Influence of trees on summer temperatures in Junín de los Andes, Patagonia, Argentina.

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Abstract:

The impact of urban trees on temperature regulation in the downtown area of Junín de los Andes, Argentina, in different seasons of the year was investigated. The research questions were: How much does surface temperature and air temperature change in the downtown area of the city of Junín de los Andes, in the different seasons of the year? How does the distribution of trees vary on the sidewalks in the city center and in San Martín Square? How does tree coverage influence: a) surface temperature and b) air temperature? How does cloud type and coverage influence surface and air temperature?

The GLOBE Program atmosphere and biosphere protocols were applied to collect data in 4 downtown streets and in San Martin square. Measurements included tree height and circumference, land cover, land surface temperature and air temperatures. The results reveal an uneven distribution of trees on the sidewalks and the Square stands out with the highest coverage. Significant temperature differences were detected between stations. The data revealed a significant correlation between tree cover and the decrease in land surface temperature in summer, demonstrating its impact on urban thermal regulation. The samplings were influenced by the ENSO phenomenon and low cloud cover in autumn, winter and summer.

Key words: Land Surface Temperature – Air Temperature – Urban Tree Height – Urban Tree Cover – Urban Microclimate

1. Research Question and Hypothesis:

Climate change has caused an increase in global average temperature of 1.1°C over the last century and models predict a further increase with more frequent heatwaves. In this context, the increase in temperature in cities, added to an increase in population, will imply the consumption of greater resources with negative impacts on the environment, health and economies, among others (IPCC, 2021a,b). For example, the 2022 heat wave in Argentina surpassed historical records in many cities (Domínguez, et al., 2022). As a mitigation measure, urban trees have become relevant because they contribute to the reduction of surface temperature and air temperature, generating an urban microclimate. (Alexander, 2021).

Understanding how surface and air temperatures change in the central area of Junín de los Andes and their relationship with tree distribution will provide insights into the role of green spaces in moderating temperatures at the local scale. To address this problem, the following research questions are proposed.

From Fall 2023 to Summer 2024:

1. How much does the land surface temperature and air temperature change in the central area of the city of Junín de los Andes during different seasons of the year?

2. How does the distribution of trees change on the sidewalks in the city center and in Square San Martín?

3. How does tree cover influence (a) land surface temperature and (b) air temperature?

4. How does cloud type and cover influence land surface temperature and air temperature?

Based on the research questions, the following hypotheses are proposed:

Hypothesis 1: The land surface temperature and air temperature in the central area of Junín de los Andes presents a significant variation between the different seasons of the year (higher during the summer and lower during the winter)

Hypothesis 2: The distribution of trees on the sidewalks in the city center and in the Square San Martín is heterogeneous, comparing the sidewalks with each other and the square.

Hypothesis 3: The greater the tree coverage, the lower land surface temperatures and air temperatures will be recorded.

Hypothesis 4: The presence of low clouds and overcast skies causes a decrease in land surface temperature and air temperature by reducing the amount of solar radiation that reaches the ground.

2. Introduction and Review of Literature:

The most drastic change in land cover is often attributed to urbanization, where impervious surfaces replace natural surfaces. For this reason, cities tend to have higher temperatures than surrounding rural areas due to the concentration of heat-radiating buildings, impermeable materials, and human activities. This phenomenon is known as urban heat island (UHI) which has negative effects on human health, energy consumption to cool environments and the environment. (Gonzalez-Trevizo, et al, 2021, Boyero, et al, 2021). Intra-urban temperature variations have received less attention than variations between urban and rural areas, however, tree height can influence shade generation. (Alexander, 2021).

Trees have the capacity to mitigate urban heat islands through various mechanisms: a) shade reduces direct solar radiation and heat absorption by urban surfaces. b) evapotranspiration from leaves releases water vapor into the atmosphere, contributing to the cooling of the surrounding air and c) trees capture greenhouse gases and polluting particles, improving air quality. (Yu, et al., 2020, Fan, 2023)

The presence of trees in the downtown area of the city of Junín de los Andes is variable with high-density areas and other treeless sectors. This paper analyzes the influence of trees on land surface temperature (LST) and air temperature (AT) by analyzing their seasonal variation. Its results can provide information for the management of green spaces that contribute to mitigating the urban heat island effect.

3. Research Methods and Materials:

The sampling site is located in the center of the city of Junín de los Andes, Argentina. The city is small with 13,086 inhabitants (INDEC, 2012) according to the 2010 CENSUS and an estimated 16,580 inhabitants in 2022 (INDEC, 2024). The city develops from North to South on one of the banks of the Chimehuín River along a valley in the foothills of the Andes. The predominant vegetation is steppe, riverine forest and established forest. A few kilometers to the west is the Andean-Patagonic forest. (Fig. 1)

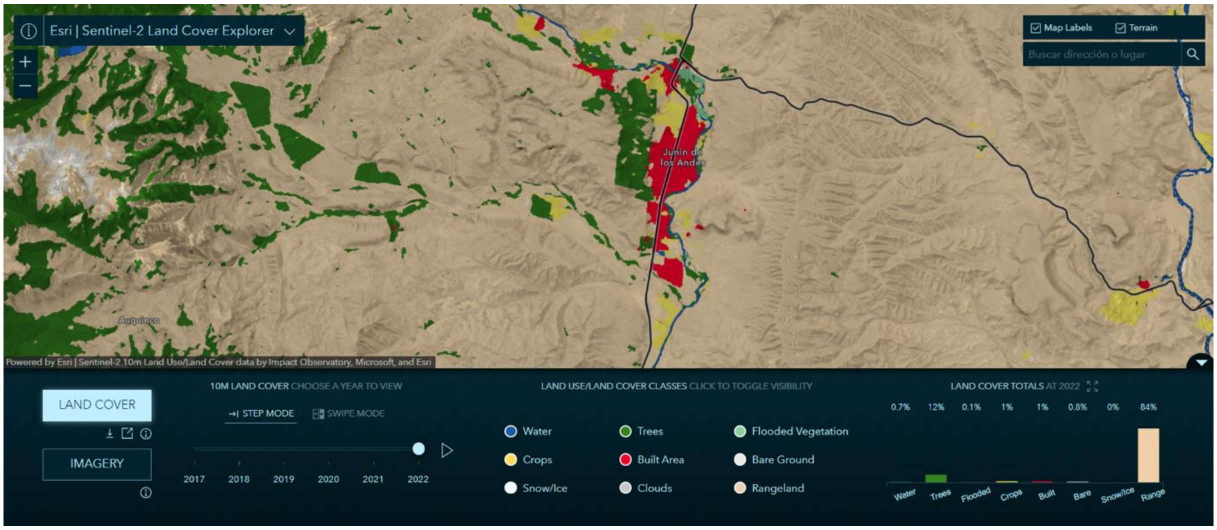

Fig. 1. Types of land cover in Junín de los Andes and surroundings. Source: Esri Land Cover.

