Research Paper

From human biomonitoring research to spatial explicit evidence and policy recommendations:

green space exposure and health effects in Flanders (Belgium)

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Abstract

Indicators for spatial patterns by analysing the Flemish area with detailed data across various geografical scales are collected in a report, the 'Ruimterapport'-'RURA'. RURA is a compilation of research results from very diverse sources, including the Department of Environment and Spatial Development of Flanders and the European Spatial Planning Observation Network (Espon). In the latest government report on spatial data and research results in Flanders (2021), an extensive chapter was dedicated to the complex interactions between environmental and spatial parameters and human health, focusing on their relevance for spatial policy. This chapter describes different environmental stressors, health outcomes, subjective appreciations and nuisances. In particular, the report presents associations of residential green space with health as an example of a spatial characteristic that may influence health. The report includes a broad range of research methods and data, a substantial part is based on Flemish human biomonitoring studies (FLEHS), carried out by the Flemish Center for Environment and Health.

In the fourth Flemish Environment and Health Study (FLEHS-4, 2016 - 2020), 428 adolescents were recruited as a representative sample of the Flemish adolescent population. Relations were analysed between spatial parameters, internal exposure biomarkers and biomarkers of health effects. FLEHS-4 examined the impact of the proportion of green space within the residential surroundings, the proximity and accessibility of green infrastructure and the proportion of agricultural area in the residential surroundings on various outcomes such as internal chemical exposure, biological parameters associated with health effects, cognition and well-being. The results of the analyses are described in RURA 2.

The main conclusions were:

- *More surrounding green space close to the residence (50m buffer) is associated with less biological ageing in adolescents.*
- *Green space, especially trees, surrounding both the residence and school in a 2000 m radius is associated with better sustained and selected attention in adolescents.*

To translate these biomonitoring results to policy advice a specific procedure was followed including dissemination of the results to the participants and a round table discussion with involved stakeholders. As human biomonitoring results in a multitude of data, not only orientated to spatial characteristics, a specific report with spatial analyses was produced.

The main conclusions with related policy advices were reported in the RURA chapter on environment and health:

Flanders is a densely populated and highly urbanized region, the available open space and green space is limited. Based on the mentioned results we can conclude that residential green space within close proximity to the residence, as well as in a wider environment, and good air quality are important for the health of adolescents. Given the fact that urbanization is increasing in Flanders as well as worldwide, it is therefore essential that an effort is made to preserve, expand and ameliorate the accessibility of the existing green spaces.

Keywords

Green space, Urbanization, Health, Flemish Environment and Health Study (FLEHS), Human biomonitoring, Policy advice

Introduction

The Flanders Spatial Report (RURA, "Ruimterapport") describes the state of the territory in Flanders and its evolution since 2018, based on available datasets (Pisman et al., 2021). The purpose of RURA is to describe the spatial appearance and functioning of Flanders, not only based on global characteristics but also giving insights in spatial differences within Flanders. To this purpose, RURA compiles research results from diverse sources. Typologies such as urbanized, peri-urban, and rural areas are distinguished; cores/ribbons and scattered developments are mapped; and finally, areas with more or less sprawl are investigated (Pisman et al., 2021).

The daily living and working environment of humans influences their physical health and well-being. This environment is determined by the social and economic context, physical and chemical environmental characteristics. Land use affects mobility, nature, green space, the quality of water, air and soil; different environmental parameters that impact the quality of the environment. This chain of impacts is illustrated in figure 1.

