BUGS

Benefits of Urban Green Space

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First Research Brief

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1 Introduction

Cities experience increasing signs of environmental stress, notably in the form of poor air quality, excessive noise, and traffic congestion. At the same time, the pace at which land is being consumed by urban development in Europe is a major concern. The enhancement of green areas has the potential to mitigate the adverse effects of urbanisation in a sustainable way, making cities more attractive to live in, reversing urban sprawl and reducing transport demand. Nowadays, there is an increasing societal support for more green space in and around cities.

Benefits of Urban Green Space (BUGS) is an EU research project aiming at developing a methodology to assess the impact of green space and settlement patterns on urban environmental quality and social well-being, and to formulate recommendations regarding the use of green space as a design tool in urban planning strategies. Addressing the impact of urban green space on such diverse areas as traffic flow and emissions, air quality, microclimate, noise, accessibility, and social well-being, this methodology will enable the deduction of a set of guidelines regarding the use of green space as a design tool for urban planning, at scales ranging from a street canyon or a park to an entire urban region. The remainder of this paper describes the objectives and overall structure of BUGS, illustrating it with results obtained for a few European urban areas.

2 Objectives and methodology

The overall objective of the BUGS methodology is to evaluate a city's potential in terms of green space enhancement, to develop planning scenarios for the effective implementation of such an enhancement, and to evaluate the subsequent environmental and socio-economic impacts using advanced modelling techniques.

At scales ranging from the street canyon to the urban park (micro-scale), the methodology evaluates the impact of trees and other vegetation on air quality and microclimate, and ways of incorporating natural porous noise-absorbing surfaces into the urban environment. Air quality is assessed in terms of percentage changes in exposure of urban citizens to concentrations of (essentially) traffic-related pollutants, such as NO_x, O_3, benzene, particulate matter, VOC's, etc. Microclimate changes are assessed quantitatively as changes in temperature, humidity, and radiation loads, amongst other indicators. Noise reduction strategies using green elements are characterised by the amount of dB decrease they induce.

At the scale of the entire city including its rural surroundings (meso-scale), an evaluation is made of the potential impact of green space and city morphology on urban sprawl, traffic congestion (including emission reductions), and air quality. Traffic is quantified in terms of numbers and fluxes of vehicles, and as percentage emission reductions. Meso-scale air quality and climate is quantified in much the same way as for the micro-scale, though with more emphasis on urban-rural interactions. Geographic maps are produced based on remote sensing, GIS, and spatial modelling techniques, bearing quantitative indications of biophysical and morphological quality (e.g., accessibility and connectivity of green areas), as well as locations for potential greening sites.

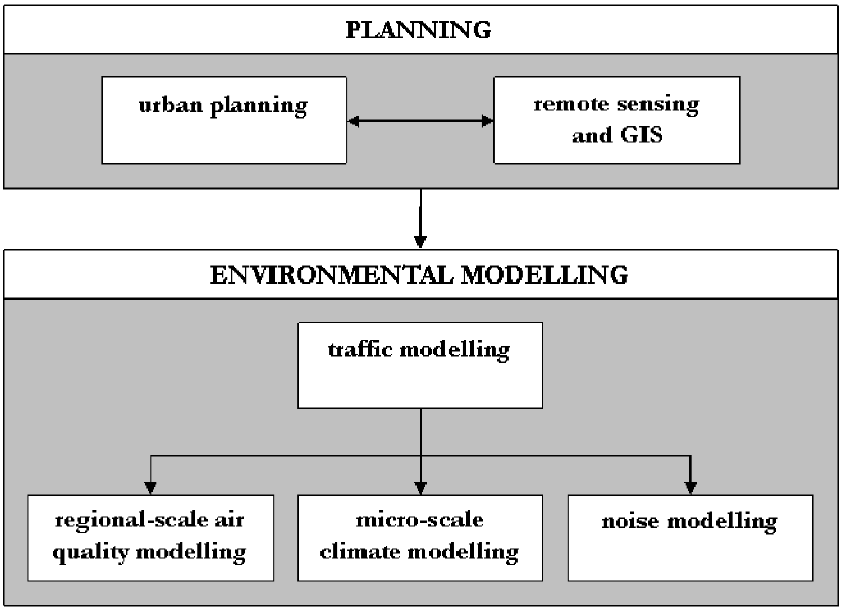


Figure 1. Schematic representation of the BUGS methodology.

