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Papers

Sensors network for the evaluations of the meteorological variables in urban green areas: development and applications.

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Abstract
The urban environment is often responsible for negative impacts on the climate and environmental comfort, due to the common climatic interference in highly built and waterproofed environments. One of the ways of mitigating negative environmental and microclimate impacts is the use of green areas in the urban environment. Thus, aiming at the analysis of environmental quality parameters of urban regions, it is essential to monitor the influence of green areas on different meteorological variables. In this sense, the use of information acquisition instruments and methodologies can positively contribute to this analysis, which can support decision-making related to urban planning. Thus, this work aims to develop a sensor network with sensor nodes to assess meteorological variables in urban green areas, aiming to analyze and discuss the influence of green areas on the behavior of CO¬2 concentration, temperature and air relative humidity parameters in an urban environment. The proposed and developed sensor nodes enabled the adequate collection of these variables and, based on the results obtained, it was possible to observe that the green area (permanent preservation area - PPA) contributed positively to these variables in the portion of the study area located in Campinas (SP), presenting lower temperature and CO2 concentration and increased air humidity. However, for the portion of Paulínia (SP), it was possible to observe little influence from the PPA. Influences on these variables, exerted by rural areas and parks, were also identified, contributing to the reduction of meteorological parameters, but different interactions were identified with the CO2 concentration, which may present a possible increase or assist in the reduction of CO2 in the air.

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INTRODUCTION

The technological advances and the changes in socio-economic concepts during the last century have directly impacted in the soil alterations (CHOAY, 1965). This way, there have been environmental consequences which began to interfere with the climate stability, elevating the level of atmospheric pollution, which is related to the excessive generation of Greenhouse Gases- GHG, leading to the global warming phenomenon (HOUGHTON; HACKLER, 2001; ROSEIRO; TANKAYANAGUI, 2004).

In this context, the urban areas may be characterized as aggressive environments due to soil sealing, low vegetation rate, intense traffic of automobiles and significant presence of industries. Besides, these areas are generally associated to high levels of atmospheric pollution, related to the economical activities, corresponding to environments of low quality air and constant polluting emissions in the atmosphere. Physical impacts on the environment are also identified in these areas, interfering directly in the microclimate and environmental comfort, due to the occurrence of events such as the heat islands and the urban "Canyons", triggered by the waterproofed environment and the difficulty of changing the temperature and access to the air currents (STEWART; OKE, 2012; SAMPAIO et al., 2007).

In recent years, mitigation measures and environmental monitoring have been developed and implemented in order to improve the urban environmental quality (WMO, 2018). Among these mitigations of environmental impacts, it is possible to identify the utilization of green areas, characterized as open space areas, active vegetation, permeable areas, being possible to assist replacing the aquifers, that is to say, Permanent Preservation Areas (PPA), parks, squares and urban conservation units (BRASIL, 2006). These green areas may positively influence the behavior of the meteorological variables of the urban microclimate, regarding the increase of the local shading, the albedo provided by the leaves and the CO_2 absorption (AMBRIZZI; ARAUJO, 2014; BOWLER et al., 2010).

Regarding the environmental quality monitoring, it is indispensable to analyze the influence of green areas in different meteorological variables. For that matter, the usage of instruments and methodologies of information acquisition may be of positive contribution, providing subsidies for the decision-making process related to the urban planning (LIU et al., 2017; CASTALDO et al., 2017).

Among the alternatives of collecting information in urban areas, it is possible to verify the application of electronic sensing technologies, which have been highlighted due to their cost-benefit and the possibility of executing *in loco* measurements in a simple way, being possible to apply on fixed structures or with the aim of automobiles and mobile collectors of meteorological parameters (WMO, 2018; SOEIRA, 2018; PULIAFITO, 2013).

On the other hand, the applications of monitoring require some efforts which seek multidisciplinary methods to make the use and development of measuring possible and the electronic sensors in meteorological stations to collect great volume of data and analysis for sufficient periods to comprehend the climate of specific regions (CARMINATI et al., 2019; TUROLLA et al., 2019; PIOPPI et al., 2020; RASHID; REMANI, 2015).

That way, this academic work aims to develop a sensor network, consisting of sensor nodes for the evaluation of meteorological variables in urban green areas, directing to analyze and discuss the influence of the green areas on the behavior of CO_2 concentration parameters, temperature and relative air humidity. The sensor nodes which have been proposed had as main requirements the possibility of monitoring diverse meteorological variables, the constructive low-cost and the capacity of storing the collected data. Another relevant attribute to the developed sensor nodes consists of embodying different sensors (expansion of the sensor node) capable of collecting other variables which begin to be relevant to the users.

METHODS AND MATERIALS

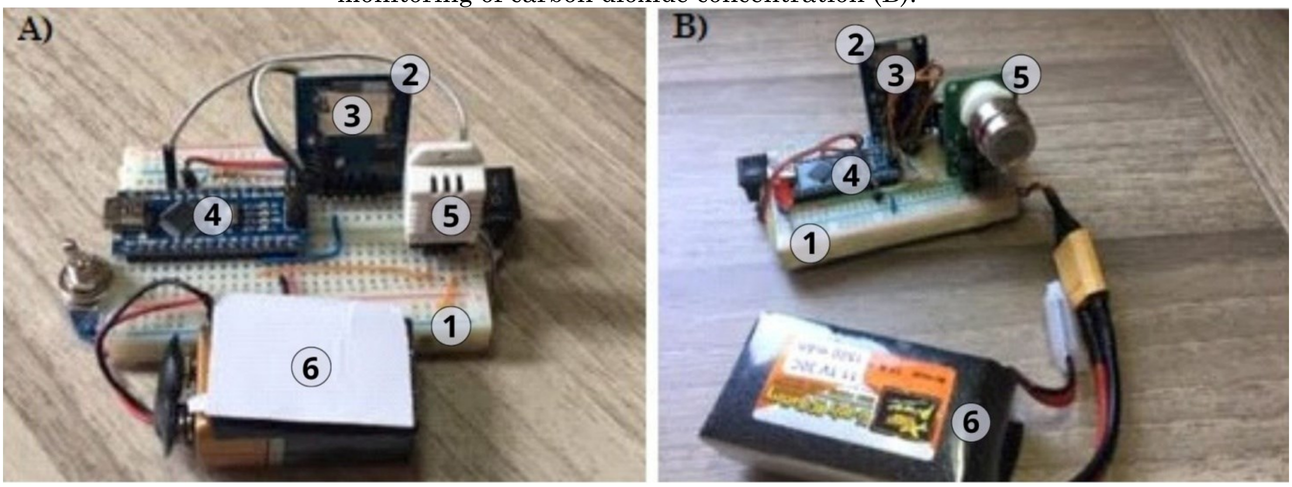
Sensor nodes development

For the study of meteorology, the parameters of relative air humidity (RH), air temperature (AT) and carbon dioxide concentration (CO_2) have been selected in order to propose the development of the sensor nodes. It is important to define that the sensor nodes are elements of a communication network responsible for collecting data of a specific environment, processing and communicating this information. Thus, the sensor nodes are constituent parts of a sensor network. In this work, a wired sensor network was proposed, composed of two sensor nodes (Figure 1), for monitoring the quantities mentioned above, since the technologies of low-cost wireless networks (one of the focuses of this work), after being tested in the field, were not suitable for robust and effective transmission of data collected in outdoor environments and with the presence of obstacles (especially the presence of buildings and many trees).