According to the Köppen-Geiger climate classification (Beck et al., 2023), the climate of Junín de los Andes is classified within the Csb category, where "C" represents a temperate climate, "s" dry summers, and "b" warm summers. The mean daily maximum temperatures reach 22ºC, the mean daily minimum 0ºC and the annual rainfall is 650 mm (Meteoblue, 2024). (Fig. 2)

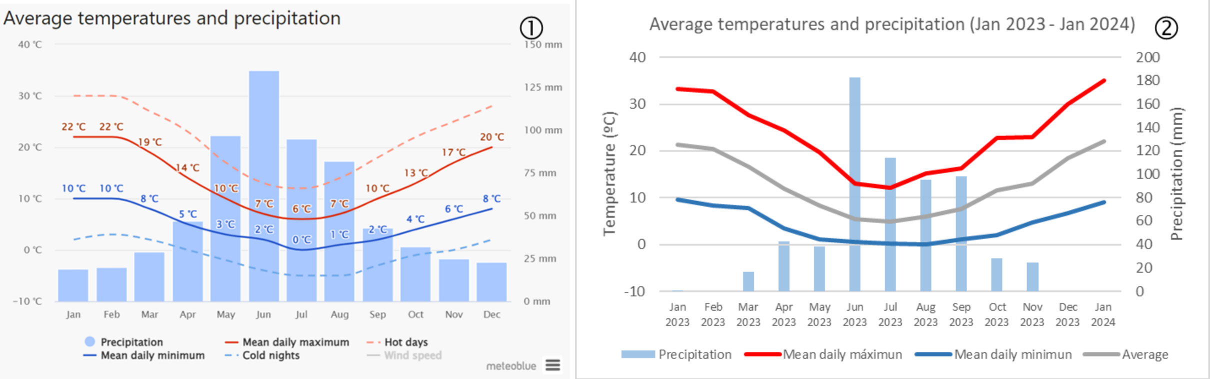

Fig. 2. Temperatures and precipitation. (1) Average data for the last 25 years. Source: Meteoblue. (2) Graph based on meteorological data from the investigation period Source: Wunderground.

Temperatures and precipitation were recorded from a weather station located approximately 500 m from the sampling site (Wunderground, 2024). During the sampling period, maximum temperatures were higher than the historical average. The mean daily maximum temperature was 35.12ºC. Annual rainfall was 642 mm, similar to the historical average. (Fig. 2)

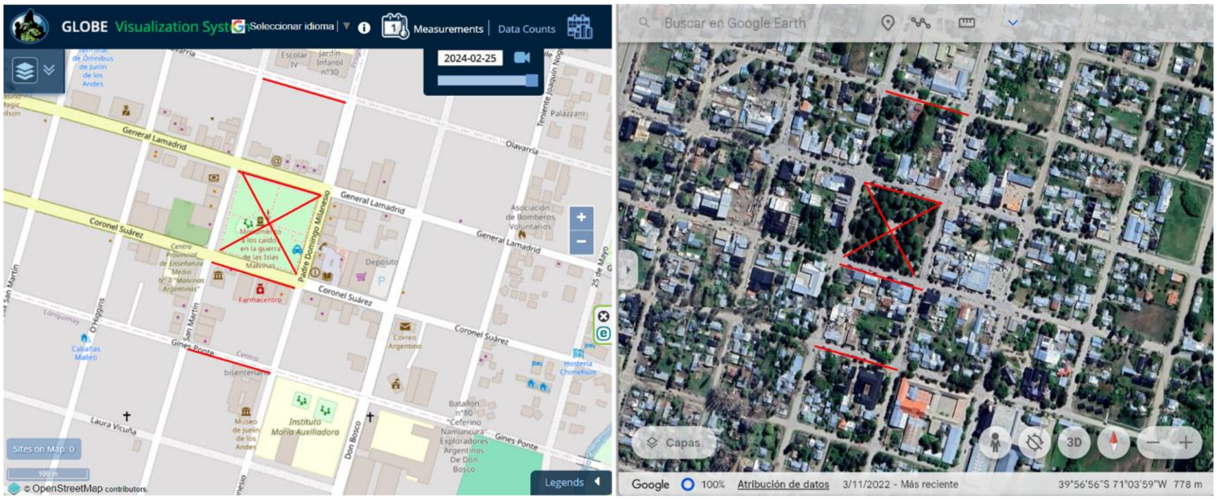

Fig. 3. Sampled and diagonal sidewalks of Square San Martín, highlighted in red. Source: GLOBE data visualization (left), Google Earth (right).

Four blocks of the center of the city of Junín de los Andes were selected: 1) Gines Ponte: Street 1, 2) Coronel Suarez: Street 2, 3) General Lamadrid: Street 3 and 4) Olavarría: Street 4 and the two diagonals of Square San Martín (which has abundant tree vegetation): a) Diagonal 1 (direction N-S) and Diagonal 2 (direction E-W) The sidewalks exposed to morning sunlight were sampled (Fig. 3)

The GLOBE Observer: Trees and Land Cover application was used to measure tree height and land cover. The circumference of the trees was measured with a 50 m measuring tape. At the sampling sites (sidewalks and the square) all trees were measured. Land cover measurements were made at each corner of the sampled trails and in the middle of the block. In the square, measured diagonals were made in each corner and in the center. (Fig. 4).

The GLOBE Observer: Clouds app was used to record cloud type and cover during temperature measurements. (Fig. 4)

The air temperature was recorded with the PS-3201 Wireless Temperature Sensor, for the surface temperature a GM320 Infrared Thermometer was used. Samplings were carried out seasonally (fall 2023 to summer 2024) from 10am to 1pm (local time). During the sampling period, temperature and precipitation patterns were influenced by the ENSO phenomenon (SMN, 2024a,b).

The following GLOBE protocols were used: Atmosphere: a) Air temperature and b) Land surface temperature. Biosphere: (a) Land cover, (b) Tree height, and (c) Tree circumference. The Modified UNESCO Classification (MUC) classification system was used for land cover classification. To estimate the percentage of tree cover, measurements were made using high-resolution satellite imagery (Airbus, March 23, 2023) through the Google Earth platform.

