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The Role of Parklands in Improving Urban Microclimates to Combat Pollution

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Abstract

The climate of a conurbation is of great importance, in particular for public health and to provide a good environment. Town planning should take into account how it can influence microclimate, especially in view of pollutant emissions by internal combustion engines. This article provides case studies of the effect of 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. The present examples conform to this pattern. The author shows the influence of different types of garden on temperature, humidity, wind, precipitation and air pollution. The results clearly show the important role of parklands in urban areas. Such gardens are the least polluted places in a town. Breezes generated by the parklands repel and disperse pollutants, while gardens contribute considerably to the air quality in cities.

Keywords: temperatures; moisture; wind; pollution; parklands

1. 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, 1995). The air has become polluted, and new diseases have 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 route ways in order to protect the environment and climate, and 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 parklands in large urban agglomerations 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, resulting from urban growth and the increasing number of cars and vehicles. In this study, the author focuses exclusively on determining the difference of the temperatures, humidity and pollutants surrounding parklands and gardens.

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

2. Materials and Methods

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

In this study, measurements of temperature and relative humidity were taken at a height of about 1.80 meters with a very powerful probe. The final value was recorded on average every 20 seconds.

Measurements concerning climate and pollutants

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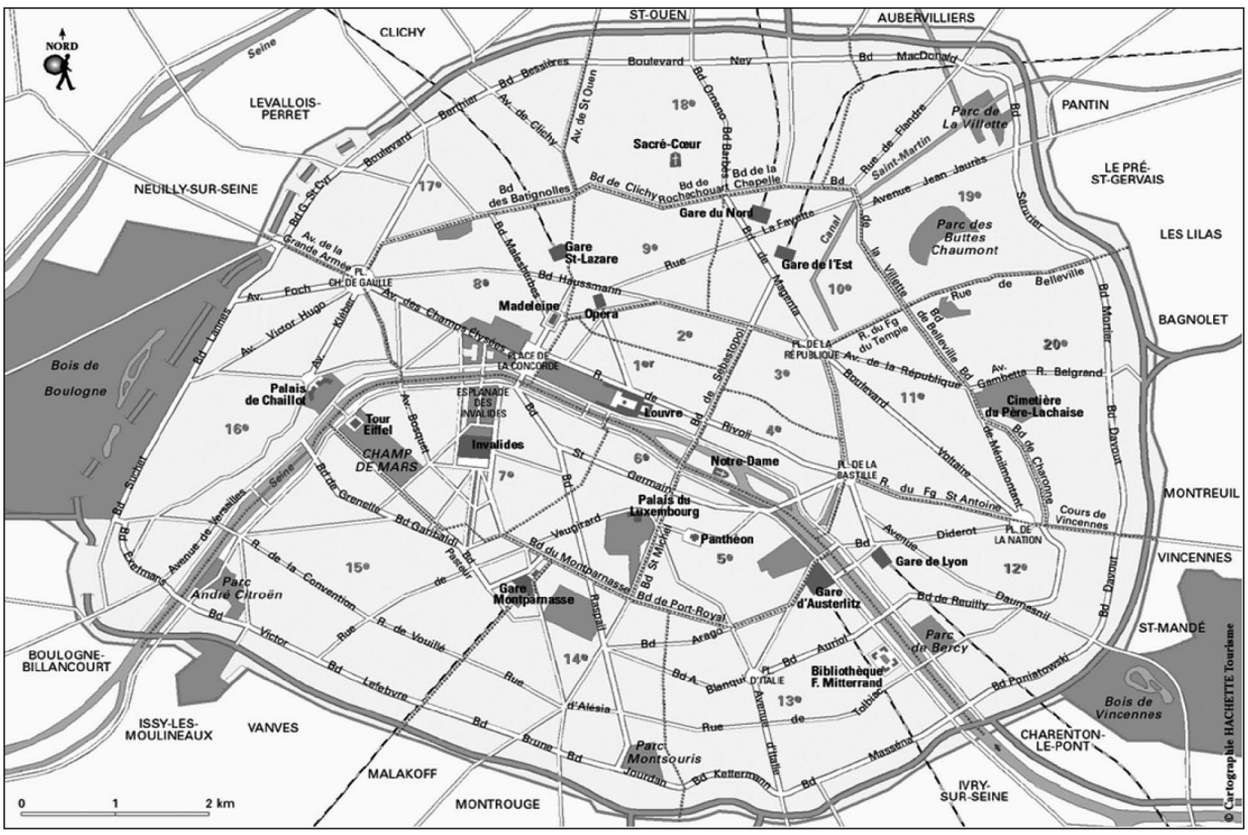