In addition to the environmental targets, particular attention is devoted to social aspects: the impact of green areas on the well being of urban citizens is examined, and citizen groups are involved in order to achieve efficient community participation in the planning process. Special care is given to aspects related to the use of green space in the development of deprived urban areas, and to issues of accessibility of green areas and citizen perception of green structures.

3 Results

The main achievement at the current stage of the project is that the individual tools, which in the future will constitute the BUGS methodology, have been developed and/or adapted to specifically address urban green space assessment, and tested on different cities throughout Europe.

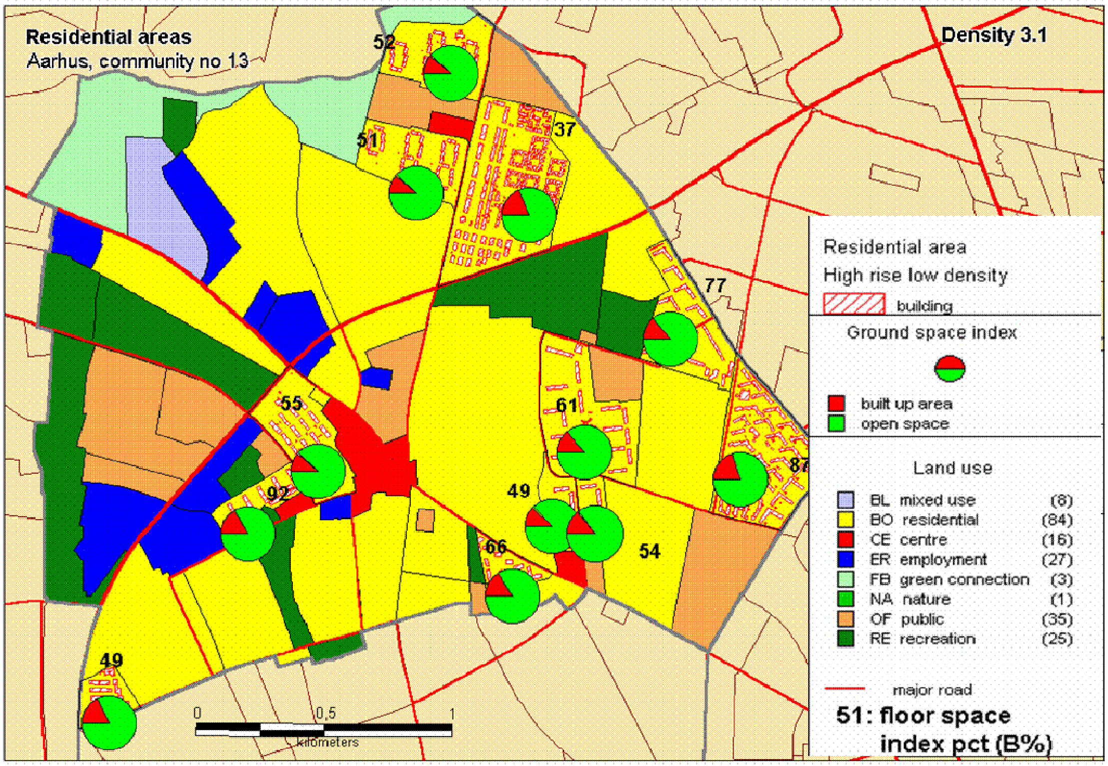


Figure 2. GIS based map of Aarhus containing indicators required in the urban green planning process.

In the remainder of this section, an overview will be given of the progress made in the development of the tools, together with scientific results obtained on individual test cases. It is important that the reader realise that the results shown here were obtained during the first project phase, in the course of which the models and methods were applied separately on different cities. Therefore, the results shown below are not yet representative of the BUGS methodology as a whole. Nevertheless, some of the results appear to be of a rather universal nature – in the sense that they are applicable elsewhere than on the areas they were tested for – and have an intrinsic scientific interest. As such, they will be used as input in the urban planning process of the second project phase, which focuses on the integrated application of the BUGS methodology on a cluster of cities in the German Ruhr area.

In the description of the results, we will follow the structure outlined in Figure 1, that is, starting with the planning methods, and subsequently presenting the environmental modelling work.

3.1 Planning

Planning activities in BUGS focus on ways of enhancing green areas in the urban environment, while minimising the consumption of open land. The goal is to develop urban planning principles that combine green and compact urban structure, and with a minimum of transport needs and a maximum of non-car-based transport in order to reduce environmental impact. Furthermore the goal is to develop a methodology to investigate the local possibilities of implementation of the green/compact concept, in a dialogue with local stakeholders.

