Relocation of the Air Quality Monitoring Stations Network for Aburrá Valley Based on Local Climatic Zones

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***Abstract*—**The majority of the urban areas in Latin America face the challenges associated with city planning and development problems, attributed to human, technical, and economical factors; therefore, we cannot ignore the issues related to climate change because the city modifies the natural landscape in a significant way transforming the radiation balance and heat content in the urbanized areas. These modifications provoke changes in the temperature distribution known as "the heat island effect". According to this phenomenon, we have the need to conceive the urban planning based on climatological patterns that will assure its sustainable functioning, including the particularities of the climate variability. In the present study, it is identified the Local Climate Zones (LCZ) in the Metropolitan Area of the Aburrá Valley (Colombia) with the objective of relocate the air quality monitoring stations as a partial solution to the problem of how to measure representative air quality levels in a city for a local scale, but with instruments that measure in the microscale.

***Keywords*—**Air quality, monitoring, local climatic zones, valley, monitoring stations.

I. Introduction

Aburrá Valley is a subregion of the department of Antioquia (Colombia) extending in the territory of ten municipalities. The valley is located in the Central Cordillera; it has an area of 1,152 km^2 with an approximate length of 60 kilometers and variable amplitude. The formation of the Aburrá Valley is the result of the geographical unit determined by Aburrá River Basin, the main waterway that runs through it from south to north and a series of tributaries that fall along its route [1].

According to the topographic and climatic characteristics of the Valley of Aburrá, it meets the conditions of airshed, defined as a partial delimited geographical area or wholly by mountain ridges or other natural attributes occupied by a volume of air with similar characteristics which provide concentration and reaction of gaseous and particulate pollutants from the air, so the Aburrá Valley is regarded as the airshed Aburrá Valley [1]. One of the biggest challenges faced by an air quality monitoring stations network composed by these features is the location of itself, especially when it comes to urban stations. The solution to the problem of the measuring of the air quality into a city to a local scale but with instruments that measure in the microscale (i.e., without rising measuring instruments above the urban canopy) may come from the concept of LCZ developed by [2]. In the words of the authors, this concept is zonal by its representation, climate by nature and local by the scale, and is expressed as it follows: "We define climate zones locally as regions of surface coverage, structure, materials and uniforms human activity, ranging from hundreds of meters to several kilometers in the horizontal scale". Of course, if it is assumed that air quality takes part of the variables that define the climate conditions of a city, so that a particular station is located in a representative place into a LZC (i.e., away from the zone peripheries and in a site of town planning average within the area), it would have a very similar condition which seems to suggest the definition in the "Protocol of background stations" (records of contaminants in these stations do not correspond to specific point sources or specific pathways). Given this concept of LCZs and a method based on GIS techniques proposed by [3] it performed an initial exercise to identify those LCZs in the Metropolitan Area of the Valley of Aburrá, whose results will be exposed for municipalities located in the central area; it is observed that, in effect, the urban territory is heterogeneous.

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II. Methodology

A. Current Location of the Air Quality Monitoring Stations in the Aburrá Valley (Colombia)

The Aburrá valley is characterized by its narrowness with the thermal inversion problems, and it is located in the Andes mountain range in Colombia. The Aburrá Valley Metropolitan area air quality monitoring network has monitored the air quality for approximately 16 years. Currently, the monitoring is performed in 22 permanent measuring locations, also in a mobile station, distributed in the municipalities that are in jurisdiction of the environmental authority (MAAV) [1], as it is shown in Fig. 1.

In the range of the air quality variables that are monitored, we can find: acid rain, total suspended particles (TSP), particles smaller than 10 micrometers (PM10), particles smaller than 2.5 micrometers (PM2.5), particles smaller than one micrometer (PM1), carbon monoxide (CO), ozone (O_3), nitrogen oxides (NOx), and sulfur dioxide (SO_2). The monitored meteorological variables are: wind speed and direction, temperature, relative humidity, precipitation, global radiation and atmospheric pressure [1].