In the academic work, two sensor nodes have been developed: one for monitoring the AT and the RH (Figure 1A) and the other for monitoring the carbon dioxide concentration (Figure 1B). The parameters RH and AT have been collected from sensor DHT22 (Figure 1A) which has precisely ±2% for humidity and ±0,5°C for the AT (AOSONG ELECTRONICS, 2020). The CO_2 concentration measures have also been held by using the sensor MG811 (Figure 1B), which allows the identification of up to 10.000 parts per million (ppm) of the gas (PARALLAX, 2010).

Besides these sensors, the sensor nodes have been constituted by protoboard plates, microprocessors (Arduino Nano V3 ATMEGA 328 Ch340), SD card adapters, SD card for storing data and a battery to support the system.

Figure 1 – Sensor nodes developed for the monitoring of the AT and the RH (A) and for the monitoring of carbon dioxide concentration (B).



1) Protoboard
2) SD card adapter
3) SD card (Data storage)
4) Microprocessor
5 A) Sensor DHT22
5 B) Sensor MG811
6 A) 9V Battery
6 B) 11V Battery

Source: The authors (2020).

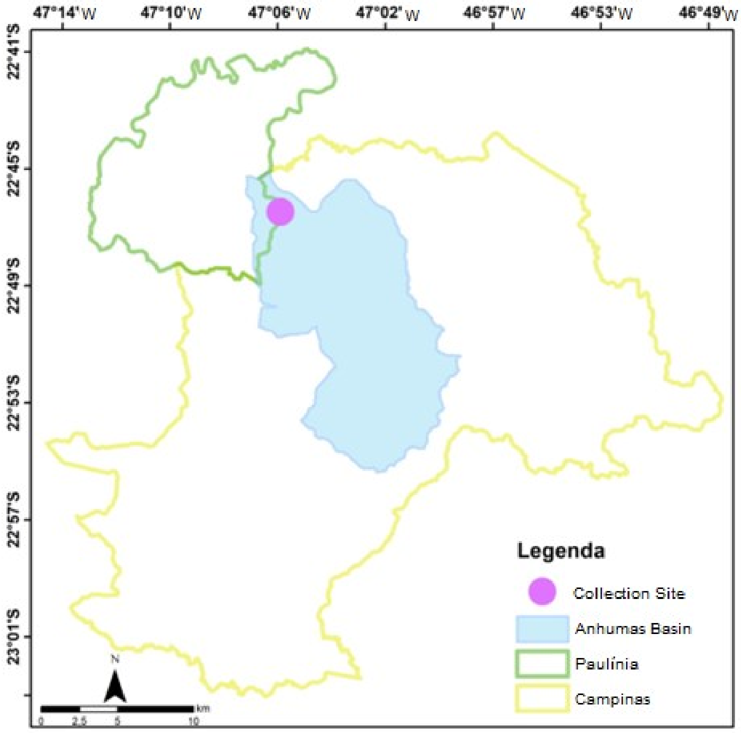
In addition to this, a code was developed in C language and implemented in the Arduino microprocessor, which allowed the processing of the collected data, the activation of additional contact keys to activate the sensor nodes, the collection of data at five-second intervals between each collection and the generation of a red LED (light emitting diode) to warn of a collection error.

Study area characterization

The study area of this academic work was delimited around a PPA located in the northwest of the hydrographic basin of the Anhumas river, established by the division of the cities of Campinas and Paulínia (SP) (Figure 2). The region is next to the Atibaia river mouth, between the Atlantic Plateau and the Peripheral Depression, containing lands composed of Argissolos, with some influence of diabase, fragments of the Atlantic Forest and wide urban occupation (GOMES et al., 2004 apud FRANCISCO, 2006).

The local climate is represented by the typical characteristics of the tropical zones of low altitude, dry winter and rainy summer, being June the coldest month of the year. The local temperature ranges values below 18°C in the winter and values above 24° in the summer, being possible to identify the climate with mesothermal characteristics of dry winter (Cwa) (FRANCISCO, 2006; JACOMAZZI, 2015).

Figure 2 – Study area location



Source: The authors (2020).

The area was delimited and treated with the aid of ArcGIS 10.3.1 software, from orthophotos extracted from the CBERS 4a satellite. A central point was inserted within the PPA and, from this location, a radius of 1,150 meters was expanded to demarcate the area of interest, at latitudes 22°45.8 and 22°47.1 South and longitudes 47°5.1 and 47°6.3 West.

The characterization of the experimental study area was built regarding the Local Climate Zones methodology– LCZ (STEWART; OKE, 2012). This classification had the goal of determining the types of consolidated areas with influence on meteorological variables. This way, the LCZs (Table 1) were identified with forestry characteristics (LCZ-A), Bodies of water (LCZ-G), Exposed Soil and Rural Area (LCZ-Cd), Industrial Area (LCZ-8D) and Residential Area (LCZ-3_2).

