

Changes in Rural Areas of the City of Carazinho (RS) between 2001 and 2020: A Temporal Analysis Using Landsat TM-7 and TM-8 Images

Alcindo Neckel, Laércio Stolfo Maculan, Leticia Muller, Dominiki Ceolin, Julia Cristina Clivatti, Paloma Toscan, Lisiane Zwirtes and Henrique Aniceto Kujawa

Postgraduate Program in Architecture and Urbanism (PPGARq-IMED), Research and Study Group on Urban Mobility (NEPMOUR), Passo Fundo/RS 99070-220, Brazil

Abstract: The analysis of satellite images is of fundamental importance in relation to understanding the evolution in land use. The general objective of this study is to analyze the changes in characteristics of rural land use in the municipality of Carazinho (RS) from 2001 to 2020 through the analysis of images taken from the Landsat TM-7 and TM-8 satellites. The TM-7 and TM-8 satellite images were classified and supervised, thus generation thematic maps with the following groups: tillage, forest, water resources and exposed soil. The analysis of this study showed that in 2001 the tillage group had an area of 10,651.6 ha, the forest group had an area of 7,248.03 ha, the water resources group occupied an area of 1,444.96 ha, and the exposed soil group occupied an area of 6,798.75 ha. When using the images taken in 2020, the same area presented the following data: the tillage group with an area of 15,941.5 ha. (60.95%), the forest group with an area of 4,320.99 ha (16.52%), water resources group with an area of 141.02 ha (0.53%), and the exposed soil group with an area of 5,747.22 ha (21.97%). The results demonstrate changes in land use during the study period, mainly with regard to the increase of cultivation areas and, consequently, the suppression of vegetation.

Key words: Land use, rural area, remote sensing, temporal analysis.

1. Introduction

Research involving remote sensing, through the analysis of the use of satellite images, has been increasingly gaining global attention, as it makes it possible to collect information that reveals the understanding of physical variations of landscape in land use [1, 2]. However, satellite images need to present more precise resolutions, which occur as a result of the development and creation of new geospatial technologies [3, 4].

Despite constant technological and scientific advances at the end of the 19th century and the beginning of the 21st century, it is necessary to understand that the increase of population constantly

changes the environment, resulting in the degradation of natural resources [5]. This process is also seen in rural areas, causing the suppression of native vegetation and the conversion of these areas to agricultural or livestock production [6].

Brazil has legislation which regulates land use and obliges forest, water and riparian forest conservation. Among the established obligations is the elaboration of the Rural Environmental Registry (CAR) which explains land use in all properties.

These changes resulting from the interference of human activities in the environment [7] require detection at local and regional levels, since they influence the dynamics of vegetation and water resources causing an impact to biodiversity [2, 6, 7].

Monitoring of environmental impacts caused by the diversity of interferences in land use enhances remote sensing as a tool capable of assisting in the analysis of

Corresponding author: Alcindo Neckel, doctor of philosophy in geography, research fields: technology, project and management for the built environment.

the environment characteristics at micro- and macro-scales [6]. Thus, remote sensing techniques [1] are considered a powerful tool for analyzing land use. However, it is necessary to consider different techniques for analyzing satellite images from different historical and current periods of land use [8].

For the Brazilian Institute of Geography and Statistics (IBGE) [9], remote sensing is a method that seeks information related to a particular object, region or phenomenon on Earth, with no physical contact. Data are obtained either by means of electromagnetic radiation, which are natural sources, such as solar energy, or by artificial sources, such as radar.

Remote sensing helps understand land use in its different forms and contexts, making it of crucial importance for assertive decision-making, which may interfere with mitigating actions for the recovery or conservation of a given location [5, 10].

Public authorities, in the three spheres of management, share the duty to monitor land use and enforce environmental legislation. Remote sensing is a useful tool for public managers to monitor the environment and to plan public policies.

The use of geographic information system (GIS) technologies is essential to recover the past and to design future landscape planning for each region. These studies focused on land use become important allies to understand temporal evolution of the analyzed areas [11].

The general objective of this study is to analyze the changes in characteristics of rural land use in the city of Carazinho (RS) from 2001 to 2020 through images taken from the Landsat TM-7 and TM-8 satellites.