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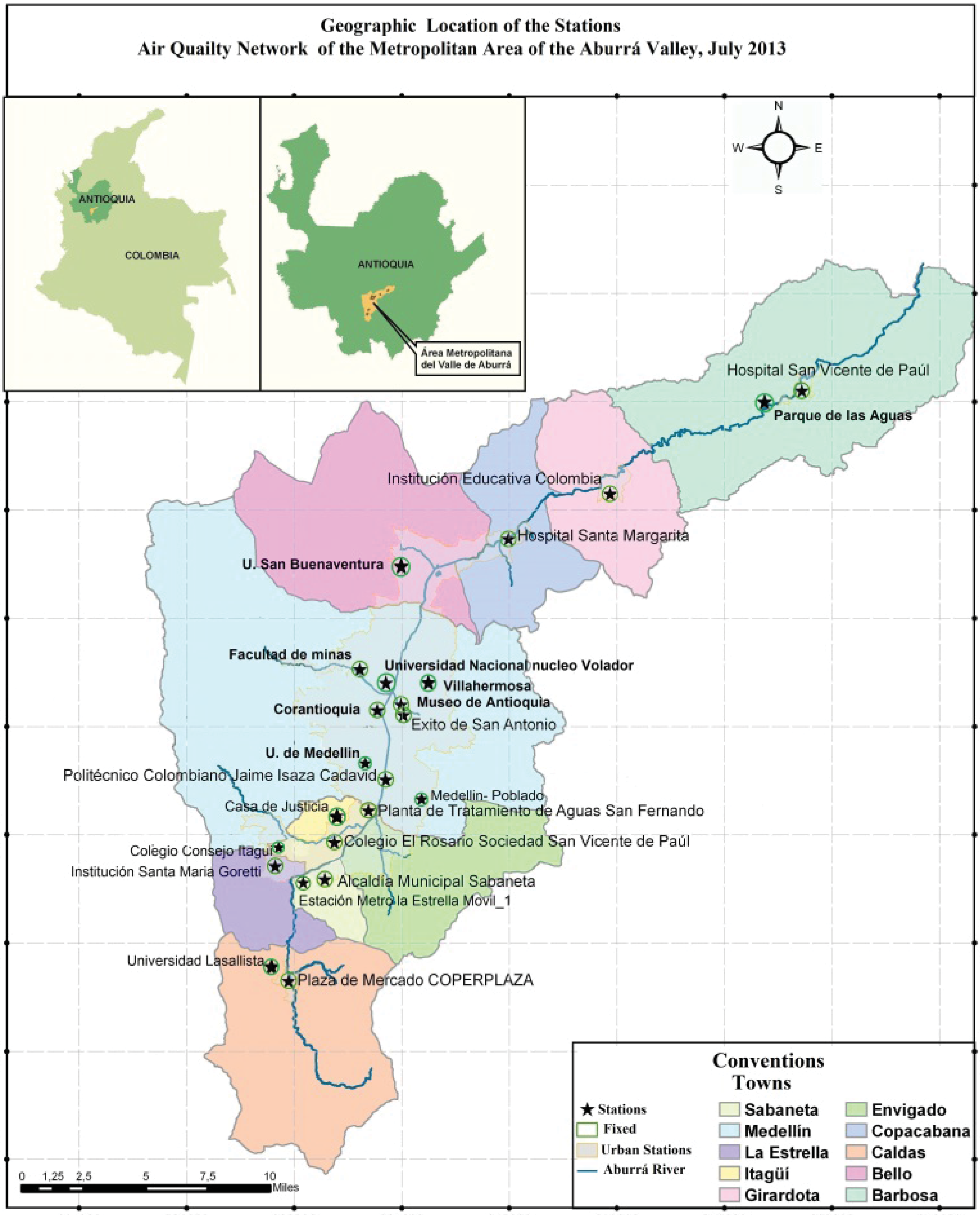

Fig. 1 Geographical positioning of the air quality monitoring stations in the Metropolitan Area of the Aburrá Valley. Update date 20/04/2015, own source

According to the monitoring and follow-up protocol for the air quality issued by Colombia´s Environment, household and territory development ministry, the objectives of the special air quality surveillance systems (SAQSS) [4] are established; it is required in the case of inhabited zones exposed to the influence of great magnitude emissions, like the Metropolitan Area of Aburrá Valley. The objectives are the following:

- Determine the fulfillment of the air quality normativity,

- Assess the control strategies of the environmental authorities,
- Observe the tendencies in the mid and long term,
- Assess the risk to the human health,
- Determine possible environmental risks,
- Activate the control procedures in emergency situations,
- Study emission sources and research concrete complains,
- Validate the air quality models,
- Support the scientific research.