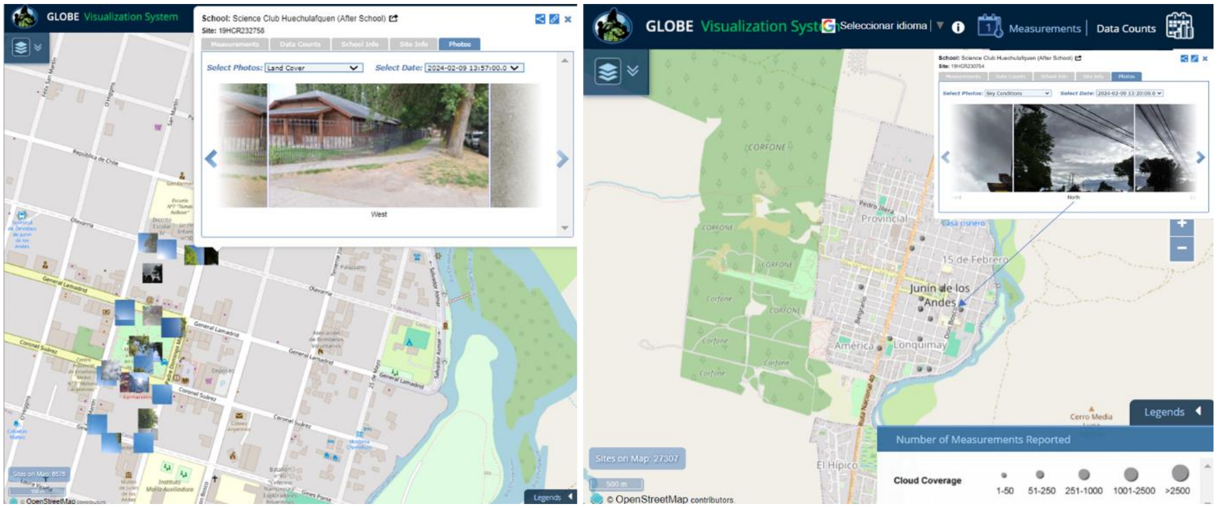

Fig. 4. Land cover (left) and cloud cover (right) measurements. Source: [GLOBE data visualization](#).

The data were processed using the computer tools Microsoft Excel 2019 and Statistica 8 (Statistica, 2007). Statistica software was used for analysis and to establish significant differences between the data. Lilliefors Normality test was used to evaluate whether the data follow a normal distribution. Breakdown & one-way ANOVA was then applied to evaluate significant differences between data groups. Analysis of variance (ANOVA) was used to compare the means between the groups and identify whether there are significant differences between them. The Levene Test of Homogeneity of Variances was used to evaluate the homogeneity of variances between the groups in order to later apply the LSD Test (Least Significant Difference) and establish significant differences. To analyze the influence of tree cover on surface and air temperature, Pearson's correlation coefficient (r) was used. The value of "r", from Pearson's correlation coefficient, quantifies the strength and direction of the linear relationship between the variables. An "r" value close to 1 indicates a perfect positive correlation, while an "r" close to -1 suggests a perfect negative correlation, a value of 0 indicates that there is no correlation between the variables. On the other hand, the "p" value corresponds to the level of statistical significance of the observed correlation. (DATAtab Team, 2024a,b, Statistica, 2007).

4. Results:

4.1. Trees

Trees are irregularly distributed on the sidewalks, with extensive areas without trees (e.g. Coronel Suarez Street) and others where tree cover is relevant although concentrated in some sections (e.g. Olavarría Street). Square San Martín has greater tree cover (Fig. 6). The predominant species in the streets are exotic plants, mostly ash trees (*Fraxinus excelsior*) and garden plum trees (*Prunus cerasifera)* and in the Square San Martín the araucaria (*Araucaria araucana*), maitén (*Maytenus boaria*) and other native and exotic species predominate. The tallest trees are located on Street 4 (Olavarría) with a high X̄= 17,21 ±8,63 m and in the Square San Martín X̄= 11,44 ±5,92 m.

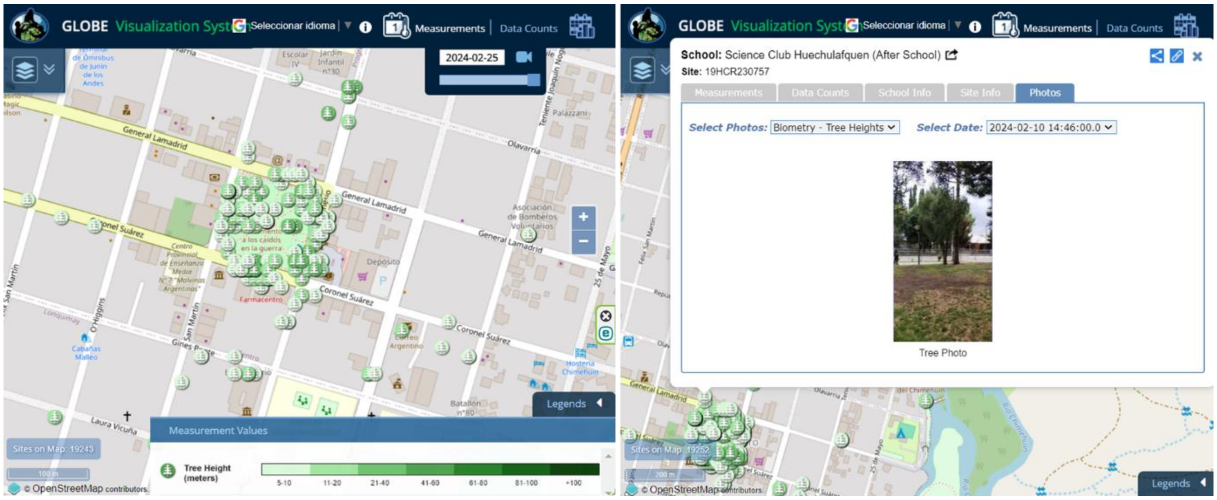
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Fig. 5. Spatial distribution of the trees measured in the study area. Source: GLOBE data visualization.

Street 4 has a greater dispersion of data with tall trees mostly, but some low trees are also found. The LSD test found significant differences in the height of the trees on street 4 with respect to the other streets. In Square San Martín most of the trees are tall, but it also has small trees.

