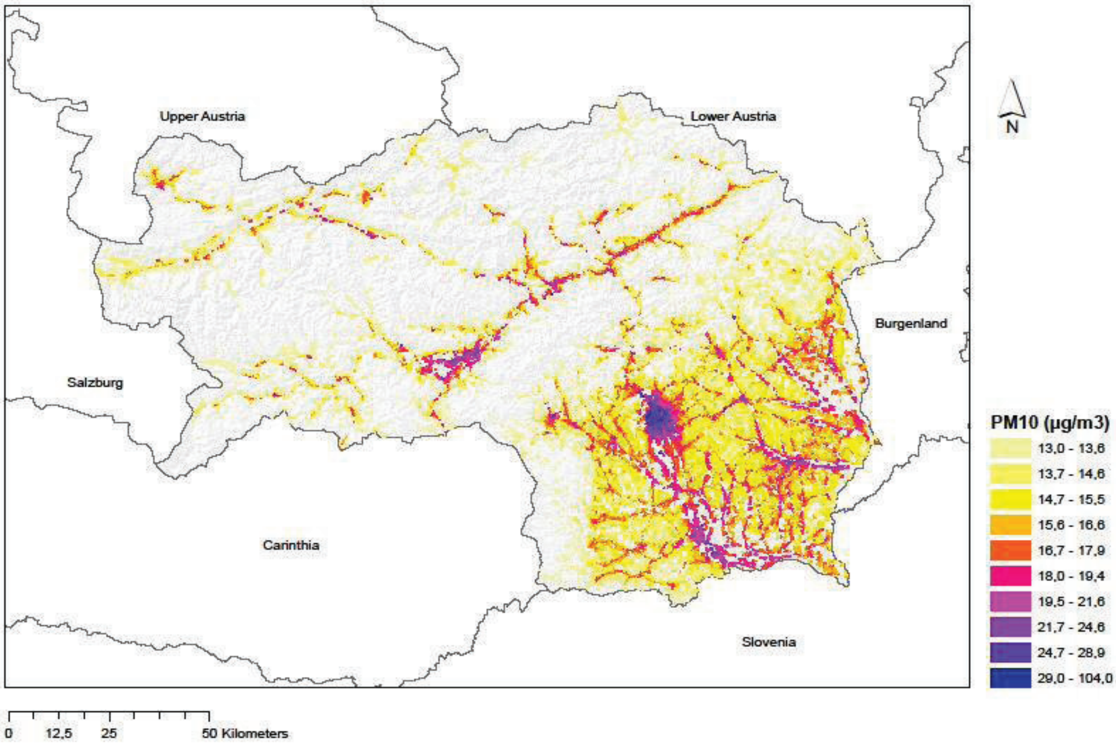

Figure 3 Hotspots of environmental exposure in Styria: Map of annual average PM_{10} dispersion in µg/m^3 divided in deciles by natural breaks

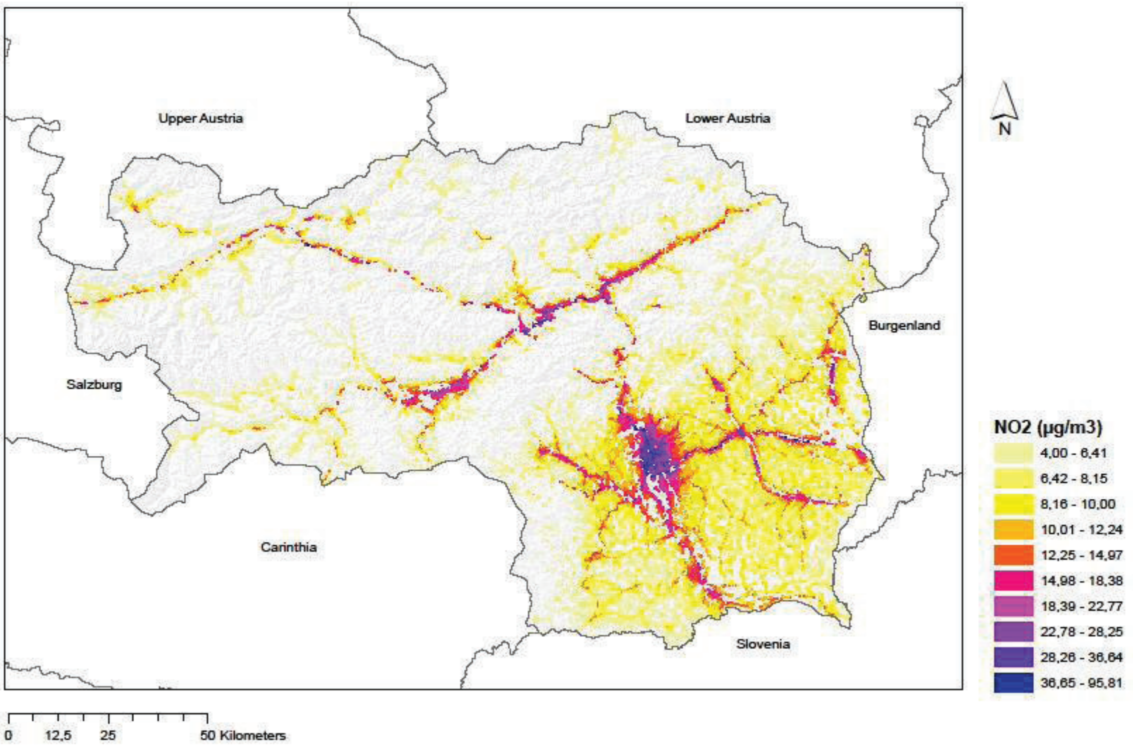

Figure 4 Hotspots of environmental exposure in Styria: Map of annual average NO_2 dispersion in µg/m^3 divided in deciles by natural breaks

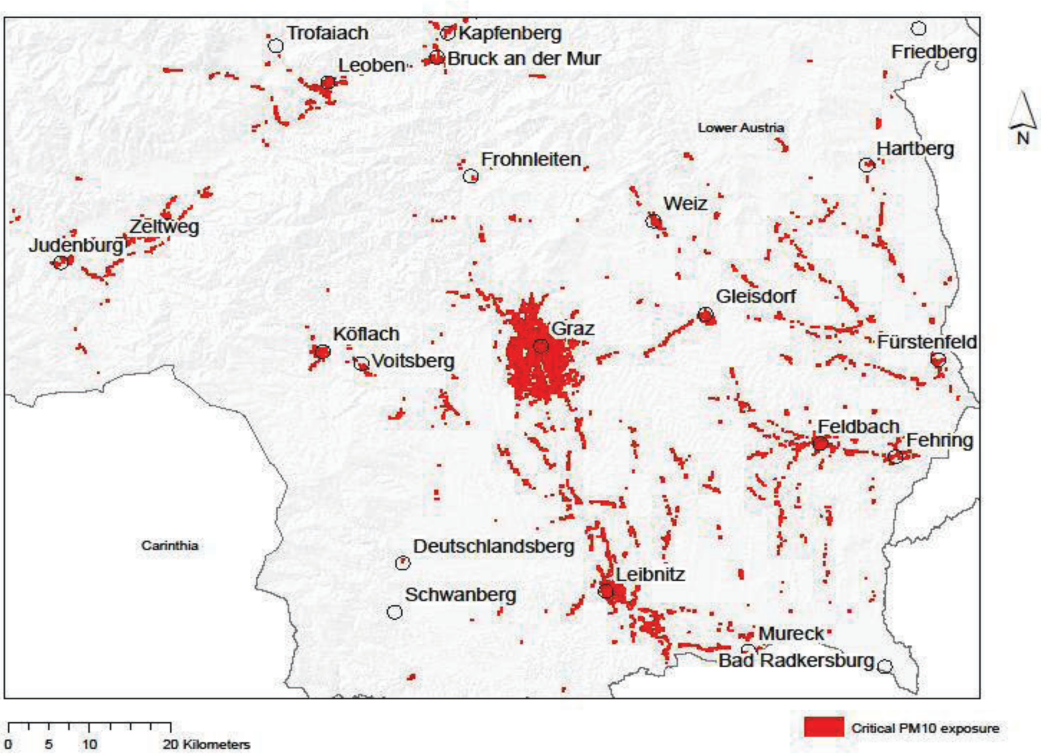

Figure 5 Hotspots of environmental exposure in Styria: Map of critical annual average PM_{10} exposure higher than 20 µg/m^3 (threshold: WHO 2018b)

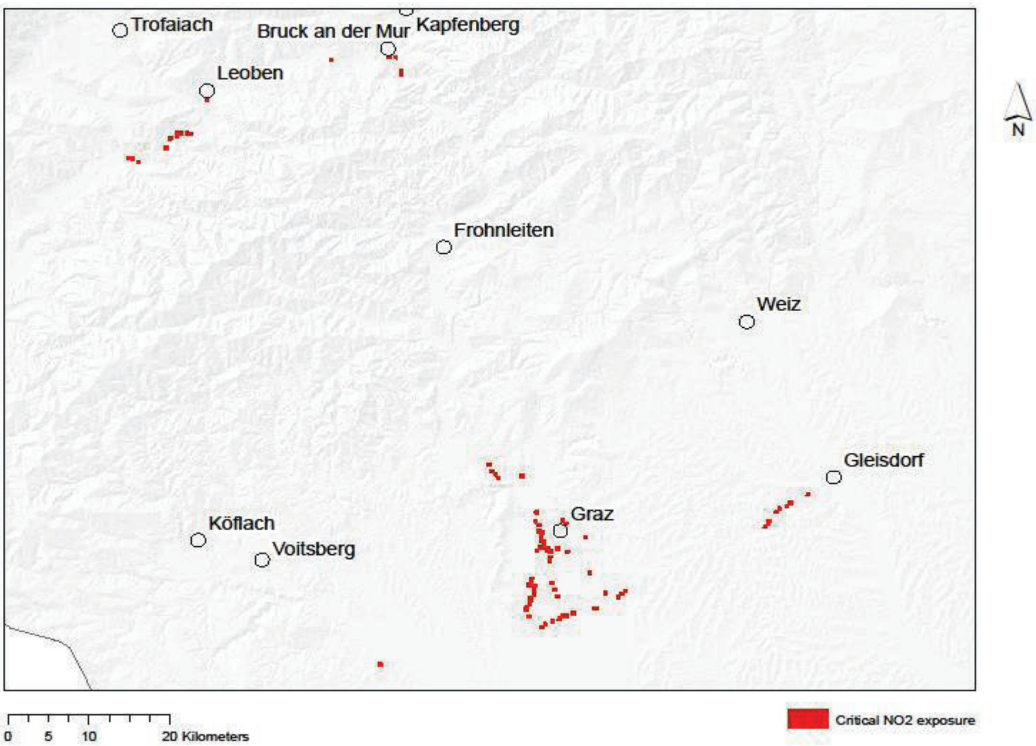

Figure 6 Hotspots of environmental exposure in Styria: Map of critical annual average NO_2 exposure higher than 40 µg/m^3 (threshold: WHO 2018b)

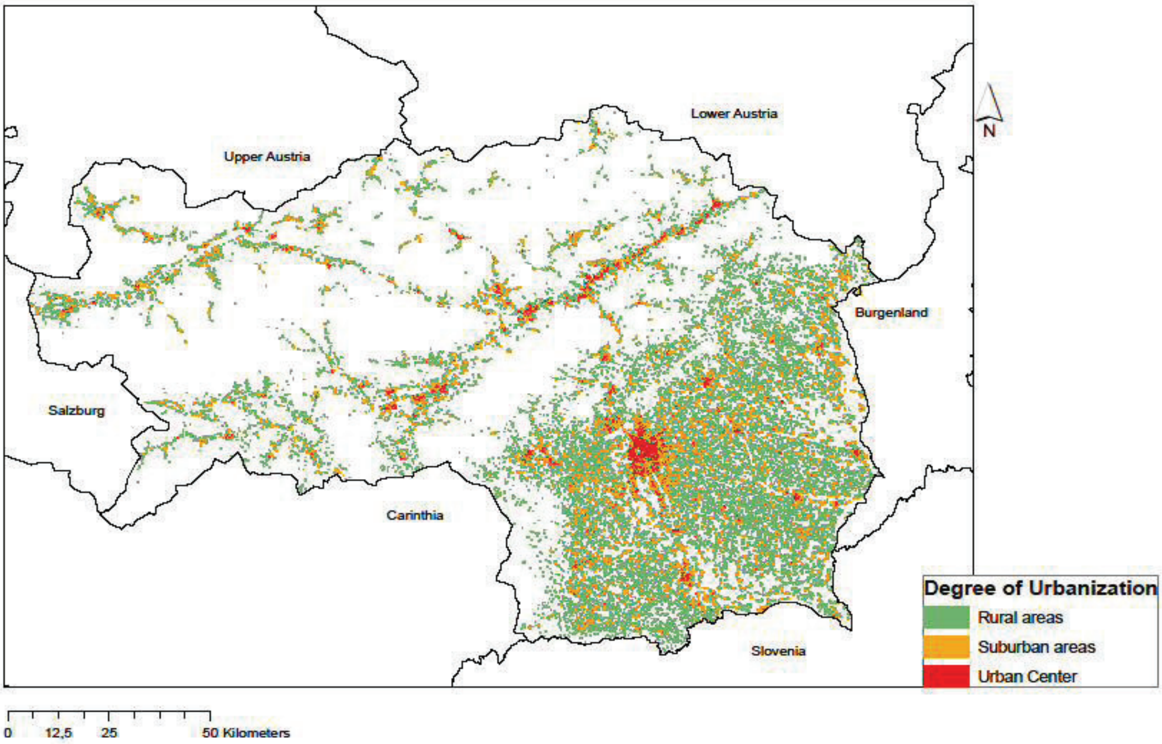

Figure 7 Degrees of Urbanization in Styria: Rural, suburban areas and urban centres according to the scheme of the European Commission (Eurostat Statistic: Explained, 2018) applied to the data set of the "integrated income and wage statistic"

