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# THE EFFECT OF GREEN SPACES ON URBAN CLIMATE AND POLLUTION

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## ABSTRACT

The climate of a conurbation is of great importance, in particular for public health and to provide good environment. Town planning should take into account how it can influence microclimate, especially in view of pollutant emissions by internal combustion engines. The objective of this study was to know the role and behaviour of green spaces in major cities on climate and air pollution. This article provides case studies of the effect of urban parklands on temperature, humidity and pollution, based on a series of formal measurements. Analysis of climatic data has found that gardens and parklands are responsible for significant precipitation. In this study, the present examples, which represent the most frequent cases found during the campaign measures, conform to this pattern. The influence of different types of gardens on temperature, humidity, wind, precipitation and the distribution of air pollution are presented. The results clearly showed the important role of parklands in urban areas. The parklands decreasing temperatures promote the reduction of urban heat island. Such green spaces, gardens and even squares are the least polluted places in a town. Breezes generated by the parklands repel and disperse pollutants, generally issue from traffic cars. Green spaces and gardens contribute significantly to improving the microclimate and reducing the rate of pollution in the city. Therefore, the parklands are the lungs of the city. The parkland should be the most important developments in the city of tomorrow.

**Key words:** Temperatures, moisture, wind, pollution, parklands

## INTRODUCTION

Climatic deterioration of overcrowded and urbanized zones is due mainly to the scarcity of parklands; grass is replaced by vast concrete surfaces where chains of buildings are built. These surface coatings and constructions modify the energy balance and contribute to the storage of heat. Moreover, the various sources of heat, such as nearby houses, industry and daily movement constitute an important thermal source. Pollution is a major problem in large towns and cities (Escourrou, 1991 and 1995). The air has become polluted and new diseases are appeared in these places. In what way do the parklands react to urban heating and to air pollution?

This study aims to establish the role and influence of parklands on climatic factors (temperature, humidity, wind and precipitation) and on air pollution. It is based on a significant campaign of measurements. The study aims to:

- Stress the importance of parklands in addition to routeways to protect the environment and climate, to mitigate the continuing transformation of urbanized areas with considerable amounts of concrete masses, which is endangering the environment and the comfort of the population.
- Emphasize the influence of parklands on the climate and on the mechanism of spreading of air pollution.

The present study of the parklands in a large urban agglomeration has involved a major sequence of measurements of climatic factors (temperature, humidity, precipitation and wind) and widespread pollutants over four years in the urban environment (CO and $SO_2$).

A major concern of the authorities in large cities worldwide is fighting pollution, against urban growth and by the increasing number of cars and vehicles. Focus was exclusively

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on the determination of the repartition of the temperatures, humidity, pollutants surrounding the parklands and the gardens.

This study offers some new elements in order to increase the understanding of the importance of a good planning of the cities on climate and pollution.

## MATERIALS AND METHODS

This article is part of a study on "An example of the changing climate by the constructions in the Paris region". The study required an intensive measurement campaign over a period of four years, and it was tried to see the influence of local amenities on the different climatic factors (temperature, humidity and wind) and the distribution of air pollution.

Measurements of temperature and relative humidity were taken at height of about 1.80 m with a very powerful probe. The final value was recorded on an average of 20 seconds.

The measures of the climatic factors and the pollutants have been taken in diverse locations. Selected sampling locations throughout this study are described in Fig. 1.

The principle of measurements was to record climatic factors (temperature, humidity, direction and wind speed) and the rate of pollutants (CO, $CO_2$ and $SO_2$) in different places in a district and in a period of time with the same apparatus.

The main parklands of Paris are the Bois de Boulogne (wood, 855 hectares in the west of Paris) and the Bois de Vincennes (wood, 955 hectares in the east of Paris).

In this article, the examples summarize most cases in the measurement campaign. The measures against pollution are limited to two pollutants:

- Carbon monoxide (CO), a colorless, odorless and toxic gas. It is produced during incomplete combustions
- Sulfur dioxide ($SO_2$) emitted from domestic homes and industrial sources

Concentrations of pollutants are given in ppm=2900 $\mu g/m^3$; values are recorded over 20 seconds at one meter above the ground surface.

The wind speed (m/s) was measured with a manometer, the recorded direction is that found with a wire.

