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Remote Sensing Applied to NDVI and LST in Urban Streets in Southern Brazil

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Abstract: Urban evolution becomes a space-transforming agent capable of changing Normalised Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) emissivity reflectance on the land surface. Therefore, this study identifies NDVI and LST variations locally, but it can also be applied in other cities on a global scale. In general, it aims to analyse NDVI and LST on surface areas of avenues and urban streets of Sector 1, located in downtown Passo Fundo, in the southern region of Brazil, from 2013 to 2020. Methodologically, treated Landsat 8 satellite images were used to obtain NDVI and LST variations in this study. Subsequently, data of 80 points in the avenues and streets of Sector 1 were collected over a distance of 100 meters spaced from each point. These data were statistically analysed concerning the dispersion of NDVI and LST from 2013 to 2020. The results revealed a strong interaction between NDVI and LST, demonstrating the need to conserve urban vegetation to improve temperature, which positively favours urban ambience indexes.

Key words: Urban evolution, temporal analysis, urbanisation, urban mobility, urban ambience.

1. Introduction

Constant transformations that occur in urban areas result from human activities over geographic space and modify land uses, thus providing different types of urban ambience [1]. Such changes in the amount of vegetation can cause variation in urban temperature [2]. In this case, urban ambience can be defined as the relationship between physical dynamics and typological variants of the built environment, including urban streets and avenues [3].

These urban streets and avenues present constructive materials of different shapes and formats that reflect emissivity temperature differently [4]. Thus, land surface reflectance is considered a critical and fundamental element that analyses the influence of soil cover concerning the amounts of sunlight absorption [4]. In this way [5], it is essential to recognise the properties that make up the land surface to identify impacts and behaviour over time as they present constant variations.

For example, it is possible to highlight some factors that may interfere in the analysis of reflectance emitted on the land surface. Thus, it can be considered the concentration of the type of aerosols, the cloud cover and also the humidity in the atmosphere, which can limit information during the capture of satellite data and negatively interfere in the land surface analysis of the Normalised Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) [4-6].

NDVI is a metric widely applied to assess vegetation index variations and uses Remote Sensing

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techniques [6]. NDVI is calculated by the reflectance of red and near-infrared (NIR) bands, obtained from the reflectance information of land surface related to biophysical parameters, including studies of urban vegetation [7].

In this context, LST becomes one of the main parameters for analysing variations in emissivity temperature on land surface and demonstrates results that originate from environmental changes in the urban environment [8]. Therefore, the variations of land temperature using Remote Sensing can identify the presence of colour patches in areas of extreme urban density [9]. Thus [10, 11], the possibility of collecting LST radiation measurements transferred from the soil to the air stands out. This varies according to several conditions, either by gases resulting from human processes generated by burning fossil fuels in motor vehicles or industrial processes.

Remote sensing application techniques offer new opportunities to assess NDVI and LST characteristics in urban areas by using digital processing of satellite images to monitor vegetation and emissivity temperature of land surface for the realisation of temporal analyses in the geographic space [4-6]. Therefore, it is perceived the existence of numerous satellite platforms orbiting the earth capable of obtaining TIR (thermal infrared) data [7, 12].

Landsat 8 used in this study is an American Earth observation satellite that provides thermal data in high spatial resolution, with details of sharp spectral colours [12]. The interpretation of such images is a direct source for understanding environmental phenomena and enabling more strategic planning in cities on a global scale [12].

Therefore, this study seeks to possibly understand variations of NDVI and LST complex parameters in the urban environment, which in addition to affecting the urban environment, directly influence the quality of life of the population. When studying these temporal, geospatial variations, one understands the instances of transformations of urban space and the evolution of current urban landscapes and their temperature dynamics in areas with an intense flow of motor vehicles [13, 14]. This study also highlights the use of technologies that can contribute to surveys and evaluations in cities globally, making it possible to propose suggestions for appropriate use for urban soil.

The general objective of this study is to analyse NDVI and LST on surface areas of the urban streets of the census sector 1, in downtown Passo Fundo (located in the southern region of Brazil) from 2013 and 2020.