Table 1 – Detailed information on the identified LCZs

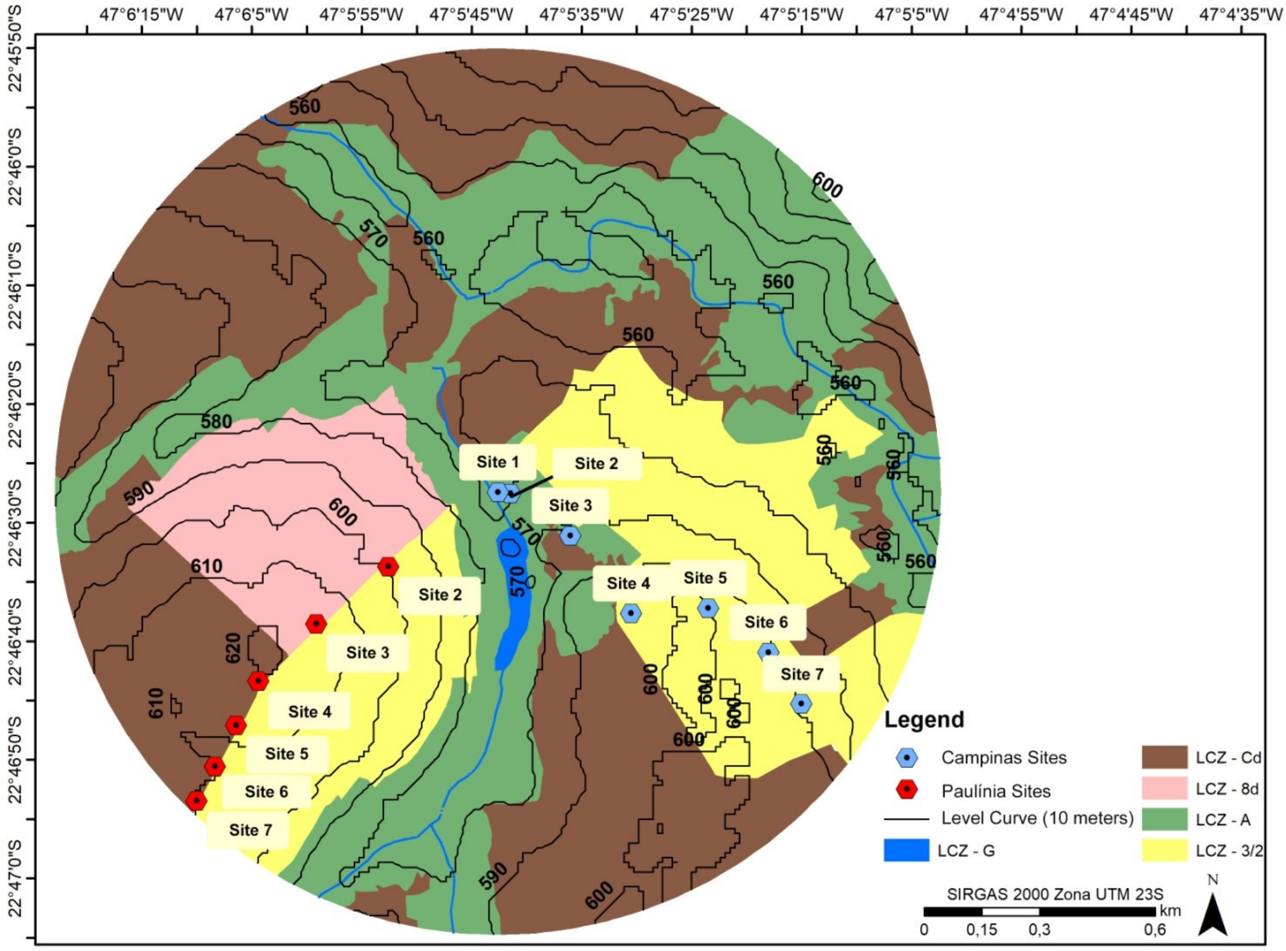
Type	LCZ	Stewart and Oke's Classification (2012)	Characteristics
Exposed Soil	Cd	Bushes (C); Ground Plantation (D).	Mix of ground vegetation, agriculture, wide forestation and urban voids.
Industrial and Commercial Activities	8d	Wide and High Structures (8); Ground Plantation (d).	Mix of constructed environment spacing between structures of 15 meters high and exposed soil.
Residential	3_2	Dense and low Constructions (3); Dense and Medium height Constructions (2)	Mix of constructed environments (7 to 8 meters) with small spacing and low width tracks.
Forest	A	Forest	Dense forestation
Bodies of Water	G	Water	Rivers and lakes

Source: The authors (2020).

Data collection distribution sites

The distribution of data collection sites was carried out in the inferior part of the study area (Figure 3), due to the easy access, being installed in public locals. Therefore, the distribution of the data collection sites used Site 1 as a common point between the two cities in which the collections had been made and 6 additional and distinct sites for each city (Campinas and Paulínia). These sites were positioned in a way to be far from the PPA and be introduced in diverse morphologies, with distinct characteristics and, consequently, with possible different influences in relation to the monitored meteorological variables.

Figure 3 – Data collection distribution sites



Source: The authors (2020).

Data were collected on July 18th and 19th, 2019 for the parts of Campinas and, on August 27th, 2019 in Paulínia; both days were sunny and the sky was clear. The collections were taken in two different periods: the morning period from 10:00 am to 11:30 am, seeking the moment with the maximum exposure to the sun radiation possible, and the afternoon period from 2:00 pm to 4:00 pm, making the data collection possible at the hottest hours of the day, enabling for analyzing the contribution of the green areas to the studied environment (MOREIRA, 2015; LANDSBERG, 1956).

To ensure that data collection could be taken within the established periods and to reduce the time gap between the measurements taken in each collection site, it has been considered to apply the mobile collect with sensor nodes methodology, by using an automobile for transport to each site. The collection at each site had a duration of three minutes with three minutes of sensor adaptation to each change of location when transiting between points. At each collection point, a sample was collected every 5 seconds, totaling 36 samples at each collection point, which meets the requirements of statistical inference.

Data analysis

The analysis of the data was performed after ascertaining and cutting outliers using the method of 1st and 3rd quartils as a reference for anomaly data identification and to ensure the reliability of the representation of the database. The AT and RH parameters showed no outliers, while the CO_2 suggested some changes, which may be associated with the peak flow of cars, wind and/or agriculture and other interferences not mappable in the local, thus, having the need for exclusion according to the method applied (MARTINS, 2014).

For the data analysis, it was chosen to use the Spearman correlation coefficient to understand whether or not there is a correlation between the behavior of the parameters studied and the distance from the PPA, thus enabling more robust interpretations and analysis of the region under study (NESBITT, 2019; BRINDLEY et al., 2019). It is noteworthy that this is a non-parametric coefficient, suitable for the application under analysis, since it is widely used for monotone functions (preserving the order-growing or decreasing).