2. Method and Materials

The city of Carazinho is located 284 km from the capital city of the State of Rio Grande do Sul (RS), Brazil, between geographic coordinates 28°17' latitude and 52°47' longitude [12]. The city limits of Carazinho are the following cities: Coqueiros do Sul, Almirante Tamandaré do Sul, Não-Me-Toque,

Colorado, Passo Fundo, Chapada, Santa Bárbara do Sul, Pontão, Coqueiros do Sul, Chapada, Santo Antônio do Planalto and Saldanha Marinho (Fig. 1).

Carazinho has a total area of 676 km², with an urban area of 115 km² and a rural area of 561 km². Its population in 2019 is estimated at 62,110 inhabitants [9].

Carazinho's economy is focused on agriculture, with an emphasis on planting crops of soybeans, corn, wheat and oats. In addition to agriculture, another activity that is important for the development of the city is beef and dairy cattle farming.

Land use maps of the rural area of Carazinho (RS) were prepared by using images taken from the Landsat-7 and Landsat-8, TM sensor, obtained on the website of the National Institute for Space Research (INPE) and processed in the Geographic Information (GIS) QGIS, version 3.10. Images taken on March 5, 2001 and March 9, 2020 were used. It was decided to use images taken on the same month so that the phenological stage of summer crops was similar on both dates.

Regarding image processing, geometric correction was initially carried out, with the application of contrast to bands 3, 4 and 5, respectively. It was decided to exclude the urban area since the diversity of spectral responses of targets makes it impossible to separate them from other areas. The delimitation of the urban area was carried out visually on the satellite image, and specific targets were confirmed.

The use of the 2020 urban area mask to crop the 2001 image in order to ensure compatible results was chosen. The images were classified by the supervised method, thus generating thematic maps of the following groups: tillage, forest, water resources and exposed soil. The exposed soil group corresponds to areas with uncultivated soil, in which the spectral response of the soil supersedes the response of the straw and the remains of the previous cultivation. The resulting thematic mapping was visually compared to band composite of RGB543.