A planning strategy has been devised following the steps outlined next. The planning starts with the establishment of reference maps, that reflect the actual situation (urban form, distribution of green, ...). They are based on information from different sources, including satellite remote sensing and locally available cadastral maps. Several such maps have been established, as shown in Figures 2 and 3, which display the ground space index and green space accessibility, respectively. The main purpose of these maps is to identify potential areas for the increase of building density and for the increase of urban green. In our planning strategy, the focus is on finding areas for increased density mainly in the inner city and in zones around local centres and traffic hubs. Potential areas include vacant sites or areas mature for conversion, as well as areas with low density. As far as the enhanced greening is concerned, the focus is on the detailed analysis of the purpose and structure of the planned greening, by reflecting on such

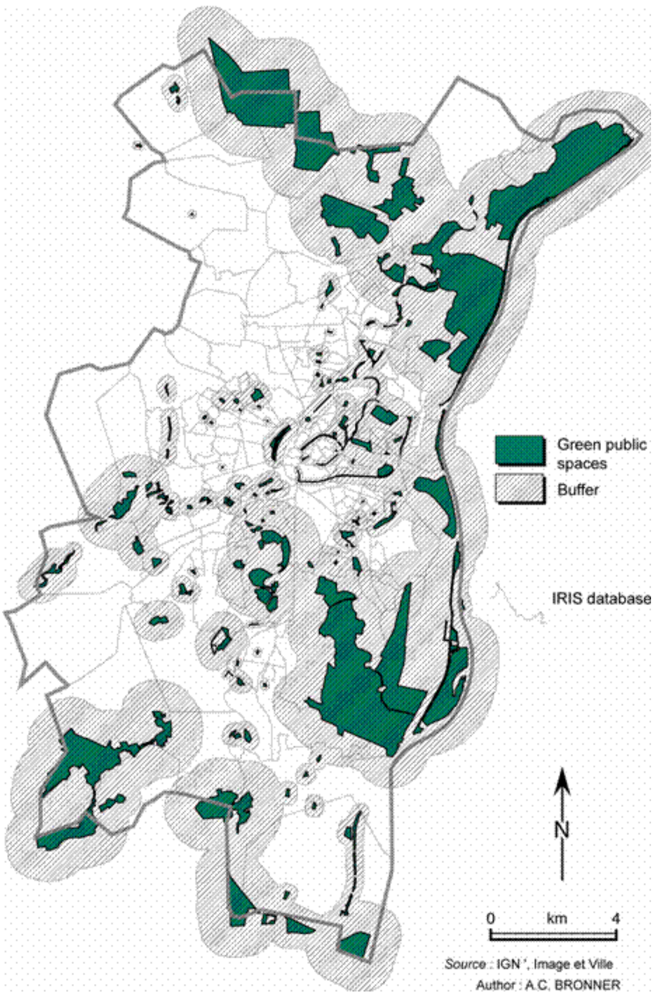


Figure 3. Accessibility of public green space in Strasbourg.

questions as which form and structure can serve several purposes, and which type of greening can be integrated in the city without consuming extra space. Also the accessibility of green areas is taken into account.

Based on this information scenarios for change are established, allowing the environmental modelling partners to test their impact on the environment. This information, in turn, is used to select a few optimal scenarios, which are then taken to the principal stakeholders using a dialogue-based process. Much attention is devoted to the presentation of the scenarios to non-professionals, using GIS maps and photo examples.

A particular aspect of our approach consists of the use of satellite imagery to establish or complement some of the maps used in the planning process. This is of crucial importance as satellite imagery contains information on the state and amount of vegetation that is often not available from other sources. At very high resolution (~ metres), the goal was to use imagery from the recently launched Ikonos or QuickBird satellite platforms. However, their price and availability appeared to be prohibitive, hence it was decided that in the future use would be made either of aircraft imagery or of imagery from the high-resolution sensor onboard the SPOT satellite, which is still capable of detecting features such as a row of trees in a street, or the degree of greenness of an urban park, both of which are required for the assessment of microclimate and noise pollution (see below). Meanwhile, algorithms have been developed to extract relevant surface features, including vegetation characteristics, from aircraft imagery, as shown in Figure 4. At the regional scale, satellite remote sensing is used to produce maps containing parameters required by the atmospheric dispersion model (see below). One of those parameters is the spatial distribution of the percentage green vegetation, which is readily derived from Landsat imagery, as displayed in Figure 5.

