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*P*ositive *h*ealth *e*ffects of the *n*atural *o*utdoor environment in *ty*pical *p*opulations in different regions in *E*urope (*PHENOTYPE*): a study programme protocol

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ABSTRACT

Introduction: Growing evidence suggests that close contact with nature brings benefits to human health and well-being, but the proposed mechanisms are still not well understood and the associations with health remain uncertain. The *P*ositive *H*ealth *E*ffects of the *N*atural *O*utdoor environment in *Ty*pical *P*opulations in different regions in *E*urope (PHENOTYPE) project investigates the interconnections between natural outdoor environments and better human health and well-being.

Aims and methods: The PHENOTYPE project explores the proposed underlying mechanisms at work (stress reduction/restorative function, physical activity, social interaction, exposure to environmental hazards) and examines the associations with health outcomes for different population groups. It implements conventional and new innovative high-tech methods to characterise the natural environment in terms of quality and quantity. Preventive as well as therapeutic effects of contact with the natural environment are being covered. PHENOTYPE further addresses implications for land-use planning and green space management. The main innovative part of the study is the evaluation of possible short-term and long-term associations of green space and health and the possible underlying mechanisms in four different countries (each with quite a different type of green space and a different use), using the same methodology, in one research programme. This type of holistic approach has not been undertaken before. Furthermore there are technological innovations such as the use of remote sensing and smartphones in the assessment of green space.

Conclusions: The project will produce a more robust evidence base on links between exposure to natural outdoor environment and human health and well-being, in addition to a better integration of human health needs into land-use planning and green space management in rural as well as urban areas.

Strengths and limitations of this study

- The *P*ositive *H*ealth *E*ffects of the *N*atural *O*utdoor environment in *Ty*pical *P*opulations in different regions in *E*urope (PHENOTYPE) project is the largest European project on green space and health.
- The PHENOTYPE project examines simultaneously the possible underlying mechanisms (stress reduction/restorative function, physical activity, social interaction, exposure to environmental hazards) for the relationship between green space and health in four different countries in Europe.
- The PHENOTYPE project examines a range of possible associations of the natural outdoor environment and health using 16 different cohorts and/registries in 4 different European countries.
- The PHENOTYPE project uses a range of novel tools and methods to assess access and use of green space including remote sensing, smartphones, audits and interviews.
- The PHENOTYPE project works closely with stakeholders and produces new information for stakeholders.

INTRODUCTION

Positive health effects of green space have been observed on longevity,[1–3] cardiovascular diseases,[4] people's self-reported general health,[5 6] mental health,[7–11] sleep patterns,[12] recovery from illness,[13] social health aspects[14–18] and birth outcomes.[19–21] Some of the associations were shown to be modified by socioeconomic status and level of urbanity, with greater benefits for

populations of a lower socioeconomic class[20 22] and those in more urban areas.[6 22] Furthermore gender has been shown to modify the relationship.[11]

Increased physical activity and social contacts, psychological restoration/stress reduction, a reduction in pollutants such as noise and air pollution, and temperature have been proposed as possible mechanisms for the health benefits of green space. Access to and/or use of green space has been associated with higher levels of physical activity[23–33] and lower levels of obesity within communities.[25 27 34–38] Studies even suggested that 'green exercise' can have even more positive mental health benefits than other kinds of exercise.[39–42]

Psychological restoration[43–45] and reduced stress and anxiety[7 8 17 46 47] have all been associated with access to and/or use of green and natural space. An inner-city study in a deprived estate in Chicago showed the benefits of green space to cognitive restoration,[48 49] self-discipline,[48] reduced aggression[49] and reduced crime,[50] with the latter also observed elsewhere recently.[51]

Furthermore a few studies have suggested that green space is associated with more social contacts and cohesion.[16 17 52] And finally, reduction in exposure to air pollution has been observed in areas with more green space,[53] as vegetation is known to reduce air pollution levels and temperature,[54–57] with some studies suggesting that the benefits are greater for socially disadvantaged groups.[55] It has also been suggested that vegetation (trees, plants) and soil may have an impact on the sound level.[57–62] Part of the appeal of green spaces may be related to pleasant acoustic environments. This may have its own, direct beneficial health effect (Health Council of the Netherlands, 2006).