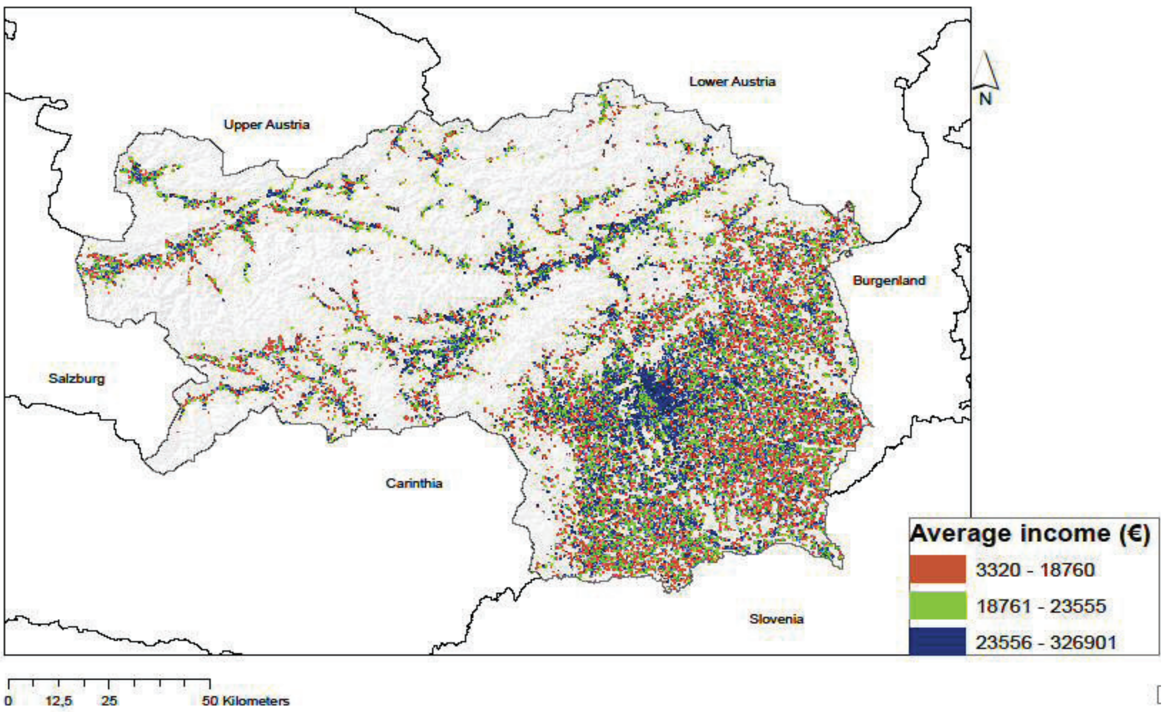

Figure 8 Features of social susceptibility in Styria: Map of the spatial distribution of three income groups divided into terciles ranging from low, to medium, to high income

Figure 2 shows an outline map of Styria visualizing features of topography, the location and the proportional population size of Graz and towns, as well as main roads respectively federal highways, the speedway and freeways. Those features were selected as important side information to locate and explain environmental inequalities. The topography indicates that mountainous areas might limit the distribution of population in Styria. Especially, in northern Styria conurbation areas are located in area interspersing valleys. The valley Mur-Mürz-Furche hosts high population and is connected by Speedway 6 and Speedway 36. The towns Mürzzuschlag, Kindberg, Krapfenberg, Bruck an der Mur, Leoben, Zeltweg, Fohnsdorf and Judenburg are located in this valley. Southern Styria is more levelled and above across the area more populated. Graz the capital city, sits in the centre of Styria and an urban conurbation area. Additionally, Graz surrounding hosts an important traffic junction as it joins the Freeway 2 connecting the north to south of Styria and the Freeway 9 connecting the east to west.

4.1. Hotspots of environmental exposure

Applying a descriptive analysis of the 2010 air pollution data (Appendix: Fehler! Verweisquelle konnte nicht gefunden werden.), the mean PM_{10} exposure is 15,95 µg/m^3 and the mean NO_2 exposure is 9,99 µg/m^3. The minimum of annual average PM_{10} exposure is 13 µg/m^3 and the maximum is 103,96 µg/m^3. PM_{10} outliers are mostly registered at quarries and gravel pits. The minimum of annual average NO_2 exposure is 4 µg/m^3 and the maximum is 95,81 µg/m^3. Outliners can be explained by tunnel portals as aggregated traffic leads to extraordinary exposure.

The visualization of annual average PM_{10} (**Figure 3**) and NO_2 (**Figure 4**) pollution per 250*250m regional grid unit in Styria shows that air-pollution dispersion is determined by the topography of the area. Valleys and flat areas feature air pollution; whereby mountainous areas feature close to non. Hotspots of air pollution, coloured in purple and blue, can be found in high population grid units. In the north-western part of Styria, the towns Bad Aussee and Liezen and surrounding grid units of the federal highways B145 and B320 are exposed to high air pollution levels. The Mur-Mürz-Furche, hosting a conurbation centre, is likewise noticeably polluted. In this area, the highest PM_{10} pollution levels are found in Zeltweg and Judenburg and the highest NO_2 pollution levels are found in Leoben, Bruck an der Mur und Krapfenberg. In the centre of Styria, especially Graz attracts attention being almost above across the area polluted with the highest PM_{10} and NO_2 pollution levels. In the south-eastern part of Styria the towns of Köflach, Voitsberg, Weiz, Hartberg, Gleisdorf, Fürstenfeld, the towns Deutschlandsberg, the towns of Leibnitz and Feldbach are highly polluted by PM_{10}. High NO_2 exposure levels are found around main roads especially next to the speedway S35 and the highways A2 and A9. The dispersion of PM_{10} and NO_2 levels show rather similar patterns. In general, high air pollution levels are found around main roads, Graz and towns. Whereby, high PM_{10} values are rather located in urban areas and high NO_2 values are rather located close to main roads.

The second kind of maps generated to identify environmental hotspots, shows regional grid units, which host critical air pollutants at the WHO threshold levels (WHO, 2018b). **Figure 5** indicates that critically PM_{10} exposure can be found in the northern part of the Mur-Mürz-Furche. Especially, the towns Bruck an der Mur, Leoben, Zeltweg and Judenburg are affected. In central Styria the towns Köflach and Voitsberg host critical PM_{10} exposure. In the south-eastern part of Styria, the towns of Weiz, Gleisdorf, Fürstendfeld, Feldbach, Fehring and Leibnitz are affected. Additionally, critical PM_{10} exposures are found in grid units sitting around main roads. In particular, Graz is above across the area critically PM_{10} polluted, albeit there are exceptions in the north-eastern part of the city.

The map showing the distribution of critical NO_2 exposure (**Figure 6**) indicates that in the northern part of Styria, the towns of Bruck an der Mur and Leoben feature critical NO_2 pollution hotspots. Again, Graz stands out as it shows the highest grid unit frequency hosting critical NO_2 exposure. Especially, the city centre and main roads are affected. Grid units hosting NO_2 critical exposure levels protrude around the freeway A9 crossing the northern limits of Graz and around the freeway A2 in the southern part of Graz. Additionally, guideline-exceeding values are found in the south-eastern part of Styria around the freeway A2.

The comparison of **Figure 5** and **Figure 6** indicates that the quantity of regional grid units showing critical NO_2 and PM_{10} exposure levels differ extensively. That can be traced back at the WHO thresholds level, which diverge widely suggesting 40 $\mu g/m^3$ of NO_2 exposure compared to 20 $\mu g/m^3$ of PM_{10} as a limit.

4.2. Features of social susceptibility

It is assumed that Styrian residents having a low income, a low level of education or with a migration background from low SES countries are social susceptible. To describe the distribution of the categories income, education and migration background in Styria, first a descriptive and second for the category income a spatial analysis was conducted.

In 2010 the data of annual average income per capita for every grid unit in Styria (Appendix: Fehler! Verweisquelle konnte nicht gefunden werden.) shows that the highest annual average income per capita is 326.901€, whereas the lowest annual average income per capita is 3.320€ leading to an income gap of 323.581€.

In 2011 23% of the Styrian residents over 15 years archived their highest educational attainment with no more than compulsory schooling. Most of the residents completed their educational path with an apprenticeship (31%). The smallest share (9%) achieved a degree of an institution of higher education. Secondary and upper secondary school was completed by 24% of the Styrian residents (Appendix: Fehler! Verweisquelle konnte nicht gefunden werden.). There are differences in the distribution of highest educational attainment between rural and urban centres. **Figure 9** demonstrates that in urban centres the percentage of people having completed a secondary and upper secondary school or a higher form of education rises.

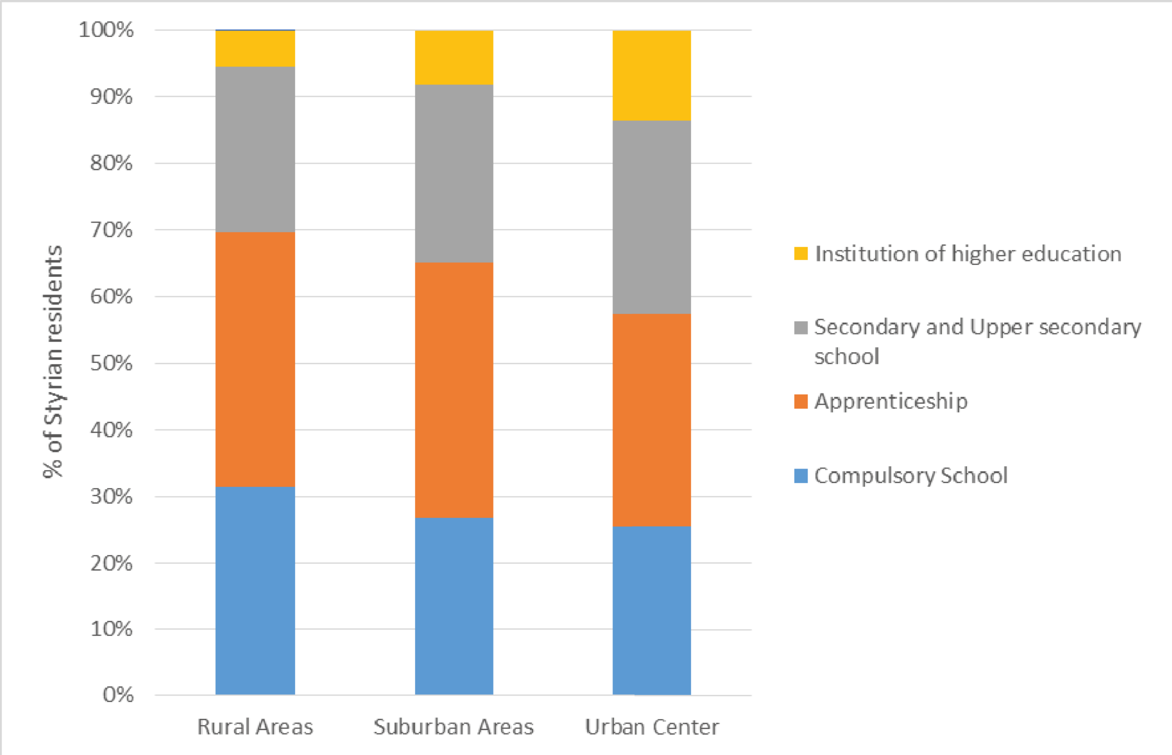

Figure 9 Features of social susceptibility: Proportional distribution of highest educational attainment of Styrian residents in rural and suburban areas and urban centres

In 2011 Austrian Census data indicate that 90% of the Styrian residents are born in Austria (Appendix: Fehler! Verweisquelle konnte nicht gefunden werden.). **Figure 10** describes the distribution of not born Austrians. Thereby, all bars showing foreign birth-countries with high SES are coloured in blue, whereby bars in green colour show foreign birth countries with low SES. All in all, the largest group of Styrian residents not born in Austria are born in former Yugoslavia (27%). The second and third largest group are born in one of the old EU-States (EU14: 20%) and in the EU states accessioned till 2004 (EU10: 15%). These birth-countries have a similar SES to that of Austria. The second largest migrant group born in a country with low SES was born in one of the new EU-states Rumania or Bulgaria (11%), followed by migrants born in Turkey (6%) and Asia (6%).