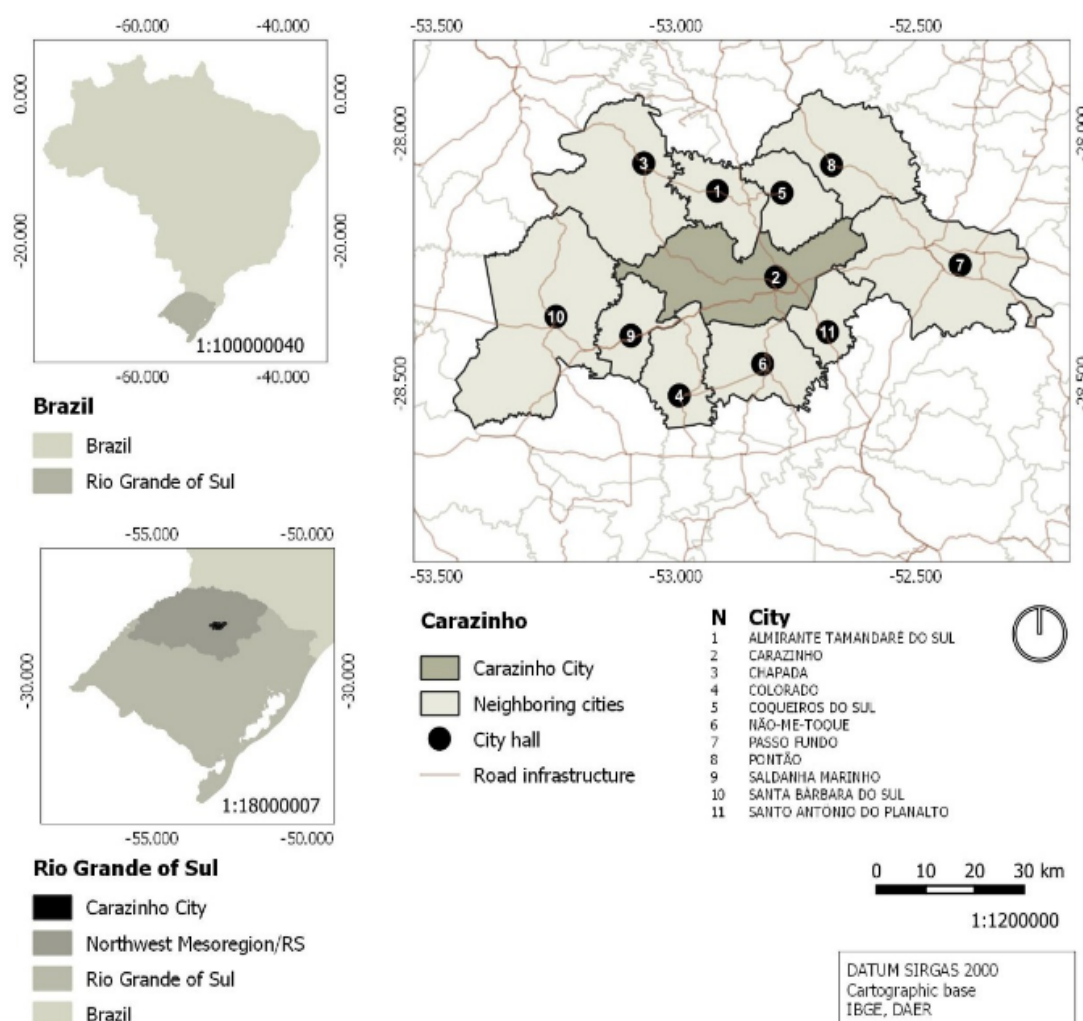


Fig. 1 Location of the city of Carazinho/RS, Brazil [9].

3. Results and Discussions

Fig. 2 shows the images taken on two dates which were generated in composite of RGB543. The two images in the demarcated areas in dark green refer to forest areas. The shades of purple and lilac in Fig. 2a and shades of brown in Fig. 2b represent the areas of exposed soil. It seems to be difficult to identify changes in land use that occurred between the two dates only by observing the image.

When observing the maps, the presence of cultivation areas which are highlighted in shades of light green is evident. Also, areas of exposed soil stand out in the first analysis. The other important

aspects are that the urban area is surrounded by the rural area, and the tillage areas are very close to the urban environment.

In the map shown in Fig. 3, it is possible to verify land use in Carazinho in March 2001. Of the total area (26,143.46 ha), most of it was occupied by areas destined to “agriculture and livestock”, accounting for 10,651.6 ha (40.74%). Afterwards, the “vegetation” group accounts for 7,248.03 ha (27.72%), which shelters woodlands, forests, and riparian forests. The “exposed soil” group has 6,798.75 ha (26.01%), mainly intended for agricultural use, but at the time of imaging, it had no vegetation cover. The “water resources” group has an area of 1,444.96 ha (5.53%).

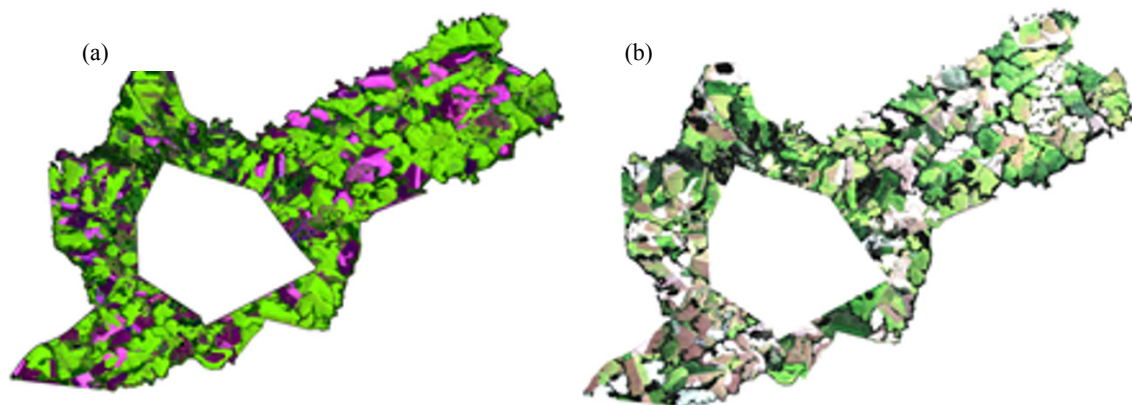


Fig. 2 Composite satellite images RGB543 of a Landsat-7 and Landsat-8. Image (a) was taken on March 5, 2001, and image (b) was taken on March 9, 2020.

