"TIERCE FORET": GREENING A PARKING LOT

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Résumé: *Un espace extérieur privatif situé à Aubervilliers (93) est en cours de transformation d'un parking recouvert d'enrobé bitumineux vers un revêtement en béton perméable avec plantations dense d'arbres. Le présent article s'intéressera à la présentation de résultats préliminaires portant sur l'évaluation de l'impact rafraîchissant, notamment sur le stress thermique d'un piéton, grâce à des mesures fixes et mobiles. Des effets bénéfiques pour le stress thermique sont observés suite notamment à la création d'ombrage par les nouveaux arbres se traduisant par une réduction de la température de l'air et de la température moyenne de rayonnement.*

Keywords: *rafraîchissement urbain, béton perméable, végétalisation.*

Summary: *A parking lot in the city of Aubervilliers (Paris metropolitan area) is under conversion from an asphalt-concrete paved area to an open green space with permeable pavement as an urban heat island countermeasure. In this paper, we present preliminary results of the impact of the site's partial conversion on pedestrian heat stress, with fixed and mobile measurement campaigns. Significant improvements of pedestrian heat stress are reported, following the creation of shade from trees resulting in reductions in air temperature and mean radiant temperature.*

Keywords: *urban heat island countermeasure, permeable concrete, urban greening*

Introduction

Urban greening is among the best-known countermeasures to the urban heat island (UHI) phenomenon (Akbari, Pomerantz, and Taha 2001). Parks in particular have been the focus of many studies, but many studies only conduct measurements after park construction (Bowler et al. 2010). However, identifying sites sufficiently ahead of time to prepare a measurement campaign before and after park construction can be difficult.

In the Paris Metropolitan Area, a site in the municipality of Aubervilliers is under study for conversion into an urban green area. The zone under study is currently used as a parking lot for the occupants of a home for young workers. It currently offers no urban amenities for pedestrians and inhabitants and its dark-colored asphalt concrete strongly absorbs solar radiation. The conversion will create a green open space with new functionality for pedestrians and inhabitants, including several trees and permeable concrete paving.

This site and its construction work schedule offer an opportunity to study the site before and after greening. Microclimatic measurements are under way to determine the site's microclimatic characteristics before and after site conversion.

This paper presents results following the partial conversion of the site, i.e. after trees are planted, most of the asphalt concrete is removed and a pervious concrete pavement is laid underneath the case measurement station.

1. Materials and Methods

1.1. Site Description

The site chosen for the study is a parking lot of about 1,200 m² for the occupants of a home for young workers in the municipality of Aubervilliers, located in the Parisian northern periphery.

The site is located in a heterogeneous urban area. The site's vicinity can be classified as LCZ 4 (open high rise), but adjacent areas vary from LCZ 2, B or D (resp. dense mid-rise, scattered trees and low plants). It is currently surrounded by tall buildings and offers no amenities for pedestrians, such as benches, shade or footpaths. The ground is made of a worn out dark-coloured impervious asphalt with an albedo of 0.13. Furthermore, the site offers little vegetation apart from peripheral flowerbeds and sparsely-planted trees. A photograph of the parking lot in its initial state (left) is provided in Figure 1.

Figure 1: Photograph of the site. Left: before conversion, right: after partial conversion in 2019. Bottom: site map and weather station positions.

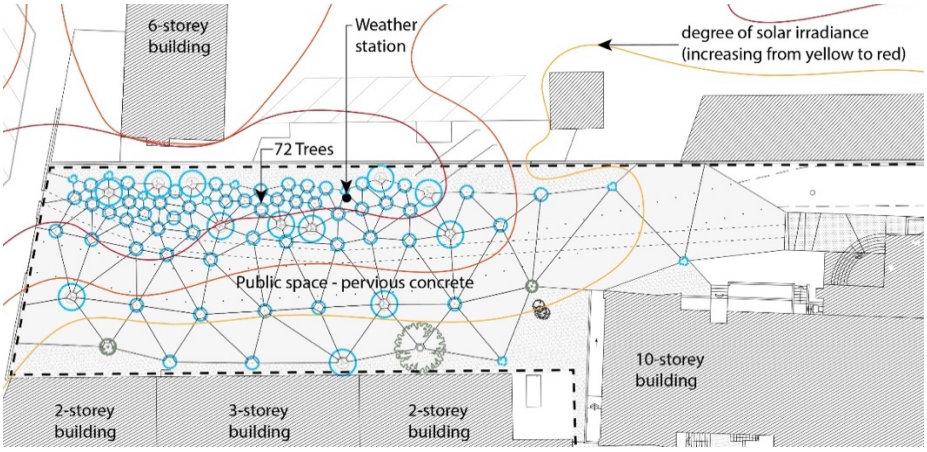

Figure 2: Project plan

Considering those characteristics, the site is a good candidate for conversion to an open green area as an urban cooling measure. The projected conversion completely rethinks this area. It will create a friendly pedestrian space for local inhabitants, no longer accessible to vehicles. As illustrated in Figure 2, trees are planted with an increased density in the sunniest areas will

create a “tertiary forest”, and the asphalt concrete pavement will be replaced entirely with light-colored permeable concrete in order to retain rainwater in the sub-layers, thus allowing the trees to grow properly and the soil to be fertile.