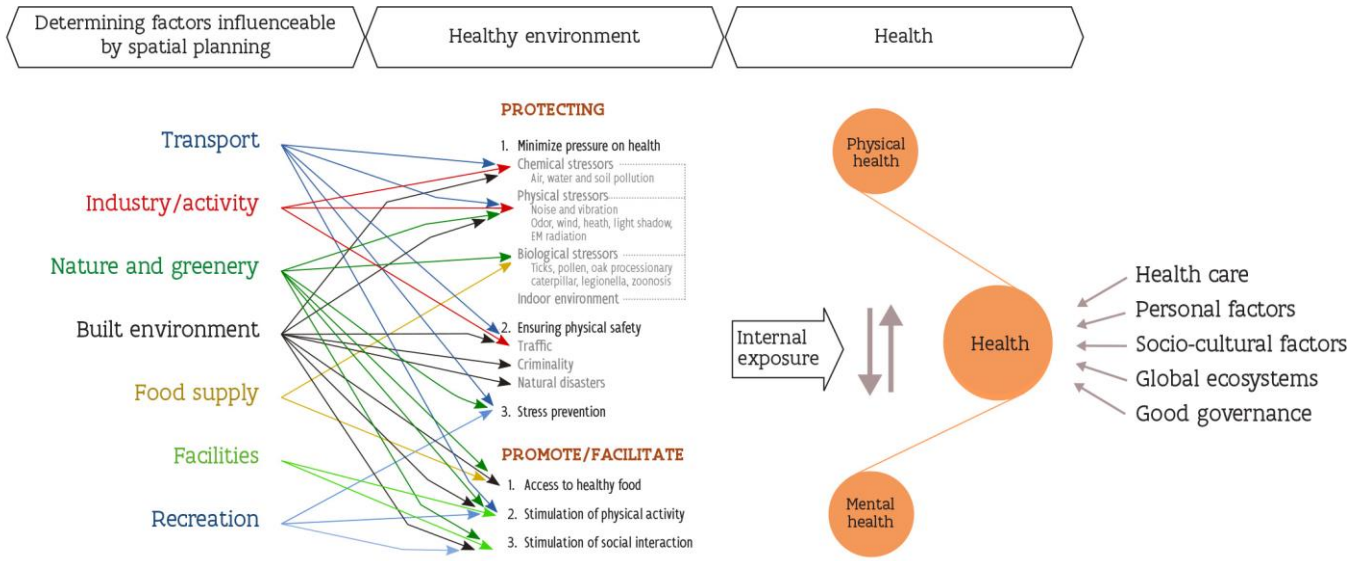

Figure 1: Environment and Health Chain. Source: Adapted from RURA

Human biomonitoring (HBM) investigates the complex relation between environment and health by measuring biomarkers of exposure to a selection of pollutants or stressors and biomarkers of health effects in humans. HBM is one of the most direct methods to measure internal exposure to pollutants through different sources and the health impact of stressors in humans. Both biomarkers of exposure and biomarkers of effect are monitored.

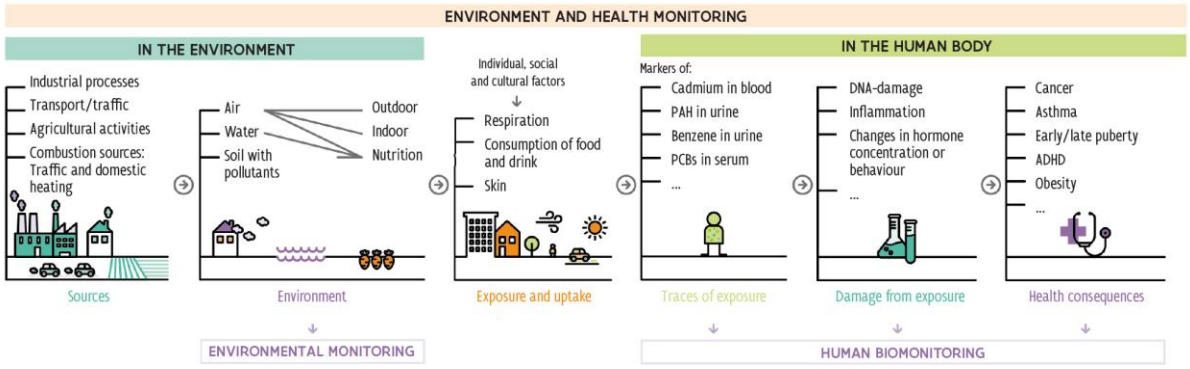

Figure 2: Environment and Health Monitoring. Source: Adapted from RURA

In Flanders, Belgium, a HBM network has been established since 2001 as part of the governmental program on environmental health surveillance. The HBM campaigns are conducted by the Flemish Center of Expertise on Environment and Health, a scientific knowledge pool for environmental health in Flanders. The consortium consists of researchers from the five Flemish universities (Antwerp, Brussels, Ghent, Hasselt, Leuven) and research institutes VITO and PIH. Up to now, the four Flemish Environment and Health Studies (FLEHS) were carried out: FLEHS I (2002-2006), FLEHS II (2007-2011), FLEHS III (2012-2015), and FLEHS IV (2016-2020) (Schoeters et al., 2022). Each cycle builds on strengths and experiences from the past and also addresses new upcoming challenges.