While growing evidence exists that close contact with nature brings benefits to human health and well-being, the proposed mechanisms are still not well understood and the associations with health remain uncertain. Furthermore, it is unclear if the possible mechanisms act in isolation or together, since with some exceptions[18] they have been studied in isolation. A coherent conceptual framework on the proposed mechanisms is currently lacking. Also, most of the research has been conducted in the northwest of Europe and the USA leaving questions about the generalisability to other regions. Inconsistency and variation in indicators (eg, type, size and quality) for green space have often made it difficult to compare results from different studies, and a better characterisation including that of quantity and quality of green and blue spaces is needed, not only for research but also for policymakers and spatial planners. Studies have often focused on access to green space without taking into account actual use of green space. While blue space may also have a positive effect on health, probably in combination with green space, there are only a few epidemiological studies investigating this.[63–65]

*P*ositive *H*ealth *E*ffects of the *N*atural *O*utdoor environment in *T*ypical *P*opulations in different regions in *E*urope (PHENOTYPE) is a collaborative research project and explores the proposed underlying mechanisms at work (stress reduction/restorative function, physical activity, social interaction, exposure to environmental hazards). PHENOTYPE is the first study designed to examine these mechanisms simultaneously in a large sample (N=4000 participants) in various European countries using the same methodology. This allows the study of specific factors while adjusting for others, and thereby strengthening the interpretation of the results. It further examines the long-term and short-term associations with health (eg, general health and well-being, mental health/neural development, stress, cardiovascular diseases, cancer and respiratory mortality and morbidity, birth outcomes and obesity) for different population groups (eg, pregnant women and/or fetus, different age groups, socioeconomic statuses (SES), ethics groups and patients), through analyses of existing cohort studies, observational studies and experiments. Preventive as well as therapeutic effects of contact with the natural environment are being evaluated. A coherent conceptual framework on the association between the natural environment and its effects on health and well-being is being developed, and it addresses implications for land-use planning and green space management.

The study includes rural and urban settings, but the main focus is on the urban environment, for a number of reasons. Most of the population lives in urban areas (75%) in Europe, making this of greater relevance to public health, and rapid urbanisation continues to reduce accessible natural environments for urban residents. Most people make more frequent use of the green spaces in their nearby living environment instead of travelling greater distances to rural areas, in particular people of lower SES, elderly people and children.[66 67] Furthermore, rural dwellers tend to have constant contact with the natural environment and it may therefore also be more difficult to assess its effects.

Lastly, the project uses an interdisciplinary and integrated approach, applying the best and most efficient methods to understand the relation between exposure to the natural environment and health. It implements conventional and innovative high-tech methods to characterise the natural environment in terms of quality and quantity. This paper provides a general overview of the research methodology of PHENOTYPE.

METHODS

Figure 1 summarises the different parts of the study and the interdependencies between the different parts, namely the characterisation of the natural environment and the way it is used, examination of the underlying mechanisms in daily life settings, short-term and long-term effects of the natural environment and the implications for management and policy of the natural environment (see overview figures 1 and online figure 1). In this section we will elaborate on each of