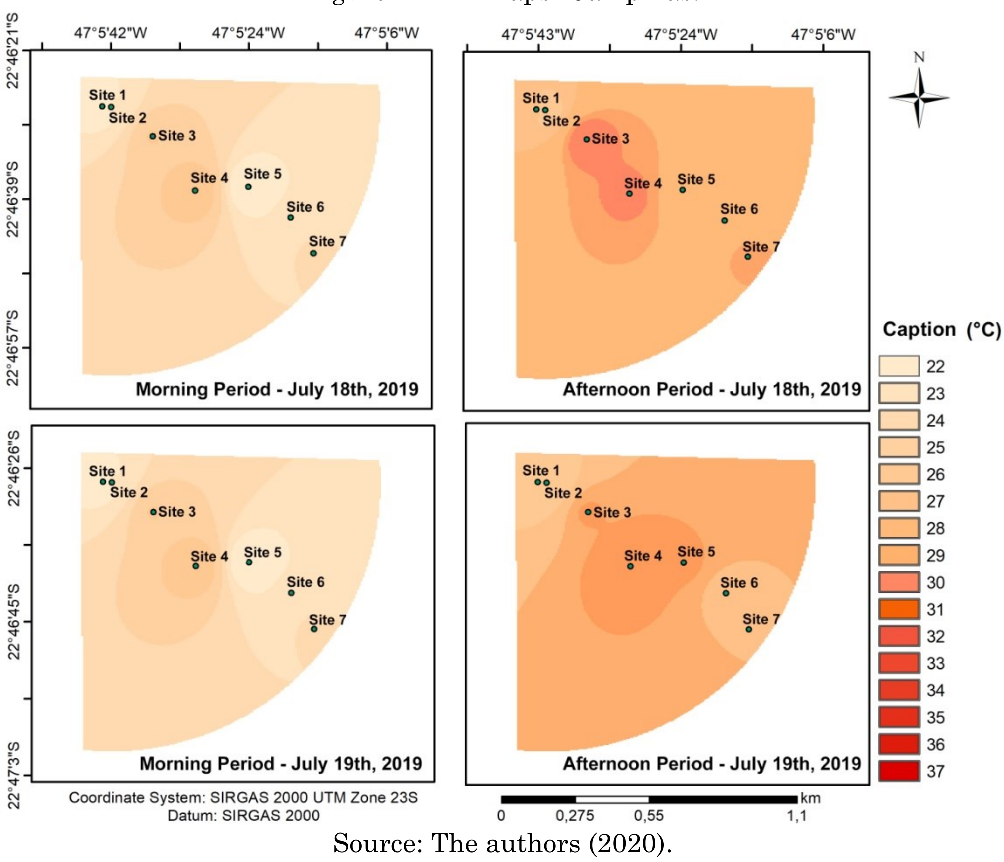
In the spatialization of the results the Inverse Distance Weighting (IDW) method was used, being developed within a geographic information system (GIS), which was chosen due to the distribution of points not being random and positioned in a rectilinear way due to the region's accessibility to public areas, not allowing the implementation of robust models such as kriging. The IDW consists of the relationship of neighbors, where, the characteristics of nearby objects are assimilated to estimate the behavior around them, enabling spatialization of the parameters studied (DEBIAZI; SOUZA, 2017; LIU et al., 2017).

RESULTS AND DISCUSSION

Temperature and Relative Air Humidity

Analyzing the obtained results related to the AT e RH in the part of Campinas, it may be observed that the hottest places were Sites 3 and 4, while the lowest temperatures were found in Sites 1 and 2, located next to the PPA. By comparing these two regions in pictures Figures 4 and 5, it is possible to observe the inversely proportional behavior among the parameters, that is, when the temperature increases, it is possible to notice the decrease of the relative air humidity. Besides, the highest temperatures were registered during the afternoon period, while the highest values of relative air humidity were registered during the morning period (Figure 5).

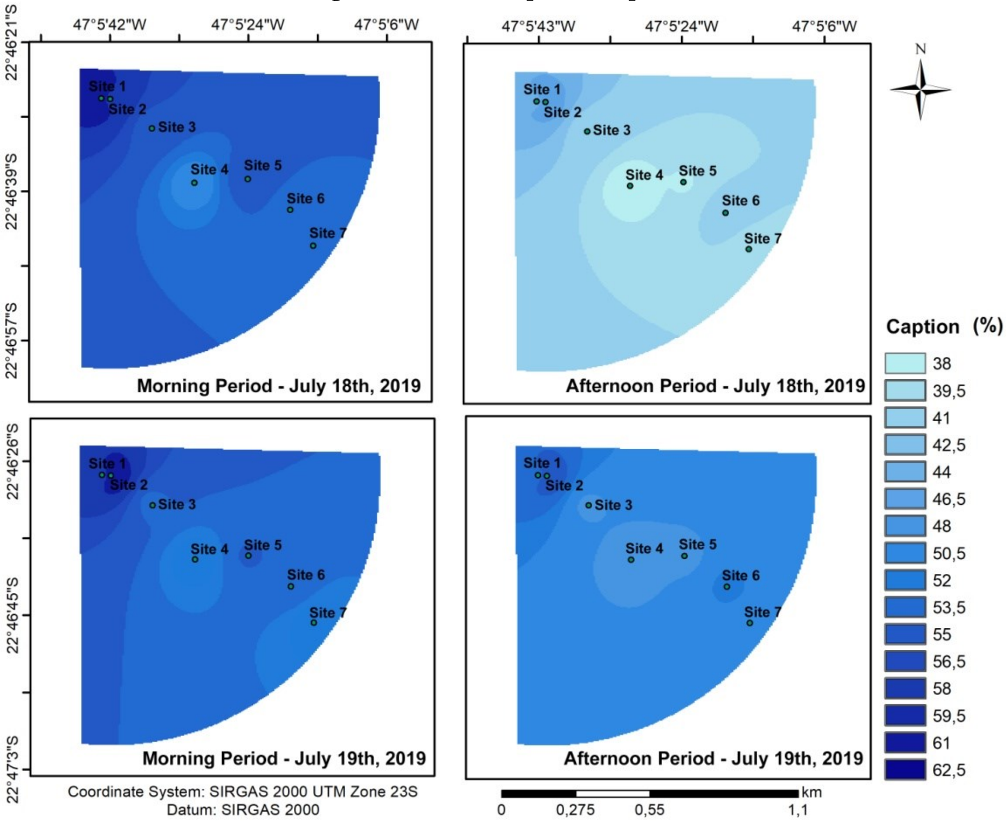
Figure 4 – AT Maps- Campinas.



Source: The authors (2020).

In general, the same behavior of AT (Figure 4) is identified, in the morning period, on July 18 and 19, while in the afternoon time, similar behavior is observed, having the focus on higher temperature near the region of Site 4. Regarding relative humidity (Figure 5), a similar behavior was observed in the morning period, while in the afternoon collections it could be observed higher humidity levels on day 19, compared to July 18, 2019.

Figure 5 – RH Maps- Campinas.



Source: The authors (2020).

By observing the results of AT of the afternoon period, on July 18th, 2019, it is possible to observe that the highest temperatures are at Sites 7, 3 and 4 and the lowest ones are at Sites 1 and 2 (closest to the PPA). In addition to it, there is a significant difference (from 2 to 5 ºC) in the temperature of Sites 1 and 2, in relation to the other sites. This same behavior could also be observed in the RH, in which the highest values were collected at sites 1 and 2, becoming apparent again in the inversely proportional relation among the parameters. In addition to it, there is the possibility to highlight that the presence of the PPA influences the parameters of AT and RH, since Sites 1 and 2, showed the lowest AT and the highest RH.

The high temperatures suggested by Sites 3 and 4 were not expected, due to the characterization of the region, composed by the proximity to the PPA, rural areas and little constructed environment. However, according to Häb *et al.* (2014) and Liu *et al.*, (2017), the answer given by the sensor may have been influenced by the direct exposure of the sensor to the ultraviolet rays, even if it had been for only three minutes during collection. In that case, the ideal was to cover the sensor node with high-level reflectance materials and with some gaps, avoiding direct radiation.