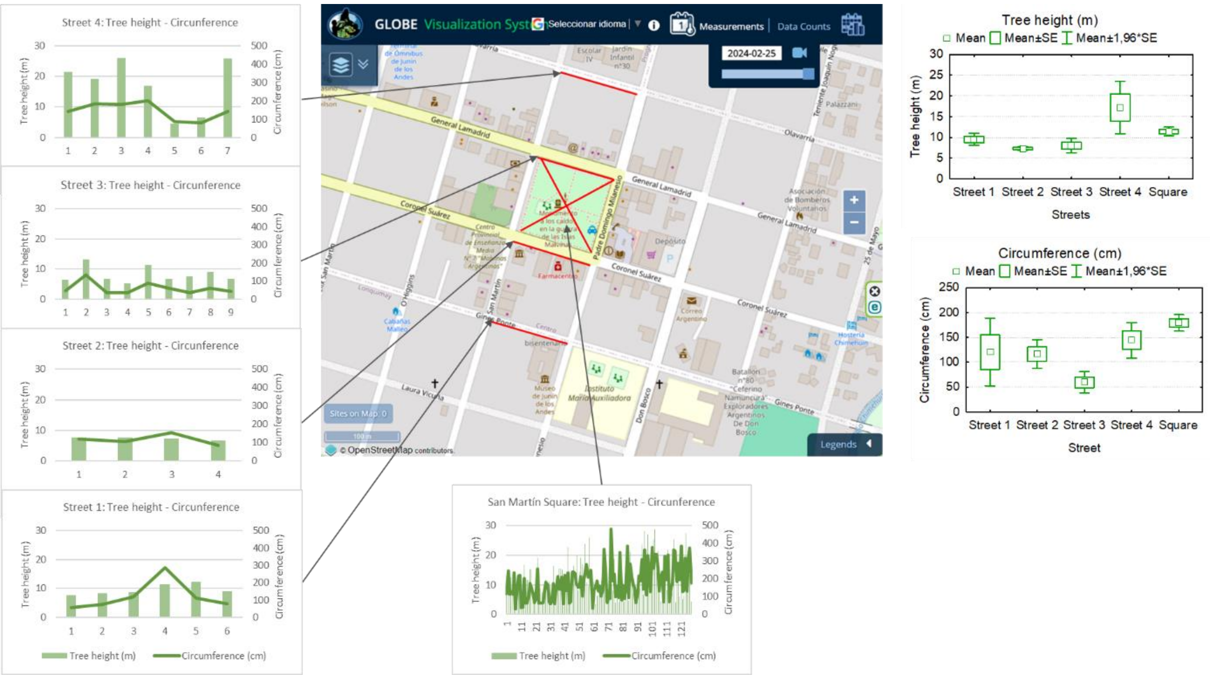

Fig. 6. Tree height and circumference. Source: GLOBE data visualization

The trees with the largest circumference are found in the Square San Martín X̄= 179,04 ±95,61cm where a sequoia (*Sequoia sempervirens*) whose circumference is 480cm also stands out. Street 3 has the trees with the smallest circumference X̄= 59,77 ±32,47 cm. The LSD test only detected significant differences in the circumference of the trees in the plaza and the trees in street 3 (General Lamadrid) (Fig. 6).

4.2. Urban land cover

Fig. 7. Percentage of tree cover and no tree cover on the sidewalks of the analyzed streets. Average MUC code of each sidewalk of the streets analyzed.

In the study sites analyzed, more than 50% of the sidewalk has no tree cover, in some cases such as streets 1 and 2 exceed 70% without coverage. Calle 2 (Coronel Suárez) has the fewest trees and has two artificial eaves. The predominant MUC codes are 92 (Urban. Commercial Property) and 93 (Urban. Roads and parking). A low percentage corresponds to the MUC code 91 (Urban. Residential Property). (Fig. 7)

4.3. Land sSurface Temperature (LST) and Air Temperature (AT)

Land surface temperature and air temperature measurements coincided with cloudy days, except in spring. Changes in surface temperature occur rapidly between areas exposed to the sun and those located in shade. On the other hand, the air temperature is more constant.

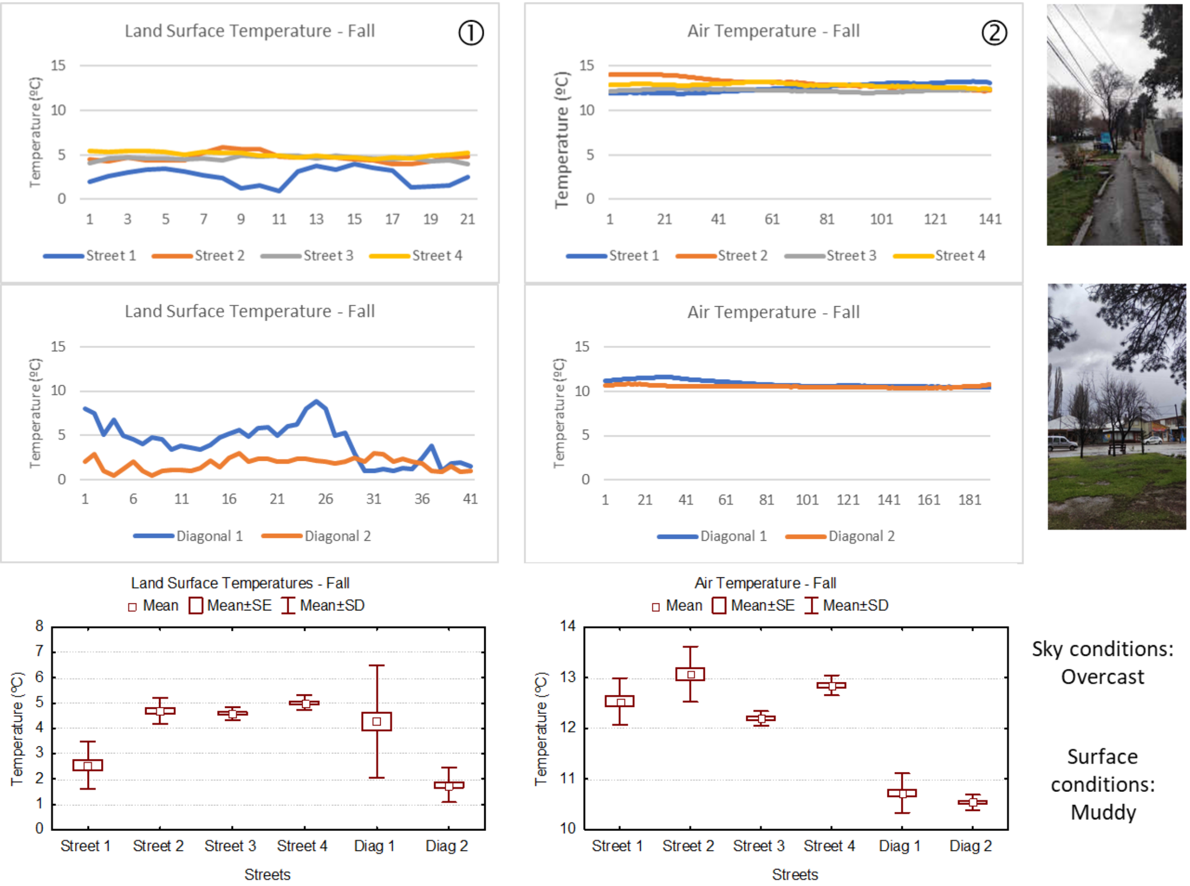

Fig. 8. Fall: Land surface temperature (1) and air temperature (2). Images of trees sky and surface condition.