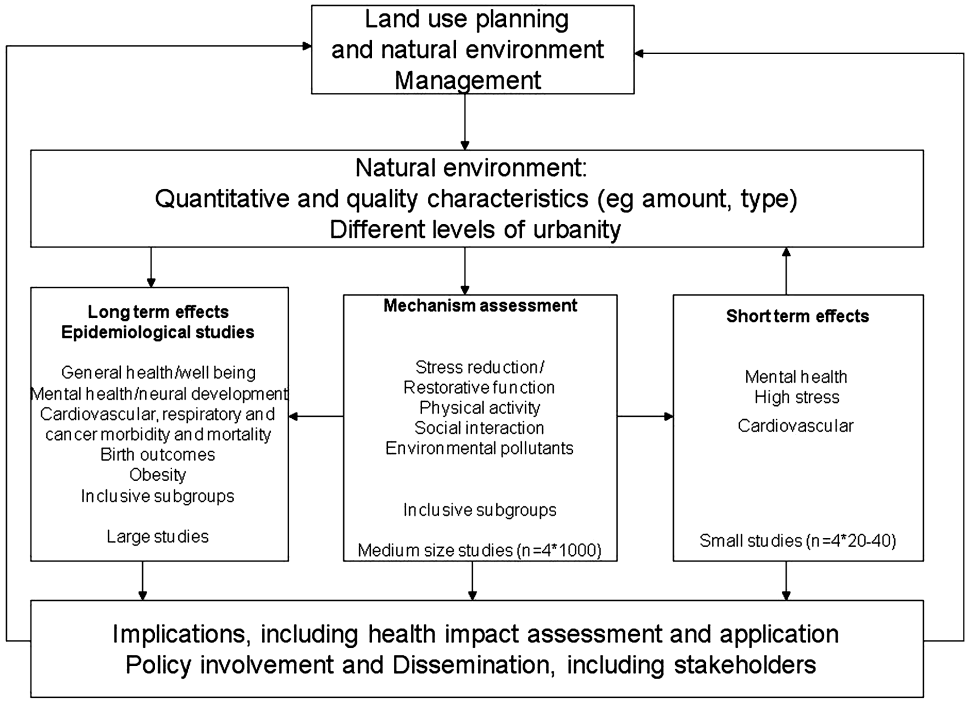

Figure 1 Interdependencies of different parts of the PHENOTYPE project.

these parts. A summary of the mechanisms, outcomes, populations and areas selected for investigation are given in box 1.

Characterising the natural environment and the way it is used

The research includes evaluation of the natural environment, which includes for the purposes of the project:

- Green spaces (eg, roof gardens, city parks, courtyards) and 'greenery'; forests, nature reserves/parks, mountains, farmland, trees, landscaping.
- Blue spaces; water bodies such as canals, ponds, creeks, rivers, beaches, etc.

Although many of these may actually not be 'natural' since they are man-made, for the purpose of the project we classify them as such.

One of the main aims of PHENOTYPE is to examine the importance of quantitative (eg, amount, type, access and use) and qualitative characteristics (eg, acoustic quality, identity, variety, safety and cleanliness) of the natural environment by collecting detailed data on these characteristics using a combination of methods. The focus lies on natural environments at different scales and distances from the home (city/town, neighbourhood, street level) and where possible also at other places where people stay (work, school, on their way to home/school, recreational). In addition, actual use of the natural environment is taken into consideration. To achieve the aim, a detailed assessment will be conducted in four case cities (Barcelona, Spain; Doetinchem, the Netherlands; Kaunas, Lithuania; and Stoke-on-Trent, UK), with less detailed assessment in other study areas.

PHENOTYPE uses conventional land-use maps, remote sensing data from satellites and aerial photography, complemented by detailed discussions with volunteers and other stakeholders living and working in the areas under study to derive comparable classifications of the natural environment in different countries. Collected data will contribute to the characterisation of the natural environment (quantitative and qualitative, eg, accessibility, acoustical quality, recreational activities, walkability, etc). For the quantitative characterisation, PHENOTYPE makes use of available land-use maps such as COordination and INformation on the Environmental programme, initiated by the European Commission (CORINE)[68] and Urban Atlas,[69] and remote sensing and aerial photography to obtain comparable indices such as NDVI[70] of the natural outdoor environment in different countries. Landsat-Enhanced Thematic Mapper Plus (ETM+) data are applied to a classification and regression tree (CART) model to categorise land cover types for the urban areas of interest.[55] Early application of the NDVI in Barcelona, Spain, showed good results[20] (see online figure 2).

To collect additional qualitative information on the natural environment and on other physical and social features, systematic observations (audits) are conducted by trained researchers in selected neighbourhoods in the four case cities using the same methods.