2. Materials and Methods

The city of Passo Fundo is located on the latitude 28°15'46" S and the longitude 52°24'25" W and is part of the state of Rio Grande do Sul (Southern Brazil) [15]. Passo Fundo has a population estimated at 203,000 people, a territorial area of 783,421 km^2, divided into 36 neighbourhoods and 22 municipal sectors. Sector 1 of Passo Fundo consists of this study site and corresponds to the city's central area, which is characterised by the presence of avenues and streets with intense flows of motor vehicles.

This study used images collected from the Landsat 8 satellite on April 8, 2013 (the satellite began to operate) and on March 17, 2020. These images were redesigned from Datum origin WGS 84/UTM zone 22N to Sirgas 2000 UTM/zone 22S. It should be pointed out that they were provided by the United States Geological Service (USGS) platform in coordination with National Aeronautics and Space Administration (NASA), which operates and distributes data from the Landsat 8 satellites. This study highlights that the Landsat 8 satellite images from 2020 are unprecedented. The unprecedented potential of this study demonstrates that despite its local character, it can be applied as the analysis methodology in other cities on a global scale, with satellite images without cloud shadows and cold fronts.

The analysis of vegetation levels by emissivity was conducted through the NDVI method, using Bands 4 and 5 (NIR) after using vegetation proportion calculations [16-18]. However, in LST analyses, band 10 (TIRS) was used [16-18]. Subsequently, by using mathematical formulas [16-18] applied to the raster calculator in QGIS, it was possible to obtain the representation and analysis of NDVI and LST variations in Sector 1, the city of Passo Fundo.

After the NDVI and LST application, an analysis of Sector 1 by station map was carried out based on the Triangular Irregular Network (TIN) distribution method, which consists of the distribution of points based on the formation of a grid in the triangle shape, applied to the studied urban surface [19].

The data obtained in the TIN collection enabled Pearson's correlation analysis, which was generated in JASP 0.13.01, available free of charge for technical and scientific uses. Thus, values for "*r*" between 1 to -1 were generated, with values close to zero (0). If it is close to 1, the increase in one variable results in the increase of the other. While, if it is close to -1, the increase in one variable causes the reduction of the other. As for the interpretation, the correlation 0.00 to 0.19 is considered very weak, 0.20 to 0.39 is weak, 0.40 to 0.69 is moderate, 0.70 to 0.89 is strong, and 0.90 to 1 is very strong [20, 21].

3. Results and Discussion

NDVI and LST results in Sector 1 in downtown Passo Fundo demonstrated extreme changes from 2013 to 2020 (Fig. 1). These changes in NDVI and LST allow a more precise understanding of the physical dynamics of vegetation and temperature on the land surface, considering the degree of emissivity captured by the satellite [16, 22].

The NDVI of Passo Fundo decreased from 2013 to 2020. Moreover, it indicates the loss of urban degradation in Sector 1 (Fig. 1), which is responsible for obtaining a better urban environment, thus positively contributing to the quality of life of the urban population [1]. In addition, when considering the segments of these analysed avenues and streets, it is observed that in addition to being commercial regions, they have a high residential density.

In this context, the accumulation of lower temperatures from 2013 to 2020 is noticed in the analysis of the LST. It may be aggregated to instances of an increasing number of buildings during this timeline. It directly interfered with the reflectance levels, as some construction materials absorb heat and the height of the buildings that prevent some sun rays from shining on these avenues and streets of Sector 1, which in turn decreases the reflectance levels in the analysed land surface (Fig. 1).

Table 1 shows the descriptive statistics applied to the data collected in 80 points sampled in Sector 1. In comparison, the standard deviation in 2013 presented a value of 2.12, and in 2020 the value decreased to 1.95. It means there was a decrease in land surface heterogeneity. This change is associated with the transformation process in the use and occupation of urban land [16-18]. Consequently, when considering changes in urban land use, it is clear to observe the presence of heat patches in isolated points, which occur systemically with high LST reflectance temperatures and act as foaming agents for impermeable surfaces [23].