If variations in measurements were not significant between the beginning and the end at a given point, the estimate was considered exact (few variations of the climatic factors were observed during the measurement process).

The apparatus made it possible to compare two recorded values in two different places. The apparatus did not always find the same values as those recorded by weather stations, recorded and provided by weather forecast of France. Others have been published in the monthly departmental bulletins of the Paris region, which exist in the Library of National Meteorology, Avenue Rapp, in Paris.

This work provides a new contribution to consideration of spaces to improve the urban climate and mitigate air pollution. The results can be used in future planning of the urban development.

## RESULTS

Gardens and parklands have particularly valuable characteristics that suit them to play a key role. They represent the lungs of large cities. They contribute to reducing temperatures throughout urban zones, especially in summer.

*Influence of parklands on temperature and humidity*

It is clear that parklands in cities are fresher than inhabited zones (Svensson, 2002). The difference is due primarily to the process of transpiration-evaporation, which consumes energy and reduces the air temperature (Williams, 2006). This freshness is perceived in streets situated near gardens. The change of temperature between a garden or park and an inhabited place (such as buildings) depends on the season and on the size of the garden. In cold weather, gardens have a lower temperature by 2°C than buildings (Won, 2003). The relative humidity (HR) and absolute humidity (HA) in the garden is generally more significant. Measurements taken in the garden of Luxembourg (surface less than 10 hectares), in cold weather (Table 1), displayed the following variations.

The same phenomenon is observed in the largest parklands (exceeding 100 hectares) in cold weather. The difference in temperature between the center of the parkland and the inhabited zone

Table 1: Temperature and humidity in cold weather near a garden and parkland

| Locality of measurement | | | T(°C) | HR (%) | HA (g/kg) |
|---|---|---|---|---|---|
| Near garden | Assas street | In front of the garden | 8.8 | 66.9 | 4.7 |
| | Garden | Inside the garden | 7.8 | 69.9 | 4.6 |
| | Center of garden | Center of the garden | 7.5 | 71 | 4.6 |
| | St Michel Bld. | In front of the garden | 8.5 | 67.5 | 4.6 |
| | St-Jacques street | Far from the garden | 9.2 | 66 | 4.8 |
| Near a parkland | Mirabeau street | Street between buildings | 6.1 | 94 | 5.5 |
| | Auteuil street | Rue perpendicular to Bois | 5.3 | 97 | 5.3 |
| | Bois de Boulogne | Centre Bois de Boulogne | 4 | 100 | 5 |

can exceed 2°C. The results of this study are presented in Table 1.

The discrepancy in the relative humidity in cold weather is more significant, between the trees of the Bois de Boulogne (a large wood) and the built-up area. In hot weather, the differences in temperature become even greater. These increases are due to the reflectivity of the ground. The relative humidity in the garden remains more significant than that recorded in built-up areas. In hot periods, parklands and gardens play an important role in reducing the temperature. The Bois de Boulogne maintains the lowest temperature in the district. The differences in temperature and moisture are generally small in the morning, and become significant in the afternoon. Table 2 shows the considerable difference in temperature and moisture between the center of the park (the Bois de Boulogne) and nearby urban areas. Humidity is almost always higher in green areas than in inhabited zones. Measurements were made in different places in the Park confirmed the results found: the locations within the park are less warm than outdoor. The variations in temperature between the garden and the inhabited zone can reach 3°C. Evaporation in the gardens and in the parklands is generally important; it takes energy and reduces the local temperature. This variation in temperature between the parklands and the inhabited zone generates a breeze from the parks to the built-up area. The importance of this breeze depends on the size of the park.

The examples cited show the importance of green spaces for the cooling temperatures. In some cities, during the summer months, the sun's rays darts on concrete surfaces which, in a state of overheating, reflect and trap energy which is