Since it is not feasible and not necessary to audit every street in a selected neighbourhood, a purposeful sample of streets is drawn, ensuring that important neighbourhood features are included. The selected neighbourhoods are divided into more or less homogeneous subareas by means of data/maps on land-use/function

Box 1 PHENOTYPE study mechanisms, outcomes, populations and regions

It will explore underlying mechanisms related to:
- Stress reduction/restorative function
- Physical activity
- Social interaction/social cohesion exposure to environmental hazards (eg, noise/acoustic quality, air pollution)

Preventative and therapeutic effects (on patients) will be considered. Outcomes of interest that are evaluated are:
- General health and well-being (including medically unexplained symptoms (MUPS))
- Mental health/neural development
- Stress
- Cardiovascular, cancer and respiratory mortality and morbidity
- Birth outcomes
- Obesity

It will examine the effects for different population groups, including more vulnerable populations:
- Pregnant women and/or fetus
- Age groups (children, elderly)
- (Lower) socioeconomic status
- Ethnic minorities
- Patients/people with specific health complaints

It will conduct comparative studies in different regions of Europe to examine any underlying regional, social and/or cultural differences related to the meanings, uses, mechanisms and health effects of the natural environment and we will include the:
- Northwest (The Netherlands, England)
- South (Spain)
- East (Lithuania)

of areas in combination with local knowledge of the area. Subsequently, trained auditors are asked to visit the subareas and observe them in a systematic way (auditing) using a paper form containing several close-ended questions. Every subarea is visited by two auditors. For the first 1–2 areas, the auditors fill in the list together, discussing completion to reach consensus. In subsequent areas, where possible, the two auditors complete the audit independently and simultaneously. Furthermore, up to two natural environments of more than one hectare in size are selected per neighbourhood using GIS. Again following training in completion of the audit, two auditors visit the environments. For the first five areas, auditors undertake the interview together, discussing completion to reach consensus, thus maximising consistency. In subsequent areas, where possible, two assessors complete the audit independently and simultaneously. In the absence of existing measures that could meet our requirements, the streetscape audit was developed for this project and the natural environment tool was adapted from existing measures. This kind of bespoke tool development is seen in similar studies, for example, by van Dillen *et al*.[71] One form is used for evaluating the streetscape, using indicators derived from the street typology developed by Leidelmeijer *et al*,[72] a list of evaluating the quality of green by van Dillen *et al*[71] and the audit tool developed by Lenthe *et al*.[73] The natural environment audit is adapted from that developed by Gidlow *et al*[74] through addition of items and domains to reflect the greater diversity in natural environments to be included (ie, different types of natural environment across four European cities). The tools were piloted and adjusted prior to use. They have not been 'validated', but there is no gold standard quality measure for natural environments against which to compare. Inter-rater reliability will be estimated through derivation of Inter-rater Correlation Coefficients (ICC) and PCA will be used to ensure that any redundant items are removed and included items are grouped sensibly into domains, before overall quality scores will be derived.

To gain insight into the way people use the natural environment, a face-to-face questionnaire survey is conducted to collect data on 1000 people in the 30 selected neighbourhoods in each of the four case cities, and an in-depth study using 'Calfit', a smartphone-based monitor of time-location patterns and momentary states, on a subsample (n=100) of the participants of the questionnaire survey (for further detailed information, see next section on underlying mechanisms). The Calfit software[75 76] runs on a Google Android operating system and as currently configured can collect data on physical activity using the motion sensor and geographical location through a global positioning system (GPS), to obtain information on minutes spent and physical activity levels in different natural environments (see online figure 3). The instrument has been validated against the Actigraph accelerometer,[75] combined with other pollution measurements to assess likely inhalation,[76] and laboratory-validated using the Cosmed metabolic monitoring system.

The work will produce different indicators of natural space that can be used in the studies described below. The aim is to make a hierarchy of indicators with simple measures on the bottom, such as NDVI that can be easily obtained for all the study areas and on the top detailed measures of, for example, green space with actual information on the quantity, quality and use that can only be obtained for only some areas after in-depth study. As part of the work, we will examine the relationship between the simple and detailed measures to understand better how detailed information on small scale can help the interpretation of health studies conducted in larger areas with only simple measures available using existing epidemiological studies and registries (see below).

Examining the underlying mechanism in the daily life setting

New data will be collected to explore in detail and simultaneously, the proposed mechanisms (physical activity, social contacts/cohesion, psychological restoration/stress reduction) underlying the relationship between the natural environment and health and well-being in the four case cities. In each of these cities

neighbourhoods varying in SES and in their distance to green space are selected. In these neighbourhoods the natural environment will be characterised, and (as aforementioned) a selection of 1000 randomly selected residents (4000 in total, 18–75 years) will participate in a questionnaire survey, 100 in a smartphone study, and 20 in in-depth interviews (see online figure 4).