The microclimatic impact of the project is evaluated by conducting measurements before and after transformation. The site and its construction schedule offer a unique opportunity to monitor the site sufficiently ahead of time. Microclimatic measurements are conducted with two weather stations installed by Météo-France. The case station is placed in the parking lot in an area where trees will be planted, while the control station is located on the rooftop approximately 30 m above the parking lot, outside of the project’s area of influence.

Trees were planted and most of the asphalt concrete was removed after partial conversion in time for measurements during summer 2019. In addition, only the area below the case station is paved with pervious concrete (see Figure 1, right), the rest of the soil remained bare.

1.2. Instrumentation

The weather stations monitor several microclimatic parameters at screen height, including those relevant to pedestrian heat stress: air temperature, relative humidity, black globe temperature, wind speed and long and shortwave upward and downward radiation fluxes, as well as a rain gauge near the control (rooftop) station. In addition, mobile measurements were conducted with a mobile weather station. The position of the stations is indicated in Figure 1 (bottom) and a photograph is shown in Figure 3.

Figure 3: Rooftop (left) and parking lot (center) fixed and mobile (right) weather stations (before conversion).

1.3. Data analysis

The cooling impact created by the site’s transformation is evaluated using the protocol described by Parison et al. (2020), based on the BACI method combined with the Lowry approach (Lowry 1977). Succinctly, the interstation difference between the case (parking lot) and control (rooftop) stations is monitored before (reference period) and after (countermeasure period) conversion on days presenting radiative conditions (clear skies and wind speed < 3 m/s) with daily minimum and maximum temperatures exceeding 16° and 25°C, respectively.

By comparing the interstation profiles, preexisting differences between stations are filtered out. By comparing the interstation profile during the reference ΔM_{ref} (before) and the countermeasure $\Delta M_{counter}$ (after) periods, the impact of the conversion I can be isolated. The procedure is summarized in equation (1), noting M as the measured meteorological parameter:

$$\Delta M_{counter} - \Delta M_{ref} = \left(M_{case,counter} - M_{ctrl,counter}\right) - \left(M_{case,ref} - M_{ctrl,ref}\right) = I \quad (1)$$

Results are tested for statistical significance.