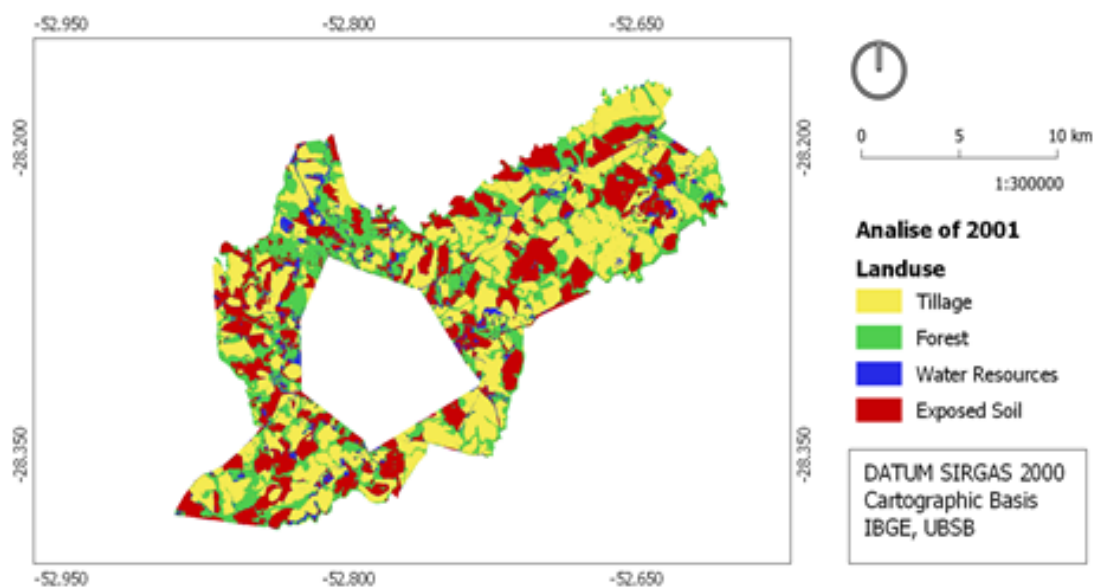


Fig. 3 Supervised classification map 2001.

Source: systematized by the authors using images taken from the Landsat TM/7 satellite (2001).

Fig. 4 shows the land use map from March 2020. On this date, most of the soil is occupied by areas for tillage, which accounted for 15,941.5 ha (60.95% of the total area) and by areas of exposed soil that accounted for 5,747.22 ha (21.97% of the total area), together totalling 82.92% of the area. The forest areas occupied 4,320.99 ha (16.52%) and, finally, the area of water resources was of 141.02 ha (0.53%). The comparison between the percentages obtained on the two dates can be seen in Fig. 5.

The most significant change occurred in relation to the tillage areas, which went from 40.74% to 60.95%, and these data reaffirm the agricultural tradition of the

region. On the other hand, the increase in areas for cultivation resulted in suppression of vegetation areas (woodlands, forests, riparian forests), as can be seen in Fig. 5.

In Fig. 5, it can be seen that the “water resources” group presented a significant decrease. The increase in areas for cultivation and for livestock, and for soil exploration, and the decrease in green areas have contributed to this reduction. In addition, since the end of 2019 the region has suffered from severe drought.