Table 2: Temperature and humidity near a garden and a parkland in hot weather

| Locality of measurement | | | T(°C) | HR( %) | HA (g/kg) |
|---|---|---|---|---|---|
| Near garden | Assas street | In front of the garden | 29.5 | 29 | 5.5 |
| | Garden | Inside the garden | 28 | 33 | 8 |
| | Center of garden | Center of the garden | 27 | 35 | 7.9 |
| | St Michel Bld. | In front of the garden | 30 | 30 | 8.2 |
| | St-Jacques street | Far from the garden | 32 | 27 | 8.3 |
| Near a parkland | Mirabeau street | Street between buildings | 31 | 39 | 11.3 |
| | Auteuil street | Street perpendicular to Bois | 29 | 44 | 11.3 |
| | Bois de Boulogne | Centre Bois de Boulogne | 27 | 47 | 10.7 |

rendered into streets and buildings. So, the city becomes a furnace. The tight quarters without wide avenues and green spaces are inadequate climate. The concrete buildings, which have replaced the trees, natural vegetation and cover the place, trap heat. Urbanites are obliged to use air conditioners, which tend to increase heat stress, consume a large amount of electric power.

While homes that overlook a garden or a green space, or those over an artery well ventilated, enjoy in summer the freshness due to the local breeze. Indeed, when two environments show significant differences in temperature, a breeze comes from cold space to the warm space. These homes have natural air conditioning and are well suited to people that do not support an increase in temperatures.

In winter, to make buildings more livable, enormous amounts of energy are consumed before being discharged to the outside: the urban districts are warmer than in the surrounding area without having necessarily more comfortable.

The planner must focus not only on the maps of urbanization but also to the comforts of urban and microclimates generated by the various urban developments, which can have very negative effects.

*Effect of parklands on pollution*

Pollution varies from place to place within a park (Goyal, 2003). The concentration of pollution is more significant outside the parkland (Pope, 1999), because of motor traffic and human activity (Cogliani, 2001). During our measurement campaigns, the movement and extent of pollution in different gardens was studied. For public gardens and small gardens (area not exceeding 1ha), pollutants penetrate easily, but planted areas nevertheless remain less polluted than nearby built-up zones. The Square de Cluny (1 hectare) is less polluted than nearby places such as the Boulevard Saint Germain (large Avenue with heavy traffic) and the de Cluny street. The results are presented in Fig. 2.

Large gardens (more than 100 hectares) are much less polluted than inhabited areas (Mittal, 2003a). The significant number of trees, being the source of the breeze, tends to push back pollutants. The directions of the breezes are local, whereas the prevailing winds are generally south-westerly in winter and north in summer. Vehicular traffic is the main source of pollution around these gardens (United Nations, 1994). During our measurements, we observed that the Jardin de Luxembourg is less polluted in the morning. In particular, sulfur dioxide ($SO_2$) scarcely penetrates it. Carbon monoxide (CO) levels tend to increase (Mayer, 1999), from low values in the morning to higher ones in the afternoon. At the exit from the garden, measured CO and $SO_2$ concentrations were very high (Pelletier, 1987). The sidewalk adjacent to the garden, presented in Fig. 3, is generally less polluted than that on the other side of the street. The streets near the garden, where frequent breezes are experienced, are less polluted (Berkowicz *et al*., 1996) than heavily built-up roads.

Some measurements were made in shops situated on the sidewalk opposite the gardens. The concentrations of CO and $SO_2$ were significant inside the shops (Faix, 1991). Bus stops situated on the sidewalk on the other side of the street from the garden are as polluted as those on the sidewalk adjacent to the garden. This is due to the role of breezes in moving the air pollution. Other gardens sampled in the present study include the Jardin de Montsouris in Paris and others around the periphery of the city. These studies confirm the widespread pollution. The Jardin de Montsouris (garden, 15 hectares) is in the southern periphery of Paris. The effect of the Jardin de Montsouris on pollution is seen in the concentration of the pollutants on the boulevards which surround this garden (Jourdan Boulevard). Pollution is much greater in streets (Alésia Street) further from the garden, which also experience heavy traffic. The results of this study are presented in Fig. 4.

When the weather is calm (anticyclone), the wind (or the breeze) that is the main asset of the dispersion is too low and sometimes zero, CO and $SO_2$ easily penetrate edge of the forest. But the large amount of pollutants is concentrated in the neighboring places. The pollution increases as one move away from the parks.