By analyzing the data collected on July 19th, 2019 (Figures 4 and 5), it is possible to identify the same behavior in both collection periods (morning and afternoon), nevertheless, considering the characteristics of a hotter day. That way, it is possible to notice a greater distance between the AT and RH values at Sites 1 and 2 in relation to the other collection sites. The peak temperature at Site 4 remained only during the morning period, while during the afternoon, it was possible to notice that Sites far from the PPA had similar behaviors.

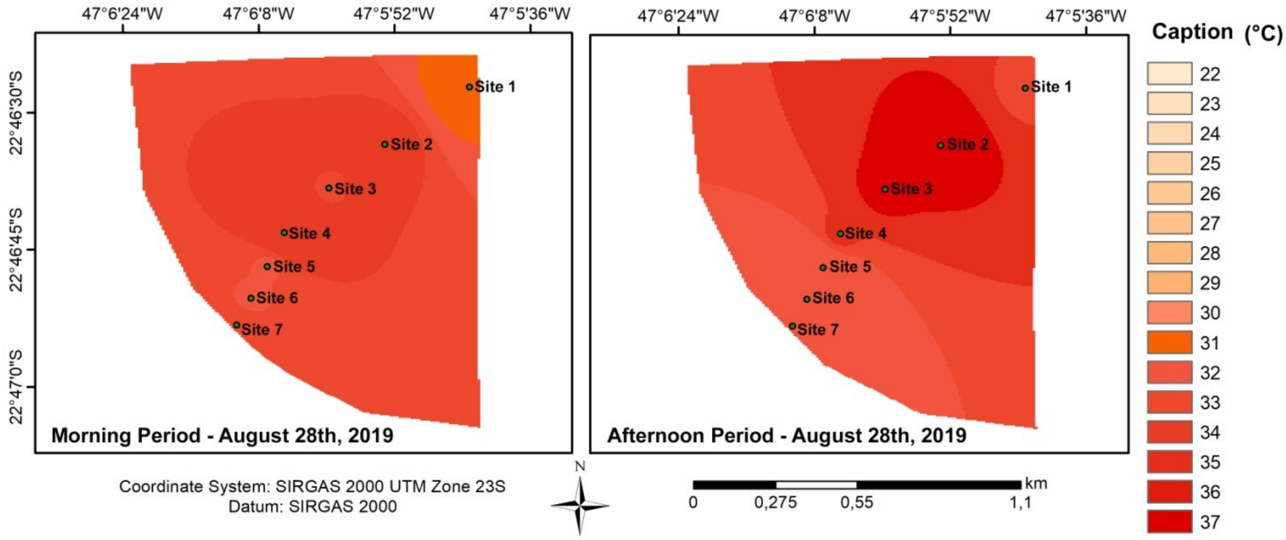
Sites 6 and 7 suggested non-expected values for AT, similar to the values of AT related to Sites 1 and 2 (closer to the PPA). For that matter, studies suggested possible interactions associated to the direction and speed of the wind, being possible to impact on the AT, highlighting the need for considering these parameters (PULIAFITO *et al.*, 2013).

At the region of Site 5, similar characteristics had been identified from Sites 1 and 2 during the morning period (lower temperatures and higher humidity). For the afternoon period, Site 5 presented similar temperature data to the sites with hotter characteristics, no vegetation and constructed area.

By analyzing the data from Paulínia, on August 28th, 2019, it is possible to highlight (Figure 6) four different behaviors in temperature. The first one at Site 1, located at PPA, is the one with the lowest temperature among all the collected sites during the morning period, while during the afternoon, it presented some similar behavior to Sites 5, 6 and 7, which are located next to the area where there is agriculture production and road with great vehicle flow. It was also possible to identify Sites 2, 3 and 4, which are located in a more constructed area and under influence of an area destined for agricultural activities, as the regions which have higher AT and RH values.

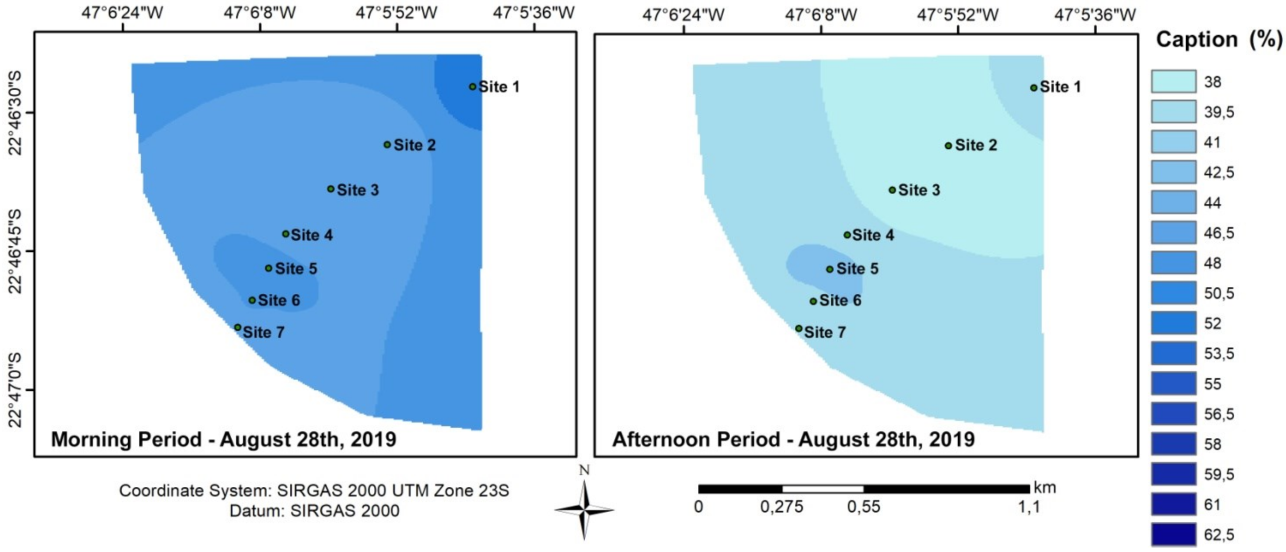
Moreover, it can be observed in Site 5 a different behavior between the morning and afternoon periods. This region has similar characteristics to Sites 6 and 7, with proximity to an expressway with medium and large automobile flow, condominium on the right and an agricultural area on the left. The measurements collected at Site 5 presented similarities with Sites 6 and 7 in the morning period with an average of 33 to 34°C of AT and RH of approximately 46%. However, at 15:00, the data collected at Site 5 behaved differently and approached the characteristics verified at Site 1. This may be associated with the occurrence of winds, thus highlighting the need for monitoring this variable (PULIAFITO et al., 2013).

Figure 6 – AT Maps –Paulínia.



Source: The authors (2020).

Figure 71 – RH Maps - Paulínia.



Source: The authors (2020).