The new environmental legislation, in relation to this case, was not sufficient to protect these forests and water resources. Economic pressure and expansion

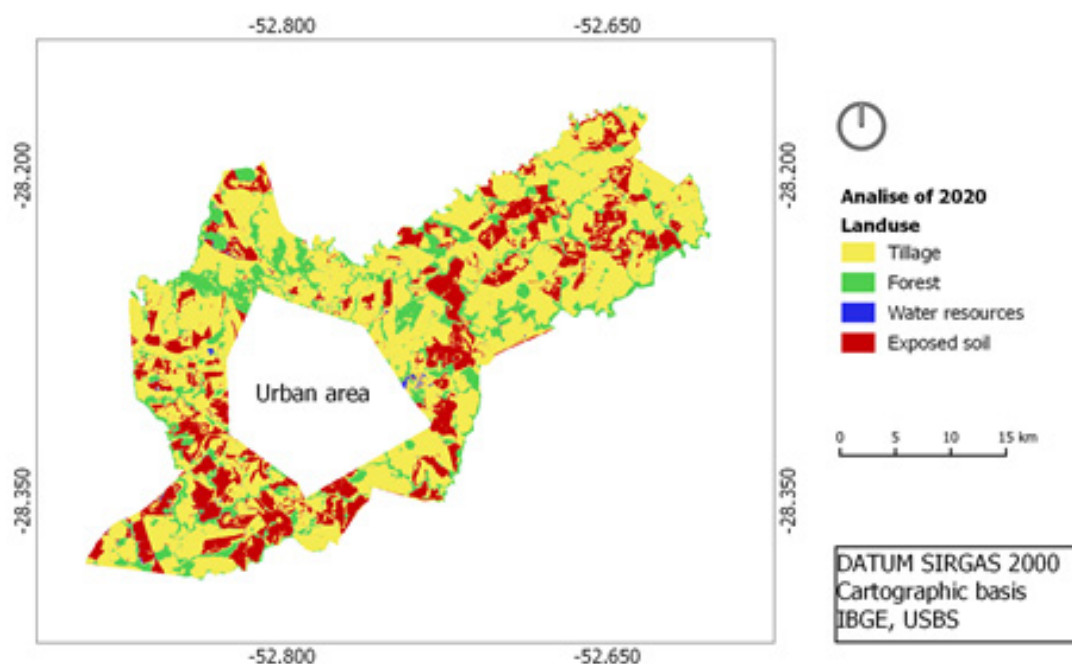


Fig. 4 Supervised classification map 2020.

Source: systematized by the authors using images taken from the Landsat TM/8 satellite (2020).

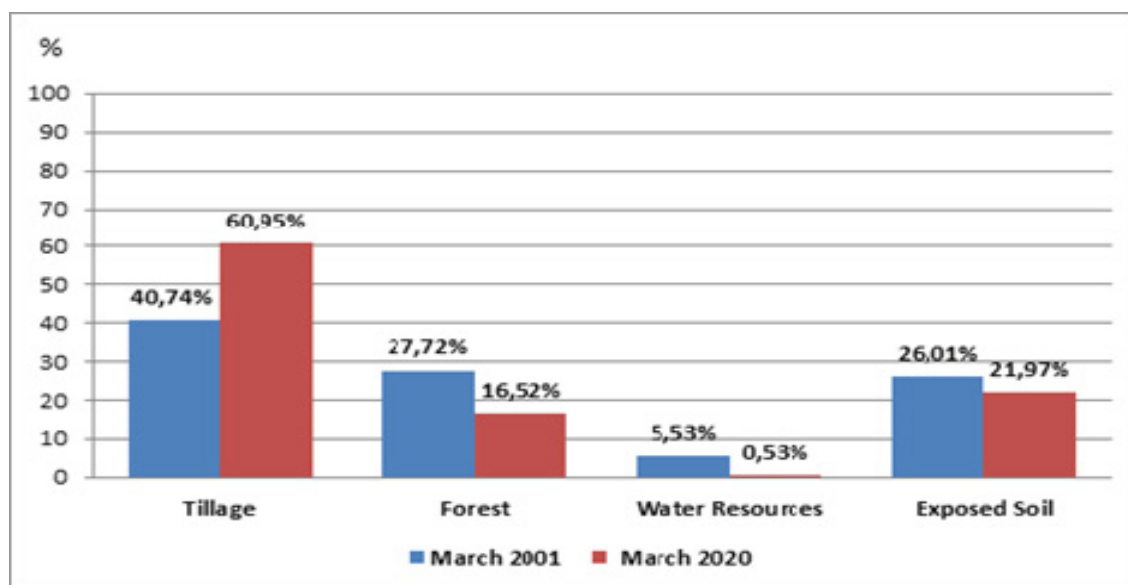


Fig. 5 Mapped groups and their respective percentages on the dates of the two images.

of soy production, which is the main agricultural product in the region under study, caused an increase in the planting area to the detriment of those areas occupied with forests and water resources.