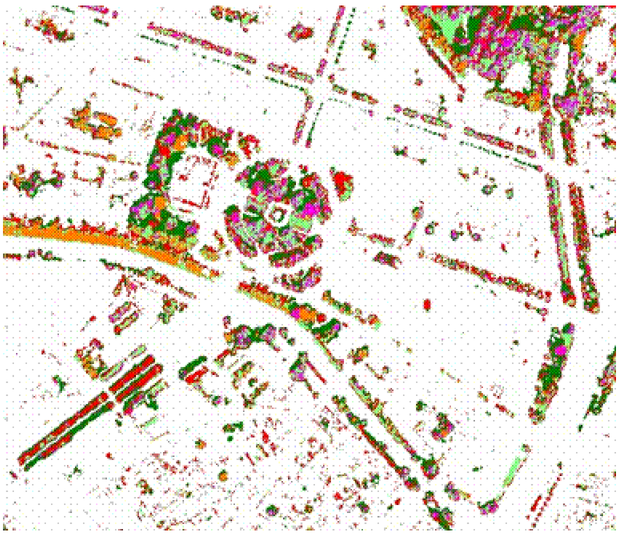
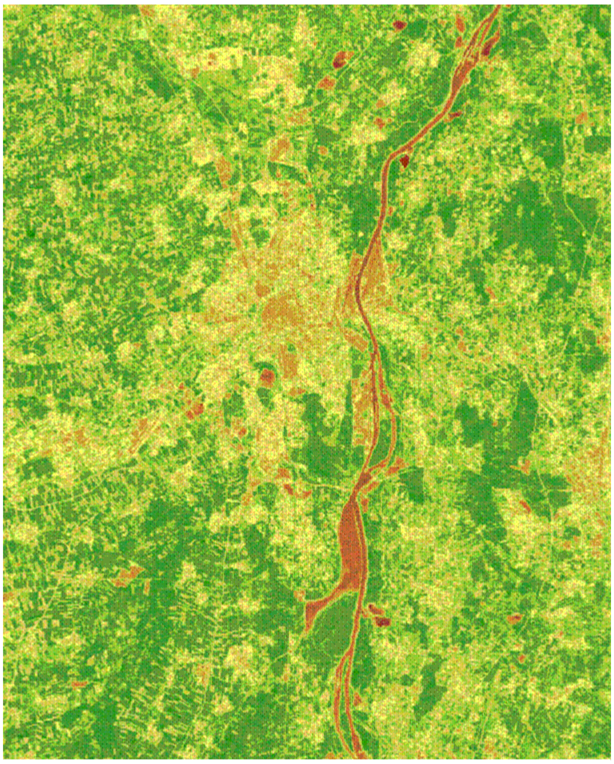


Figure 4. Vegetation types of an area in Strasbourg obtained from aerial remote sensing.

In the planning process particular attention is given to the integration of social and participatory aspects, mainly addressing the issue of how urban green space influences people's well being and sense of life quality. To this end, a pilot study has been carried out in the city of Aarhus in Denmark. This study used qualitative methods such as stop interviews, in-depth interviews, and telephone interviews, as well as field observations.



Several interesting conclusions have emerged from this study. Firstly, closeness to green effectively improves people's sense of quality of life. Public green areas have an important social function as a meeting place for all ages and social groups. Also, people prefer public from private green in wintertime more than during the summer. Perhaps more surprising is the result that people do not have to make use of public green space to value it, as green areas are important mental spaces and valuable by their sole availability, even when unused. Urban citizens prefer natural to too-orderly parks, and variation in the landscape is valued. It was also found that people only participate in planning issues when they feel threatened in 'their' green areas.

3.2 Environmental modelling

Most environmental impact assessment in BUGS is being carried out by means of computer models, which constitute a virtual laboratory of the urban environment, in which different planning scenarios can be tested on their environmental soundness. Apart from that, measurement campaigns have been carried out, the purpose of which was mainly to provide input parameters and validation data for some of the models, as well as to provide better insight into certain phenomena that influence urban environmental quality. As already mentioned in the previous section, there is a very strong link between the planning and modelling activities, as the former provide essential input to the latter.