To optimally investigate what types of natural environments and levels of accessibility are relevant in relation with the mechanisms that we investigate (physical activity, stress and restoration, social interactions and environmental pollution), and to investigate potential differences in this mechanism among the population, we use a multilevel approach and select neighbourhoods with different SES and access to the natural environment. We use existing statistical or administrative units with existing statistical or administrative units that are as similar as possible with regard to variation in population size, in Stoke-on-Trent Lower Layer Super Output Areas, in Barcelona census areas, in Kaunas voting districts and in Doetinchem neighbourhoods. Natural space and SES measures are assigned to all the units using existing data. For natural space, Urban Atlas is used for Stoke-on-Trent, Barcelona and Kaunas. Since Urban Atlas is not available for Doetinchem, data of another Dutch database ('Top10 nl') are used. For SES no comparable data existed for the four cities. Therefore partners use their own local data. Then the units are ranked on the basis of each natural space and SES. Subsequently a selection of two neighbourhoods from each combination of top, middle and bottom tertiles of SES and quintiles of the natural space is made (approximately 2×3×5=30 units). A few extra units are added to optimise contrast and reach a sufficient number of units to be able to recruit 1000 participants in each city (30 participants per units). Since there are no common person registries in these countries, participants (aged between 18 and 75) are selected using different approaches. In Doetinchem and Stoke-on-Trent, addresses are sampled randomly from the BAG Registry ('Buildings and Adresses') 2012 and a local address registry, respectively, and the person with the closest birthday to the interview data is selected at each address; in Barcelona participants are randomly selected from the person registry (empadronamiento) and in Kaunas participants are sampled randomly from a 2006 to 2009 survey of randomly sampled people of the city of Kaunas. In each case there is an over-selection of potential addresses or participants to be able to interview at least a 1000 participants (and 30/unit) in each city. The target of a 1000 participants per city was mostly based on the available budget. To enable multilevel analysis, we estimated that a minimum of 30 participants per group (or neighbourhood) were required, with a minimum of 30 groups.

The questionnaire survey was designed to investigate three potential mechanisms in relation to natural environments and health: via physical activity, stress and restoration and social interactions. In addition, questions are included about environmental worries and reactions to perceived exposures (air pollution, noise, etc). The choice of indicators was based on these three mechanisms and was achieved via an interactive process of experts within the PHENOTYPE team. As much as possible questions were derived from existing and validated indices, some tailored to the specific objectives of PHENOTYPE. The questionnaire was developed in English and was translated (and back translated) into Dutch, Spanish, Catalan, and Lithuanian. The questionnaire was developed to be applied in an oral interview of at maximum 60 min. In Kaunas it is not common to have face-to-face interviews; therefore a written questionnaire is sent by post to the selected people. The questionnaire was piloted by all partners, with specific attention to comprehensibility, clarity and duration and was adapted at some points based on outcomes of these pilots.

The final questionnaire is structured along four main clusters of questions: (I) Green and blue spaces; (II) Residential situation: dwelling and neighbourhood; (III) Well-being and health; and (IV) Personal characteristics. Per mechanism questions are asked about availability, use, importance and satisfaction. In the sequencing of the questions we strive for a coherent set of questions per cluster moving from general to specific and from 'easy' to more intruding questions. Furthermore, most of the answer categories moved from neutral negative towards positive items. For all answers showcards have been developed by RIVM, to make it easier for interviewers and respondents, and to speed up the interview process. A separate instruction document was developed to train the interviewers. The questionnaire ended with an optional pencil paper attention test (Color Trails Test).[77]

Finally, for the smartphone study at least 100 volunteers from each country are randomly selected from the participants of the questionnaire survey who indicated that they were willing to participate in the smartphone study. For these participants, during the subsequent seven days the emotional state of the participant, the local environment (eg, different quantities or qualities of natural space) and the social setting are assessed with the smartphone and the innovative Calfit technology. Besides objective geolocation and physical activity (see section Characterising the natural environment), subjective data on stress reduction/restoration and social contacts are collected simultaneously. The latter data are collected through interactive diaries capable of eliciting ecological momentary assessment (EMA). EMA is a novel approach to elicit responses to electronic surveys throughout the course of daily life.[78] The participant receives prompts at random intervals to complete small surveys on the phone, which then have time and location stamp.