In Fig. 6, cropping of the images is shown. It can be noticed that Figs. 6a-6c (2001) taken from Landsat-7 present shades with greater saturation when compared

to Figs. 6d-6f (2020) taken from Landsat-8. When resolution and clarity of the images are analyzed, it is evident that most recent images (2020) have greater clarity and quality.

Concerning land use, cropping also shows the results presented in the statistical data, that is, the increase in areas of cultivation, as seen in Fig. 6d

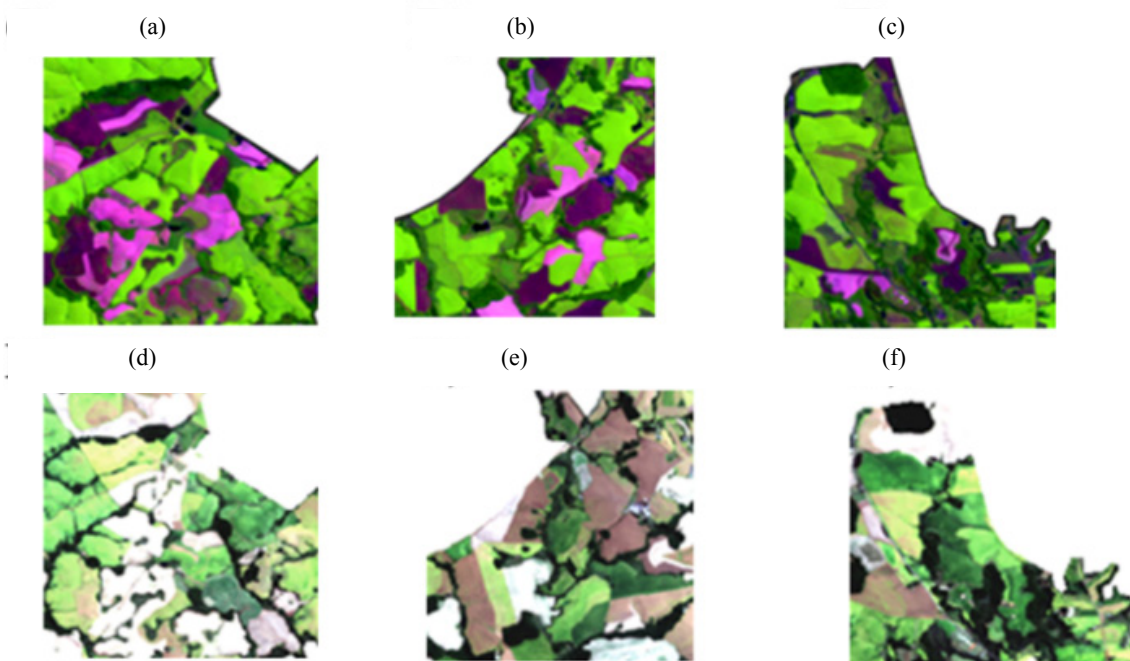


Fig. 6 Composite of the city of Carazinho/RS divided into three groups in order to analyze changes from 2001 to 2020. Composite satellite image RGB543 of Landsat-7 and Landsat-8. Images (a, b, c) were taken on March 5, 2001 and images (d, e, f) were taken on March 9, 2020.

in relation to the same area in 2001. Also, another important aspect to be highlighted is the decrease in areas of woodlands and forests that are replaced to tillage, as shown in Fig. 6e.

Both cropping images taken in 2001 (Figs. 6a-6c) and 2020 (Figs. 6d-6f) do not have a significant area of water resources. However, both cropping images present the same riparian forest area.

4. Conclusions

Through this study, a spatio-temporal analysis of the rural area of the city of Carazinho was carried out and it revealed preoccupying data regarding the reduction of forest areas to the detriment of increased agricultural areas in the city.