Fig.1. City of Paris, Showing the Principal Gardens and Parklands, which were the Measurement Zones (Gray Zones)

were taken in diverse locations. Selected sampling locations throughout this study are described in Fig.1.

The main parklands of Paris (Fig.1.) 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 of the measurements, while the measures against pollution are limited to two pollutants:

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

Concentrations of pollutants are given in ppm=2900µg/m^3; values are recorded over a period of 20 seconds 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 are not significant between the beginning and the end at a given point, the estimate is 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 does not always find the same values as those recorded by weather stations, as recorded and provided by the 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, on Avenue Rapp in Paris.

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

3. Influence of Parklands on Temperature and Humidity

It is clear that parklands in cities are fresher than inhabited zones. 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. 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

Table 1. Temperature and Humidity on January 31st, 1994 from 8:00 am to 9:00 am

	Locality of measurement	T °C	HR %	HA g/kg
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

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 can exceed 2°C (Table 2.).

Table 2. Temperature and Humidity on January 21st, 1993 from 8:00 am to 10:00 am at the Bois de Boulogne

	Locality of measurement	T °C	HR %	HA g/kg
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

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 (Table 3.).

Table 3. Temperature and Humidity near the Jardin de Luxembourg on June 23rd, 1994 from 2: 00 pm to 3: 00 pm

	Locality of measurement	T °C	HR %	HA g/kg
Assas Street	The 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.	The front of the garden	30	30	8,2
St-Jacques Street	Far from the garden	32	27	8,3

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 4. 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.

Table 4. Temperature and Humidity on August 8th, 1994 from 1:00 pm to 3:00 pm at the Bois de Boulogne

	Locality of measurement	T °C	HR %	HA g/kg
Mirabeau Street	Street in urban zone	31	39	11,3
Auteuil Street	St. perpendicular to Bois	29	44	11,3
Bois de Boulogne	Center Bois de Boulogne	27	47	10,7

Measurements taken in different places in the Park confirmed the results found: the locations within the park are less warm than the inhabited area. 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 consumes 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 in cooling temperatures. In some cities, during the summer months, the sun's rays strike concrete surfaces, which, in a state of overheating, reflect and trap energy, which enters streets and buildings, and the city becomes a furnace. Congested areas without wide avenues and green spaces are inadequate to deal with the climate because the concrete buildings, which have replaced the trees and natural vegetation, store heat. Urbanites are obliged to use air conditioners, which consume a large amount of electric power and tend to increase heat stress.

In summer, the homes that overlook a garden or a green space, or those over a well-ventilated artery, enjoy freshness due to the local breeze. Indeed, when two environments show significant differences in temperature, a breeze comes from the 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 temperature.