From the people who participate in the questionnaire survey and the CALFIT study and who indicate they want to volunteer, 80 people (20 in each case city) are approached for semistructured interviews. These interviews are conducted to gain more detailed information on specific topics included in the questionnaire survey and CALFIT/EMA. Topics addressed include the motivation for travel routes,

the associations of natural environment with mood, behaviour and well-being, the attitude towards and importance of (experiences with) natural environment and reasons for using or not using the natural environment.

Epidemiological studies to examine long-term effects of the natural environment

By using existing epidemiological studies and registries and linking these to the natural space indicators described earlier, the association between natural environment and a range of different long-term health outcomes will be examined in an efficient and cost-effective manner. PHENOTYPE makes use of 16 existing cohorts and registries with good health outcome data in Spain, the Netherlands, Lithuania and UK (see online table 1), linking these to newly created natural environment indicators. Comparable estimates are produced for various regions in Europe for the associations with pregnancy outcomes, fetus development, children's health and adult population morbidity and mortality. We specifically focus on:

- The natural outdoor environment and ethnicity, SES, women's health and pregnancy outcomes;
- The natural outdoor environment and fetus development, birth weight and gestational age;
- The natural outdoor environment and general development, neurodevelopment, cognitive function and respiratory health in children;
- The natural outdoor environment and respiratory health in various European cities;
- The natural outdoor environment and general health, physical activity, specific morbidity and mortality.

The assessment of natural environment indicators will be mainly based on satellite data and land-use maps such as CORINE and Urban Atlas, and sometimes local data. This will restrict to some extent the evaluation of the association with the natural environment, but this is the only realistic and achievable approach. All studies examine the role of SES, which has been suggested as an effect modifier for the relationship between exposure to the natural environment and health benefits. The European Community Respiratory Health study (ECRHS)[79] further allows for examination of exposure to the natural outdoor environment and associations with health in a range of different European cities. Some cohorts such as the Born in Bradford study[80] offer a unique opportunity to investigate the role of ethnicity in the relationship between exposure to the natural outdoor environment and health benefits. In Bradford study half of the participants are from Pakistani background, with information on the mother and baby from pregnancy to early years in life.

Experiments to examine short-term effects of the natural environment

To examine short-term effects of the natural environment on health and well-being, one or more experimental studies are conducted in each country in which individuals are exposed to different types of natural and urban environments (ie, environmental conditions). The majority of data collection is field-based to maximise the ecological (as well as internal) validity of any observed effects.

Using a range of (1) psychological and physiological indicators relevant to the various possible mechanisms, and (2) healthy and patient population groups (with mental and/or somatic morbidities) we will collectively explore:

- Preventive and therapeutic effects of natural environments;
- Immediate and sustained changes in affective, cognitive and physiological responses indicative of well-being while engaged in a natural environment, and after leaving a natural environment;
- Neurobiological responses to viewing natural or urban scenes before/after experiencing stress.

Through variation in experimental design, each partner makes a novel contribution(s) to the area as (details in see online table 2):

- UK: In healthy individuals, study 1 compares immediate and postexposure psychophysiological effects of urban versus natural environments to explore whether any beneficial effects are sustained following single exposures; and study 2 uses longer term follow-up and repeated exposure to natural environments to explore whether any effects are accumulated, sustained or attenuated.
- The Netherlands: An experimental functional MRI study is conducted in healthy individuals to investigate neurobiological responses to viewing natural or urban scenes before/after experiencing stress; that is, whether viewing natural compared to urban scenery can prevent or buffer against stress responses, and how this is represented in brain activation patterns.
- Spain: In individuals with elevated stress levels, group-based exposure and EMA (using CALFIT technology) are used to explore the role of social interaction and the nature of physical activity, in immediate and longer term responses. Ecological validity will be enhanced through 'free-living' activities within environments, rather than controlling activities, again, using EMA, GPS and accelerometry to monitor the nature (and perceptions) of this activity.
- Lithuania: A clinical population with established coronary artery disease is recruited to evaluate the therapeutic effect of the natural environment. The outcomes of this experiment may have direct clinical applications for the use of urban and different types of natural environment in cardiac rehabilitation.