The traffic model occupies a strategic position between the two, as planning measures implemented in the traffic model directly affect all three other environmental models through their impact on emissions of air pollutants and noise. Traffic modelling and associated emissions modelling have been performed on the urban area of Brno in the Czech Republic. A traffic network representative of the Brno area was created (Figure 6) by means of a simulation software, and traffic intensities on this network where calibrated using census data. The simulated traffic intensities where subsequently used to calculate the associated vehicle emissions. Vehicles were split into different categories, according to the type of fuel, transport mode (passenger, freight, ...), and the presence of a catalytic converter. Emissions were calculated for a series of relevant pollutants including CO, CO_2, CH_4, NMVOC, NO_x, SO_2, and particulate matter.

Figure 6. Traffic network of Brno, the blue lines (left panel) corresponding road network extensions contained in the 2010 Urban Area Plan, and red lines (right panel) corresponding to added cycling routes.

Subsequently, traffic flows and emissions were calculated based on scenarios for 2010, using the Brno Urban Area Plan as a basis. The results indicate that, despite the expected cleaner car technologies, the emissions increase because of the projected increased number of cars. Using the 2010 scenario as a basis, an extra scenario was calculated by introducing extra cycling routes in the 2010 traffic network (Figure 6). However, the impact of these cycling routes turned out to be negligible: the estimated total daily distance travelled by all cars in Brno was reduced by a mere 0.015 %, and the emissions were reduced correspondingly.

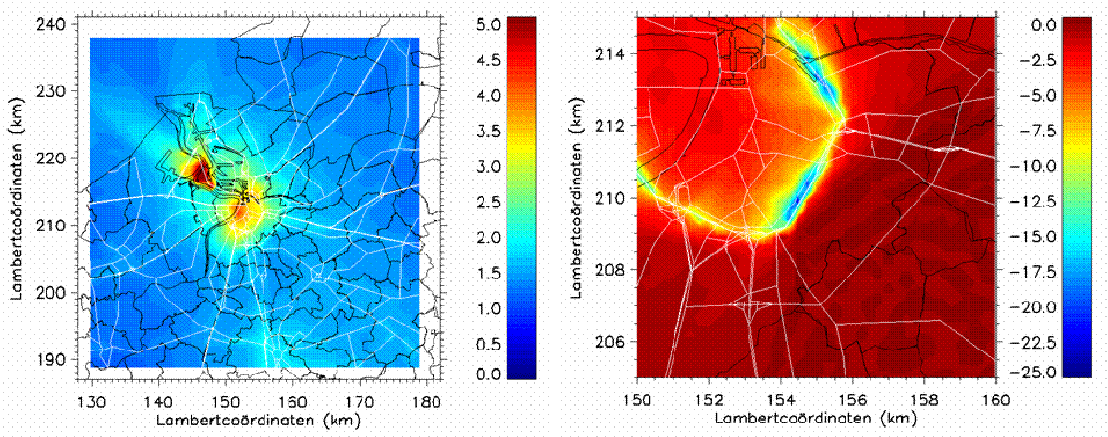


Figure 7. Simulated benzene concentrations for the Antwerp region (left panel) and simulated percentage reductions of benzene concentrations after cutting emissions from the Ring highway (right panel).

Next in the chain of environmental models, BUGS contains a regional-scale atmospheric dispersion model. A first series of simulations was carried out for the region of Antwerp (Belgium) for a week in March 1998, for the carcinogenic pollutant benzene. The spatial distribution of simulated surface concentration values (Figure 7) showed a very good agreement (less than 15 % difference) with observations from an intensive measurement campaign that had previously taken place during the same week. Both simulation and observation indicate that urban values are about twice as high as those found over the surrounding rural areas. Subsequently, a simulation was performed in which all the emissions from the Antwerp Ring way were cut off. This scenario was inspired by the current debate about putting a 'roof' on the Ring, which should protect people living close by from its air and noise pollution, and which should provide space for new green areas. As displayed in Figure 7, cutting those emissions effectively reduces benzene concentrations by up to 25 % in areas immediately surrounding the Ring. A high-resolution assessment, based on simple analytical dispersion models, confirmed the local character of the concentration decrease, not extending significantly beyond 200 m from the source (Figure 8).