It is evident that the main reasons that support the use of a SAQSS of this type have to do with the protection of human populations, ecosystems and the environment.

B. Air Quality Monitoring Stations Classification According to the SAQSS

In the Protocol (SAQSS), the air quality monitoring stations are classified according to the following criteria [4]:

1) According to the type of area where the monitoring station is located:
- Urban: Located in a totally urbanized area (the percentage of urban coverage and the dimensions for a check-up area are not specified).
- Suburban: Located in a majorly urbanized area, but mixed with non-urbanized areas (the urbanized percentage is not specified)
- Rural: the stations that are not considered as urban or suburban.

2) According to the data representativeness in the scale of time: This is, if the station remains more than one year in the same position (considered fixed or permanent), or if it lasts for less than a year (considered as indicative station)
3) According to the dominant emissions:
- Traffic: Pollutants emissions captured by the station mainly generated by the nearby vehicle circulation.
- Critical Point: Stations located at the base ground level, are used as reference for epidemiological studies.
- Industrial: They are used to monitor punctual pollutants emissions mainly form industrial origin.
- Background: the contaminant´s register in these stations does not correspond to specific punctual sources nor specific routes.
- Special Purpose stations: the registers serve as reference for studies oriented to the analysis of high quality data and its interpreting.

C. How to Monitor in a City Representative Levels of Air Quality for the Local Scale

One of the biggest challenges faced by an air quality monitoring network composed by stations with these characteristics, is the equipment´s location, even more when we are dealing with urban stations. In order to protect the human health, the protocol recommends: "the sampling points should be positioned in the sense that they provide the data of the areas located inside a zone of interest, that concentrate more than 50.000 inhabitants and register the highest concentrations that the population can direct or indirectly be exposed during a significant period, in comparison with the average period used for the limit value or values calculated. They should be positioned in a manner that they provide data about the registered levels in other areas and agglomerations that are representative of the population´s degree of exposure. In general, they also will be located, in a way that the measurement of microenvironments in the vicinity is avoided" [4]. The contradictory (not to say confusing) sense of this recommendations is noticed.

In one hand, it is said that the stations should be located where the highest concentrations arise, and in the other hand, it suggests that the registers correspond to the representative values of the exposure degree. One thing does not necessarily imply the other (the maximum value rarely matches or gets close to the sample´s representative values), the most convenient is to suppose that the networks, moreover in a SAQSS should be in conditions of measuring the maximum values (associated to fixed sources, mobile, or eventual) as the "representatives" for a zone (background stations); a different case is the station location for special purposes.

D. Local Climate Zones

One thing is being able to find places in a city where the air quality monitoring stations do not measure the data corresponding to microclimates.

Fig. 2 shows a very well known classification of the three spatial urban scales. The mesoscale covers extensions up to several kilometers, the local scale collects signals form 1 kilometer up to several kilometers, and the microscale covers form 1 meter, up to hundreds of meters. Therefore, with the objective of receiving signals corresponding to the local atmosphere and mesoscale, the guide for meteorological instruments and observation methods of the WMO (2008, chapter 11) [5] recommends to locate the measurement sensors in heights above the ground level between 1.5 ZH (densely built areas) and 5 ZH (disperse infrastructure), where ZH is the average height of the buildings and trees in the surroundings.

It is to say, for example: in a neighborhood with disperse constructions that have an average of 3 meters of height, the sensors should be located at 15 meters above the ground; but if the buildings are about 20 meters tall, the instruments should be risen between 30 and 100 meters above the ground level, depending if the infrastructure is dense or disperse, in the way that the instruments can receive the signals outside the rugose sublayer of the atmosphere. The conclusion seems to lead to a dilemma: we have two possibilities; we can measure the atmosphere breathed by the urban population or we measure the local scale or mesoscale.