Implications, policy and guidelines and involvement of stakeholders

Guidelines

PHENOTYPE will provide recommendations for policymakers and guidelines for professional practitioners involved with spatial planning and health to create natural environments that promote health and well-being. For this,

we focus on a human ecological perspective which allows for a better integration of human health needs into land-use planning and green space management in rural and urban areas.[81] Currently legal standards that have been developed with economic, technological and political priorities in mind, are leading in urban design, whereas the lifestyle, sense of community, identity and health and well-being of local populations have been largely undervalued. The guidelines will reflect the importance of considering environmental, social, economic and other components of the natural and built environments in ways that also take into account and result from the point of view of citizens. PHENOTYPE will complement the common quantitative approach by valorising the social/human functions of these environments, especially their contribution to promoting health and quality of life.

Following this broad and innovative approach, PHENOTYPE will formulate, test and validate a set of recommendations and guidelines concerning the desired characteristics of different types of natural environments in urban and rural areas, specifically their characteristic features, accessibility to them for different population groups, as well as their facilities, maintenance and services. By doing so, the work will overcome the existing applicability gap between information and knowledge accumulated by much research and policy definition and implementation.

The guidelines for professional practitioners involved with spatial planning and health will consider three core topics in relation to each of the natural environment being considered:

1. Qualitative characteristics of natural environments; recommendations concerning surface area, vegetation, water sources, ambient noise levels, views and microclimate;
2. Facilities, maintenance and services; recommendations about the kinds of communal facilities and services provided in each type of natural environment, as well as suggested levels of maintenance;
3. Accessibility guidelines to natural environments; including requirements about access to different types of natural environments such as allotments, neighbourhood parks, children's playgrounds and nature reserves.

The baseline for the work is first, the compilation and analysis of currently available information from existing databases and literature, and later new data collected by the project as described above. This will be complemented by the engagement with appropriate stakeholders to assess scope for development. These insights will be combined into a conceptual framework on the underlying mechanisms of the effects of the natural environment on health and well-being.

Stakeholders and dissemination

The participation provides a forum for project assurance and benefits for PHENOTYPE are summarised as follows:

- A more robust evidence base on links between exposure to natural outdoor environment and human health/well-being for various regions in Europe. We expect to develop a better understanding of the potential mechanisms.
- A better integration of human needs into land-use planning and green space management in rural as well as urban areas. Furthermore, the application of these needs in practical guidelines.

Stakeholder involvement is critical for bringing outside (policy) ideas into the research planning, to increase the usefulness of the research, and to assure a better implementation of the results of the project (see online figure 5). In a research project, this is often limited because the lack of interest of stakeholders and the limited resources and efforts of consortia.

From the start, PHENOTYPE actively sought to establish and maintain relations and dialogues with and between key stakeholders from local, regional and national health and environment authorities, institutions and the international research community. These include policymakers, architects, urban planners, natural space managers, health professionals and the international research community. This group is highly diverse, as we are looking at a range of professions within the participant areas of environment and health, from volunteers to scientists, community workers and policy developers. PHENOTYPE has thus far been successful in its engagement activities, providing continuous opportunities for information exchange and collaborations. These contribute to strengthening networking between researchers, policymakers and stakeholders in order to facilitate the transfer of scientific knowledge to policy development, to exchange ideas about best practice and to help identify emerging issues on the natural outdoor environment and its mechanisms to improve health.

The PHENOTYPE website http://www.phenotype.eu provides an overview of the project, progress, actualities, surveys and publications. The site has a sign up form for periodic newsletters through which all stakeholders are regularly informed. It guarantees continuous visibility, and provides a means for interested parties to respond to activities, or to contact it with invitations to attend workshops, etc. PHENOTYPE is also found on social media—Twitter (@greenhealth4eu) and LinkedIn. The PHENOTYPE databases and overall results will be exploitable by policymakers at national and international levels in areas including urban planning and health.