Table 2 presents the statistical correlation analysis applied to the NDVI and LST indexes from 2013 to 2020. The 2013 and 2020 NDVI indexes reveal a strong correlation as there is a dependency between these variables. These data demonstrate the improvement of the vegetation in Sector 1. However, the other variables present a moderate correlation. Thus, it can be stated that the relationship between LST and NDVI is significant, as shown by the *p*-value.

As for the NDVI, Sector 1, we presented an average value of 0.133541 in 2013, whereas in 2020, the value corresponding to 0.13270. Through the analysis of these data, it is possible to perceive a bit significant reduction. This analysis can be justified as this is a consolidated area of the city, where the present vegetation cover undergoes constant changes. It can be noticed that the city of Passo Fundo needs a specific plan for the management of the green network through the evaluation of places for possible urban interventions.

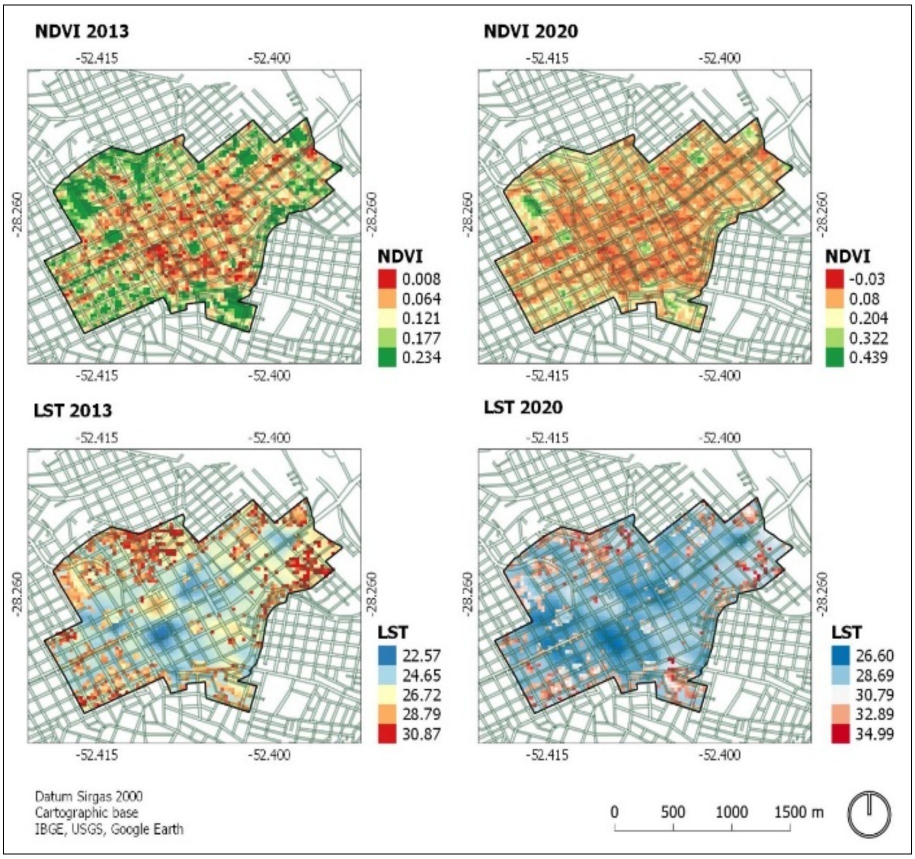

Fig. 1 Representation of NDVI and LST levels of the avenues and streets of Sector 1 in the city of Passo Fundo from 2013 to 2020.

Table 1 Representative statistics of NDVI and LST collected from 80 points sampled from 2013 and 2020.

Variables	LST-2020	LST-2013	NDVI-2020	NDVI-2013
Valid	80	80	80	80
Missing	0	0	0	0
Mean	29.87716	27.01770	0.13270	0.13541
Std. deviation	1.95961	2.12804	0.08216	0.08597
Minimum	26.98981	23.57733	0.01237	-0.01071
Maximum	34.23767	31.81711	0.33939	0.32684

Table 2 Pearson's correlations applied to the data collected in 80 points sampled in this study.