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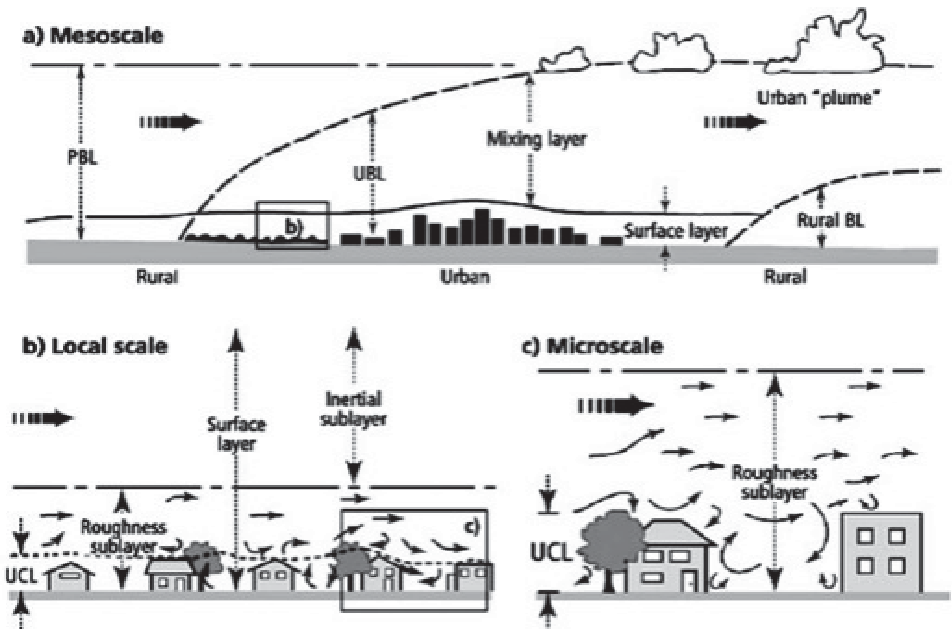

Fig. 2 Three spatial scales of the urban environment according to [6]

The partial solution to the problem on how to measure the representative air quality levels for a local scale, but with instruments that measure the microscale (this is, without having to rise the measuring equipment above the urban canopy), can be derived from the concept of the LCZs, elaborated by [2]. In the words of these authors, this concept is zonal due to its representation, climatic by nature and local by scale, and it is expressed in the following terms: "We define the local climate zones as superficial coverage regions, structure, materials, and uniform human activity, that extend from hundreds of meters until several kilometers in the horizontal scale". Of course, if it is supposed that the air quality makes part of the variables that define the climatic conditions in a city, in a way that a particular station is located in a representative position inside an LCZ (this is, far away from the zonal peripheries and in an average urbanism location inside the zone), we would have a very similar condition to the one suggested in the protocol for the background stations.

III. Results

A. Identification of the LCZs in the Metropolitan area of Aburrá Valley

Having into account the LCZs concept and a method based on GIS techniques proposed by [3] a first exercise has been made to identify those LCZs in the Metropolitan area of Aburrá Valley; its results are sketched in Fig. 3, for the municipalities located in the central area.

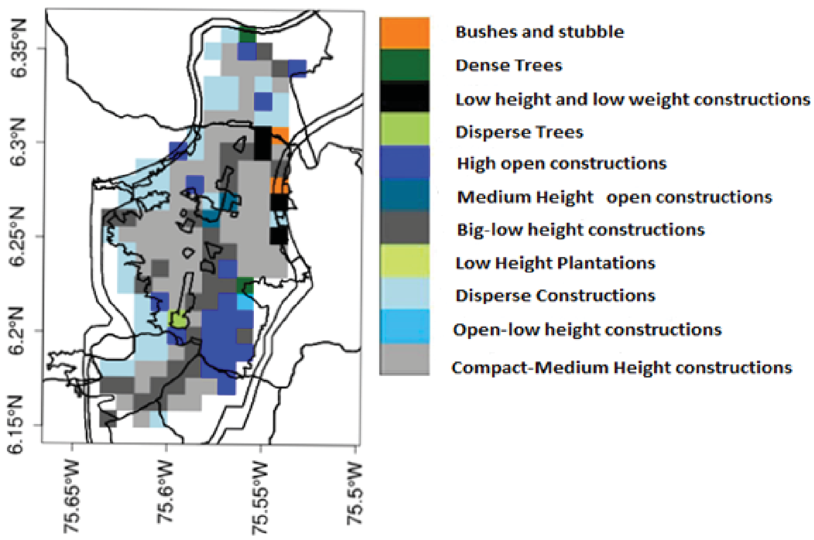

Fig. 3 Preliminary LCZ map for the municipalities in the Metropolitan area of Aburrá valley

