



## Neighbourhood greenness and income of occupants in four German areas: GINIplus and LISApplus



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### ABSTRACT

**Objective:** We investigated whether families with lower individual-level socioeconomic status (SES) reside in less green neighbourhoods in four areas in Germany.

**Methods:** Data were collected within two German birth cohorts – GINIplus and LISApplus. Net equivalent household income was categorized into study area-specific tertiles and used as a proxy for individual-level SES. Neighbourhood greenness was calculated in 500-m buffers around home addresses as: 1) the mean normalized difference vegetation index (NDVI); 2) percent tree cover. Associations between income and neighbourhood greenness were assessed per study area using adjusted linear regression models.

**Results:** In the Munich and Leipzig areas, families in the low and medium income tertiles resided in neighbourhoods with lower NDVI compared to those in the high income tertile (mean percent change in NDVI:  $-4.0$  (95% confidence interval =  $-6.7$  to  $-1.3$ ) and  $-5.5$  ( $-10.9$  to  $-0.2$ ), respectively). In contrast, in the Wesel area, families in the low income tertile resided in neighbourhoods with higher NDVI (2.9 (0.5–5.3)). Only the association in the Munich area was replicated when using tree cover instead of the NDVI.

**Conclusions:** This study provides suggestive evidence that the presence and direction of associations between greenness and SES is region-specific in Germany. The degree of urbanization did not clarify this heterogeneity completely.

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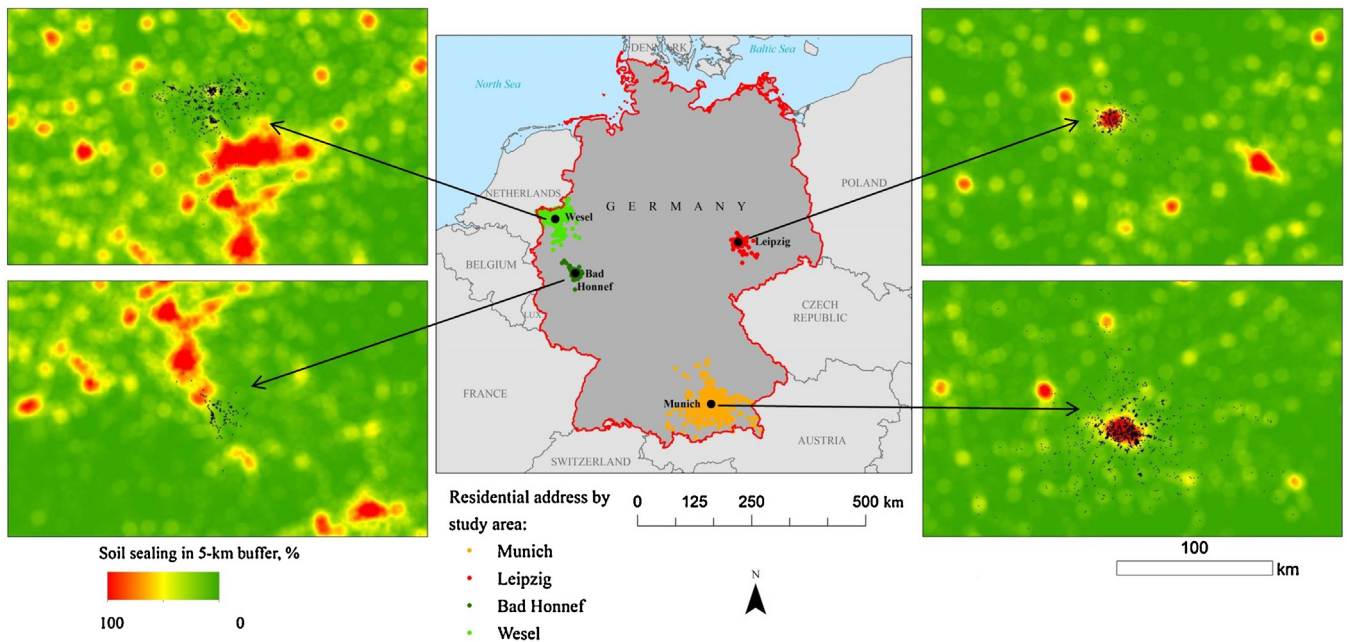
## 1. Introduction

Epidemiological research suggests that residing in a green neighbourhood is beneficial for many health outcomes (James et al., 2015; Hartig et al., 2014), in particular mental health (Gascon et al.,