Variable	Pearson's *r*/*p*-value	LST-2020	NDVI-2020	NDVI-2013	LST-2013
1. LST-2020	Pearson's *r*	-			
	p-value	-			
2. NDVI-2020	Pearson's *r*	0.64776	-		
	p-value	8.34222e-11	-		
3. NDVI-2013	Pearson's *r*	0.61783	0.87071	-	
	p-value	1.02701e-9	9.37980e-26	-	
4. LST-2013	Pearson's *r*	0.68099	0.54214	0.60538	-
	p-value	3.63745e-12	2.05843e-7	2.70513e-9	-

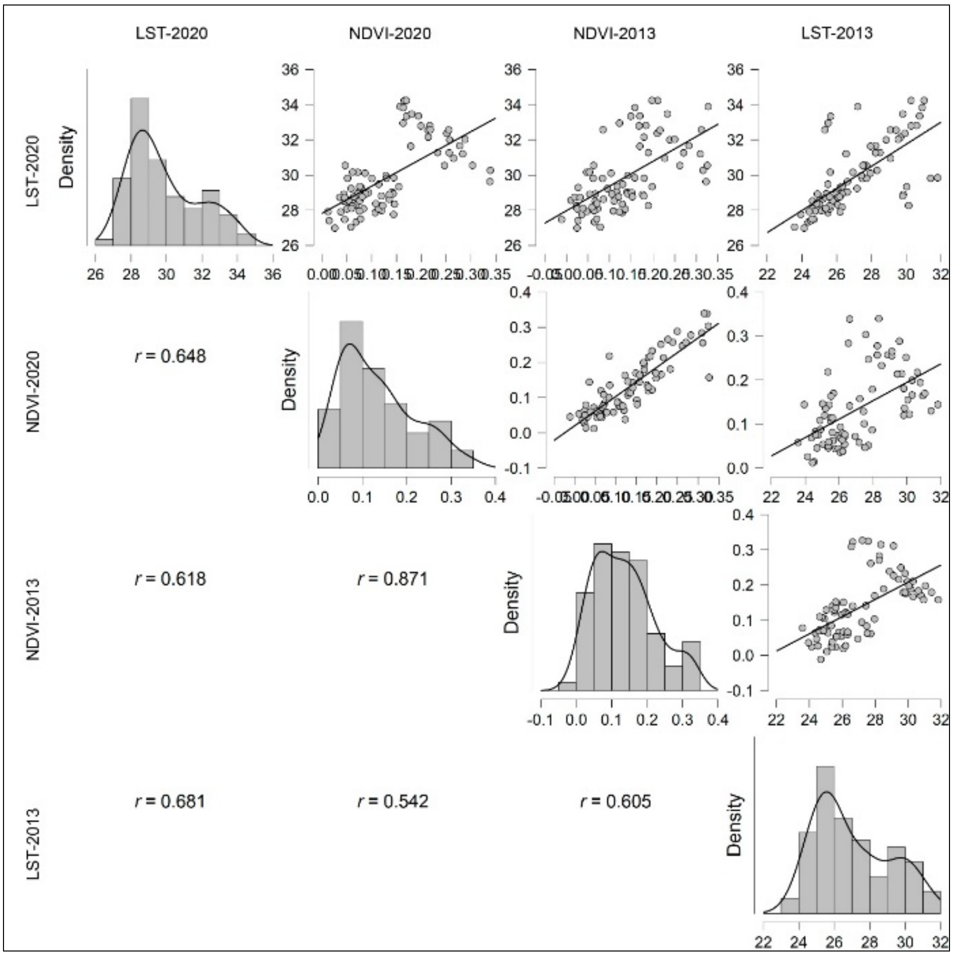

Fig. 2 Analysis of dispersion applied to the data of 80 points sampled in the study.

Through Fig. 2, it can be observed that the "*r*" values were positive and generated an increase in NDVI, which means that there is an increase in the LST values. Regarding NDVI, values from 0.00 to 0.20 are analysed, with smaller dispersion and temperatures ranging from 27 to 31 °C. In this context, the NDVI varied from 0.20 to 0.35, generating higher dispersion and temperatures (30 to 35 °C). Thus, it can be said that lower NDVI indexes point to densification of the built area, which represents shaded and colder areas when compared to the vegetation zones generated by the NDVI.

