INTRODUCTION AND OBJECTIVE

- Trees and green infrastructures in general are often used in the urban environment as pollution mitigation strategy. However, the impact of urban vegetation on air quality, in particular in streets, is quite complex.
- Main effects of urban vegetation on air quality: aerodynamic effects (i.e. the presence of trees modifies wind flow around them changing the distribution of pollutants) and deposition effects (i.e. a fraction of pollutant is removed from the air by means of deposition on tree leaves and absorption through stomata) (Buccolieri et al., 2018).
- Previous studies in a Pamplona’s neighbourhood (Santiago et al., 2017a) indicated that the aerodynamic effects of trees on street pollution are stronger than deposition.

This study aims to quantify how the street ventilation changes due to the planting of trees with different foliage density. The idea is to get more insight about the relationship among street vegetation, ventilation and pollution concentration.

STUDY AREA AND SCENARIOS DESCRIPTION

- Study area: A district of Pamplona (northern Spain).
  - Mean building height: 20 m approximately (ranges from 11 m to 51 m).
  - Vegetation: Area projected in a horizontal plane respect to the total plan area of streets and squares is 13.8%.
  - Mean height of trees ranges from 5 m to 12 m (see Fig. 1).
  - Deciduous trees. Low foliage (LAD 0.1 m²/m²) was considered in March.
- Several scenarios (real and virtual) investigated by CFD modelling (Table 1).
- In a real tree-free street (STREET A), several scenarios were simulated assuming new virtual trees, which are located in the center of the street and their located crowds at the same height (from 4 m to 10 m tall).
- A case of bad air quality conditions were selected corresponding to the early morning (8 am) of an average day of March 2015 (high concentrations of NOx occurred).
- Typical meteorological conditions (prevailing wind direction (Northwest) and average wind speed) at this hour were computed from meteorological data recorded at a nearby station.

EFFECTS OF STREET TREES ON NOx CONCENTRATION

To analyze the aerodynamic effects, we focus on scenarios without considering deposition.
- For the whole neighbourhood with the current vegetation location, a LAD variation from 0.1 to 0.5 m²/m² increases the spatially-averaged concentration at 3 m height by 7.2 %.
- The influence of new trees in the STREET A indicate changes in average concentrations less than 0.05 % and 0.18 % for LAD = 0.1 m²/m² and 0.5 m²/m², respectively.
- Focusing on the STREET A, the averaged concentration within this street at 3 m height increases up to 1.5 % as LAD of all neighbour trees increases, and by 1.6 % and 12 % when new trees with LAD = 0.1 m²/m² and 0.5 m²/m² are considered, respectively (Table 2).

VENTILATION ASSESSMENT IN STREET A

- STREET A was assumed as a prism composed by 4 lateral planes (Planes 1-2 parallel to the street and 3-4 perpendicular to the street) and a plane in the top (Plane 5). Plane 5 is located 1 m above the height of the tallest building (± 28 m) (Fig. 5).
- Wind flow is from Northwest which is almost perpendicular to street orientation (Fig. 5), and then, the most part of flow enters into the street through Plane 1.
- The average flow rate q was computed at each plane following: where V'x is the velocity perpendicular to each plane.
- In Table 3, the percentage at each plane of the total flow rate which enters in the street is shown. Negative values indicate flow direction is towards outside the street (i.e. air leaving the streams) and positive values are those entering the street.
- The higher tree LAD, the higher concentrations in the whole neighbourhood due to the decrease of average velocity other than to be considered the top part.
- The new trees configuration affects the flow rates and the normal velocities (Table 3):
  - Increases the average flow rate in the parallel direction increasing at 157 %.
  - Modifies the flow rate at the perpendicular planes to street direction (3 and 4) and LAD = 0.5 m²/m², the flow outward the street decreases up to 40 % approximately for plane 3. However, these average values are not representative for the whole street. Due to street intersections, there are parts of the street with horizontal vortices and others with channeling in different directions.
- The new trees configuration modifies the average wind flow properties (wind speed normal to street (V'x) and parallel to street (V'y), vertical wind speed (W') and turbulent kinetic energy (TKE)) in STREET A (Fig. 6): A) Average parallel wind speed decreases for new vegetation scenario, especially within and below the vegetation canopy.
  - Concerning vertical wind speed, downward wind speed within and below the vegetation canopy is lower for new vegetation scenarios, while upward wind speed over the new trees is stronger with vertical turbulence at the top. This effect is more relevant in other scenarios with no trees in STREET A.
- A decrease of TKE within vegetation canopy is clearly observed.
- These processes are stronger for new trees configuration with LAD 0.5 m²/m².

CONCLUSIONS

In the whole neighbourhood, average concentrations increases and average wind speed is lower when LAD increases.
- Within the STREET A new trees induces an increase of average concentrations (spatially with high LAD) because:
  - average wind speed parallel to the street (parallel ventilation) is reduced;
  - downward wind speed within new vegetation canopy is reduced (weaker ventilation) within and below the vegetation canopy, while upward wind speed slightly increases over the trees (more ventilation);
  - TKE decreases within and below new vegetation canopy.

These results could be useful for urban planners to build sustainable design of vegetation within streets, although local effects within the street should also be taken into account.

REFERENCES

Buccolieri, R. Sánchez, A., Martí, M., Carles, T., 2017a: Environmental impact of urban trees (oak) on urban air quality: Local scale evaluation. Environmental Pollution 223, 772-784.