The analysis through land use maps helped learn more about the dynamics in land use as well as the changes that occurred during this study interval. It could also be noticed that when the applied methodology compares two different periods, it provides information for understanding, planning and future perspectives.

The significant increase in the planting area to the detriment of forest and water resources areas is a warning to public managers and the local population, and demonstrates the need for more effective public policies and awareness of people in order to protect the environment.

Acknowledgements

We wish to thank IMED, PPGArq/IMED and the Brazilian Institute for Space Research (INPE) for making satellite images available to us; and the Brazilian Institute of Geography and Statistics (IBGE) for providing geospatial information of Carazinho from its database.

References

- [1] Das, P., Behera, M. D., Pal, S., Chowdary, V. M., Behera, P. R., and Singh, T. P. 2020. "Studying Land Use Dynamics Using Decadal Satellite Images and Dyna-CLUE Model in the Mahanadi River Basin, India." *Environmental Monitoring and Assessment* 191: 1-17.
- [2] Mondal, M. D., Sharma, N., Kappas, M., and Garg, P. 2015. "Critical Assessment of Land Use Land Cover Dynamics Using Multi-Temporal Satellite Images."

- Environments* 2: 61-90.
- [3] Andreano, M. S., Benedetti, R., Piersimoni, F., and Savio, G. 2020. "Mapping Poverty of Latin American and Caribbean Countries from Heaven through Night-Light Satellite Images." *Social Indicators Research* 17: 1-30.
 - [4] Tan, C., Zhou, X., Zhang, P., Wang, Z., Wang, D., Guo, W., and Yun, F. 2020. "Predicting Grain Protein Content of Field-Grown Winter Wheat with Satellite Images and Partial Least Square Algorithm." *Plos One* 15: 1-15.
 - [5] Gülersoy, A. E. 2013. "Farklı Uzaktan Algılama Teknikleri Kullanılarak Arazi Örtüsü/Kullanımında meydana gelen değişimlerin incelenmesi: Manisa Merkez İlçesi Örneği (1986-2010)." *Turkish Studies: International Periodical for the Languages, Literature and History of Turkish or Turkic* 8: 1915-34.
 - [6] Corazza, R., Neckel, A., and Cambrussi, L. P. 2018. "Avaliação das mudanças no uso do solo em áreas rurais no município de Passo Fundo/RS entre 1989 e 2011 com uso de imagens Landsat TM-5." *Revista de Arquitetura Imed* 7: 68-83. (in Portuguese)
 - [7] Sitayeb, T., and Benabdeli, K. 2008. "Contribution à l'étude de la dynamique de l'occupation des sols de la plaine de la Macta (Algérie) à l'aide de la télédétection et des systèmes d'information géographique." *Comptes Rendus Biologies* 331: 466-74.
 - [8] Khan, I. A., Khan, M. R., Baig, M. H. A., Hussain, Z., Hameed, N., and Khan, J. A. 2020. "Assessment of Forest Cover and Carbon Stock Changes in Sub-tropical Pine Forest of Azad Jammu & Kashmir (AJK), Pakistan Using Multi-temporal Landsat Satellite Data and Field Inventory." *Plos One* 15: 1-19.
 - [9] IBGE. 2020. "Sensoriamento Remoto." Accessed May 2, 2020. <https://atlascolar.ibge.gov.br/conceitos-gerais/o-que-e-cartografia/sensoriamento-remoto.html>.
 - [10] Wu, S., and Chen, H. 2020. "Smart City Oriented Remote Sensing Image Fusion Methods Based on Convolution Sampling and Spatial Transformation." *Computer Communications* 157: 444-50.
 - [11] Barbosa, I. S., Andrade, L. A., and Almeida, J. A. P. 2019. "Evolução da cobertura vegetal e uso agrícola do solo no município de Lagoa Seca, PB." *Revista Brasileira de Engenharia Agrícola e Ambiental* 13 (5): 615-22.
 - [12] IBGE. 2017. "População." Accessed May 2, 2020. <https://cidades.ibge.gov.br/brasil/rs/carazinho/panorama>.