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

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

4. Effect of Parklands on Pollution

Pollution varies from place to place within a park. The concentration of pollution is more significant outside the parkland, because of motor traffic and human activity (Cogliani, 2001). During the measurement campaigns, the authors studied the movement and extent of pollution in different gardens. For public gardens and small gardens (area not exceeding 1 hectare), 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 Boulevard

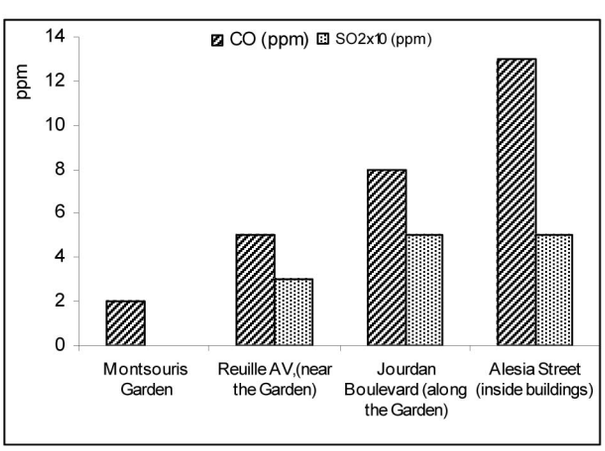

Fig.2. Distribution of Pollutants Near a Small Garden

Saint Germain (large Avenue with heavy traffic) and de Cluny Street (Fig.2.).

Large gardens (more than 100 hectares) are much less polluted than inhabited areas. 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 the measurements, the author 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 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 (Fig.3.).

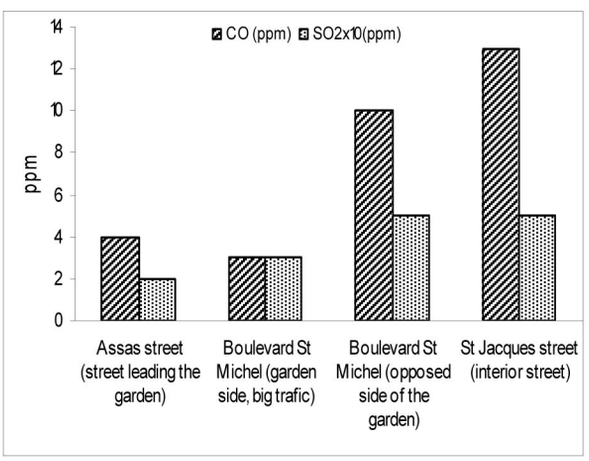

Fig.3. Distribution of Pollutants Near the Jardin Luxembourg

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 (Fig.4.).

When the weather is calm (anticyclone), the wind (or

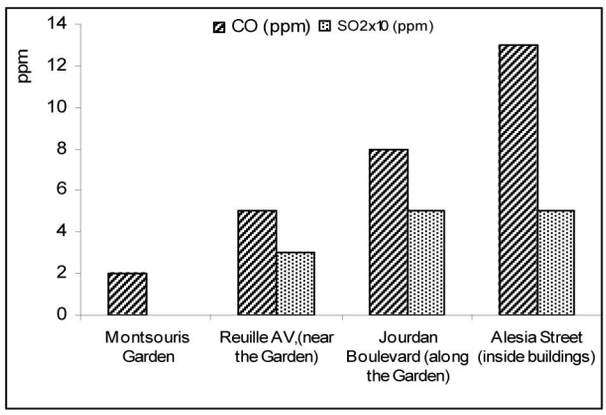

Fig.4. Distribution of Pollutants Near the Jardin de Montsouris

the breeze) that is the main asset of the dispersion is too low and sometimes zero, so that CO and SO_2 easily penetrate the edge of the forest. But the large amount of pollutants is concentrated in neighboring areas, while the pollution increases as one moves away from the parks.

The breeze of a garden or park is very effective locally: concentrating pollutants at the boundary of the built environment. The areas around the Vincennes Park (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 (area less than 100 hectares) in all types of weather (Fig.5.).

Fig.5. Distribution of Pollutants Near the Bois de Boulogne

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 examples show the importance of green spaces to reduce pollution.

When we speak about car pollution we think at first of emissions of polluting gases, but we should not forget that bad planning is in itself a source of

pollution. The distribution of pollution in urban areas depends on the architectural disposition; it also depends on the nature of the arteries.