Land Surface Temperature in Fall: Average land surface temperatures in fall were $\bar{X}$= 3.62 ±1.75ºC with a thermal amplitude of 3.24ºC. During the measurement carried out in fall, low clouds and overcast skies were recorded, and there was light intermittent rain. The lowest land surface temperatures are recorded in street 1 and diagonal 2, the LSD Test detected significant differences with the other streets. Streets 2, 3 and 4 with intermediate temperatures have significant differences with diagonal 2. The land surface temperatures of diagonal 1 are higher than diagonal 2 with statistically significant differences. (Fig. 8)

Air Temperature in fall: Air temperatures in autumn are higher than surface temperatures. The average air temperature in autumn was $\bar{X}$= 11.65 ±1.09ºC with a thermal amplitude of 2.53ºC. The LSD Test detected significant differences in air temperature between all streets and diagonals. (Fig. 8)

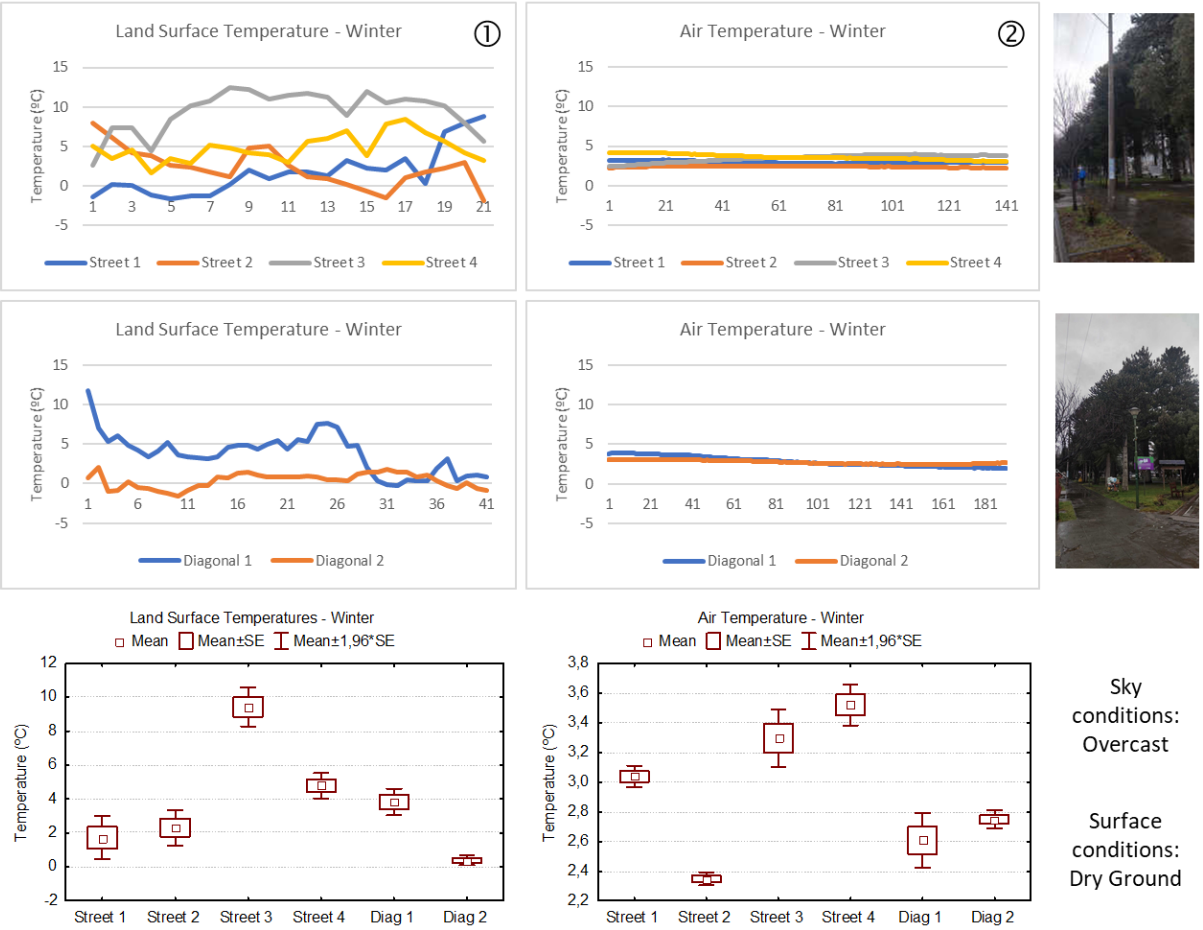

Fig. 9. Winter: Land surface temperature (1) and air temperature (2). Images of trees sky and surface condition.

Land surface temperature in winter: Average land surface temperatures in winter were X̄= 3,35 ±3,54ºC with a thermal amplitude of 9,05ºC. During the measurement carried out in fall, low clouds and overcast skies. The land surface temperatures of street 3 are high, the LSD Test found significant differences with all streets and diagonals. On the other hand, in diagonal 2, the lowest temperatures were recorded and also shows significant differences in relation to all the other streets and diagonals. Streets 1 and 2, with low temperatures, have significant differences with streets 3 and 4 and Diagonal 1. (Fig. 9)

Air Temperature in Winter: The average air temperature in winter was X̄= 2.86 ±0.52ºC with a thermal amplitude of 1.17ºC. The lowest temperatures were recorded in street 2 and LSD Test detected significant differences with all streets and diagonals. The air temperature on diagonals 1 and 2 also has significant differences from the other streets. On the other hand, street 1 with intermediate temperature has significant differences with the other streets and diagonals. (Fig. 9)