The region of Sites 6 and 7 (Figures 6 and 7) involves a mix of vegetation, agricultural activity, and a constant flow of medium and large vehicles and condominiums. Thus, for this area, higher temperature levels were expected, but the parameters presented the best result in the region of Paulínia (lower temperatures and higher humidity). This can be justified by the influence of winds and the absence of the urban "canyon" phenomenon in this area. In fact, for the region of Sites 5, 6 and 7, due to its proximity to rural areas, the phenomenon of Canyon does not happen in the same way as in the other points of Paulínia, thus being able to reduce the amount of heat stored in asphalt and walls, due to the consolidated agricultural activity in the region. In addition, because the region is associated with this activity and has soil with low vegetation, it enables the influence of winds, and may also contribute to the reduction of temperatures (SOEIRA, 2018; GRIMMOND; OKE, 1999).

On the whole, it can be observed that the location of the PPA did not have much effect on the points installed in Paulínia's parcel, with the exception of Site 1, located next to the PPA. In this sense, it is noted that Sites 2, 3 and 4 presented higher levels of AT and lower levels of RH, possibly conditioned to their location between condominiums and areas of industrial economic activity. Sites 1, 5, 6 and 7 showed lower temperatures than the other regions, which can be explained by the presence of vegetation in this area.

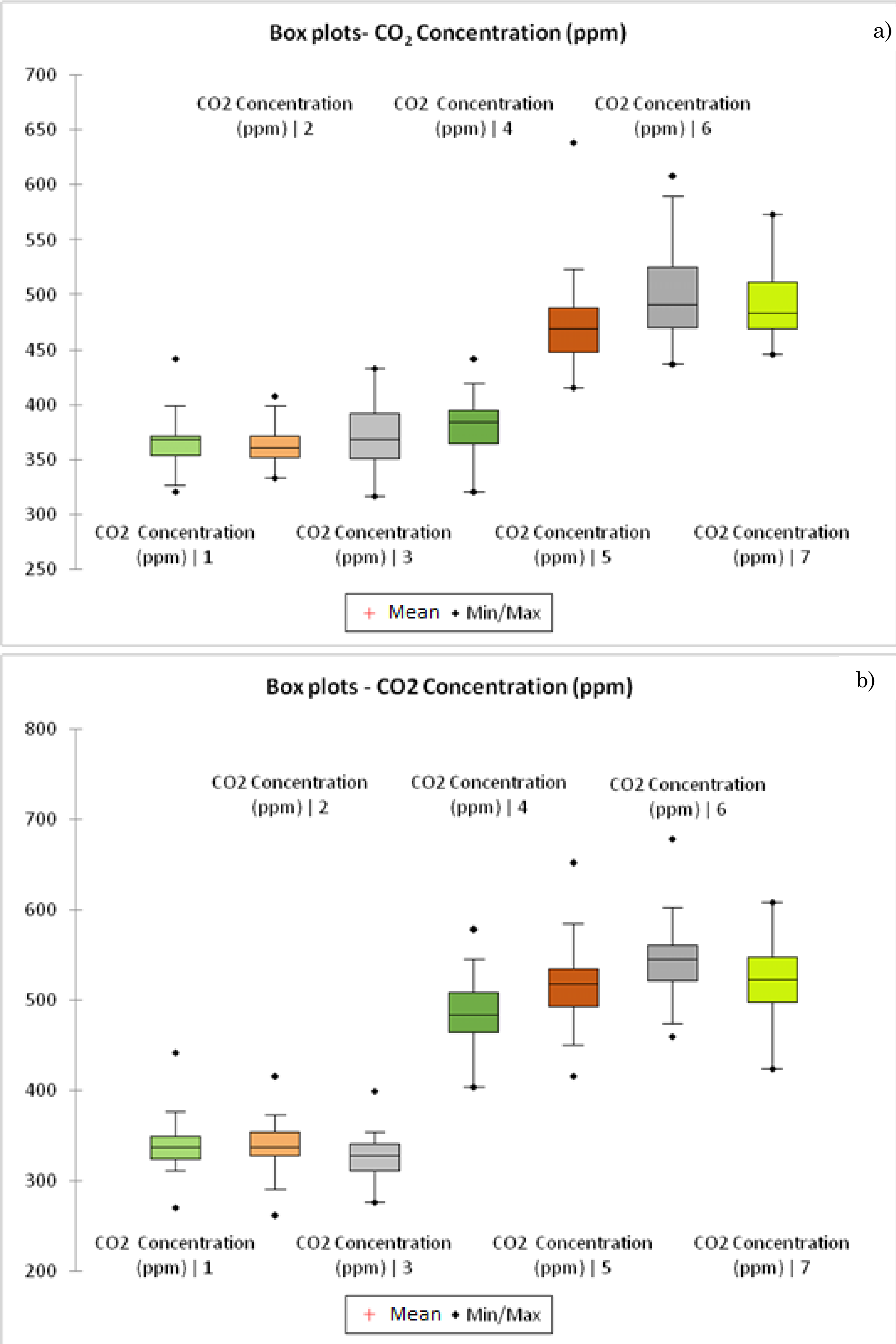
It is important to point out that the maps (Figures 6 and 7) clearly illustrate the behavior of Sites 5, 6 and 7, which presented mild RH and AT conditions in the afternoon period, resembling the behavior of Site1 next to the PPA.