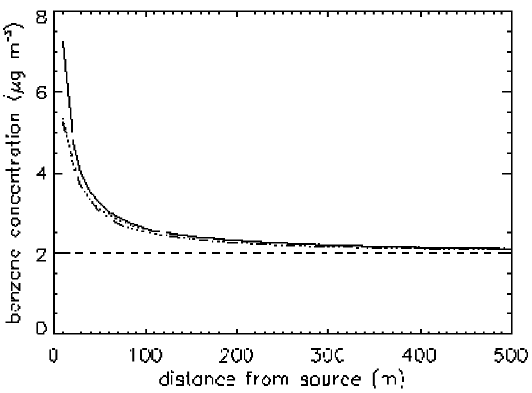


Figure 8. Simulated benzene concentrations as a function of distance to the Antwerp Ring highway.

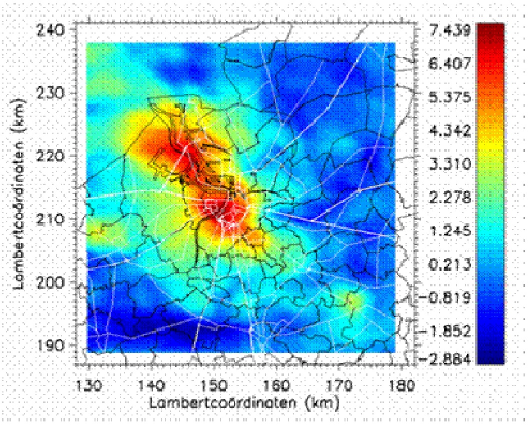


Figure 9. Simulated percentage increase of surface ozone concentrations for the Antwerp region following land use change.

A second set of simulations was performed for the same area, for a 5-day period in May 1998 during which surface ozone values reached high concentration levels. Comparison of simulated concentration time series with station data showed a fair agreement, with differences in the daily maxima generally less than 20 %. In the subsequent sensitivity simulations relatively drastic greening scenarios were implemented. As an example, Figure 9 shows the percentage change in surface ozone concentration induced by enhancing the contrast between the city (green reduced) and its surroundings (made greener). Over the city, which becomes hotter in this scenario, one finds higher ozone concentrations by up to 7 %.

Figure 10. Measurement campaigns (left panel: winter; right panel: summer) to estimate the effect of ground cover on noise propagation.

At much smaller scales – up to a few hundred metres – an assessment has been made of the impact of urban vegetation on noise, micro-climate, and air quality. Excessive noise, mainly caused by traffic, is one of the main nuisance factors in the urban environment. In BUGS, noise pollution is dealt with by means of measurements and computer modelling.

Measurements were performed to evaluate the impact of vegetation on noise attenuation (Figure 10). Some of the results are displayed in Figure 11, which clearly shows the attenuating effect of forest and grass cover on noise levels at 80 m from the source. It should be noted that at shorter distances the effect is less pronunciated, meaning that

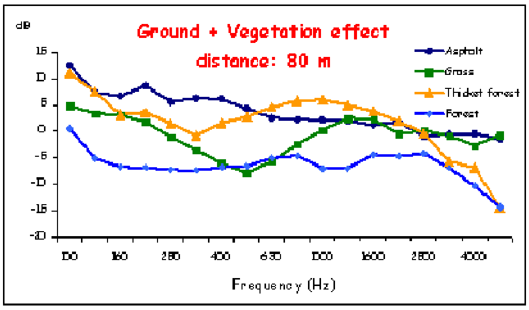


Figure 11. Noise attenuation as a function of frequency, for differing ground cover.

vegetation needs a hundred metres or so to yield a significant impact on noise propagation. It should also be noted that, despite the forest cover being apparently more efficient for noise attenuation, it is allegedly due to the groundcover effect (surface below trees is very porous owing to the presence of leaf litter and low vegetation) rather than to the trees themselves.