The open space is limited in Flanders. In Flanders and abroad, a big part of the population is living in cities, (Tonne et al., 2021) 40,9% in Flanders. Cities are changing and are increasingly investing in green and blue infrastructures. Also, in more rural areas open space is reorganized. FLEHS IV investigated to what extent the proximity and accessibility of green infrastructures and agricultural areas may have impact on the internal chemical exposure levels and on biological parameters that are related to health outcomes.

Based on the data produced in FLEHS IV, these spatial factors and the links with health are described in the Flemish context and disseminated through the RURA-chapter on Environment and Health. This chapter focuses on the spatial factors of which the link with human health is well documented, as spatial policy can play an important role in the complex interplay between environment and human health.

FLEHS IV findings on spatial parameters and health

Methods

In FLEHS IV, 610 adolescents (14-15 year old) were recruited in the course of 2017–2018, including 428 adolescents as a representative sample of the Flemish population, for the reference campaign, and 182 adolescents (14-15 year old) from a previous HBM campaign in new borns (FLEHS I) were followed up during puberty. The Center examined to what extent the proximity and accessibility of green infrastructure and the proximity of agricultural areas have an impact on various outcomes such as internal chemical exposure, biological parameters associated with health, cognition and well-being.

For this purpose, the spatial characteristics of the home and school environment of the 610 adolescents were mapped. In the framework of FLEHS IV, the amount of green space within different radii around the adolescents' home address and their school was calculated based on the high-resolution Green Map Flanders of 2012 from the Agency for Geographic Information Flanders (AGIV). Further, the accessibility

to neighborhood green space was assessed and the urbanisation typology (urban, suburban, rural) was considered. Residential exposure to air pollution was calculated for each participant based on data from IRCEL using a spatial interpolation model (Janssen et al., 2008; Lefebvre et al., 2013). Additionally, the urinary carbon load was used as a measure for the participant's exposure to traffic. (Saenen et al, 2017). Exposure and effect markers were analysed 'in relation to the spatial and environmental characteristics of the dwelling's location. To assess exposure to pesticides, biomarkers for pesticides belonging to different chemical classes, active compounds and metabolites were measured in FLEHS IV. (Schoeters et al., 2022). In the reference campaign molecular and physiological aspects of the adolescents' stress response were studied as biological mechanisms that may help underpin the relationship between residential landscape and health. (Verheyen VJ et al, 2021). Telomere length was determined in white blood cells as a biomarker for biological aging that can reflect the negative impact of stressors at the molecular level. Concentrations of cortisol in hair were measured as a marker for the stress level. In the group of 428 adolescents additionally the stress response was studied. To investigate the association of green space exposure with neurocognition in adolescents, attention was assessed with Stroop Test (selective attention) and Continuous Performance Test (sustained and selective attention). Behaviour was determined based on the Strengths and Difficulties Questionnaire. (Bijnens et al, 2022). Adolescent's perception of green space in the residential environment was also investigated using a questionnaire. (Verheyen VJ et al, 2020)

Multilevel regression analyses were used to investigate relationships between spatial parameters and biomarkers. Analyses were adjusted for variables that may influence the exposure biomarkers and may be linked to the variable of interest such as smoking behavior, BMI, being breastfed, household educational attainment and neighborhood urbanicity.

Findings

More surrounding green close to the residence (50m buffer) was associated with longer telomere length (less biological aging) after adjusting for age, gender, passive smoking, maternal education and province. This association appeared to be stronger for the residential address at birth than for the current address and was more pronounced for participants from urban or suburban areas Compared to participants from rural areas. After adjustment for annual exposure to air pollution this relationship remains significant. Time spent in greenspace, air pollution or mental well-being did not appear to influence this association.

Surrounding green space in a 2000m radius was associated with a faster reaction time in adolescents. Especially green with a high vegetation height, trees, was important in this relation. The presence of accessible greenery (> 30 ha) on at least 1600m from the house and accessible greenery (>60 ha, <3200m) was associated with a better attention score. There was no link between green space and the reported behavioural problems in adolescents.

The share of green space in a buffer of 100 m around the home is also associated with a decrease in the likelihood of respiratory infections. Participants who had access to green and where there is high greenery around the house, showed less repairable DNA damage and a healthier diastolic blood pressure. However, the link between green space and health is not unambiguously. For example, high greenery close to the house (buffer 50 m) has an unfavorable effect on inflammatory reactions in the airways and increases the risk of asthmatic symptoms.