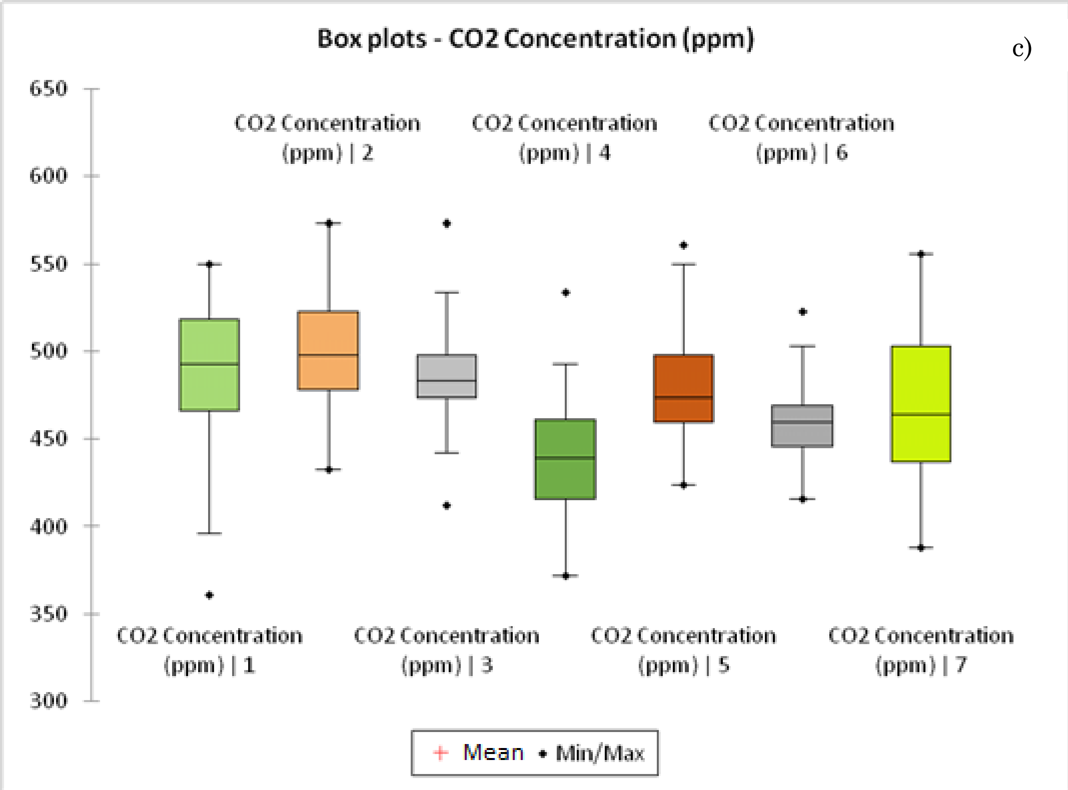
CO_2 Concentration

The results regarding the CO_2 concentration collections on July 18, 2019, in the Campinas plot (Figures 8a and 9) made it possible to observe, in the morning period, two distinct groups, the first with lower averages, between 350 and 400 ppm at Sites 1,2,3 and 4, while the second (5, 6 and 7), located entirely within a residential area next to the road, with concentration averages ranging between 450 and 500 ppm. Thus, it is identified lower concentrations are associated with the proximity of the collection points with the PPA and the high concentrations in residential and impermeable environments.

For the afternoon results on July 18th (Figures 8b and 9), it is possible to observe similar characteristics to the morning period, however, collection Site 4 had an increase in CO_2 concentration from an average of 400ppm, in the morning period, to about 500ppm and approaching the points far from the PPA.

Figure 8 – Box Plot Graphics of CO_2 Concentration in the morning (a) in the afternoon (b) on July 18th, 2019, in Campinas and on July 27th, 2019, in Paulínia (c).





Source: The authors (2020).

The difference in CO_2 concentration between the two periods found at Site 4, near agricultural activities, may be linked to the difference in temperature and heat saturation over the soil, which may increase the level of CO_2 emission by decomposition of organic matter in the soil. Within this justification, Landsberg (1956) and Moreira et. al (2015) highlight 3:00 pm as the ideal time due to the temperature being close to 30°C and humidity at 60%, thus, causing the action of microorganisms and decomposition of organic matter to increase, generating greater availability of CO_2 in the region studied.

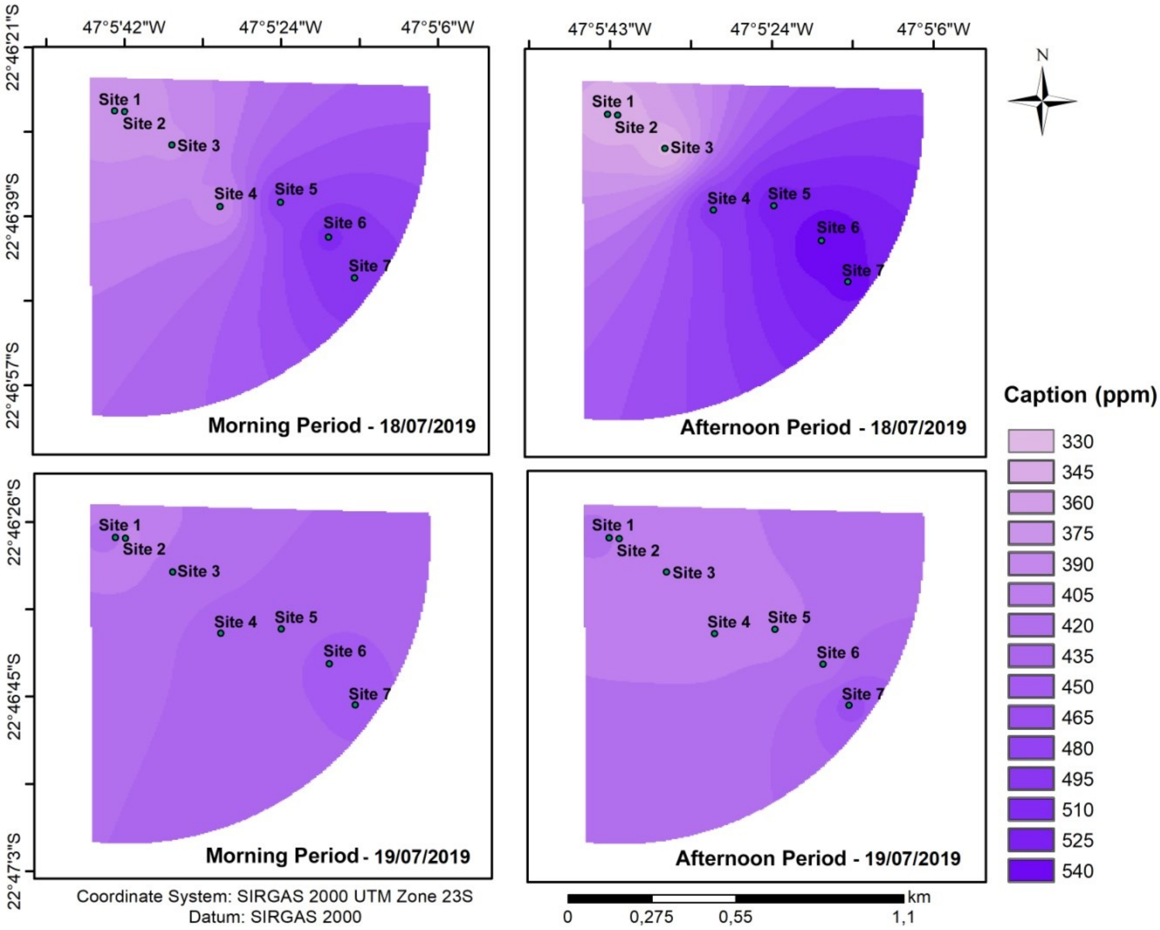
In the results for 07/19/2019 (Figure 9), in the morning and afternoon periods, no discrepancy was identified between the collection points, with some exceptions for the data from Sites 6 and 7 in the period that showed the CO_2 concentration slightly above the other points. In the afternoon period, it can be seen an average prominently higher than the others in the measurements of Site 7. Both Sites (6 and 7) have as main characteristics their proximity to the road with constant traffic of medium and large cars, corroborating the result.

Overall, in Campinas, higher levels of CO_2 were identified on day 18 (Figure 9), with the main highlight being Sites 5, 6, and 7 located near the road with a constant flow of medium and large vehicles.