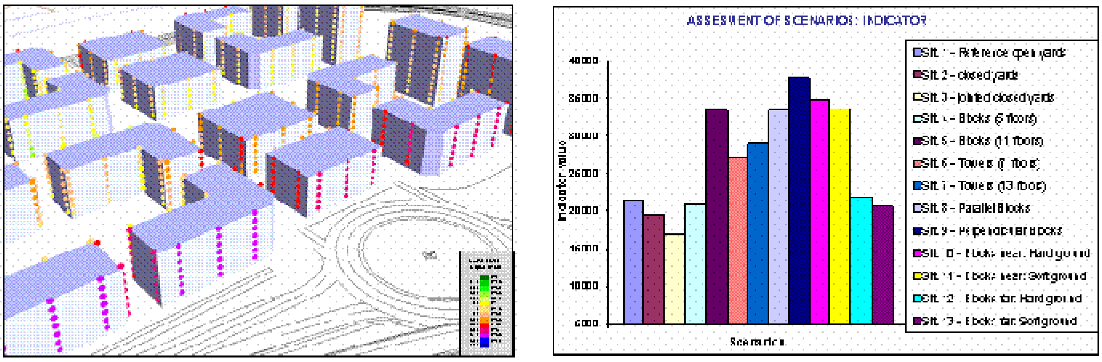


Figure 12. Left panel: receptor points (coloured dots) used to calculate the noise indicator. Right panel: calculated noise indicator for different building configurations and types of ground cover.

As far as the computer modelling of noise is concerned, particular attention has been devoted to the development of a noise indicator. This indicator combines calculated noise levels (in dB) with information regarding the type of dwellings (e.g., whether noise sensitive rooms are at the street side or at the back of buildings), making it representative of human noise exposure. The advantage of this indicator is its capacity to represent complex noise fields by a single number, allowing a straightforward intercomparison of different scenarios. Figure 12 shows the receptor points at building facades used in the calculation of the noise indicator for a particular new housing scheme in Vitoria (Spain). Several such schemes have been processed by the noise model, using different building and array types, and ground cover (soft versus hard). The resulting indicator value for each of the scenarios is also displayed in Figure 12. Apart from obvious effects related to the distance and orientation with respect to the source, effects caused by building type and ground cover are apparent.

Figure 13. Streets where microclimatic measurements were performed, with sparse (left panel) and dense (right panel) tree cover.

Micro-climate and local-scale air quality were also studied by means of measurement campaigns and computer simulations. The focus was on analysing local-scale effects of vegetation in urban street canyons and parks. The purpose of the measurement campaigns was to yield insight in the microclimatic effects of vegetation, and to constitute an observational data set against which to compare model simulation results. During the first project year, measurement stations were installed and operated at two sites, comparable apart from their tree cover density. They were located, respectively, in an urban street canyon with and another without trees (Figure 13). During the second year, measurements were performed to analyse the effect of a mid-sized urban park on local climate and air quality.

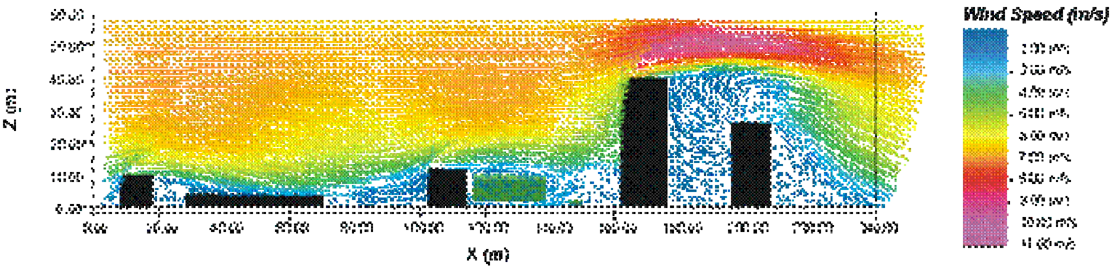


Figure 14. Simulated air flow with the obstacle-resolving microclimatic model.

The computer model (Figure 14) was run for the measurement sites, demonstrating its capability of reproducing the effects of vegetation on the microscale atmospheric environment. The results mentioned next were obtained from a combination of measurements and model analyses.

As far as microclimate is concerned, it was found that the presence of trees in the urban environment reduces daily peak temperatures during summer (Figure 15), thus having a positive effect on human thermal comfort by reducing heat stress. Note that, although this effect is found to be rather significant, it is also found to be very localised. For example, the daytime cooling effect of a medium-sized urban park does not generally extend beyond approximately 100 m from its edges, and the effect of tree cover inside a street is even more localised.

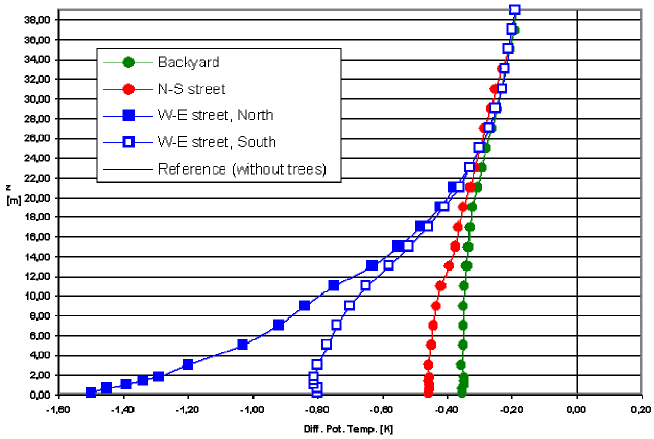


Figure 15. Daytime temperature differences in streets with and without vegetation.