With regard to farming in the residential environment, the Environment and Health Center has established that young people with more agriculture near the home (in a buffer of 2 km), had more

AMPA in their bodies. This is a breakdown product of the herbicide glyphosate. For several others pesticides, this difference was not observed. (Poelmans et al., 2021).

One out of two adolescents considered green space (such as parks and forests) to be very important, for instance to connect with nature, to relax, to meet each other and to play sports. Adolescents from households with a lower income, a lower level of education and/or a foreign origin more often indicated that they do not have access to green space in the neighborhood and were less likely to have a garden or a view of greenery from their own home.

For the communication of the results to the participants of the campaign and to the general public the infographic presented below was developed.

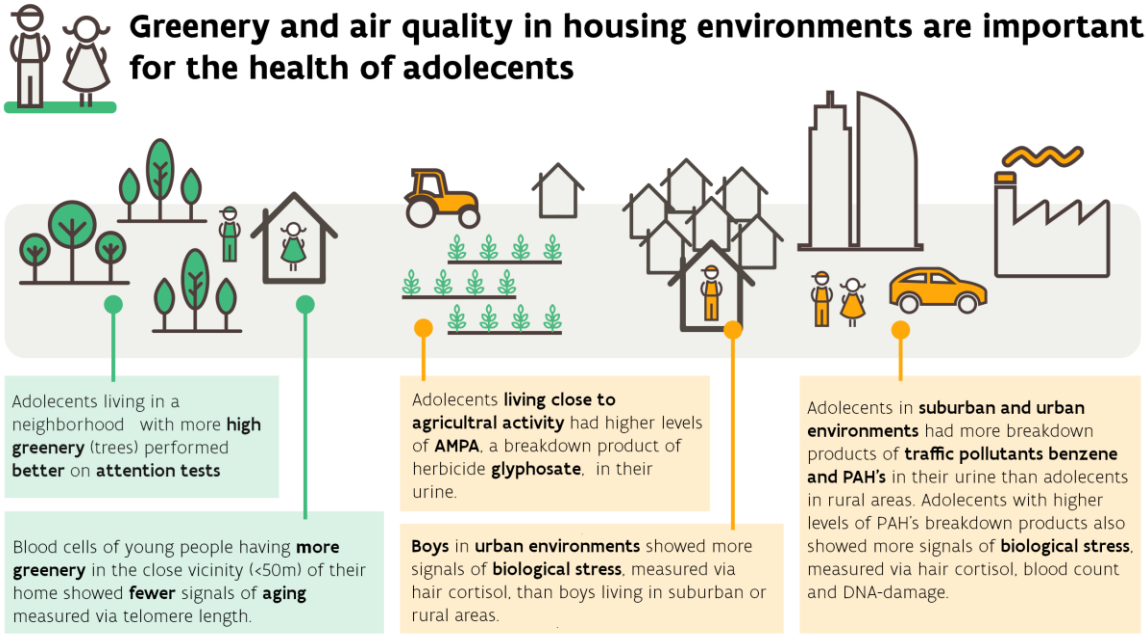

Figure 3: Infographic Importance greenery and indoor air for health. Source: Adapted form the Flemish Center of Expertise on Environment and Health

Involving stakeholders

In order to support the societal and policy relevance of the research findings, the Flemish Center of Expertise on Environment and Health works actively to engage with policy actors and societal stakeholders. Transparency about the research practice and access to the research results are important cornerstones in this respect, while at the same time paying attention to ethical considerations and protection of the privacy and personal data of research participants. The dialogue with the competent and commissioning policy administrations takes place structurally in a steering committee and over the years joint guidelines have been developed for the external communication and involvement of stakeholders in the research process (Loots et al., 2016). In addition, a stepwise and participatory procedure has been developed for the prioritisation and further interpretation of the study results for policy goals (i.e. a 'phased plan for action').

This systematic and stepwise approach was first developed and successfully experimented as a co-production between the Center and the environment and health administrations in FLESH I, and has since been incorporated in the research cycle (Keune et al., 2009; Reynders et al, 2017.