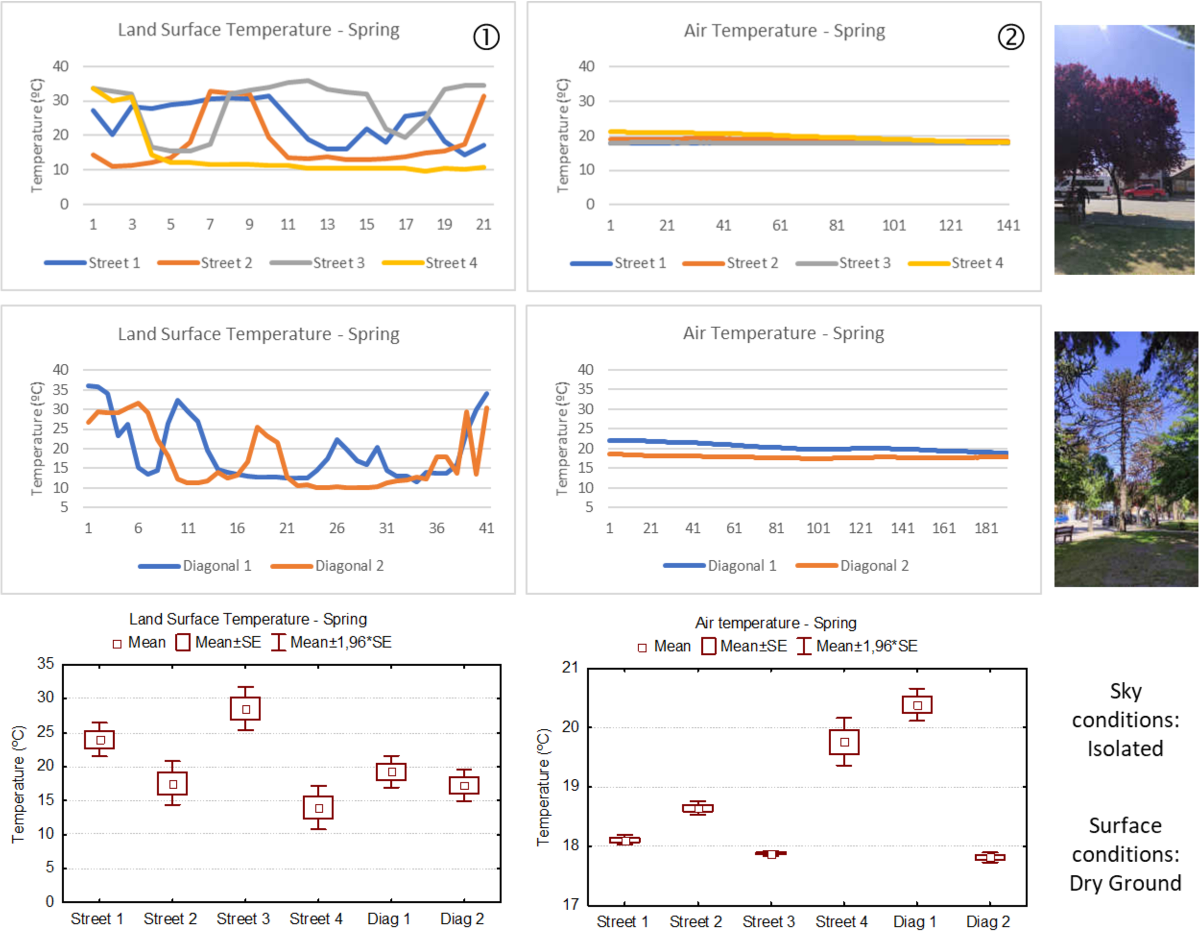

Fig. 10. Spring: Land surface temperature (1) and air temperature (2). Images of trees sky and surface condition.

Land surface Temperature in Spring: The average land surface temperature in spring was X̄= 19,66 ±8.44ºC with a thermal amplitude of 14.57ºC. During the spring temperature record, the atmospheric conditions were characterized by the presence of clear and sunny skies. The highest surface temperature in spring was recorded in street 3, the LSD Test found significant differences with the other streets and diagonals. Street 1 with intermediate temperature has significant differences with all streets and diagonals. Both diagonals with similar temperatures have significant differences with streets 1 and 3. The lowest temperature was recorded in street 4 with significant differences with streets 1, 2 and diagonal 1 (Fig. 10)

Air Temperature in Spring: The average air temperature in spring was X̄= 18.84 ±1.21ºC with a thermal amplitude of 2.57ºC. The highest temperature is recorded on diagonal 1, the LSD Test found significant differences with the other streets and diagonals. Street 4 with an intermediate temperature also has significant differences with all other streets and diagonals. Streets 1, 3 and diagonal 2 with the lowest temperatures have significant differences with streets 2, 4 and diagonal 1. (Fig. 10)

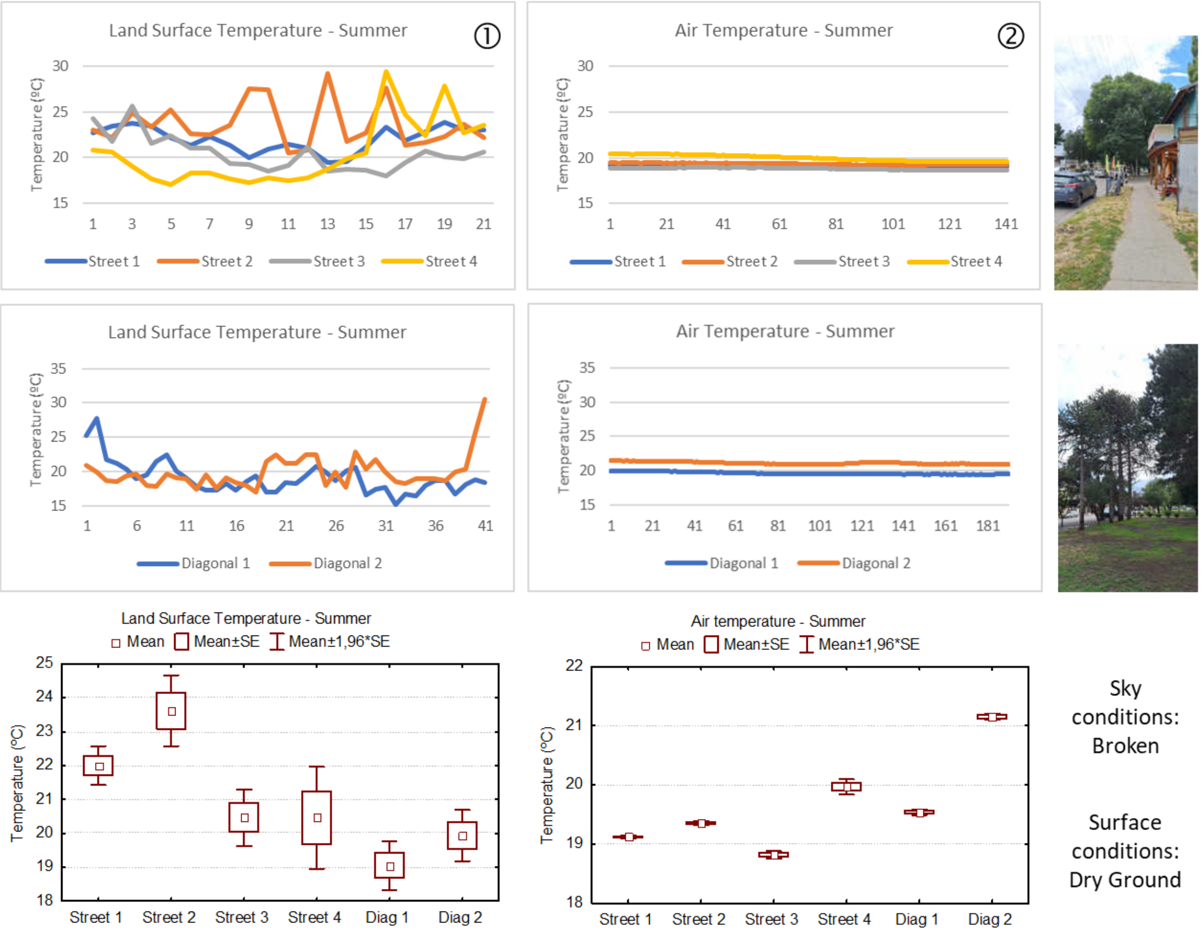

Fig. 11. Summer: Land surface temperature (1) and air temperature (2). Images of trees sky and surface condition.