The breeze of the garden or a park is very effective local: it requires pollutants to be concentrated in the built environment boundary. The areas around the park Vincennes (wood, 955 hectares in the

east of Paris) are badly polluted. Pollutants are pushed into the narrow streets where the airflow is difficult (Ademe, 2006).
The really large parklands, such as the Bois de Boulogne (wood, 855 hectares) in the west of Paris, and the Bois de Vincennes in the east, are less polluted than the gardens (surface lower than 100 hectares) in all types of weather. The results of this study are presented in Fig. 5.
Breezes from the great parklands are important and play a major role in pushing away pollutants. The streets situated along these gardens witness lower pollution than roads situated within inhabited zones.
The distribution of pollution in urban areas depends on the architectural disposition; it also depends on the shape of the Arteries and the proximity of a green space. A broad avenue, which gives away in a green space, with a higher traffic, is less polluted, because the dispersion of pollutants is better. We found that the narrow streets of tight quarters with a low traffic tend to be more polluted than the broader avenues with traffic important, because the evacuation of pollutants is bad.
Urbanites living walkways overlooking a large green area are much more protected from the effects of pollution (IngegaÈrd, 2000). People living in close quarters and unventilated are much more vulnerable by the disease due to air pollution: such as asthma. The boulevards along the gardens and green spaces are also polluted. Many urbanites enjoy doing jogging along the wide avenues and, indeed, inhale a large amount of pollutants and get tired easily. These places are also popular at major sporting events. The exercises sports must take place within the garden and the green space to preserve the athlete of the harmful effects of pollution.

*Effect of parklands on the precipitation*

Parklands have an effect on precipitation. Generally speaking, they increase rain (Burian, 2002), due to the higher humidity in these inhabited places (Calvet, 1984). The difference can be astonishing, as seen by comparing Leo Lagrange (inhabited zone) with La Fisanderie, situated within the Park de Vincennes (east of Paris). The stations situated near the Bois de Boulogne are more watered than the meteorological station of la Tour St-Jacques set in a very small square in middle of the city of Paris. The results of this study are presented in Fig. 6.
Examination of the difference in precipitation (1991-2005), presented in Fig. 7, between an inhabited zone, a garden, and parkland, shows these differences between a garden (Jardin de Luxembourg), an inhabited zone and L'Observatoire of Paris: the gardens are better watered than the inhabited zones.
The green spaces and gardens in an urban area play a significant role in changing the local climate. The increased rainfall promotes air quality in the city: a benefit to the urbanite (Park, 2002).
Gardens and parklands also cause breezes, which have a valuable role in moving pollutants through the roads leading to and from the green. The high concentration of pollution in such streets is due to the absence of accurate town planning. If a large concrete construction is built without significant openings near large parkland then it will cause a high concentration of pollutants nearby, which are not able to be dispersed by breezes. The examples given lead to the following conclusions for future planning:

- A built-up area should not be constructed longitudinally near parklands and green spaces. Breeze must be allowed to circulate, to disperse pollutants and reduce high temperatures;
- Planning for large avenues facing gardens or a large parkland, and crossing the nearby inhabited space, is very important. Such avenues act as passages for breeze emanating from the parkland and blowing pollution away from the built area. This is a very effective means of cleansing the town air;
- Implementing gardens and parklands in large towns and conurbations allows inhabitants to find less polluted places within the town for rest and leisure;
- Planning large parklands in a large city is essential, because they contribute, through the induced breeze, to cleaning the air of city pollutants and dust. They are also ideal places for sportsmen to exercise because the rate of pollution is very weak.

## DISCUSSION

Gardens and parklands are consequently vital factors to consider in the planning of large cities. Their advantages include: low pollution zone, dispersion of pollution, creation of breeze, increasing the rainfall, and reducing high temperatures.

Within the coming years, and because of the warming of the planet, the rise in temperatures and air pollution will reduce the quality of urban daily life. Planners have a responsibility to do all they can to mitigate these effects in the built environment.

The phenomenon of urban heat island, the freshness of green spaces, the impact of urbanization on rainfall and concentration of air pollution have been widely studied in many cities around the world by specialists in the urban environment as Escourrou Gisele (Université Paris Sorbonne, France), So Won Yoon, Dong Kun Lee (Department of Environmental Science & Landscape Architecture, SangMyung University An So-Dong, ChonAn City Chung Nam, South Korea) IngegaÈrd Eliasson and Marie K. Svensson (Laboratory of Climatology at Physical Geography, Department of Earth Sciences, GoÈteborg University, Sweden). Our research confirms some of the results found by these researchers.

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