Specifically, for the research theme on green space and health, two roundtable discussions with stakeholders were organized, one at the start of the research cycle (2016) to discuss the problem definition and the research plan, and a second at the end of the research (2020) to discuss the (collective) interpretation and potential policy uptake of the results, from a diversity of perspectives. In addition to representatives from the research consortium and the commissioning government, a diverse group of stakeholders took part in the discussions, including government organizations responsible for environment, preventive health care, nature, spatial planning, agriculture and education, associations of local authorities, environmental and nature organizations, a farmers' union, an association for spatial planners and a commissioner's office for children's rights. Detailed reports of the roundtables (in Dutch) are published on the website of the Center (Coertjens et al., 2016; Coertjens et al., 2020).

During the first round table (on the research design), a significant part of the discussion went to a conceptual clarification of the concept of 'green space', with attention to an underlying diversity, and in a context of urbanisation, densification and interweaving of functions. Secondly, the importance of subjective perceptions and societal support for green space was emphasized, to which the study could contribute, but which may also influence the relationship between green space and health. And in anticipation of policy uptake, the importance of integration of various knowledge sources was emphasised, as well as adapted communication towards different publics and translation into clear guidelines (e.g. typologies) for spatial planners who want to apply the insights in practice. During the second round table (on the research results and main messages for policy making), the results were positively received by all participants, as it provides further scientific support for the hypothesis that green space is good for our health. Since the study was conducted in adolescents, some participants specifically linked the results to the right to a healthy living environment for each child. At the same time, it was pointed out that the findings remain rather general and further integration of other knowledge sources as well as diversification for various contexts remains necessary in order to arrive at concrete recommendations for spatial policy and practice. Finally, various current and planned projects and policy goals were identified for which the results could provide important support. This last point was also further explored in an online Webinar in which approximately 100 participants from policy, science and society participated.

A dialogue on the relevant environmental health knowledge with these adjacent policy fields and their framing of the environmental health issues was set up. This cross-cutting approach allows the interweaving of environmental aspects in other policy domains and vice versa, specific concerns with regard to environmental health from other policy fields could be taken into account and included in the study design and interpretation of study results. In return we hope to have increased awareness and support from other sectors for dealing and taking care of environmental impacts and improve opportunities for policy integration.

Policy advice: use of HBM results to support the spatial planning policy

The study shows that green space surrounding the residence and school combined is associated with better sustained and selected attention and with less biological aging in adolescents.

The Flanders Spatial Report cites the HBM results and the HBM based conclusions that residential green space within close proximity to the residence, as well as in a wider environment, are important for adolescents' health. Given the fact that urbanization is increasing in Flanders as well as in the rest of the world, it is therefore essential that an effort is made to preserve and expand the existing greenspaces and to further improve ambient air quality.

Discussion

The basic objective of Flemish environmental and health policy is to strive for a high level of protection for the current and future generation. After all, a polluted and stressful environment can increase the disease burden considerably, including psychosocial disorders in humans. (Buekers et al., 2022). Since 2002, the Flemish Center of Expertise on Environment and Health performs policy-relevant research based on the principles of scientific research which assesses the presence and health impact of environmental stressors in humans. The objective of mapping the pressure on health by certain (spatial) factors and stressors is not sufficient in this regard. The results of this research must be translated into solution-oriented policy (Reynders et al., 2017).

The HBM results and their policy translation support an evidence-based environmental and spatial policy contributing to a healthy environment and healthy behavior. Multidisciplinarity, knowledge transfer and strong interactions with policy working groups are essential in this regard.

The chain of impacts in the relation between environment and health is represented in figure 1. The system diagram does not completely describe the full situation, but it does allow to indicate drivers (desirable or undesirable) and interaction between the various activities, available space, policy and external influences to be mapped out.

A number of health effects of green space were identified in FLEHS IV. By extension, these go hand in hand with the mental and physical health benefits of nature (EEA report, nr 21/2019) within the living environment by improving air quality (capture of particulate matter), reducing noise pollution and heat stress. This brings us to a concrete Flemish challenge in spatial policy: broadening the Flemish HBM program to include nuisance (perception), well-being in relation to the quality of the living environment, relation of space (use)-climate-health with specific focus on the urban context and dynamic exposure. HBM research yields a multitude of interesting data about the environment and health. But the translation to policy measures is not always indisputable. Both scientifically and societal, there is often a great deal of disagreement and/or uncertainty about, among other things, the (health-related) importance of the results, the causal pathway, possible solutions for identified problems and priorities for policy. That is why, within the framework of the first Center of expertise on Environment and Health, 'The Phase Plan' was developed, a procedure for further interpreting the results of HBM campaigns and translating them into policy actions in a transparent, systematic and participatory manner. In other words, the Phase Plan is a follow-up trajectory to HBM research, in which researchers, policymakers and societal stakeholders participate.