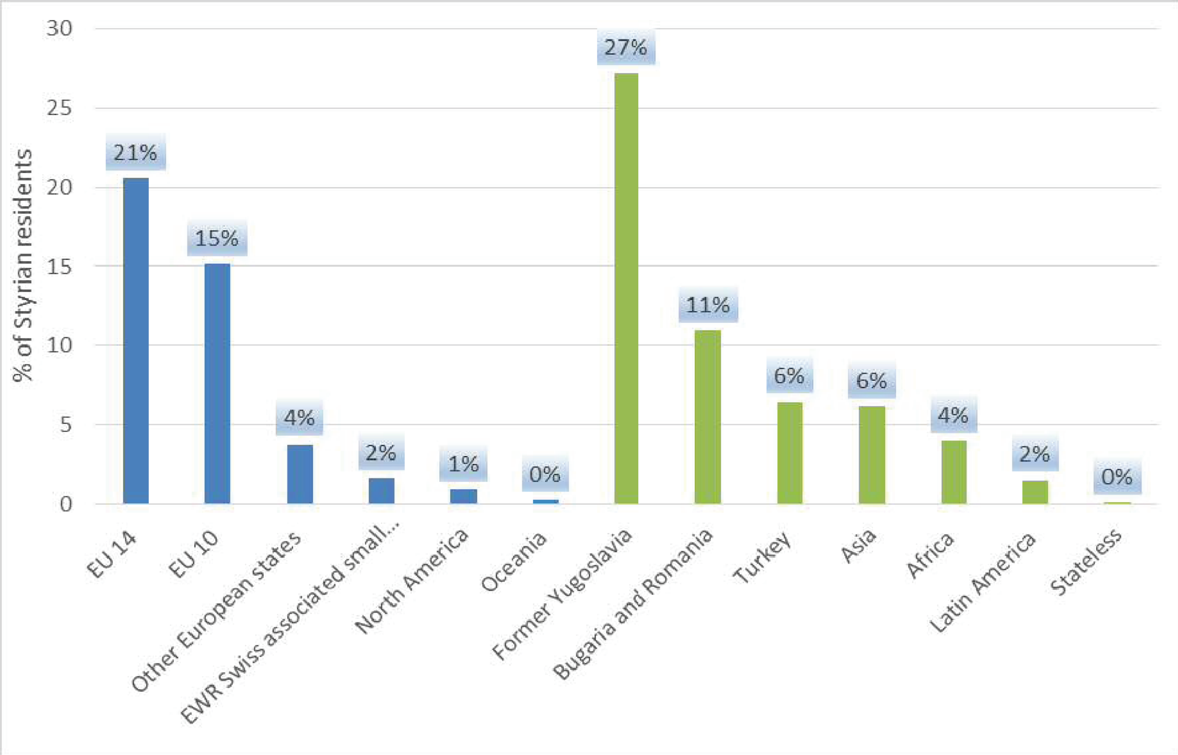

Figure 10 Features of social susceptibility: Proportional distribution of Styrian residents divided by their birthplace without Austria; blue bars sign birth-countries with high SES, green bars sign birth countries with low SES

Figure 8 shows social susceptible areas in Styria elucidated by the distribution of income. The map features grid units demonstrating the spatial distribution of low annual average income, middle income and high-income in 2010. It becomes visible that income distribution is not the same across area. In the north-western part of Styria in sparsely populated areas the distribution patterns of income are somewhat similar. Town-centres and suburban areas host middle-income with some high-income grid units, whereby low-income grid units are located more rural. In central Styria Graz and its surrounding hosts many high-income grid units, especially in the north-eastern part of the city . The further afar from Graz the more diverse the distribution of income becomes. Different income categories very close by are found in the south-east of Styria. In general, low and middle-income grid units are mostly located in low population density areas and high-income grid units are located around and inside Graz and towns.

5. Findings

5.1. Income and air pollution exposure

To elucidate the association between the burden of air pollution and different income groups the two metrics of mean PM_{10} and NO_2 exposure were plotted against the deciles of annual average income.

In the total of Styria, the results show positive relations between air pollution and income groups, indicating a weak association between high exposure levels and high income (Appendix: Fehler! Verweisquelle konnte nicht gefunden werden. and Fehler! Verweisquelle konnte nicht gefunden werden.). Hence, the datasets were separated by the degrees of urbanization.

Figure 11 and **Figure 12** show the distribution of average air pollution by decile income groups separated by the degrees of urbanization. It comes into view that the levels of average PM_{10} and NO_2 in µg/m^3 rises with the degree of urbanization. Styrian residents in urban centres carry a higher burden of air pollution than people in rural and suburban areas. In urban centres, the income group carrying the overall highest burden of PM_{10} pollution is about 12 µg/m^3 higher exposed than income groups living in rural areas and about 10 µg/m^3 higher exposed than the most affected income group in suburban areas. Looking at the exposure levels of NO_2 in association with decile income groups, the differences in exposure become even more striking. In urban centres, the income group carrying the highest burden of NO_2 pollution is about 20 µg/m^3 higher exposed than the income groups living in rural areas and about 17 µg/m^3 higher exposed than the most affected income group in suburban areas.

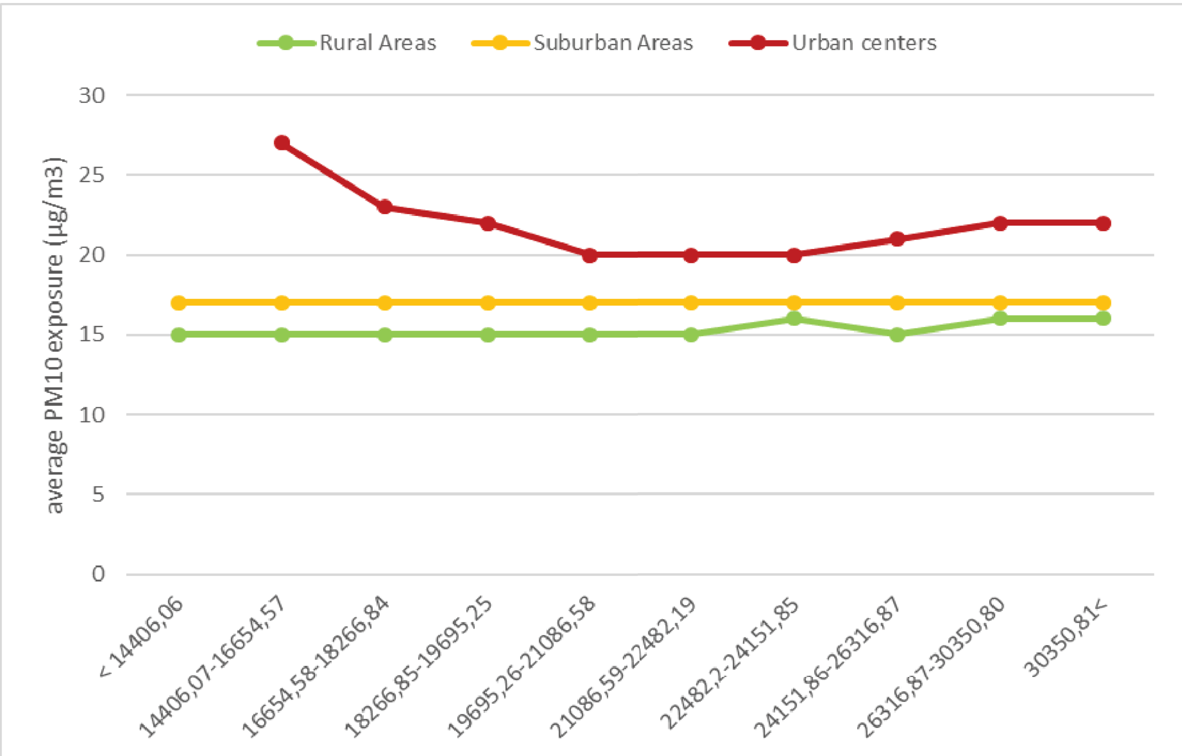

Figure 11 Burden of pollution: Line chart shows the average PM_{10} exposure affecting decile annual average income groups divided by the degrees of urbanization

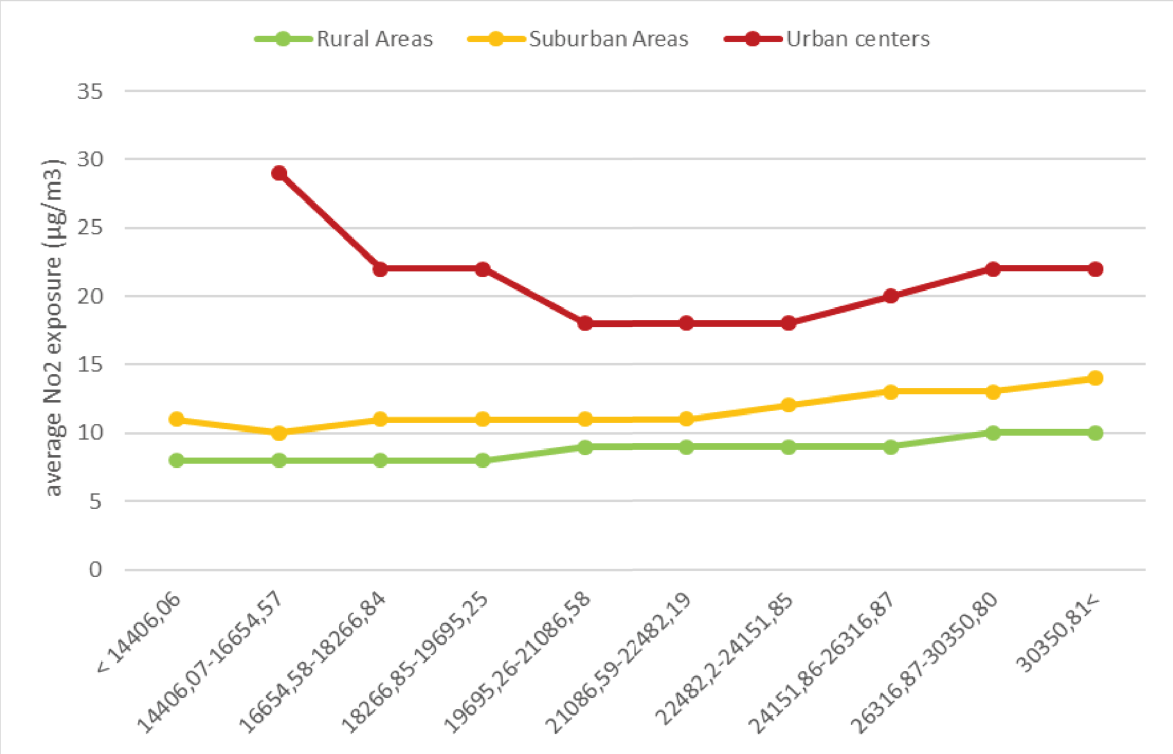

Figure 12 Burden of pollution: Line chart shows the average NO_2 exposure affecting decile annual average income groups divided by the degrees of urbanization

In urban centres the lowest income group, receiving an annual average income of 14406,07 - 16654,57 €, is compared to the other income groups the highest burdened one. This applies to both air pollutants. The average exposure level affecting the lowest income group is 28 µg/m³ PM_{10} and 29 µg/m³ NO_2. At least, referring to PM_{10} these values exceed by far the specified annual average of 20 µg/m_2 at the WHO air quality threshold level, claiming serious health damages by non-compliance. Further, in urban centres the findings of double burden are true for 360 819 Styrian residents receiving the lower third of income, ranging between 14406,07 - 19695,25 €**.** In urban centres **Figure 11** shows that WHO air pollution threshold exceeding levels of PM_{10} affect all income groups. Thereby, middle-income groups are least polluted, but still at the threshold level. The highest income group, receiving an annual average income between 26916,87- 326901 €, do carry higher air pollution burden than intermediate income groups, albeit lower exposure levels than the lowest income groups. The annual average exposure levels differ extensively between the lowest income group and the two highest income groups. The lowest income group is about 7 µg/m³ of average PM_{10} and NO_2 higher exposed than the two highest income groups. This amount is therefore important as outcomes of health studies indicate that the relative risk (upper and lower 95% CI) for mortality through PM_{10} exposure rises for an increase of 10 µg/m³ about 1:043 (Künzli et al, 2000). With regards to NO_2 exposure leading to all-cause mortality the change in risk per 10 µg/m³ is 5,5% (95% CI 3,1%,8,0%) (Hoek et al, 2013). It is hypothesized that low-income groups in urban centres are in greater risk for mortality through air pollution exposure than middle income and high-income groups.

In rural areas findings (Appendix: **Table 8** Spearman Rho correlation between air pollutants and decile income groups in suburban areas
) indicate a significant (p = 0,01) weak positive correlation between the decile income groups and average PM_{10} (rho = 0,155) and average NO_2 (rho = 0,228) exposure levels. There is no evidence of the expected environmental inequality and no WHO threshold exceeding exposure in rural areas.

In suburban areas **Figure 11** shows that average PM_{10} exposure levels are almost the same across all income groups. The average NO_2 exposure levels raises slightly to an exposure level of about 14 $\mu g/m^3$ starting with the second lowest income group till the highest income group. The correlation between income groups and PM_{10} (rho = 0,059) and NO_2 (rho= 0,242) is significant (p=0,01) but weak (Appendix: **Table 9** Spearman Rho correlation between air pollutants and decile income groups in rural areas
). In alignment to rural areas there is no evidence of expected environmental inequality and no WHO threshold exceeding exposure in suburban areas.

In urban centres, the correlation between income groups and PM_{10} (rho=0,055) and NO_2 (rho=0,14) exposure levels are significantly (p=0,01) but weak (Appendix**:** Fehler! Verweisquelle konnte nicht gefunden werden.). In urban areas there is evidence of the expected environmental inequality. The PM_{10} values in urban areas exceed the WHO threshold, albeit NO_2 values do not exceed the WHO threshold levels.

5.2. Education and air pollution

To elucidate any differences of the burden of air pollution with regards to the highest level of education the spatial characteristics of the highest educational attainment were allocated with the spatial exposure levels of air pollutants. Thereby, the air pollutants were separated in “non-critical “ as they do not exceed the WHO threshold levels and “critical exposure” as they exceed the WHO threshold levels.

Figure 13 and **Figure 15** shows the burden of pollution. It was assessed by plotting the distribution of critical exposure and non-critical exposure levels of annual average NO_2 and PM_{10} separated by the highest educational attainment for every recorded Styrian resident older than 15 years. **Figure 15** shows that the highest share of critically PM10 exposure affects residents with the highest level of education. 45% of the residents having completed their educational path with a degree in an institution of higher education are critically PM_{10} exposed. 32% of residents with a degree in secondary or upper secondary school compared to 25% of residents completed an apprenticeship and 28% with compulsory schooling are critically PM_{10} exposed.