Analyzing the results from Paulínia (Figures 8c and 10) one can observe CO_2 concentration levels closer together. However, one notices lower values of CO_2 at Sites 5, 6 and 7, if compared to Sites 1, 2 and 3. Despite the close contact of Sites 5, 6 and 7 with intense vehicle flows, which could elevate the CO_2 content, it did not suffer from excessive CO_2 increase due to the proximity to rural areas, which may have contributed to the reduction of CO_2 concentrations as a result of CO_2 absorption by plants and constant ventilation (CASTALDO et al., 2017; BOWLER et al., 2010).

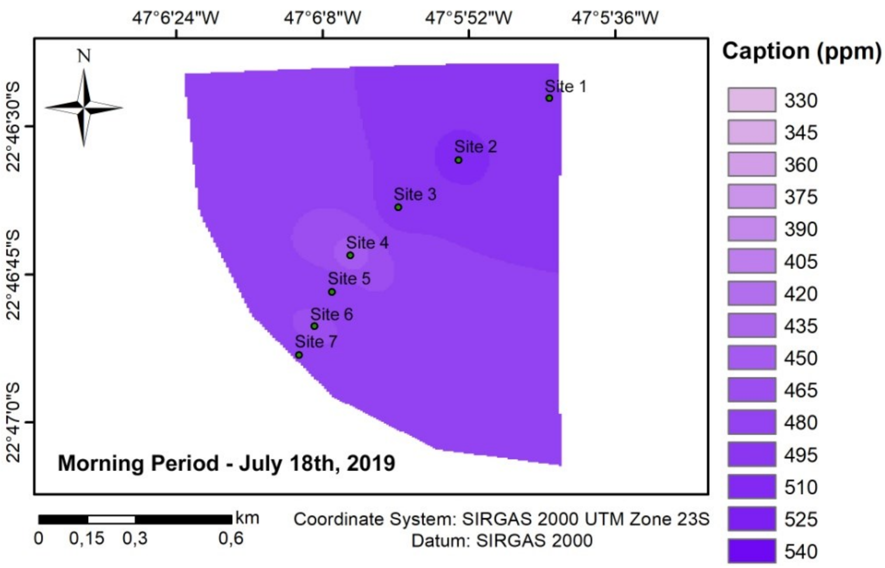
It can also be highlighted that CO_2 levels were higher in Paulínia than in Campinas. The data collected on days 18 and 19 indicated lower concentration near the green areas, where it is worth reiterating the interaction of the agricultural area near Sites 5, 6 and 7, where they were constantly in contact with intense flow of cars.

Figure 9 - CO_2 Concentration for the proportion of Campinas



Source: The authors (2020).

Figure 10 - CO_2 Concentration for the proportion of Paulínia



Source: The authors (2020).

PPA influence analysis regarding the behavior of the meteorological variables

The results of the analysis of the influence of distance from the PPA in Campinas (Table 2) on AT, RH and CO_2 determined according to Spearman's correlation showed a positive correlation for the variables AT and CO_2, indicating that the greater the distance from the PPA the higher the values of these parameters. Negative correlations were identified in RH, indicating a reduction in humidity as the points moved away from the PPA and reached more impervious areas.

For the Paulínia parcel (Table 2), we observed zero correlation for the AT in the morning period, indicating no influence of the distance from the PPA on the behavior of this variable. In the afternoon period the correlation was negative, indicating that the greater the distance from the PPA, the lower the values of AT.

For humidity, the correlation was negative in the morning period, while in the afternoon, the behavior was positive, indicating that the greater the distance from the PPA, the higher the values of RH, illustrating the importance of agricultural areas for the studied region of Paulínia.

Regarding the CO_2 concentration, a negative correlation is observed in the morning period, indicating that the greater the distance from the PPA, the lower the CO_2 concentration values.

Table 2 - Spearman's Correlation

Collecting Days	Period	Spearman's Correlation		
		Air Temperature x Distance	Relative air humidity x Distance	CO_2 Concentration x Distance
July, 18th Campinas	Morning	0,071	-0,714	0,929
	Afternoon	0,357	-0,536	0,857
July,19th Campinas	Morning	0,536	-0,571	0,821
	Afternoon	0,393	-0,321	0,536
August, 27th Paulínia	Morning	0	-0,143	-0,714
	Afternoon	-0,679	0,679	-

Source: The authors (2020).

Analysis of the Implemented Sensor Network

To implement the sensor network, field tests were initially performed with low-cost wireless technologies (IEEE 802.11 and IEEE 802.15.4 standards, specifically), since this was one of the focuses of the work. These tests showed that the low-cost wireless technologies used were not suitable for the proposed application, due to the data collection environment being outdoors with the presence of various obstacles to data transmission (buildings and vegetation of different sizes).

Aiming to enable the monitoring of the quantities mentioned above, we proposed the use of a wired sensor network, from the implementation of two distinct sensor nodes. The network implemented met all the requirements proposed as a goal, allowing the monitoring of several meteorological variables, with low-cost construction and with storage capacity of the collected data. Moreover, the sensor nodes were developed so as to allow the incorporation of new different sensors (expansion of the sensor node) capable of collecting other variables that may be of interest to the user.

CONCLUSIONS

Considering the result analysis obtained, it is possible to conclude that:

- The proposed and implemented sensor nodes were able to collect the AT, the RH and the CO_2 concentration properly, aiming to evaluate these meteorological variables in green urban areas.
- It has been possible to verify the contribution of the PPA to the collected variables in the part of Campinas, identifying its influence on the reduction of AT and CO_2 concentration and for the increase of the RH in that region.
- For the part of Paulínia, the PPA did not show great influence on the collected variables, but, the rural activity areas suggested a possible contribution to the microclimate and the CO_2 concentration.

It is important to emphasize that the developed sensor nodes have met the requirements of great storage capacity and low-cost (about 75% cheaper than the measurement systems which are commercially available). Besides, they allow future expansions with the incorporation of new sensors for measuring pertinent quantities.

As some suggestions for future academic work, it is possible to highlight: (a) the incorporation of other sensors to the developed sensor nodes, which allow the monitoring of variables such as the direction and the speed of the wind, (b) the accomplishing of studies for the verification of the influence of the agricultural areas of that region in the analyzed meteorological variables and in the CO_2 concentration, (c) build some projection/cover for the DHT22 sensors in order to guarantee the non-alteration of the data under solar exposure.

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AUTHORS' CONTRIBUTION

Jô Vinícius Barrozo Chaves, Lia Toledo Moreira Mota and Regina Márcia Longo developed the methodology. Jô Vinícius Barrozo Chaves, Lia Toledo Moreira Mota, José Ricardo Alves and Daniel Braga Barro designed, planned and built the sensor nodes. Jô Vinícius Barrozo Chaves carried out the characterization of the study area, data collection in the field and application of statistical methods. Jô Vinícius Barrozo Chaves, Mota, Lia Toledo Moreira Mota and Admilson Írio Ribeiro wrote the text.