The need to apply projects that enhance recovery of the urban vegetation for the normalisation of the urban temperature of the land surface was observed through the NDVI and the LST analyses. Thus, NDVI and LST analyses can serve as technical and highly scientific tools for analyses that can improve the built environment [16, 24].

4. Conclusion

This study analysed NDVI and LST on surface areas of the avenues and urban streets of Sector 1, in the city centre of Passo Fundo, from 2013 to 2020. It highlighted the importance of using Remote Sensing, which allowed collecting data demonstrating the decrease in urban vegetation, which significantly interferes in emissivity temperature variations.

Thus, this study suggests that public policies that guarantee conservation and recovery of urban vegetation should be designed, not only for the city of Passo Fundo but also on a global scale, as the urban ambience needs improvements favouring the quality of life of the urban population.

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References

[1] Neckel, A., Silva, J. L. da., Saraiva, P. P., Kujawa, H. A., Araldi, J., and Paladini, E. P. 2020. "Estimating the Economic Value of Urban Parks in Brazil, the Case of the City of Passo Fundo." *Journal of Cleaner Production* 264 (10): 121369.

[2] Guyot, M., Araldi, A., Fusco, G., and Thomas, I. 2021. "The Urban Form of Brussels from the Street Perspective: The Role of Vegetation in the Definition of the Urban Fabric." *Landscape and Urban Planning* 205 (2): 103947.

[3] Cloud, R., and Jamal, A. 2017. "The Impact of Constructivism Density of the Urban Tissue in Improving the Physical Urban Ambience of the Free Space—The Street—for Saharian Cities. The Study of the Case City of Biskra." *Energy Procedia* 119: 201-13.

[4] Latorre, M. L., Dias, A. V., Shimabukuro, Y. E., and Carvalho Júnior, O. A. de. 2001. "The Influence of the Effects of Lighting Geometry on the Analysis of Land Surface Targets Obtained from AVIRIS Data." *Anais X SBSR, INPE*, 1293-300.

[5] Santamaria-Artigas, A., Vermote, E. F., Franch, B., Roger, J. C. E., and Skakun, S. 2021. "Evaluation of the AVHRR Surface Reflectance Long Term Data Record between 1984 and 2011." *International Journal of Applied Earth Observation And Geoinformation* 98 (June): 102317.

[6] Zhang, H., Ma, J., Chen, C., and Tian, X. 2020. "NDVI-Net: A Fusion Network for Generating High-Resolution Normalised Difference Vegetation Index in Remote Sensing." *Isprs Journal of Photogrammetry and Remote Sensing* 168 (Oct.): 182-96.

[7] Firozjaei, M. K., Sedighi, A., Firozjaei, H. K., Kiavarz, M., Homaee, M., Arsanjani, J. J., Makki, M., Naimi, B., and Alavipanah, S. K. 2021. "A Historical and Future Impact Assessment of Mining Activities on Surface Biophysical Characteristics Change: A Remote Sensing-Based Approach." *Ecological Indicators* 122 (Mar.): 107264.

[8] Wang, W., Samat, A., Abuduwaili, J., and Ge, Y. 2021. "Quantifying the Influences of Land Surface Parameters on LST Variations Based on GeoDetector Model in Syr Darya Basin, Central Asia." *Journal of Arid Environments* 186 (Mar.): 104415.

[9] Tiwari, A., Kumar, P., Kalaiarasan, G., and Ottosen, T. B. 2021. "The Impacts of Existing and Hypothetical Green Infrastructure Scenarios on Urban Heat Island Formation." *Environmental Pollution* 274: 115898.

[10] Eleftheriou, D., Kiachidis, K., Kalmintzis, G., Kalea, A., Bantasis, C., Koumadoraki, P., Spathara, M. E., Tsolaki, A., Tzampazidou, M. I., and Gemitzi, A. 2018. "Determination of Annual and Seasonal Daytime and Nighttime Trends of MODIS LST over Greece—Climate Change Implications." *Science of the Total Environment* 616-617 (Mar.): 937-47.