As far as local-scale air quality is concerned, the effect of parks is very different from the effect of trees in street canyons. A park generally experiences improved air quality conditions compared to the rest of the city, mainly owing to the absence of emission sources inside a park. Furthermore, trees in a park filter pollutant particles from the atmosphere, albeit rather modestly. The presence of trees in a street canyon, on the other hand, may actually result in an increase of ground-level pollutant concentrations (Figure 16). This is caused by the fact that the tree crown forms an effective barrier for vertical exchange of air, thus impeding fresh air from above

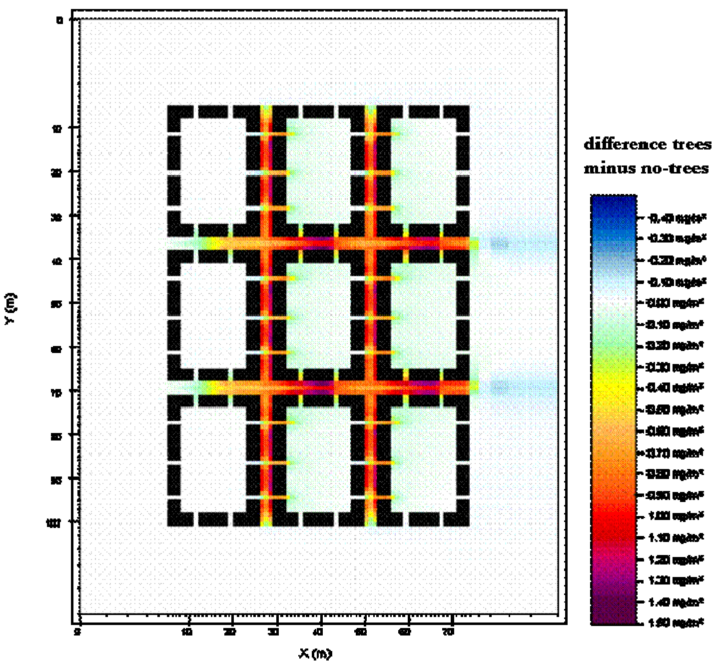


Figure 16. Particle concentration difference between streets with and without tree cover. Red colours indicate higher concentrations in streets with trees.

the canopy to penetrate below and remove the locally emitted (mainly traffic-related) atmospheric pollutants. In other studies, planting trees in streets has often been promoted as a means for improving air quality, owing to the leaves' filtering capacity for pollutant particles and gases. The present study demonstrates that this filtering effect is very small, especially for the more harmful small particles. The reduced ventilation capacity for locally emitted pollutants, caused by dense tree crowns, significantly outweighs the advantages of enhanced filtering.

4 Conclusions

The inter-related issues of urban sprawl, traffic congestion, noise, and air pollution are major socio-economic problems faced by most European cities. A methodology is currently being developed for evaluating the role of green space and urban form in alleviating the adverse effects of urbanisation, mainly focusing on the environment, but also accounting for socio-economic aspects. The objectives and methodology were briefly outlined, and results obtained from case studies performed on several European cities were presented.

One of the main achievements is that new tools have been developed to better quantify and analyse urban green space, partly based on satellite remote sensing. At the regional scale, it has been found that drastic land use changes are required to obtain significant effects. For instance, each new 'green' cycling route only marginally decreases traffic volumes, and putting a green belt around a city affects ozone concentrations at the 10 % level approximately. At smaller scales, impacts appear to be more important yet very localised. Noise levels are significantly attenuated when a porous ground cover (e.g., grass) is used instead of concrete near busy roads. In street canyons, it was found that a dense tree cover, while beneficial for human thermal comfort, may have a large adverse effect on air quality by blocking vertical air exchange, a phenomenon which has direct practical implications for green urban planning. Finally, socially-oriented studies have been carried out, showing that closeness to urban green increases quality of life, even for those who do not make use of it, and that natural (forest-like) parks are preferred rather than too orderly ones.