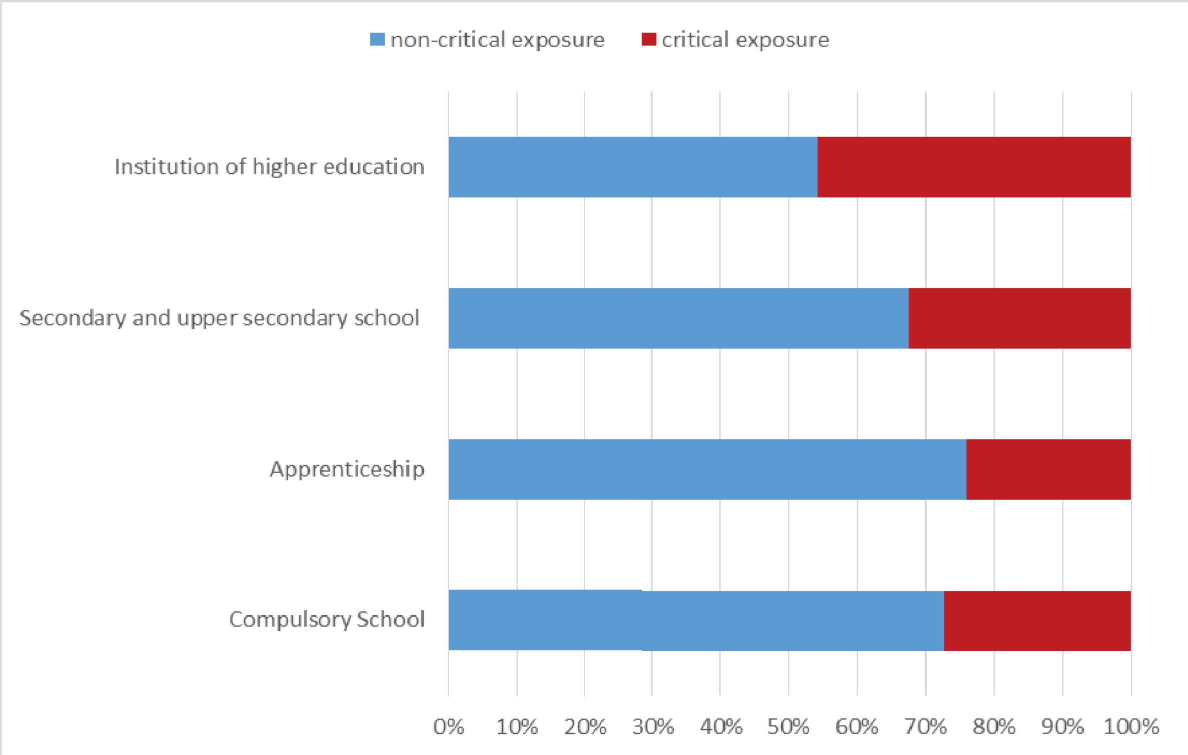

Figure 13 Burden of pollution: Distribution of PM_{10} "non-critical exposure" and "critical exposure" according to the WHO threshold level of 20 µg/m³ divided by highest educational attainment in Styria

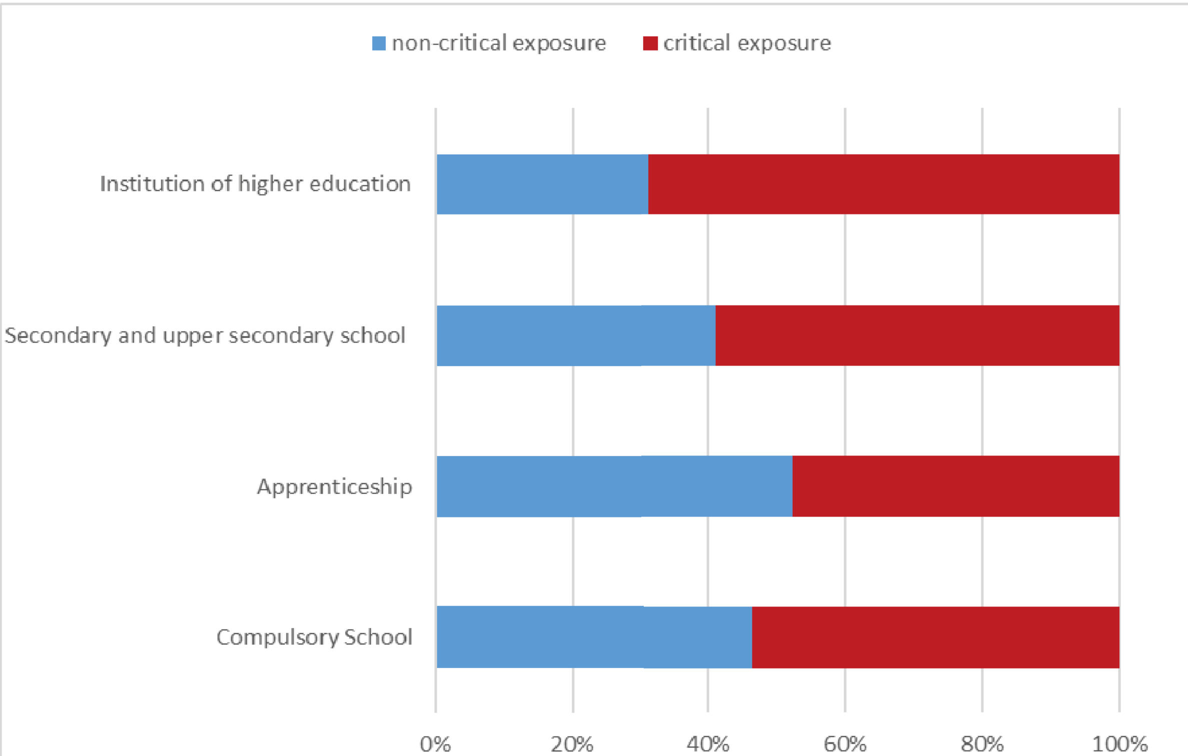

Figure 14 Burden of pollution: Distribution of PM_{10} "non-critical exposure" and "critical exposure" according to the WHO threshold level of 20 µg/m³ divided by highest educational attainment in urban areas

Figure 9 in *chapter 4.2* shows that the major proportion of higher forms of educational attainments emerge in urban centres (45%) compared to the share in suburban areas (35%) and rural areas (30%). **Figure 5** and **Figure 6** in *chapter 4.1.* indicate that critical exposure levels emerge almost exclusively in urban centres. **Figure 14** shows the association between critical PM_{10} exposure and highest educational attainment in urban areas. Comparing the association between critical air pollution exposure and highest educational attainment in total Styria (**Figure 13**) with urban areas only (**Figure 14**) it becomes obvious that the patterns are similar indicating an unexpected inequality, albeit in urban areas more residents are critically exposed.

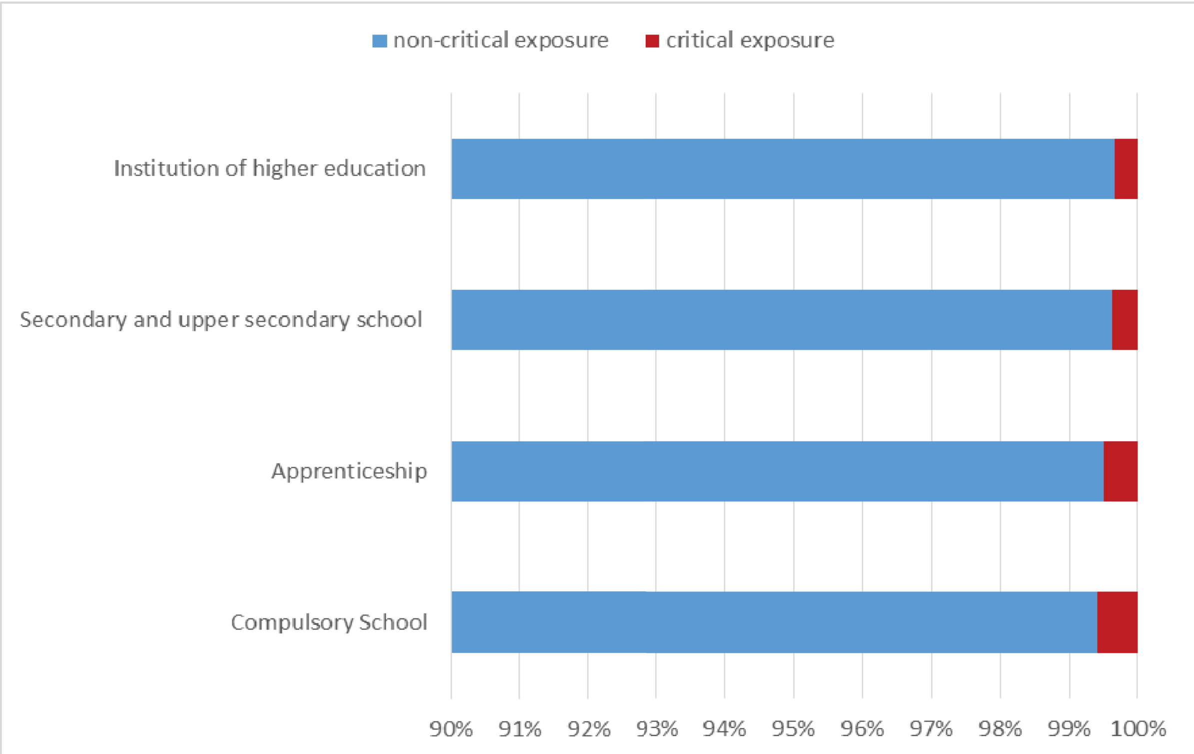

Figure 15 Burden of pollution: Distribution of NO2 "non-critical exposure" and "critical exposure" according to the WHO threshold level of 40 µg/m³ divided by highest educational attainment in Styria

Figure 15 shows the burden of NO_2 pollution indicating that the lower the highest educational attainment the higher the Styrian residents are critical exposed at the NO_2 WHO threshold level. In total Styria less than 0,5% in every educational group is exposed to critical NO_2 levels. In urban areas the share of residents being exposed to critical levels rises to about 1%. In conclusion, there is a weak pronounced evidence of environmental inequality in urban areas and an even more weak pronounced evidence of environmental inequality in total Styria.

5.3. Migration background and air pollution exposure

To elucidate any differences between Styrian residents born in countries with low SES and residents born in countries with high SES including Austria, in terms of burden of air pollution, the spatial characteristics of birthplace were allocated with the spatial exposure levels of air pollutants. For this purpose the air pollutants were separated in "non-critical exposure" as they do not exceed the WHO threshold levels and "critical exposure" as they exceed the WHO threshold levels.

Figure 16 and **Figure 19 s**how the burden of air pollution by identifying "non-critical exposure" and "critical exposure" levels affecting all Styrian residents by different birth country groups. Looking at the critical exposure levels of PM_{10} (**Figure 16)** it comes into view that a higher share of Styrian residents born in countries with low SES is exposed to critical levels than Styrian residents born in Austria and countries with high SES. The highest share of critical PM_{10} exposure levels affects Styrian with unknown birthplace. The recorded amount of stateless people is rather small and no definite conclusion can be drawn by the data. This makes Styrian residents born in Africa, followed by residents born in Turkey and Latin America to the largest from critical pollution burdened groups. For Styrian residents born in former Yugoslavia, respectively the largest migrant group in Austria, it is 33% more likely to be exposed to critical PM_{10} levels than born Austrians.

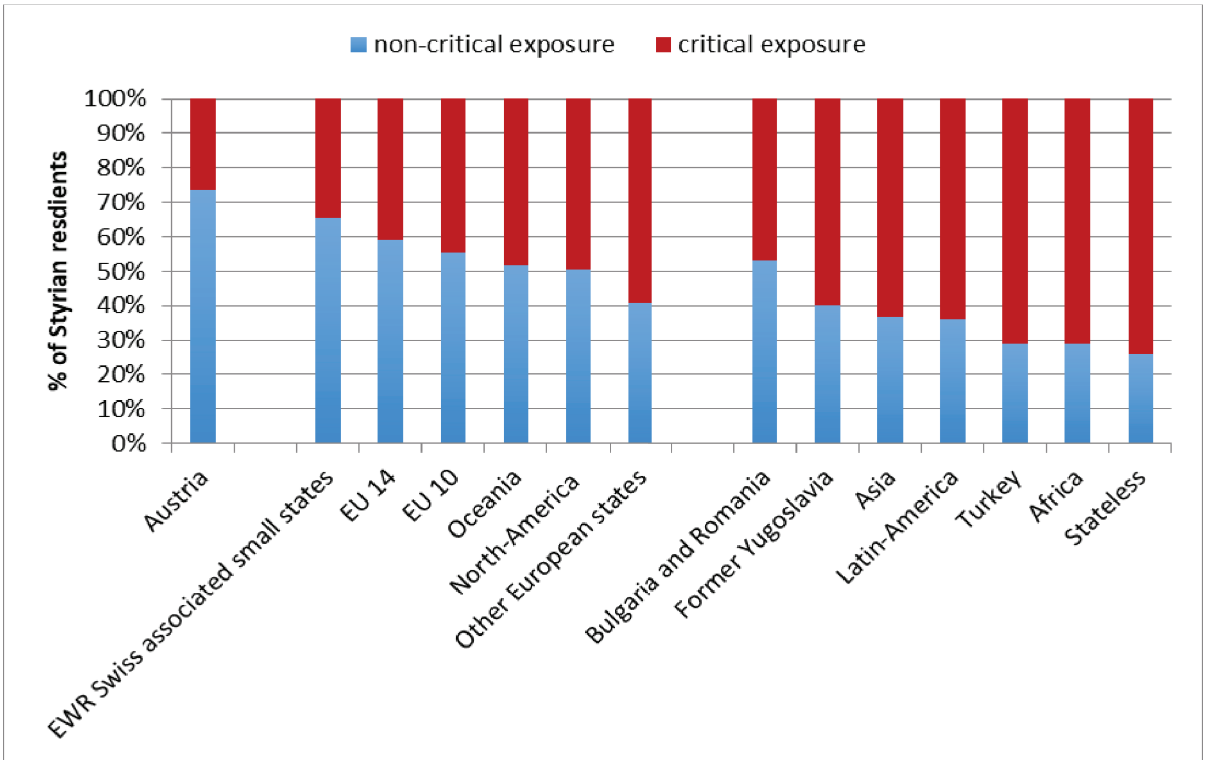

Figure 16 Burden of pollution: Distribution of PM_{10} "non-critical exposure" and "critical exposure" according to the WHO threshold level of 20 µg/m³ divided by birthplace in Styria