[11] Oliveira, M. L. S., Neckel, A., Pinto, D., Maculan, L. S., Zanchett, M. R. D., and Silva, L. F. O. 2021. "Air Pollutants and Their Degradation of a Historic Building in the Largest Metropolitan Area in Latin America." *Chemosphere* 277 (37): 130286.

[12] Abdullah, H., Omar, D. K., Polat, N., Bilgili, A. V., and Sharef, S. H. 2020. "A Comparison between Day and Night Land Surface Temperatures Using Acquired Satellite Thermal Infrared Data in a Winter Wheat Field." *Remote Sensing Applications: Society and Environment* 19 (Aug.): 100368.

[13] Kan, Z., Wong, M. S., and Zhu, R. 2020. "Understanding Space-Time Patterns of Vehicular Emission Flows in Urban Areas Using Geospatial Technique." *Computers, Environment and Urban Systems* 79 (4): 101399.

[14] Jeong, J., Shen, Y., Oh, T., Céspedes, S., Benamar, N., Wetterwald, M., and Härri, J. 2021. "A Comprehensive Survey on Vehicular Networks for Smart Roads: A Focus on IP-Based Approaches." *Vehicular Communications* 29 (4): 100334.

[15] Ibge. 2021. "Diretoria de Pesquisas, Coordenação de População e Indicadores Sociais, Estimativas." Accessed Mar. 2021. https://cidades.ibge.gov.br/brasil/rs/porto-alegre/panorama.

[16] Toscan, P. C., Neckel, A., Korcelski, C., Maculan, L. S., Maroni, D., Fuga, T. M., Cambrussi, L. P., Kujawa, H. A., Bodah, E. T., and Bodah, B. W. 2020. "Urban Cemeteries in Southern Brazil: An Analysis of Planimetric Variations, Vegetation Indices and Temperature." *Journal of Civil Engineering and Architecture* 14 (11): 617-24.

[17] Chemura, A., Mutanga, O., and Dube, T. 2017. "Integrating Age in the Detection and Mapping of Incongruous Patches in Coffee (*Coffea arabica*) Plantations Using Multi-temporal Landsat 8 NDVI Anomalies." *International Journal of Applied Earth*

Observation and Geoinformation 57: 1-13.

[18] Rodriguez-Galiano, V., Pardo-Iguzquiza, E., Sanchez-Castillo, M., Chica-Olmo, M., and Chica-Rivas, M. 2012. "Downscaling Landsat 7 ETM+ Thermal Imagery Using Land Surface Temperature and NDVI Images." *International Journal of Applied Earth Observation and Geoinformation* 18 (1): 515-27.

[19] Ali, T., and Mehrabian, A. 2009. "A Novel Computational Paradigm for Creating a Triangular Irregular Network (TIN) from LiDAR Data." *Nonlinear Analysis: Theory, Methods & Applications* 71 (12): 624-9.

[20] Altman, M. 2020. "A More Scientific Approach to Applied Economics: Reconstructing Statistical, Analytical Significance, and Correlation Analysis." *Economic Analysis and Policy* 66: 315-24.

[21] Meng, S., Tong, C., Lan, T., and Yu, H. 2020. "Canonical Correlation Analysis-Based Explicit Relation Discovery for Statistical Process Monitoring." *Journal of the Franklin Institute* 357 (8): 5004-18.

[22] Julien, Y., and Sobrino, J. A. 2009. "The Yearly Land Cover Dynamics (YLCD) Method: An Analysis of Global Vegetation from NDVI and LST Parameters." *Remote Sensing of Environment* 113 (2): 329-34.

[23] Sekertekin, A., and Zadbagher, E. 2021. "Simulation of Future Land Surface Temperature Distribution and Evaluating Surface Urban Heat Island Based on Impervious Surface Area." *Ecological Indicators* 122 (1): 107230.

[24] Saha, S., Saha, A., Das, M., Saha, A., Sarkar, R., and Das, A. 2021. "Analysing Spatial Relationship between Land Use/Land Cover (LULC) and Land Surface Temperature (LST) of Three Urban Agglomerations (UAs) of Eastern India." *Remote Sensing Applications: Society and Environment* 22 (3): 100507.