For the same reason, it is important to disseminate the results in communication platforms such as the RURA report, to stimulate the social debate on weight of evidence, solutions and policy measures.

Today, there is recognition that the dynamic between the environment, health and well-being is complex, with exposure to multiple stressors leading to combined effects, mediated by social status. (EEA report, n° 21/2019). A quarter of the burden of disease worldwide is due to unhealthy environments, and specifically to urban or built-up aspects. In high-income countries such as Belgium, it mainly concerns non-communicable diseases due to air pollution, noise and odor nuisance, physical inactivity, unhealthy diet and a lack of high-quality open space. They are included in the representation in figure 1. In RURA some of these separate phenomena are described. However, all phenomena are part of a larger whole with a system nature of cause effect relationships. Creating an environment that encourages sustainable and healthy choices has many more benefits (financial, environmental and health,…) than approaching health purely as an individual choice. It is therefore not surprising that the health sector is looking at the spatial discipline. The 'Health in All Policies' approach aims to systematically and transparently consider

the health impact of (policy) decisions, to seek collaboration and to avoid health risks in order to improve the health of residents and health inequalities. That way health policy moves into other policy areas, including environmental policy. In Flanders, too, health is increasingly on the spatial policy and research agenda. (Vervoort et al., 2022) The phase-plan approach proves to be a successful way to implement scientific health evidence into spatial planning and environmental planning policy. Spatial and environmental policy could benefit from more spatial explicit results. It would be therefore be interesting to look at in dept which spatial and environmental research questions could benefit from research through HBM. This requires a phase plan-like collaboration combining interdisciplinary expertise at the start of a campaign.

In addition, HBM results are a cross section snap shot and RURA is a status report. Successive HBM-cycles with attention for continuity result in insight in evolution of biomarker concentrations from past to present and future and signify an added value for policy evaluation and policy adjustment.

In het Flemish HBM campaigns considerable efforts are made for socio-demographic analyses with attention for vulnerable population groups and vulnerable life stages. Recruitment of a study population is easily biased towards participants of higher socio- economic class (SES), in particular in a context of environmental studies. Recent efforts by the Flemish Center of Expertise on Environment and Health showed that representativity to include different participants with different socio-economic status, ethnicity and educational level can be improved but it requires specific approaches and study material. (Morrens et al, 2015) Moreover, there is evidence that SES has an indirect but significant influence on chemical exposure and health (it is a proxy for behaviour and life style). Since we expected that the theme of use of open space is closely intertwined with SES an approach to include and study social diversity in the adolescent population that was recruited, was applied. Doing so, the representativity for geographic distribution of the participants was maintained as important, given the statistical representativeness of the study that was strived for.

In the FLEHS campaigns, as in other international studies, internal exposure to chemicals was associated with socio-economic status and/or the migration background. This relationship is positive for some substances and negative for others. Similar differences have also been identified for some effect markers. This indicates that this population is more vulnerable to exposure to some chemicals and to harmful effects of exposure (Morrens et al., 2020). The WHO Regional Office for Europe (2016) review on the link between urban green space and health cites several studies pointing to the importance of access to green space for socially disadvantaged populations: the health benefits of access to and use of green space is relatively larger for these groups.

Conclusion

As pictured in figure 1, health is determined by a complexity of parameters of which a number can be influenced by spatial policy. As described in this paper, in the Flanders environmental policy, results of HBM substantiate these policy measures with the objective of prevention and health improvement, an example of the concept ‘health in all policies’.

Green space offer positive outcomes for people living, working and spending their free time in these places by mitigating environmental pollution and supporting biodiversity, improving health and well-being and fostering social cohesion. The dynamic between the environment, health and well-being is complex, with exposure to multiple stressors leading to combined effects, mediated by social status.

These research activities and the results are described in the Flanders Spatial Report (RURA) for dissemination to a large public. In this way, scientific research on the relation between environment and health and the communication of the results contribute to the public debate about spatial policy.

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