CONCLUSION

The PHENOTYPE project is an FP7 collaborative action, funded by the EC to explore the mechanisms underlying positive short-term and long-term health effects for different population groups. PHENOTYPE applies conventional and new innovative high-tech methods to characterise the

Table 1 Limitations of current green space work and work undertaken by PHENOTYPE to address these

Limitations of current available work	What PHENOTYPE will do
▶ Inconsistency and variation in indicators for green or natural space have often made it difficult to compare results from different studies	▶ Minimise the potential differences due to classification of natural space, by combining the use of conventional maps and data sources with remote sensing data and aerial photography, gather individual-level data through detailed discussions with participants living in the areas, and use considerable stakeholder engagement to develop comparable classifications of the natural environment in different countries ▶ Produce a more robust and comparable evidence base on links between exposure to natural outdoor environment and human health and well-being
▶ A number of disease outcomes have been studied but, besides the routinely collected data (which use ICD coding), not always in a standardised and comparable manner in different countries	▶ Produce a more robust and comparable evidence base on links between exposure to natural outdoor environment and human health and well-being, using well studied and new outcomes with standardisation between countries
▶ Potentially very sensitive groups such as pregnant women/ fetus have not been studied at all	▶ Extend the evidence base to new outcomes and vulnerable populations, for example, pregnant women and their fetus, chronic respiratory and cardiovascular patients, ethnic minorities and low socioeconomic class
▶ Most studies focused on green space; the evidence base for the effects of blue space is very limited	▶ Not only examine the effects of green space, but also of blue space
▶ Most of the green space studies have been conducted in the USA or the northwest of Europe	▶ Conduct comparable studies across Europe and produce evidence for northwestern, eastern and southern Europe. This will deliver insights into regional, social and/or cultural differences in relation to natural space
▶ Most studies do not include actual use of the natural environment	▶ Consider actual use of the natural environment, an often neglected but fundamental indicator in relation to exposure to natural environments
▶ There appeared to be differences in social group, with some apparently benefiting more than others from natural space, but the evidence is sparse	▶ Produce a more robust and comparable evidence base on links between exposure to natural outdoor environment and human health and well-being, with special attention to effect modification by social groups
▶ A number of potential mechanisms have been suggested, including increased physical activity and social contacts for those living near natural space, natural environments exerting stress lowering or attention restoring effects, and reducing environmental hazards (eg, air pollution, high temperatures). However, the studies of potential mechanisms have often been limited to assessing one mechanism at the time, which increases the likelihood of unmeasured confounding effects and misses the opportunity to study these potentially interrelated mechanisms in coherence. ▶ To study the mechanisms in coherence even though they may be interrelated	▶ Examine the proposed mechanisms (physical activity, stress, social contacts, and environmental risk factors) simultaneously in a large sample in various countries (WP2). This will enable us to study specific factors while adjusting for others, and thereby strengthening the interpretation of the results
▶ Unable to answer what specific quantitative and qualitative characteristics of the natural environment have a positive effect on health and well-being, and through what pathways is still largely unknown	▶ Make classifications for the type and level of the indicators, which is important for policymakers ▶ Examine the importance of quantitative (amount, type, access, use) and qualitative characteristics (acoustic quality, identity, variety, safety) of the natural environment

Continued

Table 1 Continued

Limitations of current available work	What PHENOTYPE will do
▶ Limited research exploring the sustained affective, cognitive and physiological responses to a single exposure and the effects of a repeated exposure to the same natural environment	▶ Explore longer term changes in affective, cognitive function and physiological indicators that have to date only been studied during, or immediately after engagement with the natural environment
▶ Unable to explain how policymakers and planners can design a natural environment to maximise health benefits	▶ Explore the immediate, maintained and long-term effects of repeated engagement with the same natural environment on affective, cognitive function, and physiological indicators of well-being
▶ Guidelines of lifestyle, health and well-being have largely undervalued local populations	▶ Include lifestyle, health and well-being factors of the local populations

ICD, International Classification of Disease.

natural environment in terms of quality and quantity. Preventive as well as therapeutic effects of contact with the natural environment will be covered. The proposed work aims to address the limitations of some of the studies that have been published so far (table 1). Furthermore it addresses implications for land-use planning and green space management. The project will produce a more robust evidence base on links between exposure to natural outdoor environment and human health and well-being. This in turn will contribute to improved integration of human health needs into land-use planning and green space management in rural and urban areas.

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