Land surface temperature in Summer: The average surface temperature in summer was X̄= 20.57 ±2.80ºC with a thermal amplitude of 4.57ºC. During the summer temperature record, the sky was fragmented with low cloud cover. Greater variability was recorded in land surface temperatures than in air temperatures. Street 2 has the highest temperature and the LSD Test found significant differences with the other streets and diagonals. Street 1 with intermediate land surface temperature also has significant differences with the other streets and diagonals. Diagonal 1 has the lowest temperature with significant differences with the other streets. (Fig. 11)

Air Temperature in Summer: Average air temperatures in summer are X̄= 19.82 ±0.84ºC with a thermal amplitude of 2.34ºC. The LSD Test detected significant differences between the air temperature in all streets and the diagonals. (Fig. 11)

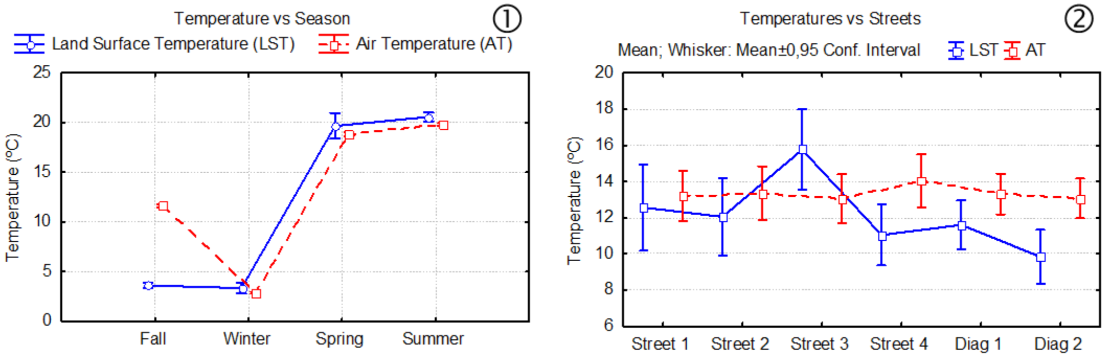

Fig. 12. Comparison of land surface temperature and air temperatures between: (1) seasons and (2) streets and diagonals.

Land surface temperatures presented greater variability in winter and spring, compared to the other seasons of the year, with street 3 standing out with the highest temperatures. Land surface temperatures in fall and winter are low and the LSD test found significant differences with spring and summer surface temperatures. Air temperature had little variability in each season. The LSD test found significant differences between all seasons. (Fig. 12.1)

In the comparison between the streets and diagonals in land surface temperatures, the LSD test found significant differences between street 3 and the other streets and diagonals. Significant differences were also detected between street 1 and diagonal 2. The air temperature was similar in all streets and diagonals. (Fig. 12.2)

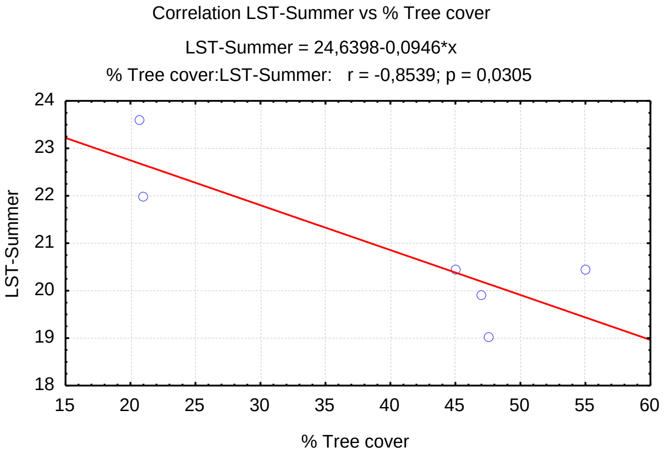

Fig. 13. Correlation between tree cover and land surface temperature in summer.

Only a significant correlation was found between the surface temperature in summer and the percentage of tree cover.

Discussion:

Urbanizations produce major changes in land cover by modifying albedo and waterproofing surfaces. The increase in population causes the growth of cities and in this context, it is important to study the role of trees in the regulation of urban temperature. There are few studies in Argentina on this topic. In the city of Mendoza, they evaluated the impact of the Central Park of Mendoza (Argentina) on the air temperatures of its built environment in the last ten years and found that trees significantly reduce air temperature (Ruiz, et al., 2022). In the same city, the role of trees was evaluated among various cooling strategies in arid areas compared to a city in humid areas (Alchapar, et al., 2017). In the city of Bahía Blanca, a decrease in air temperature under the shade of trees was also recorded (Duval, et al., 2020) and similar results were obtained for 4 cities in northwestern Argentina (Gioia, et al., 2014 The present study was carried out in Northern Patagonia, in a small city surrounded by a steppe landscape and is one of the first to evaluate the role of trees in urban temperature regulation in this region. The results have important implications for urban planning and the design of heat mitigation strategies in arid and semi-arid cities. Considering the impact of shade on temperature for urban trees, deciduous species are recommended that reduce solar radiation during spring and summer, thus favoring a decrease in temperature. In addition, these species allow light to pass through during fall and winter, periods in which they require higher temperatures.

In future research, it is recommended to intensify the number of measurements of land surface temperature and air temperature during the hours of greatest solar radiation in spring and summer. Additionally, compare the impact of tree shade on days with high low cloud cover and clear days. A broader sampling of streets can help find correlations between tree height and temperatures.

Conclusions:

The sampling period was influenced by the ENSO phenomenon (SMN, 2024a,b) and higher air temperatures than the historical average were recorded, while precipitation was similar. Fall and winter land surface temperature and air temperatures were significantly lower than spring and summer. On street 3 (Olavarría), with the highest density of low-lying and deciduous trees, the highest land surface temperatures (LST) were recorded in spring, possibly because their leaves were just beginning to sprout.

The fall, winter and summer samplings were influenced by the coverage of low clouds that decreased solar radiation. Only in the spring sampling were no clouds recorded.

The density of trees in the center of the city of Junín de los Andes is irregular. The square and street 3 stand out with the greatest density of trees. Street 2 (Coronel Suarez), with the most commercial activity, is the one with the fewest trees and 25% of its surface is covered by artificial eaves that reduce solar radiation.

The trees on the streets are deciduous, therefore, they have a greater influence on the decrease in solar radiation in spring and summer, however, most of the trees in the square are evergreen, generating shade in all seasons. The impact of shade on temperature is important, for example, in the summer sampling, on street 4 (Olavarría) the surface temperature ranged from 29.4ºC in the sun to 20ºC in the shade (ΔT 9,4ºC) with 2 meters of distance between measurements. In air temperature the differences were lower, 20.4ºC in areas with greater solar radiation, to 19.6ºC in shaded areas (ΔT 0.8ºC). In the present work we detected a significant correlation of the impact of tree shade on the reduction of surface temperature during summer. This finding demonstrates the role of urban trees as a regulator of local temperature to mitigate the effects of climate change. Several authors have documented similar findings for other cities. (Alchapar, et al., 2017, Alexander, 2021, Duval, et al., 2020, Gioia, et al, 2014, Guo, et al., 2023, Ruiz, et al., 2022, Sharmin, et al., 2023, Yu, et al., 2020)

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Bibliography:

Alchapar, N. L., Pezzuto, C. C., Correa, E. N., & Chebel Labaki, L. (2017). The impact of different cooling strategies on urban air temperatures: the cases of Campinas, Brazil and Mendoza, Argentina. *Theoretical and Applied Climatology*, *130*, 35-50.

Alexander, C. (2021). Influence of the proportion, height and proximity of vegetation and buildings on urban land surface temperature. *International Journal of Applied Earth Observation and Geoinformation*, *95*, 102265.