2015) and birth weight (Dzhambov et al., 2014). Interestingly, many studies investigating the effects of neighbourhood vegetation level (i.e. greenness) on health report that associations appear strongest among those of low individual-level socioeconomic status (SES) (James et al., 2015). Several hypotheses have been proposed to explain such differences. In particular, people with low individual-level SES are more likely to be less mobile and therefore spend more time close to their residence. Consequently, they are also more likely to be more influenced by their neighbourhood (Maas, 2008). Moreover, it was reported that people residing in green places

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**Fig. 1.** Map of Germany with plotted residences of study participants, highlighted by study area, together with zoomed in maps with underlying urbanization degree. Urbanization degree map is based on percent sealed soil in 5-km buffer (0% (green) to 100% (red)). The map was created based on a raster dataset with a spatial resolution of 100 m for 2006, freely available from the European Environment Agency (Source: <http://www.eea.europa.eu/data-and-maps/data/eea-fast-track-service-precursor-on-land-monitoring-degree-of-soil-sealing#tab-additional-information>). Residences at places with <25% soil sealed were classified as rural and those with  $\geq 25\%$  sealed as urban (Fuertes et al., 2016). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

have lower levels of health inequality related to income deprivation (Mitchell and Popham, 2008).

As was demonstrated by Astell-Burt et al. (2014) using data from five Australian cities, greenness is not equally distributed across space, and neighbourhoods with lower area-level SES (here measured by higher percentage of low income residents) may lack vegetation. However, inequality in access to greenness could differ in urban and rural settings. In particular, the nationwide study conducted in the USA (Wen et al., 2013) demonstrated that higher neighbourhood poverty levels were associated with lower percentages of green spaces in urban and suburban areas while in rural areas, this association was in the opposite direction.

The existing studies on greenness effects on health controlled for individual- and/or area-level SES and examined potential effect modification by SES in statistical analyses. However, to date, only a few of such studies have reported associations (model estimates, correlation coefficients or results of bivariate analyses) between individual-level SES and neighbourhood greenness. Therefore, in this article, we specifically focused on investigating whether families with lower individual-level SES reside in less green neighbourhoods in four areas in Germany.

## 2. Methods

### 2.1. Study populations

Data for this secondary analysis were obtained from parent-completed questionnaires of participants in the 15-year follow-ups of two ongoing multicenter population-based German birth cohorts – GINIplus and the LISApplus. Briefly, GINIplus participants were recruited in the cities of Munich ( $n = 2949$ ) and Wesel ( $n = 3042$ ) between 1995 and 1998. The GINIplus consists of two study groups: an observational study group and a study group that participated in an intervention trial with hypoallergenic formulae (von Berg et al., 2010). LISApplus is a pure observational population-based cohort recruited in the cities of Munich ( $n = 1467$ ), Leipzig

( $n = 976$ ), Wesel ( $n = 348$ ) and Bad Honnef ( $n = 306$ ) between 1997 and 1999 (Zutavern et al., 2006). The GINIplus and LISApplus studies have been approved by their local ethics committees and informed consent was obtained from all families.

### 2.2. Study areas

As the birth cohorts have nearly identical study designs, data were pooled. However, given that the four study areas covered by these two cohorts differ substantially in terms of land area, population size, land use patterns and income situation (Bundesamt für Kartographie und Geodäsie, 2013; CORINE 2006; Bundesinstitut für Bau-, Stadt- und Raumforschung, 2012), associations are presented for the four distinct geographical study areas – Munich, Leipzig, Bad Honnef and Wesel.

Briefly, the Munich families resided in the city of Munich and the 30 adjacent counties in Bavaria, southern Germany (Fig. 1 and Table 1). Compared to the other study areas, the Munich area has the largest land area (25018.6 km<sup>2</sup>) and its average net household income per person is the highest (2018.5 eur/month).

The Leipzig families resided in the city of Leipzig and the 5 adjacent counties in Saxony, eastern Germany (Fig. 1 and Table 1). The population of this area (1582390 inhabitants) and its average net household income per person (1458.4 eur/month) are the lowest of the four study areas. Natural vegetated land covers 10% of the land area (the lowest of the study areas) while agricultural land covers 63% (the highest) (CORINE 2006).

The Bad Honnef families resided in the city of Bad Honnef and the 7 adjacent counties in North Rhine-Westphalia and Rheinland-Pfalz, western Germany, which is close to the Ruhr area (Fig. 1 and Table 1). The proportions of natural and agricultural land in this area are comparable to those in the Munich area, but the size of the land area is the smallest (5273.8 km<sup>2</sup>).

The Wesel families resided in the city of Wesel and the 15 adjacent counties in North Rhine-Westphalia, western Germany, which is again close to the Ruhr area (Fig. 1 and Table 1). This study area

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