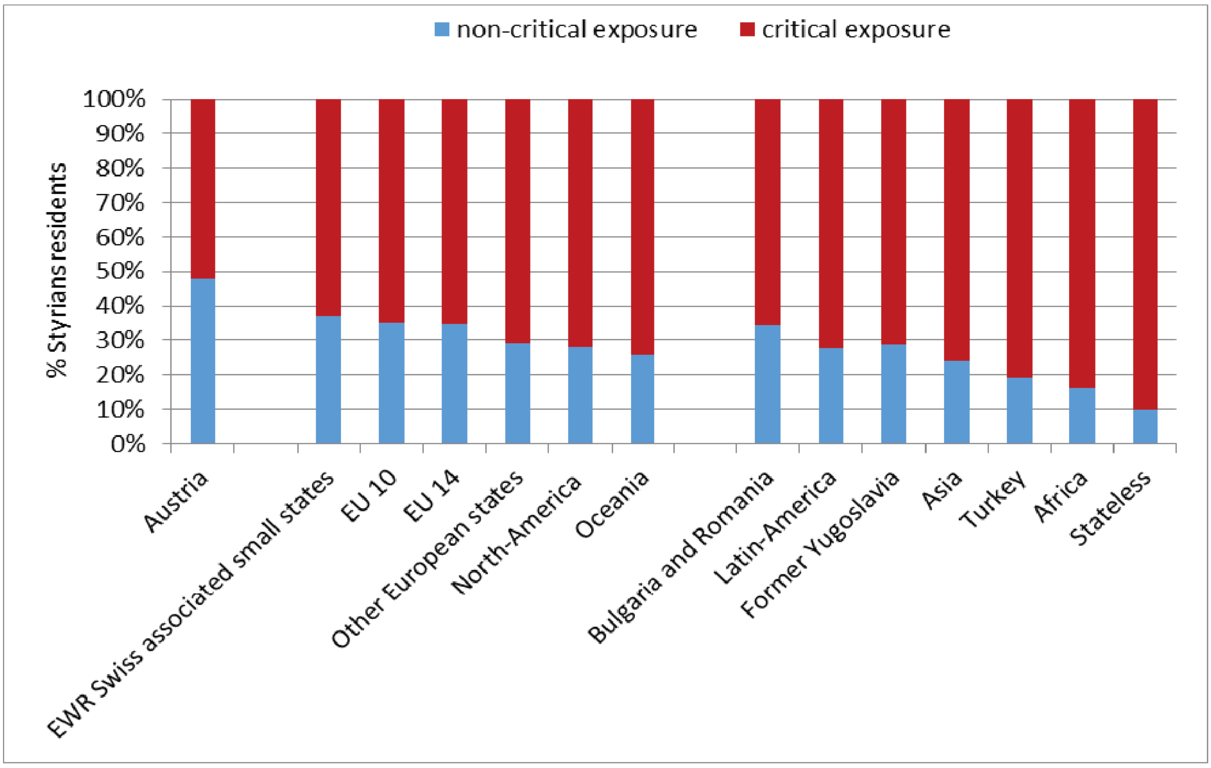

Figure 17 Burden of pollution: Distribution of PM_{10} "non-critical exposure" and "critical exposure" according to the WHO threshold level of 20 µg/m³ divided by birthplace in urban centres

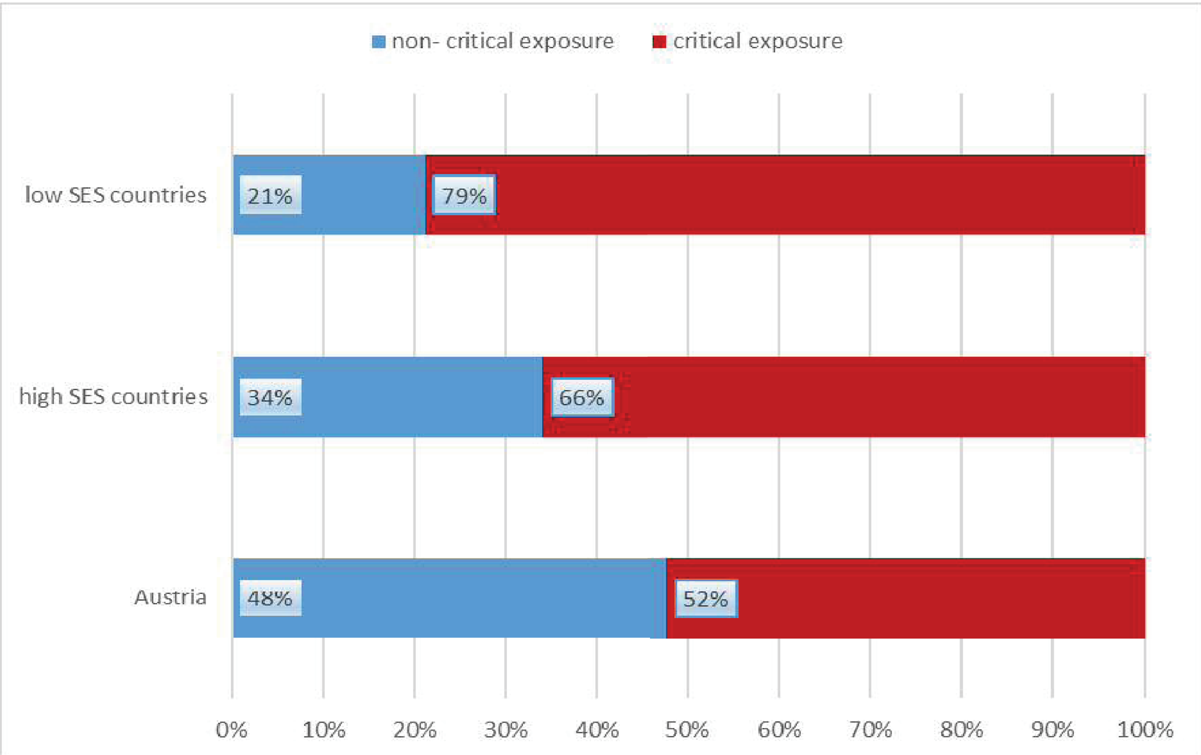

Figure 18 Burden of pollution: Distribution of PM_{10} "non-critical exposure" and "critical exposure" according the WHO threshold level of 20 µg/m³ divided by birthplace in low SES and high SES countries and Austria in urban centres

Figure 17 shows that the level of critical exposure is higher in urban areas than in the total of Styria. Comparing the order of birthplaces in the total of Styria and urban areas only there are marginal changes. But the general pattern, where people born in low SES countries are more exposed to critical exposure levels than people born in high SES countries including Austria, remains the same. **Figure 18** highlights this evidence of inequality in urban areas by contrasting critical exposure levels affecting people born in low SES countries to people born in high SES countries and Austria. For Styrian residents born in a country with low SES it is 27% more likely to live in areas that are critically PM_{10} exposed than people born in Austria.

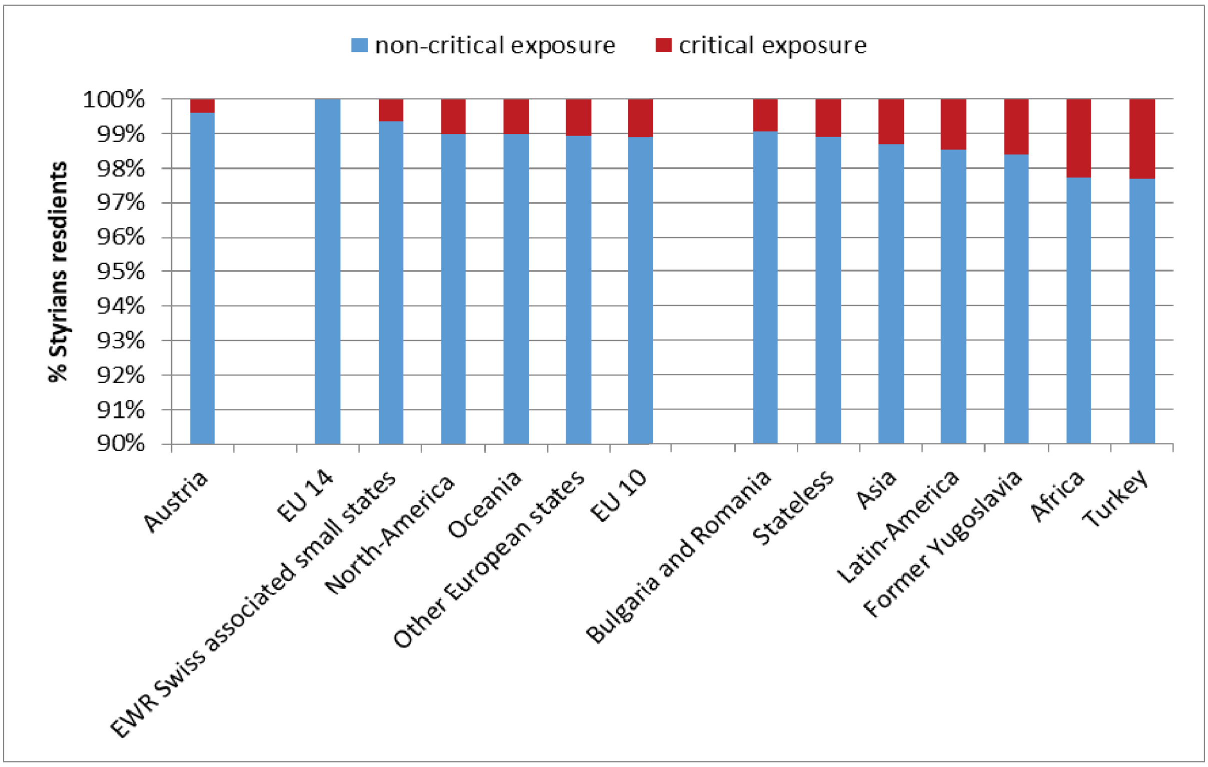

Figure 19 Burden of pollution: Distribution of NO_2 "non-critical exposure" and "critical exposure" according to the WHO threshold level of 40 µg/m³ divided by birthplace in Styria

Figure 19 shows the distribution of NO_2 "non-critical exposure" and "critical exposure" at the WHO threshold level of 40 µg/m³ affecting Styrian residents separated by their birthplace. It is indicated that the share of people with low SES birth countries being critical exposed is higher than the share of residents born in countries with high SES including Austria. The highest share of critical NO_2 exposure carry Styrian residents born in Turkey and Africa. The count of grid units affected at NO_2 WHO threshold level is rather small. Looking at the distribution pattern of critical NO_2 exposure in urban areas only people born in countries with low SES are likewise most exposed. Once more the level of exposure is higher in urban areas.

6. Discussion

Table 4 Two-dimensional summary of the findings indicating type of inequality relation (+ inequality meaning lower socio-economic status is associated with higher pollution levels; - inverse relationship meaning higher socio-economic status is associated with higher pollution levels; ~ no inequality) and intensity of exposure (dark red for high count of grid units with critical exposure to a lighter red for a low count to an even lighter red for a very low count and white for no critical exposure at all)

	NO_2				PM_{10}			
	Styria	rural	suburban	urban	Styria	rural	suburban	urban
Income	-	-	-	+	-	-	~	+
Education	+	~	+	+	-	~	-	-
Place of birth	+	+	+	+	+	+	+	+

Following the EJ Framework to elucidate environmental inequality in Styria the first part of data analysis shows that Styria has hotspots of environmental pollution in terms of an unequal spatial distribution of annual average PM_{10} and NO_2 emission in 2010. In general it could be shown that urban centres are noticeably higher polluted than rural and suburban areas. With regard to PM_{10} exposure, urban centres are polluted at the WHO threshold level above across Styria. Furthermore, features of social susceptibility are assessed by a descriptive and spatial analysis of income, highest educational attainment and migration background. These variables are likewise not equally distributed in Styria.

These results of this thesis presented in Fehler! Verweisquelle konnte nicht gefunden werden. indicate that the hypothesis introduced in *chapter 1.1*. that *less wealthy and less educated people as well as those having a migration background are more likely to live in areas with high air pollution exposure* can be accepted to some extent. For overall Styria only country of birth shows an inequity, whereas income and education are only unequal within urban areas.

One of the key findings of this study shows that low income groups in Styrian urban areas do suffer from double burdens as low income is associated with higher pollution levels. In urban areas evidence of environmental inequality was found for the lowest income groups. They receive the lowest annual average income and they do carry the highest burden of both PM_{10} and NO_2 exposure in the total of Styria. Thereby, PM_{10} exposure levels are above the WHO threshold level, albeit NO_2 levels are not. Further, the distribution of air pollution burden affecting income groups is not linear. On one hand the intermediate income groups are least exposed. On the other hand, the highest income group carry higher air pollution burden than intermediate income groups, albeit lowest income groups carry by far the highest air pollution burden. In suburban and rural areas NO_2 and PM_{10} exposure is for all groups below the WHO threshold level and no evidence for inequality.

The second key finding concerns the positive correlation of critical PM_{10} and NO_2 exposure above WHO air pollution threshold levels with migration background. Outcomes show that in all Styrian areas the share of Styrian residents born in countries with low SES being exposed to critical levels is higher than the share of residents born in Austria or countries with high SES. However, the level of critical exposure differs depending on population density. It has to be noted that the count of grid units above the NO_2 WHO threshold level is rather small. Both pollutants have the highest level of critical exposure in urban areas. In this areas Styrian residents born in Africa or in Turkey are overall the most critically air pollution burdened groups.

The findings concerning highest educational attainment in association with air pollution exposure show less pronounced evidence of environmental inequalities than income in urban areas and migration background. The association between critical PM_{10} exposure and highest educational attainment in different areas shows no inequality or unexpected inequality, albeit in urban areas the level of critical exposure is higher than in the other areas. With regards to critical NO_2 exposure it has again to be noted that the count of grid units above the NO_2 WHO threshold level is rather small. So analysis indicates that there is a weak pronounced evidence of environmental inequality for critical NO_2 exposure in urban areas and an even more weak pronounced evidence of environmental inequality in suburban areas and in the total of Styria. Regarding highest educational attainment there is no evidence of environmental inequality in rural areas.