Beck, H. E., McVicar, T. R., Vergopolan, N., Berg, A., Lutsko, N. J., Dufour, A., ... & Miralles, D. G. (2023). High-resolution (1 km) Köppen-Geiger maps for 1901–2099 based on constrained CMIP6 projections. *Scientific data*, *10*(1), 724.

Boyero, L., Datri, L., Lopez, M., Rodríguez Morata, C., Robertazzi, M., Lopez, H., ... & Matteucci, S. (2021). Urban planning in arid Northern Patagonia cities to maximize local ecosystem services provision. In *Ecosystem Services in Patagonia: A Multi-Criteria Approach for an Integrated Assessment* (pp. 349-377). Cham: Springer International Publishing.

DATAtab Team (2024a). *DATAtab: Online Statistics Calculator: Análisis de la varianza (ANOVA).* DATAtab e.U. Graz, Austria. https://datatab.es/tutorial/anova

DATAtab Team (2024b). *DATAtab: Online Statistics Calculator: Correlación de Pearson.* DATAtab e.U. Graz, Austria. https://datatab.es/tutorial/pearson-correlation

Dominguez, D. A., Poggi, M. M., Stella, J. L., & Skansi, M. D. L. M. (2022). *Ola de calor y temperaturas extremas de enero de 2022 en Argentina.* Servicio Meteorológico Nacional. https://repositorio.smn.gob.ar/bitstream/handle/20.500.12160/2427/0036ID2023_POSTER.pdf

Duval, V.S., Benedetti, G.M. & Baudis, K. (2020). El impacto del arbolado de alineación en el microclima urbano. Bahía Blanca, Argentina. *Investigaciones Geográficas* (73), 171-188.

Esri (2024). Esri Land Cover. https://livingatlas.arcgis.com/landcover/

Fan, J. (2023) Urban Greening Could Help Achieve Carbon Neutrality Goals. EOS. AGU. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2023MS003867

Gioia, A., Paolini, L., Malizia, A., Oltra-Carrió, R., & Sobrino, J. A. (2014). Size matters: vegetation patch size and surface temperature relationship in foothills cities of northwestern Argentina. *Urban ecosystems*, *17*, 1161-1174.

Gonzalez-Trevizo, M. E., Martinez-Torres, K. E., Armendariz-Lopez, J. F., Santamouris, M., Bojorquez-Morales, G., & Luna-Leon, A. (2021). Research trends on environmental, energy and vulnerability impacts of Urban Heat Islands: An overview. *Energy and Buildings*, *246*, 111051.

Guo, A., He, T., Yue, W., Xiao, W., Yang, J., Zhang, M., & Li, M. (2023). Contribution of urban trees in reducing land surface temperature: Evidence from china's major cities. *International Journal of Applied Earth Observation and Geoinformation*, *125*, 103570.

Instituto Nacional de Estadística y Censos (INDEC). (2012). *Censo nacional de población, hogares y viviendas 2010: Censo del Bicentenario: Resultados definitivos.* Serie B Nº 2 (1a ed.). Buenos Aires: INDEC.

Instituto Nacional de Estadística y Censos (INDEC). (2024). *Censo 2022.* https://www.indec.gob.ar/indec/web/Nivel4-Tema-2-41-165

IPCC (2021a) *Cambio Climático 2021: un resumen para todo el mundo.* WMO. UNEP. https://www.ipcc.ch/report/ar6/wg1/downloads/outreach/IPCC_AR6_WGI_SummaryForAll_Spanish.pdf

IPCC (2021b) *Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. WMO. UNEP. https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf

Meteoblue (2024). *Datos históricos simulados de clima y tiempo para Junín de los Andes.* https://acortar.link/eZij7U

Ruiz, M. A., Colli, M. F., Martinez, C. F., & Correa-Cantaloube, E. N. (2022). Park cool island and built environment. A ten-year evaluation in Parque Central, Mendoza-Argentina. *Sustainable Cities and Society*, *79*, 103681.

Servicio Meteorológico Nacional (SMN). (2024a) *¡Llegó El Niño! Se declaró el comienzo del fenómeno en Argentina: ¿qué impactos tiene en el clima?* https://acortar.link/4Xj9H0

Servicio Meteorológico Nacional (SMN). (2024b) *El Niño/La Niña.* Informes mensuales. https://www.smn.gob.ar/enos

Sharmin, M., Tjoelker, M. G., Pfautsch, S., Esperon-Rodriguez, M., Rymer, P. D., & Power, S. A. (2023). Tree crown traits and planting context contribute to reducing urban heat. *Urban Forestry & Urban Greening*, *83*, 127913.

StatSoft, Inc. (2007). STATISTICA (data analysis software system), version 8.0

The GLOBE Program (2023). *"Trees within LAC" Campaign. RCO - LAC.* https://acortar.link/8bTA26

The GLOBE Program (2023). *GLOBE Observer app.* https://acortar.link/jFC727

The GLOBE Program (2023). *MUC Field Guide, A Key to Land Cover Classification. Global Learning and Observations to Benefit the Environment*. https://www.globe.gov/documents/355050/5a2ab7cc-2fdc-41dc-b7a3-59e3b110e25f

The GLOBE Program (2023). *The GLOBE Teacher's Guide. Atmosphere and biosphere protocols.* https://www.globe.gov/do-globe/globe-protocols

The GLOBE Program (2023). *Trees Around the GLOBE Student Research Campaign.* https://acortar.link/nifshT

The GLOBE Program (2023). *Urban Heat Island Effect.* https://acortar.link/S1AwmZ

Wunderground (2024). Wundermap. Junín de los Andes, Neuquen, Argentina. Station ID: INEUQUNJ4. https://www.wunderground.com/wundermap

Yu, Q., Ji, W., Pu, R., Landry, S., Acheampong, M., O'Neil-Dunne, J., ... & Tanim, S. H. (2020). A preliminary exploration of the cooling effect of tree shade in urban landscapes. *International Journal of Applied Earth Observation and Geoinformation*, *92*, 102161.

Badge Descriptions/Justifications:

I AM A PROBLEM SOLVER: The present research demonstrated the impact of shade from urban trees on the decrease in surface temperature in summer. In a context of climate change, recognizing the role of urban trees and planning their management helps mitigate the impact of heat waves in the summer, contributes to the reduction of energy consumption to cool environments, provides comfort, among others. The results of the research contribute to the planning and management of urban trees in the city of Junín de los Andes and could be extrapolated to other cities with similar climatic conditions.

I MAKE AN IMPACT: In Argentina there is little research on the role of trees in surface and air temperature in cities. Our research demonstrates the impact of tree shade in reducing solar radiation and lowering surface temperatures. The results benefit society, raise awareness about the importance of urban trees and the need to adequately plan their distribution.

I AM A DATA SCIENTIST: To carry out the research, data on tree height, circumference, tree cover, surface and air temperatures were collected. The data were processed using statistical methods to establish significant differences between the groups. The statistical treatment of the data allowed us to reach relevant conclusions that provided solvency to make recommendations for the management of urban trees in the city. Ideas for future research are also provided.