2. Results and discussions

2.1. Fixed Measurements

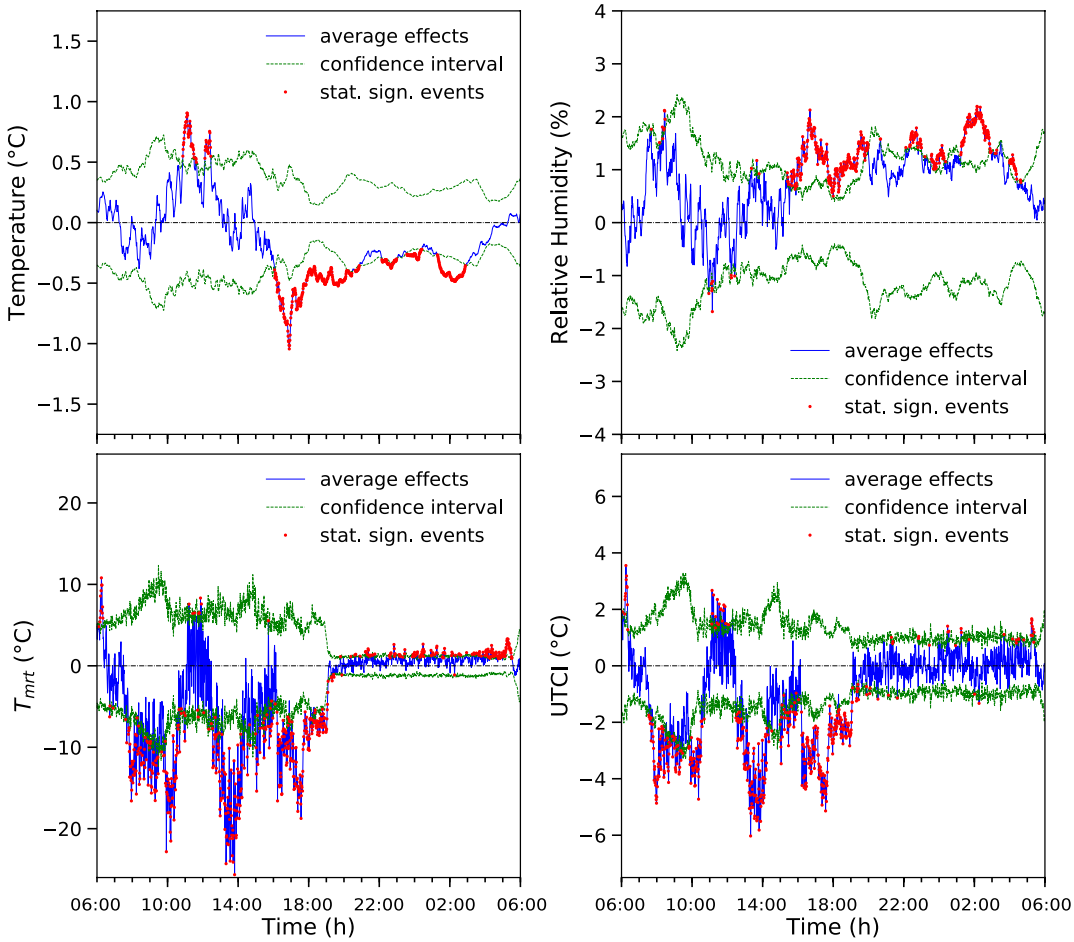

Figure 4: Microclimatic impacts of the site's partial renovation. Assessment based on 18 observation days before and 16 after conversion.

Figure 4 illustrates the microclimatic impacts of the site's partial transformation following the removal of the (partial) asphalt concrete pavement and the planting of trees. The impacts on air temperature, relative humidity and mean radiant temperature (MRT) are reported as well as their combined impact on the Universal Thermal Climate Index (UTCI). Maximum and mean effects are summarized in Table 1.

Table 1: Maximum and mean microclimatic effects

	Air temperature	*Relative humidity*	*MRT*	*UTCI*
Max	-1.0°C	+2.2%	-25.7°C	-6.0°C
Mean	-0.3°C	+1.3%	-7.5°C	-2.5°C
Time of max effect	4:54 pm	11:09 am	1:47 pm	1:18 pm

As can be seen, the microclimatic impacts of the site's partial transformation are quite significant, with three peak cooling effects visible with UTCI, the maximum effect reaching -6.0°C. These are principally attributable to morning and afternoon shade, causing a max reduction in MRT of 25.7°C. Air temperature is reduced up to 1.0°C at the end of the afternoon, while it is briefly increased by 0.9°C around noon. Finally, only minor increases in relative humidity of up to +2.2% are observed during the evening and night. In addition, the observed change is statistically significant for all parameters at least 35% of the day.

Looking at the details, it is clear from the observations that the shade provided by the trees planted in the immediate vicinity of the weather station has a very significant impact in the morning from 8-11 am, 1-3:30 pm and from 5-6 pm on MRT and UTCI. However, conditions seem to have marginally worsened around noon, perhaps due to the reduced thermal inertia of the unsealed soil. In addition, unsealing the soils around the station appears to have increased relative humidity, although climatic differences between 2018 and 2019 also contribute to this. It should be noted that the increase in RH does not have a significant detrimental impact on pedestrian heat stress given how dry conditions are to start with.

2.2. Mobile Measurements

Prior to site transformation, mobile measurements were conducted in June 2018 to estimate the microclimatic spatial distribution before conversion. These were performed on a typical summer day, i.e. with low wind speeds (<3m/s), clear sky and minimum and maximum daily air temperatures respectively greater than 16° and 25°C. These weather conditions match for days of Pasquill Stability Class A or A-B (Pasquill 1961). From these measurements, the Universal Thermal Climate Index (UTCI) equivalent temperature was calculated at several points, as indicated in Figure 5.

Figure 5: Thermal stress indicator (UTCI) on site before conversion measured on eight different locations on June the 26th of 2018, from 1 pm to 3 pm (local time)

As can be seen, strong microclimatic variations are observed between shaded and insolated areas. All measurements performed under trees or building shading exhibit no thermal stress. On the other hand, measurements conducted under direct insolation (indicated with a red dot) show a high level of thermal stress, exceeding 35°C equivalent temperature.

A new mobile measurement campaign will be conducted during summer 2020 to assess the change obtained with the complete transformation.

Conclusion

The partial conversion of a parking lot into a green space with 72 trees and pervious concrete pavement was studied as an UHI countermeasure in the Paris metropolitan area. The site was

monitored with fixed and mobile weather stations in order to determine the impact of the conversion on the site's microclimate. The impacts of partial conversion, following the removal of most of the asphalt concrete and the plantation of 72 trees were assessed.

A significant improvement of pedestrian heat stress is observed thanks to the shading provided by the trees with reductions of MRT and UTCI of up to 27.5°C and 8.1°C, respectively. Air temperature is also positively affected with a maximum reduction of up to 1.4°C. Finally, unsealing the soil led to an increase in relative humidity by up to 5%.

In addition, a preliminary mobile measurement campaign was conducted to investigate the spatial distribution of heat stress before conversion at eight different locations. Results show that no thermal stress is observed in the shade and high heat stress in the sun.

Mobile measurements will be conducted during summer 2020 after site conversion is completed, with the new pervious pavement in place over the entire site.

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