What kind of urban planning solutions can be considered in order to reduce pollution?

• The development of an urban district is only possible with the implementation of a green space or garden.

• A low density of buildings (no tight quarters)

• The presence of a green belt around the city promotes the circulation of breeze.

• The breeze that comes from a garden and green space must be able to move along the broad avenues that cross urban areas.

This study led to the following observations:

• Urbanites living in tight quarters suffer from significant levels of pollution,

• Those who live surrounded by greenery are more protected from the harmful effects of pollution,

• Jogging as practised by city dwellers should take place in green spaces and not around polluted places.

5. Effect of Parklands on Precipitation

Parklands have an effect on precipitation (Dettwiller, 1970). Generally speaking, they increase rain, due to the higher humidity (Calvet, 1984). The high humidity is due to the process of transpiration-evaporation, which consumes energy and reduces the air temperature. In urban areas, the warm air masses tend to rise. The influence of the unstable and sensitive temperature promotes the rise of air masses. This ascension occurs through thermal gradient, which determines its speed and creates an increase in precipitation. The difference can be astonishing, as can be seen by comparing Leo Lagrange (inhabited zone) with La Fisanderie, situated within the Parc 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 the middle of Paris (Fig.6.).

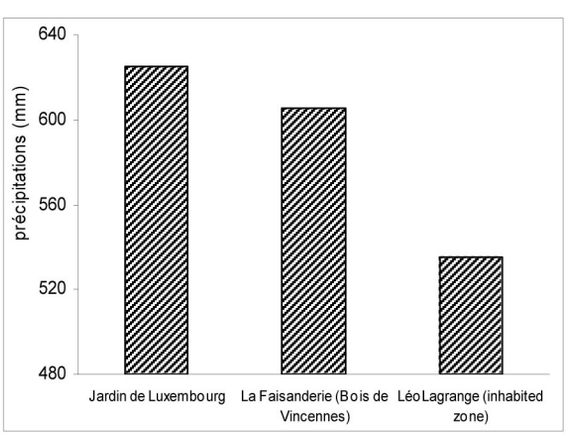

Fig.6. Difference in Precipitation (1991-93) between a Garden, Parkland and an Inhabited Zone

Examination of the difference in precipitation (1991-1993) between an inhabited zone, a garden, and parkland, shows these differences between a garden (the Jardin de Luxembourg), an inhabited zone and L'Observatoire of Paris: the gardens are better watered than the inhabited zones (Fig.7.).

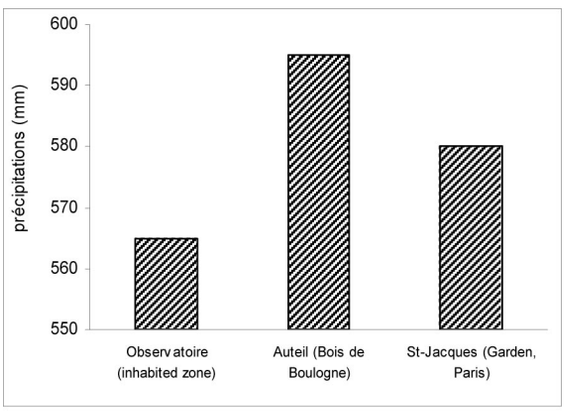

Fig.7. Difference in Precipitation (1991-93) between an Inhabited Zone, a Garden and Parkland

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, which is of benefit to urbanites.

6. Conclusion

Gardens and parklands have particularly valuable characteristics that make them suitable for playing such a key role. They represent the lungs of large cities, contribute to reducing temperatures throughout urban zones, especially in summer, and also increase precipitation and improve air quality.

Gardens and parklands also cause breezes, which have a valuable role in moving pollutants through the roads leading to and from the green area. 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 dispersed by breezes. The examples given lead to the following conclusions concerning 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 blow 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 level of pollution is very low.

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.

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