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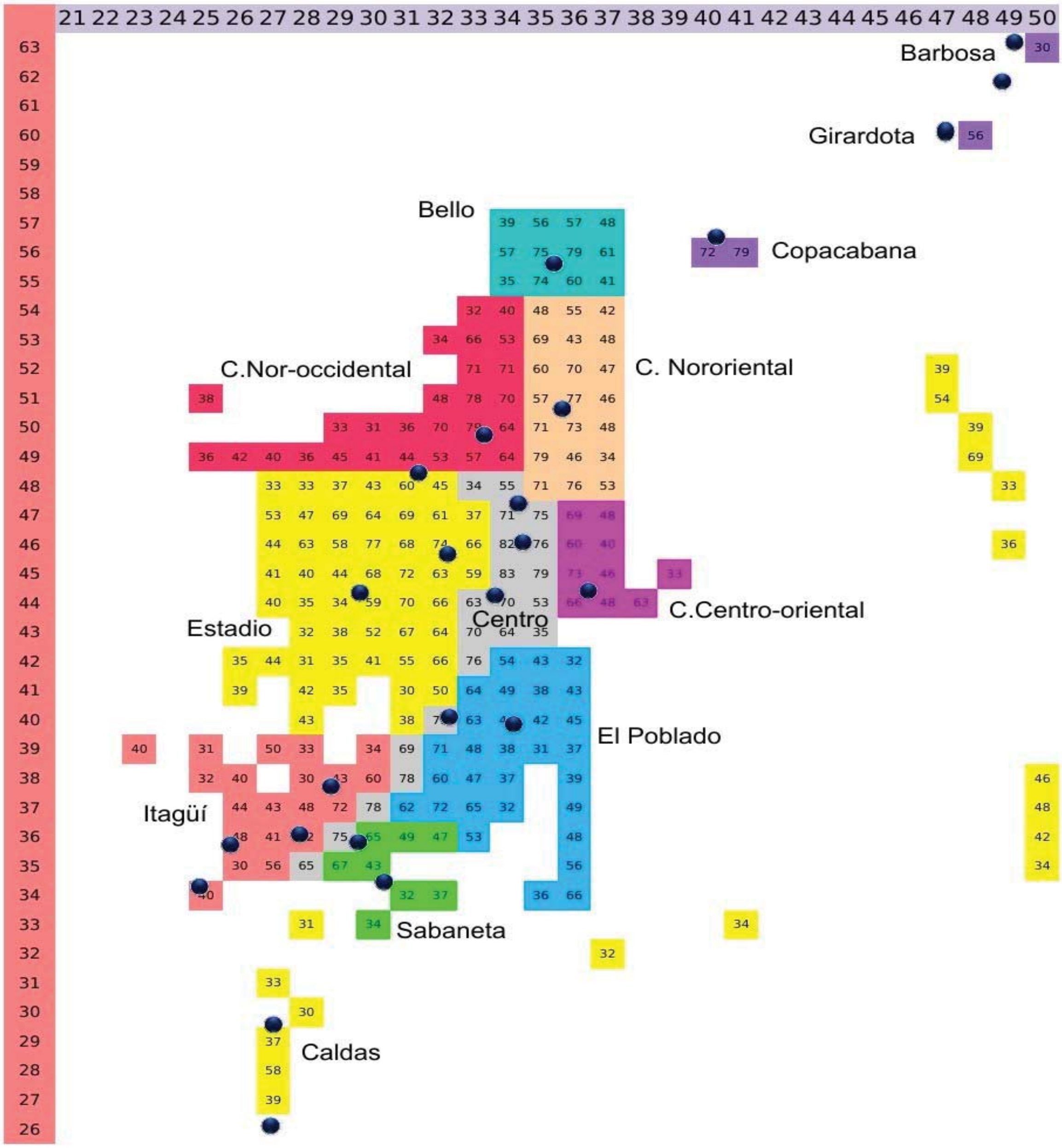