In the following subchapters the findings are placed into a theoretical framework. First, outcomes are related to similar studies analysing environmental inequalities through the introduction of modelled air pollution data. Secondly, possible explanations of the inequalities are introduced. Finally, the strengths and limitations of the applied method are elaborated.

6.1. Discussion of the findings with state of the art outcomes

Traditionally EJ research, predominantly conducted in the US, applies the unit-hazard coincidence and the distance-based method, demonstrating the existence of racial and socioeconomic disparities in the distribution of a wide variety of environmental hazards (Mohai and Saha 2006). Hajat et al. (2015) review socioeconomic disparities and air pollution exposure at global level. It could be shown that in North America, Asia, Africa and other parts of the world low SES communities carry higher burden of critical air pollutants than high SES communities do (Hajat, Hsia, and O´Neill 2015). Thereby, some of these studies use dispersion models to assess inequalities. This thesis adds on this specific research strand. On this account research approaches differ in spatial scale, pollutants of interest, geographic location, methodology implemented (Gray, Edwards, and Miranda 2013) and there is no standardised procedure yet. The relationship between the geographical distribution of vulnerable communities and modelled air pollution is complex and underling mechanisms are neither in the US nor in the European context comprehensively understood (Fecht et al. 2015).

Comparing the similarities and differences between the US and the European approaches Laurent (2011) hypothesizes that European research highlights the social conditions, whereas

US research focuses on racial dimension of discrimination producing environmental inequalities. Focus and data selection of this thesis refers to both of these perspectives. The thesis found environmental inequalities in urban areas for both low-income groups and Styrian residents having a migration background from countries with low SES. The social composition of migrants and racial minorities experiencing racial discrimination differs extensively between the US and Austria. Especially, African-Americans, Hispanics and Native Americans in the US (Laurent 2011) and in Austria especially first and second generation migrants from former Yugoslavia, Turkey and African countries are threatened by racial discrimination (Hoffmann 2014). In order to assess environmental inequalities by analysing the association between modelled air pollution exposure and ethnic composition or SES recent studies in the US resembles very similar outcomes (Clark, Millet, and Marshall 2014; Gray, Edwards, and Miranda 2013) as those of this thesis. The assessment in North Carolina by Gray, Edwards and Miranda (2013) indicates that lower SES and higher minority characteristic are consistently associated with slightly higher air pollution exposure. US nation-wide patterns assessed by Clark, Millet and Marshall (2014) show that Asians and Hispanics do carry in urban areas often the highest NO_2 exposure whereas Whites are least exposed.

In order to find more general pattern of environmental inequality recent European studies hypothesized that especially in urban areas socio-economically disadvantaged persons are exposed to health threatening air pollution levels which results in a double burden for these groups (de Schutter et al. 2017). In the European context there is almost no evidence of environmental inequality in relation to modelled air pollution exposure in rural areas (de Schutter et al. 2017). In order to explain this pattern, Wheeler and Ben-Shlomo (2005) suggest that the conception of population in rural areas is not uniform, since rural households consist of either wealthier commuter population living next to conurbation and main roads or poorer population in more remote and less polluted areas. This diverse situation might lead to a compensatory effect in statistical analysis neither resulting in double burdens nor double blessings. This master thesis implemented a different scheme of the degrees of urbanization than Wheeler and Ben Shlomo (2005). Still, the outcomes are somewhat similar. Styrian residents in suburban areas living next to conurbation and main roads are slightly more exposed to air pollutants than residents living in more remote areas.

Outcomes of US research indicate that people with lower socio-economic position tend to be higher exposed to air pollution (Morello-Frosch et al. 2002). Analysing national patterns of environmental injustice and inequality in the US for modelled NO_2 exposure, Clark, Millet and Marshall (2014) show that populations in urban areas with low-income carry the highest air pollution burden (Clark, Millet, and Marshall 2014). In the European context, the outcomes are more mixed (de Schutter et al. 2017). In Styria the initial findings resemble the outcomes of the US studies, indicating that in urban areas the lowest income-groups carry the highest burdens. But the distribution of air pollution burden is not linear across income groups. The highest income groups do carry higher air pollution burden than intermediate income groups, albeit the lowest income groups are exposed to the highest pollution levels. In order to explain the association between high income and high air pollution in urban areas Fecht et al. (2015) suggest that gentrification of inner city areas could be decisive for this. It is assumed that people of higher social classes tend to tolerate high exposure of air pollution in order to enjoy a multitude of benefits association with inner city living (Fecht et al. 2015). In the Styrian context the rapid rise of house prices in urban areas especially in Graz (Mundt and Wagner

2017) coupled with the finding of this thesis supports the gentrification theory of Fecht et al. (2015).

In the Netherland and the UK a strong association between PM_{10} and NO_2 air pollutants and environmental inequality was predominantly observed in urban areas or along busy roads (Fecht et al. 2015). Those results resemble the outcome of this thesis as in Styria critical PM_{10} and NO_2 air pollution is mainly located in urban areas and next to main roads. Fecht et al. (2015) show that the burden differs by different air pollutants. These outcomes, however, cannot be reproduced in this thesis. Concerning the relation between air pollution exposure and income groups show very similar patterns for both PM_{10} and NO_2.

The juxtaposition of highest educational attainment and air pollution exposures shows that, referring to PM_{10}, the share of Styrian residents being critically exposed rises slightly with higher education. This outcome is conclusive as the percentage of people having completed higher forms of education rises with an increase of population density. It is hypothesized that Styrian residents living in rural areas are less educated but likewise less polluted. Education is only used in very few studies as explanatory category to assess environmental inequality caused by air pollution (de Schutter et al. 2017). These studies likewise reveal less pronounced associations between education and air pollution exposure (Diekmann and Meyer 2011).

It is hypothesized that Styrian residents with migration background tend to live in suburban or urban areas. Findings of this thesis show that residents born in countries with low SES carry a higher share of critical air pollution than residents born in countries with high SES including Austria. One possible explanation could be that residents born in low SES countries live in less affluent urban areas with more intense traffic than residents born in high SES countries including Austria. Diekmann and Mayer (2011) indicate very similar aspects in Switzerland, where people from Western Europe carry no higher burden than people with Swiss residency, whereas people from Southern Europe, Balkan States, Eastern Europe and from non-European countries (Asia, South America and Africa) live in places with higher air pollution. In order to explain this pattern Diekmann and Mayer (2011) related income and education to environmental indicators. Outcomes do not show any significant correlations. Diekmann and Mayer (2011) conclude that income does not explain the increased air pollution burden of migrants from other countries than Western Europe, albeit outcomes show that environmental pressure decreases strongly when residential property has been purchased (Diekmann and Meyer 2011).

However, the comparison of this thesis outcomes with outcomes from other studies have to be discussed in more detail since small changes in methods might result in changed inequity patterns. Further, *chapter 6.2.* discusses theoretically the explanatory factors of the observed inequalities.

6.2. Explanations of the observed inequalities

Landrigan et al. 2017 quoted that environmental inequality is not only a concern of poor countries, but much more a matter of all countries. Styria located in Austria is a good example for wealthy states showing evidence of environmental inequalities. In order to find explanations of the observed inequalities EJ state of the art research identifies the increasing social metabolism and an uneven distribution of power and income as a driver for unjust distributed burdens of pollution (Martinez-Alier et al. 2014).

In Styria air pollution exposure is a well-known problem (Gressenberger et al. 2016). Even though, political interventions somewhat lead to an avoidance and reduction of air pollution exposure (Gressenberger et al. 2016), frequent assessments show guideline exceeding air pollution exposure, especially particular matter, ozone and nitrogen oxides (Amt der SteiermEM CSL_CITATION {"citationID":". The outcomes show that these exceedances almost exclusively occur in urban areas or close to major roads in suburban areas. On the one hand the mountainous terrain of Styria where urban areas are mainly located in basins with unfavourable meteorology, are explanatory for high air pollution levels (Gressenberger et al. 2016). In Styria the expansions of conurbations (Gressenberger et al. 2016) is closely interlinked to an increasing urban metabolism. In Styria the urban metabolism is explanatory as high energy and material consumption lead to high waste production and guideline exceeding air pollution outputs.

The literature related to this field and this research reveal an uneven distribution of income in Styria. This is somewhat a typical pattern of Austria where the richest 5% of the households do own 45% of the entire property and the bottom 50% owns only 4% (Stoppacher and Edler 2016). Stoppacher and Edler (2016) show in their report “Armut in der Steiermark” (“Poverty in Styria”) that there is a rapid growth of people who rely on state support. This rising social inequalities are attributed to an ongoing casualization of employees and a simultaneous increase of living costs (Stoppacher and Edler 2016). It is hypothesized that in Styria, unlikely to the outcomes of Switzerland (Diekmann and Meyer 2011), income is a major explanation of the unequal distribution of environmental burdens where low-income groups carry the highest environmental burden. Additionally, poverty is not exclusively connected to the lack of money. The driver of poverty can be attributed to the lack of access, especially access to education, health care, sanitation services and access to participation in legal and political processes (Landrigan et al. 2017).

But income is not a sufficient explanatory factor for environmental inequalities in the case of migrant groups born in low SES countries. Income can be an explanatory factor as the “Armut in der Steiermark” report identifies migrants as a major social group in risk of poverty (Stoppacher and Edler 2016). The risk of poverty can be explained to some extend with the findings of Stoppacher and Edler (2016) showing that migrants are impaired by multiple disadvantages like limited access to labour markets, educational institutions, social services and social integration (Stoppacher and Edler 2016). Taking a closer look at the access to the housing market, as housing is a crucial dimension of environmental inequalities (de Schutter et al. 2017), Schoibl (2011) shows that migrants are disadvantaged at the housing market regardless of their income. In comparison to people born in Austria migrants tend to live in smaller flats, carry higher housing costs and are limited in their decision where to live, as they are confronted with discrimination at the housing market (Schoibl 2011).

The socio-economic data show different distribution patterns in rural and urban areas, which is well known in literature as urban-rural gap (Stoppacher and Edler 2016). This means that in social-conurbation areas social problems and inequalities become more visible than in rural regions.

6.3. Methodological strengths and limitations

Traditionally EJ research applies the unit-hazard coincidence and the distance-based method demonstrating the existence of racial and socioeconomic disparities in the distribution of a wide variety of environmental hazards (Mohai and Saha 2006). The evaluation of environmental inequalities caused by air pollutants, assessed through pollution dispersion models, is still at the beginning. Recent studies differ in spatial scale, pollutants, geographic location, methodology implemented (Gray, Edwards, and Miranda 2013) and there is no standardised procedure yet.

By calibrating the dispersion of air pollution data with observed pollution not only polluting facilities but all sources of pollution are included. In Europe the number industrial facilities with high harming potential has decreased over recent decades and has been outsourced to Eastern Europe or emerging and developing countries (Padilla et al 2014). Therefore, the harming potential of air pollutants emerging by diffuse emissions from traffic and hazardous substances within products (Diekmann and Meyer 2010) is essential for assessing environmental inequalities in Austria. Diekmann und Meyer (2010) quoted that dispersion models on a small scale are the most specific method to evaluate the actual burden of pollution. This methodological strength can be confirmed in this thesis. But the assessment of environmental inequalities through grid units comes along with a limitation, known as the modified areal unit problem (MAUP) (ESRI 2018). This methodological weakness implicates that different spatial unit sizes lead to different expressions of social and environmental characteristic. This problem is well known in disciplines working with spatial data (ESRI 2018). Hajat et al. (2015) assumed that smaller sizes of grid units tend to improve reliability and accuracy of the observed burdens. Therefore, the smallest available grid unit size was used in this thesis.

In the following paragraph a brief description of the arisen issues and applied solutions concerning data availability in Austria is provided in order to give guidance for further research. The first step of this thesis was to get modelled air pollution data on a fine scale. The evaluation of environmental inequalities through dispersion models depends strongly on political and scientific agendas to evaluate the current state of air pollution exposure. With other words, the possibility to conduct research bases on geographic regions where monitoring stations (Gray, Edwards, and Miranda 2013) and dispersion modelling expertise is available and not necessarily on the suspect of environmental inequalities. Austria provides a good example for this. Even though there is a legal obligation of air pollution monitoring in Austria the implementations differ extensively between the federal states. In order to fulfil this obligation, the federal state of Styria finances small scale air pollution dispersion models. At this point in time this approach is unique in Austria. The dispersion models were available for the year 2010. While writing this thesis Mag. Ingrid Payer and Mag. Dr. Dietmar Öttl of the ABT 15 Energy, Housing, Technic department of air quality monitoring of Styria are working on the latest version of dispersion models. The availability of this data was directive to define a geographical research area in Austria. Having adequate modelled air pollution data at hand, the next step was to purchase appropriate socio-economic data on a small spatial scale from the Austrian Statistical Office. Thereby, three issues were encountered. First, not all social-economic characteristics, like income, are generally provided on a spatial scale. Second the data sets are not free of charge. Third, the availability of continuous grid units is determined by the strict data protections rules of the Austrian Statistical Office. The threshold defines four residents per grid unit to report associated numbers. Grid units with less than four residents are suppressed. The first issue was solved, as the Austrian Statistical Office agreed to georeference the integrated income and wage statistic and the characteristics of "place of birth" and "highest educational attainment" were already available in grid unit sizes of 250*250m and 500*500m. This leads to one of the key strengths of this thesis, as income data was available for analysis. A scholarship of the Alpen- Adria University of Klagenfurt (Austria) facilitated the purchase of these data sets. The third problem became obsolete as the 250*250m data sets showed non-restrictive loss of information. The grid unit size of 500*500m, which was likewise available, would have led to a loss of spatial explicit determination of pollution burdens. For example, critical exposure levels evolving next to main roads are on the bigger grid unit size no longer visible. The grid-unit size of 250*250m is in comparison to other research conducted in this field an adequate fine resolution and likewise an absolute strength of this research.

Despite the strengths, there are several methodological limitations. The association between air pollution exposure and social characteristics assessed by statistical data for regional grid units give only information about environmental pollution in the place of residents. Air pollution exposure in other life spheres as workplace and daily moving in traffic are dismissed (Hajat et al. 2015).

In this thesis critical air pollution exposure of particular matter and nitrogen dioxide relies on the most up to date information on thresholds defined by the WHO. Since the definition of the thresholds the evidence base for adverse health effects by air pollutants has become broader (WHO 2018b). As a consequence, the WHO started to work towards an update of the Global Air Quality Guidelines, which had not been published while writing this thesis. A re-examination of the data with future thresholds would possibly change the results of this thesis. Furthermore, Briggs, Abellan, and Fecht (2008) suggest that the health of people suffering by environmental inequality is not affected by single environmental exposure but rather by a complex environmental exposure mixture as environmental exposures rarely occur separately.

7. Conclusion

The current prevalent, linear, to-make-use-dispose economic paradigm has driven the social metabolism to an unprecedented extent (Landrigan et al. 2017). Amongst other environmental crises, this results in health threatening air pollution, which causes often unequal shared burdens in the population. EJ discourses played a decisive role in introducing this into the public discourse. Based on EJ research, the first study in Austria investigates the unequal share of air pollution burdens emitted from industrial facilities. Outcomes show evidence of environmental inequalities to some extent. Inspired by EJ research approaches, conducted in the US and in the European context, assessing environmental inequalities caused by air pollution through small scale dispersion models (Hajat, Hsia, and OCSL_CITATION this thesis aims to contribute to the EJ discourse in Austria.

Data availability was directive to define a geographical area of research. Thus, Styria was chosen since modelled air pollution data is available in a high resolution. The thesis addresses the question, , *if air pollutants affect different social groups of residents of the Austrian federal state of Styria equally?* This study breaks new ground as it assesses environmental inequalities on a small scale through the juxtaposition of modelled air pollution data and socio-economic data across the area. The assessment of environmental inequalities through the introduction of air pollution dispersion models on a small scale is at this time the most specific method to evaluate the actual burden of pollution.

One of the key findings of this study shows that low income groups in Styrian urban areas do suffer from double burdens. They receive the lowest annual average income and they do carry the highest burden of both PM_{10} and NO_2 exposure in the total of Styria. Thereby, PM_{10} exposure levels are above WHO threshold level, and NO_2 levels are below. Further, the distribution of air pollution burden affecting income groups is not linear. On the one hand the intermediate income groups are least exposed. On the other hand, the highest income groups carry higher air pollution burden than intermediate income groups, albeit lower exposure levels than the lowest income groups. High exposure levels in urban areas affecting high income groups have been noticed in EJ literature before (Fecht et al. 2015). It is suggested that gentrification of inner city areas could be the reason for this (Fecht et al. 2015). The second key finding concerns the juxtaposition of critical PM_{10} and NO_2 exposure above WHO air pollution threshold levels and migration background. Outcomes show that in all Styrian areas the share of Styrian residents born in countries with low SES being exposed to critical levels is higher than the share of residents born in Austria or countries with high SES. These outcomes are in alignment with EJ research conducted in the US (Gray, Edwards and Miranda 2013 and Clark, Millet and Marshall 2014) and in Europe (Diekmann and Mayer 2011). However, the level of critical exposure differs depending on population density, whereby urban areas are most affected. The findings concerning highest educational attainment in association with air pollution exposure show less pronounced evidence of environmental inequalities than income in urban areas and migration background. Only the association between NO_2 exposure and education indicates a weak pronounced evidence of environmental inequality in urban areas and an even more weak pronounced evidence of environmental inequality in suburban areas and in the total of Styria. Income distribution seems to be on the one hand the most important explanatory factor of observed environmental inequalities, albeit it is assumed that place of origin is likewise decisive. To understand the underlying mechanisms for these patterns, more research is needed.

It has to be acknowledged that the chosen methodology goes along with some general limitations. First the implementation of modelled air pollution data and social-economic characteristics per grid units only assess the burden of pollution at the place of residents (Hajat et al. 2015). Other life spheres are dismissed (Hajat et al. 2015). Secondly, assessing the burden of only single environmental exposures do not picture the complexity of the situation, as environmental exposure to various hazards rarely occurs separately (Briggs, Abellan, and Fecht 2008). Thirdly, air pollution threshold levels indicating health damage by exceeding thresholds must be handled with care, as dose impact correlations in epidemiological research are only incomprehensively understood (Künzli et al. 2000). The WHO started to work towards an update of the Global Air Quality Guidelines (WHO, 2018b), which will be for further environmental inequality research decisive.

This thesis contributes to widen the knowledge about environmental inequalities in Austria. It is out of question that environmental inequalities are an underestimated concern in Austria and more research is needed. Thereby, two perspectives are crucial in order to provoke adequate policy responses. Firstly, Austria has major blind spots regarding unobserved environmental inequalities. In order to emphasis an Austrian-wide assessment of environmental inequalities, the provision of actual small-scale environmental and socio-economic data must be ensured. Secondly, environmental inequality research must be combined with epidemiological research to specify the actual health burden of environmental exposure in relation to socio-economic status. Thirdly, the proposed explanations of the observed inequalities have to be verified and enhanced.

Environmental inequality research in Austria offers a big opportunity towards a healthy living environment for all (de Schutter et al. 2017). By learning about the underling mechanisms of environmental inequalities it is hoped that more research enhances the development and adoption of social-ecological policy responses (de Schutter et al. 2017).

8. References

Agyeman, Julian, and Bob Evans. 2004. '"Just Sustainability": The Emerging Discourse of Environmental Justice in Britain?' *Geographical Journal* 170 (2): 155–64.Amt der Steiermärkischen Landesregierung. 2017. 'Saubere Luft'. Http://Www.Umwelt.Steiermark.at/Cms/Ziel/2054533/DE/. 2017.

Been, Vicki. 1993. 'What's Fairness Got to Do with It? Environmental Justice and the Siting of Locally Undesirable Land Uses'. *Cornell L.Rev.* 78 (1001).

Briggs, David, Juan J. Abellan, and Daniela Fecht. 2008. 'Environmental Inequity in England: Small Area Associations between Socio-Economic Status and Environmental Pollution'. *Social Science & Medicine* 67 (10): 1612–29. https://doi.org/10.1016/j.socscimed.2008.06.040.

Bryant, B.I., and Paul Mohai. 1992. 'Race and the Incidence of Environmental Hazards: A Time for Discourse.' Boulder: Westview Press.

Bullard, Robert. 1990. 'Dumping in Dixi: Race, Class, and Environmental Quality.' Boulder: Westview Press.

Bullard, Robert, Paul Mohai, Robin Saha, and Beverly Wright. 2008. 'Toxic wastes and race at twenty: why race still matters after all of these years'. Gal.Bullart.W. Figures and Tables.

Clark, Lara P., Dylan B. Millet, and Julian D. Marshall. 2014. 'National Patterns in Environmental Injustice and Inequality: Outdoor NO2 Air Pollution in the United States.' *PLoS ONE* 9 (4): e94431. https://doi.org/10.1371/journal.pone.0094431.

Davies, Anna R. 2006. 'Environmental Justice as Subtext or Omission: Examining Discourses of Anti-Incineration Campaigning in Ireland'. *Geoforum* 37 (5): 708–24. https://doi.org/10.1016/j.geoforum.2005.06.005.

Diekmann, Andreas, and Reto Meyer. 2010. 'Demokratischer Smog? Eine Empirische Untersuchung Zum Zusammenhang Zwischen Sozialschicht Und Umweltbelastungen'. *KZfSS Kölner Zeitschrift Für Soziologie Und Sozialpsychologie* 62 (3): 437–57. https://doi.org/10.1007/s11577-010-0108-z.

———. 2011. 'Democratic Smog? An Empirical Study on the Correlation between Social Class and Environmental Pollution'. UMID 2. Special Issue 2 Environmental Justice. Berlin: Federal Office for Radiation Protection (BfS), Federal Institute for Risk Assessment (BfR), Robert Koch Institute (RKI), Federal Environment Agency (UBA).

EPA. 2017. 'Learn About Environmental Justice'. Https://Www.Epa.Gov/Environmentaljustice/Learn-about-Environmental-Justice. 11 January 2017.

ESRI. 2018. 'GIS Dictionary: MAUP'. Https://Support.Esri.Com/En/Other-Resources/Gis-Dictionary/Term/Maup. 19 March 2018.

European Environment Agency. 2017. 'Air Quality in Europe - 2017 Report'. No 13/2017. Luxembourg: Publications Office of the European Union.

Eurostat Statistic Explained. 2018. 'Degree of Urbanisation Classification- 2011 Revision'. Http://Ec.Europa.Eu/Eurostat/Statistics-Explained/Index.Php/Degree_of_urbanisation_classification_-_2011_revision. 7 March 2018.

Fecht, Daniela, Paul Fischer, Léa Fortunato, Gerard Hoek, Kees de Hoogh, Marten Marra, Hanneke Kruize, Danielle Vienneau, Rob Beelen, and Anna Hansell. 2015. 'Associations between Air Pollution and Socioeconomic Characteristics, Ethnicity and Age Profile of Neighbourhoods in England and the Netherlands'. *Environmental Pollution* 198 (March): 201–10. https://doi.org/10.1016/j.envpol.2014.12.014.

Glatter-Götz, Helene. 2016. 'Environmental Justice: How Equally Is the Pollution Burden Spread in Austria?' Master´s Thesis, Vienna: Alpen-Adria University: Institute of Social

Ecology.
Gray, Simone C., Sharon E. Edwards, and Marie Lynn Miranda. 2013. ‘Race, Socioeconomic Status, and Air Pollution Exposure in North Carolina’. *Environmental Research* 126 (October): 152–58. https://doi.org/10.1016/j.envres.2013.06.005.
Gressenberger, Heinz, Doris Hary, Richard Koudelka, Waltraud Köberl, Gertrude Mikula, Andreas Murg, Dietmar Öttl, et al. 2016. ‘Luftgütemessung in Der Steiermark Jahresbericht 2015’. LU-08-2016. Graz: Amt der Steiermärkischen Landesregierung Abteilung 15, Referat Luftreinhaltung.
Hajat, Anjum, Charlene Hsia, and Marie S. O´Neill. 2015. ‘Socioeconomic Disparities and Air Pollution Exposure: A Global Review’ Curr Envir Health Rpt (2): 440–50. https://doi.org/10.1007/s40572-015-0069-5.
Hoffmann, Agnes. 2014. ‘Postkolonieale Repräsentationen von Migrant*innen Im Aktuellen Österreichischen Integrationsdiskurs’. Diplomarbeit, Wien: Universität Wien.
Hohenblum, Philipp, Marina Fröhlich, Lorenz Moosmann, Sigrid Scharf, Maria Uhl, Claudia Gundacker, Hans-Peter Hutter, Michael Kundi, Marie Jansson, and Peter Tappler. 2008. ‘LUKI- Luft Und Kinder: Einfluss Der Innenraumluft Auf Die Gesundheit von Kindern in Ganztagsschulen’. Wien: Umweltbundesamt.
Inter-Agency and Expert Group on SDG Indicators. 2016. ‘SUSTAINABLE DEVELOPMENT GOAL 3 Ensure Healthy Lives and Promote Well-Being for All at All Ages’. Https://Sustainabledevelopment.Un.Org/Sdg3. March 2016.
Kekulé, Alexander. 2018. ‘Hysterie Ums Falsche’. *Zeit*, 7 November 2018, 46 edition.
Künzli, N, R Kaiser, S Medina, M Studnicka, O Chanel, P Filliger, M Herry, et al. 2000. ‘Public-Health Impact of Outdoor and Traffic-Related Air Pollution: A European Assessment’. *The Lancet* 356 (9232): 795–801. https://doi.org/10.1016/S0140-6736(00)02653-2.
Landrigan, Philip J, Richard Fuller, Nereus J R Acosta, Olusoji Adeyi, Robert Arnold, Niladri (Nil) Basu, Abdoulaye Bibi Baldé, et al. 2017. ‘The Lancet Commission on Pollution and Health’. *The Lancet*, October. https://doi.org/10.1016/S0140-6736(17)32345-0.
Laurent, Éloi. 2010. ‘Environmental Justice and Environmental Inequalities: A European Perspective’. Paris: Observation Francais des Conjonctures Economiques.
———. 2011. ‘Issues in Environmental Justice within the European Union’ Ecological Economics (70): 1846–53.
Lerner, Steve. 2010. Sacifice Zones- The Front Lines of Toxic Chemical Exposure in the United States. Cambridge, Massachusetts: The MIT Press.
Martinez-Alier, Joan, Isabelle Anguelovski, Patrick Bond, Daniela Del Bene, Frederico Demaria, Julien-Francois Gerber, Lucie Greyl, et al. 2014. ‘Between Activism and Science: Grassroots Concepts for Sustainability Coined by Environmental Justice Organizations’. *Journal of Political Ecology*, no. 21: 19–60.
Mayer, Andreas, Willi Haas, and Dominik Wiedenhofer. 2017. ‘How Countries’ Resource Use History Matters for Human Well-Being – An Investigation of Global Patterns in Cumulative Material Flows from 1950 to 2010’. *Ecological Economics* 134 (April): 1–10. https://doi.org/10.1016/j.ecolecon.2016.11.017.
Mitchell, G., and D. Dorling. 2003. ‘An Environmental Justice Analysis of British Air Quality.’ *Environment and Planning*, no. A 35: 909–29.
Mohai, Paul, and Robin Saha. 2006. ‘Reassessing Racial and Socioeconomic Disparities in Environmental Justice Research’. *Demography* 43 (2): 383–99. https://doi.org/10.1353/dem.2006.0017.
———. 2007. ‘Racial Inequality in the Distribution of Hazardous Waste: A National-Level Reassessment’. *Environmental Studies Faculty Publications* 2.