Fig. 4 Relocation proposal of the monitoring stations in the current air quality network (small blue circles)

It is observed that, in fact, the urban territory is heterogeneous. The medium height compact zones predominate in the left margin of the river and the northeastern commune; an epicenter of big dimension and low heights is distinguished all along the fluvial axis (mainly corresponds to storehouses, industries and commerce); and some open zones with higher heights majorly concentrated in the southern part of the valley. Additionally, it is observed that the air quality monitoring stations located in the municipalities in the center of the metropolitan area are near the road axis, the storehouses and industries that developed in parallel to the Medellin´s river canal. Other stations (As Medellin´s University, San Buenaventura and el Poblado´s universities) occupy locations in the urban periphery, and some others (Jaime Isaza Cadavid Polytechnical institution and El Voldador nucleus.) are in contact lines between LCZ´s.

B. Relocation Proposal of the Monitoring Stations Based on the LCZs

All of above is with the objective of generating an improvement proposal of the air quality monitoring network for the Metropolitan area of the Aburrá Valley.

The basic location criteria for the stations, without generating opposition to the protocol´s criteria, follow the next parameters of complementary character:

- It is intended that the representative registers of a location are taken according to the urban background stations, as the protocol suggests

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- It is not intended to excessively increase the number of stations. More than expanding the current station number, the problems consist in positioning them correctly according to the monitoring objectives clearly defined.
- Although the majority of the pollutant emissions to the atmosphere come from the vehicle traffic, the number of traffic stations should be reduced to give priority to the urban background monitoring, which allows to have a more complete idea of the urban air quality, and therefore, allows to advance in the understanding of the effect of such air quality in the morbidity and mortality patterns in the population.
- Each municipality in the metropolitan area should have at least one station located in the municipal head, in a position where it indicates the "average" or "representative" atmospheric conditions of the urban center.

According to the protocol, having into account the objectives defined for a SAQSS the following network for the Metropolitan area of the Aburrá Valley is proposed.

1) Urban background stations: each municipality in the Metropolitan area of the Aburrá Valley should count, with at least, with one urban background station, located in representative sites of the urban area. Because of its magnitude, it is advised for the Medellin´s Municipality to have at least six urban background stations, according to the LCZ distribution. The station located in Downtown Medellin (for example, in the Antioquia´s museum) could be considered as critical point.
2) Traffic stations: depending on the chosen number of stations, it is suggested to position the equipment near to the areas where the vehicular traffic seems more significant
3) Suburban background stations: two stations are suggested, one in the north (in a thematic water park called "Parque de las Aguas") and the other one in the south (in Caldas).
4) Due to the known condition of atmospheric pollutant concentrations in the municipality of Itagüí, it is advised to locate there at least three stations: one of them in the urban expansion zone. One of the two remaining stations could be considered as the industrial type, due to the significant amount industries and storehouses in this municipality.

Fig. 3 shows the relocation proposal for the air quality stations. The Metropolitan area is divided in "identified sectors form a synergic analysis between topography, soil coverage and LCZ. The small squares and the numbers inside them correspond to 1 kilometer cells.

IV. Conclusion

The diversity and complexity of the urban climates are specific characteristics of the city environment, they can be observed at different analysis scales, and it prevents from any spatial generalization or homogenized supposition, this is why it is necessary to monitor the air quality in the Metropolitan area of the Aburrá Valley based on the local climatic zones.

The decision taking around the urban planning and the air quality monitoring should be strengthened by the inclusion of the local climatic variability, because it allows the execution of the mentioned urban planning with multidimensional and transdisciplinary.

The partial solution to the problem on how to measure the representative air quality levels for the local scale, but with instruments that measure the microscale (this is, without having to elevate the measuring equipment above the urban canopy), can be derived from the LCZ, elaborated by [2].

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