———. 2015. ‘Which Came First, People or Pollution? A Review of Theory and Evidence from Longitudinal Environmental Justice Studies’. *Environmental Research Letters* 10 (12): 125011.
Morello-Frosch, R., M. Paster, C. Porras, and J. Sadd. 2002. ‘Environmental Justice and Regional Inequality in Southern California: Implications for Future Research’. *Environ. Health Perspect* 110: 149–54.
Mundt, Alexis, and Karin Wagner. 2017. ‘Regionale Wohnungspreisindizes in Österreich-Erste Erkenntnisse Auf Basis Hedonischer Modelle’. Wien: Institut für Immobilien, Bauen und Wohnen; Österreichische Nationalbank.
Padilla, Cindy M, Wahida Kihal-Talantikite, Verónica M Vieira, Philippe Rosselo, Geraldine LeNir, Denis Zmirou-Navier, and Severine Deguen. 2014. ‘Air Quality and Social Deprivation in Four French Metropolitan Areas – A Localized Spatiotemporal Environmental Inequality Analysis’. *Environmental Research* 134 (October): 315–24. https://doi.org/10.1016/j.envres.2014.07.017.
Richardson, Elizabeth A., Jamie Pearce, Helena Tunstall, Richard Mitchell, and Niamh K. Shortt. 2013. ‘Particulate Air Pollution and Health Inequalities: A Europe-Wide Ecological Analysis’. *International Journal of Health Geographics* 12 (1): 34. https://doi.org/10.1186/1476-072X-12-34.
Schlosberg, D. 2009. ‘Defining Environmental Justice: Theories, Movements, and Nature.’ *Oxford University Press*.
Schoibl, Heinz. 2011. ‘Equality in Housing-Gleichbehandlung Am Wohnungsmark’. Sozialwissenschaftliche Studie im Rahmen des PROGRESS-Projekts ‘Equality in Housing’. Salzburg.
Schutter, Liesbeth de, Hanspeter Wieland, Burcu Gözet, and Stefan Giljum. 2017. ‘Environmental Inequality in Europe-Towards an Environmental Justice Framework for Austria in an EU Contect’. Wien: Institute for Ecological Economics (WU).
Siedl, Sandra. 2016. ‘Socio-Spatial Distribution of Road Traffic Noise in Vienna, Austria’. Master´s Thesis (Joint Degree Programm), Vienna: University of Natural Resources and Life Sciences: Department of Economics and Social Sciences.
Sieferle, Rolf Peter. 2003. ‘Nachhaltigkeit in Universalhistorischer Perspektive. ’ In *Umweltgeschichte.Themen Und Perspektiven*, edited by Wolfram Siemann, 39–60. München: H.Beck.
Statistik Austria. 2017. ‘Integegrierte Statistik Der Lohn- Und Einkommenssteuer: Begrifferklärung’.
Stoppacher, Peter, and Marina Edler. 2016. ‘Armut in Der Steiermark - Eine Bestandsaufnahme in Unterschiedlichen Bereichen’. Graz: Institut für Arbeitsmarktbetreuung und -forschung.
Towers, G. 2000. ‘Applying the Political Geography of Scale: Grassroots Strategies and Environmental Justice’. *Professional Geographer*, 23–36.
Umweltbundesamt. 2017a. ‘Feinstaub (PM10)’. Http://Www.Umweltbundesamt.at/Umweltsituation/Luft/Luftschadstoffe/Staub/Pm10/. 2017.
———. 2017b. ‘Stickstoffoxide’. Http://Www.Umweltbundesamt.at/Umweltsituation/Luft/Luftschadstoffe/Nox/. 2017.
United Nations Economic Comission for Europe. 2015. ‘Recommendations for the 2020 Cenuses of Population and Housing’. Conderence of European Statisticians. New York and Geneva: United Nations.
Vogtenhuber, Stefan, Lorenz Lassnigg, Eduard Stöger, Markus Bönisch, Klaus Trenkwalder, and Michael Bruneforth. 2016. ‘Indikatoren F: Outcome - Wirkung Des Schulsystems’. In

Nationaler Bildungsbericht Österreich 2015. Das Schulsystem Im Spiegel von Daten Und Indikatoren, edited by Michael Bruneforth, Lorenz Lassnigg, Stefan Vogtenhuber, Claudia Schreiner, and Simone Breit. Vol. 1. Graz: Leykam.
Walker, Gordon. 2012. *Environmental Justice: Concepts, Evidence and Politics*. London: Routledge.
WHO. 2018a. 'Air Pollution'. Http://Www.Who.Int/Topics/Air_pollution/En/. 2018.
———. 2018b. 'Update of WHO Global Air Quality Guidelines'. Http://Www.Euro.Who.Int/En/Health-Topics/Environment-and-Health/Air-Quality/Activities/Update-of-Who-Global-Air-Quality-Guidelines. 2018.

9. Appendix

Table 5 Descriptive Analysis

Variable	Number of grid units	Minimum	Maximum	Mean	Median	Standard Deviation
The ecological dimension: Air pollution						
PM_{10} annual average concentration (µm/m^3)	35380	13,00	103,96	15,95	15,29	2,68
NO_2 annual average concentration (µ/m^3)	35380	4,00	95,81	9,99	8,35	5,49
The socioeconomic dimension: Total income						
Integrated income and wage statistic (€)	35380	13.419	28.197.154	566.961	206.782	1.241.793
Residents per 250m grid unit (count)	35380	4	972	24	9	50,40
Annual average of total income (€/ capita)	35380	3.320	326.901	22.184	21.087	8.683
The socioeconomic dimension: Residents by highest educational attainment						
Compulsory school (count per grid unit)	35055	0	437	8	4	17,28
Apprenticeship (count per grid unit)	35055	0	422	10	4	19,30
Vocational school (count per grid unit)	35055	0	126	4	2	7,24
Grammar school (count per grid unit)	35055	0	293	2	0	7,80
Vocational school with higher educational entrance qualification (count per grid unit)	35055	0	174	2	1	5,92
College (count per grid unit)	35055	0	24	0	0	0,78

Institution of higher education other than University (count per grid unit)	35055	0	52	1	0	1,57
University (count per grid unit)	35055	0	450	2	0	11,34
The socioeconomic dimension: Population by country of birth:						
Austria (count per grid unit)	35055	0	1150	29	13	57,79
EU states 14 (count per grid unit)	35055	0	77	1	0	2,62
EU states 10 (count per grid unit)	35055	0	59	0	0	1,97
EU states 2 (count per grid unit)	35055	0	67	0	0	1,77
Former Yugoslavia without Slovenia (count per grid unit)	35055	0	195	1	0	5,76
Turkey (count per grid unit)	35055	0	129	0	0	2,20
EWR Swiss associated small states (count per grid unit)	35055	0	6	0	0	0,28
Other European states (count per grid unit)	35055	0	73	0	0	1,17
Africa (count per grid unit)	35055	0	59	0	0	1,27
North America (count per grid unit)	35055	0	11	0	0	0,26
Latin America (count per grid unit)	35055	0	29	0	0	0,45
Asia without Turkey/Cyprus (count per grid unit)	35055	0	78	0	0	1,65
Oceania (count per grid unit)	35055	0	6	0	0	0,11
Stateless/unknown (count per grid unit)	35055	0	3	0	0	0,06

Figure 20 Features of social susceptibility: Proportional distribution of Styrian residents divided by their highest educational attainment

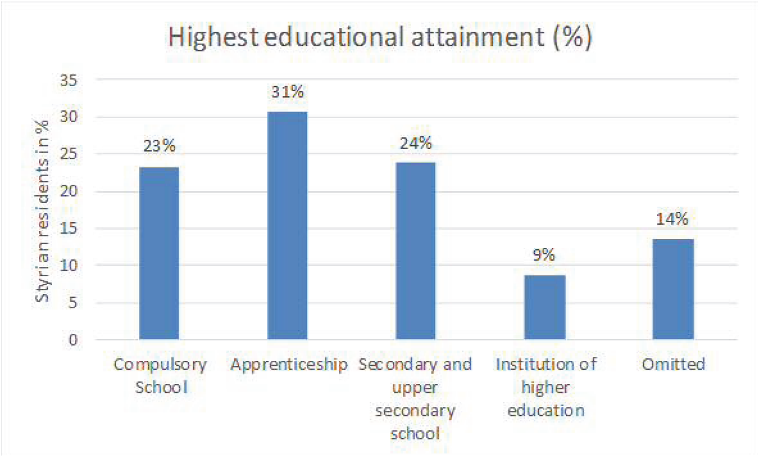

Table 6 Features of social susceptibility: Quantities of Styrian residents divided by their birthplace

	Residents in %	Frequencies
Austria	90	1031788
EU states 14	2	23490
EU states 10	2	17309
EU states 2	1	12485
Former Yugoslavia without Slovenia	3	32250
Turkey	1	7365
EWR Swiss associated small states	0	1836
Other European states	0	4314
Africa	0	4572
North America	0	1077
Latin America	0	1778
Asia without Turkey/Cyprus	1	7291
Oceania	0	291
Stateless/unknown	0	93

Figure 21 Burden of pollution: : Distribution of annual average PM_{10} exposure affecting decile annual average income groups in the total of Styria

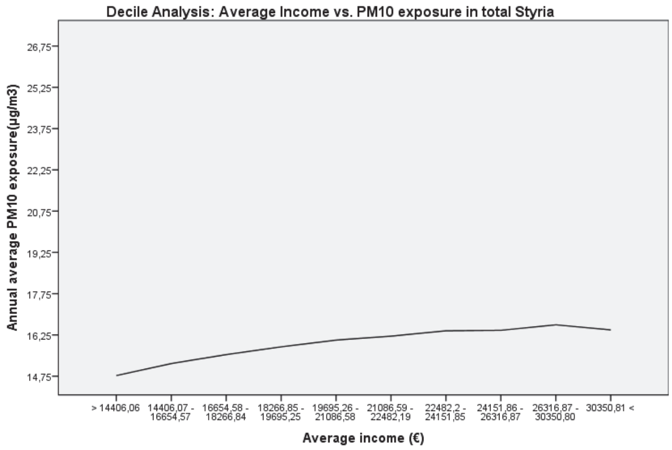

Figure 22 Burden of pollution: Distribution of annual average NO_2 exposure affecting decile annual average income groups in the total of Styria

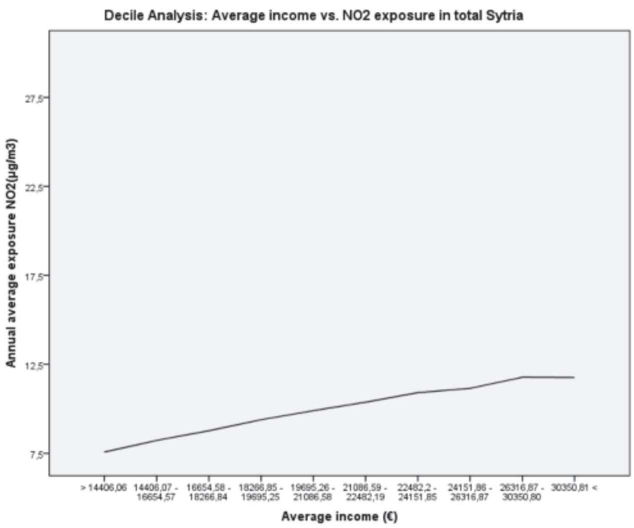

Table 7 Spearman Rho correlation between air pollutants and decile income groups in rural areas

Korrelationen[a]

			NO2(µg/m3)	PM10(µg/m3)	Income in Decile
Spearman-Rho	NO2(µg/m3)	Korrelationskoeffizient	1,000	,834**	,228**
		Sig. (2-seitig)	.	,000	,000
		N	25376	25376	25376
	PM10(µg/m3)	Korrelationskoeffizient	,834**	1,000	,155**
		Sig. (2-seitig)	,000	.	,000
		N	25376	25376	25376
	von klein zu groß!!	Korrelationskoeffizient	,228**	,155**	1,000
		Sig. (2-seitig)	,000	,000	.
		N	25376	25376	25376

**. Die Korrelation ist auf dem 0,01 Niveau signifikant (zweiseitig).

a. Urbanisierungsgrad = Rural Area

Table 8 Spearman Rho correlation between air pollutants and decile income groups in suburban areas

Korrelationen[a]

			NO2(µg/m3)	PM10(µg/m3)	Income in Decile
Spearman-Rho	NO2(µg/m3)	Korrelationskoeffizient	1,000	,784**	,242**
		Sig. (2-seitig)	.	,000	,000
		N	8496	8496	8496
	PM10(µg/m3)	Korrelationskoeffizient	,784**	1,000	,059**
		Sig. (2-seitig)	,000	.	,000
		N	8496	8496	8496
	von klein zu groß!!	Korrelationskoeffizient	,242**	,059**	1,000
		Sig. (2-seitig)	,000	,000	.
		N	8496	8496	8496

**. Die Korrelation ist auf dem 0,01 Niveau signifikant (zweiseitig).

a. Urbanisierungsgrad = Suburban Area

Table 9 Spearman Rho correlation between air pollutants and decile income groups in rural areas

Korrelationen[a]

			NO2(µg/m3)	PM10(µg/m3)	Income in Decile
Spearman-Rho	NO2(µg/m3)	Korrelationskoeffizient	1,000	,871**	,140**
		Sig. (2-seitig)	.	,000	,000
		N	1508	1508	1508
	PM10(µg/m3)	Korrelationskoeffizient	,871**	1,000	,055*
		Sig. (2-seitig)	,000	.	,032
		N	1508	1508	1508
	von klein zu groß!!	Korrelationskoeffizient	,140**	,055*	1,000
		Sig. (2-seitig)	,000	,032	.
		N	1508	1508	1508

**. Die Korrelation ist auf dem 0,01 Niveau signifikant (zweiseitig).

*. Die Korrelation ist auf dem 0,05 Niveau signifikant (zweiseitig).

a. Urbanisierungsgrad = Urban centre

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