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Multi-temporal analysis of the growth of the built-up land in the Jayllihuaya population center between 2004 -2018 and prediction to 2025.

Análisis multi-temporal del crecimiento del Suelo edificado en el Centro Poblado de Jayllihuaya entre los años 2004 -2018 y predicción al 2025

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Contribución de los autores

RMM: Conceptualización, investigación, análisis de imágenes, redacción de manuscrito.

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Conflict of interest

The authors declare that they have no conflicts of interest

Conflicto de interés

Los autores declaran no tener conflictos de interés

Abstract

The town center of Jayllihuaya is the area of urban expansion of the nearest city of Puno and more favorable conditions for the satisfaction of the demand of land and own house between Puno families and migrants to this lake city, so this study shows the growth of the ground built between 2004 and 2018 to determine the trend and average growth rate to

2025 using remote sensing and GIS methods in the management of the territory, resulting in the ground built in the CP of Jayllihuaya grows in an exponential-polynomial form of second order with an average growth rate of 16.37% per year, which means that by 2025 it is expected that the ground built will be 61.55 Ha which is double compared to 30.19 Ha in 2018, which implies that the town of Jayllihuaya will be occupied almost 6 years in full, which alerts the authorities and managers of the territory to take the necessary measures.

Keywords: GIS, Urban growth and spectral signatures

Resumen

El centro poblado de Jayllihuaya es el área de expansión urbana de la ciudad de Puno más próxima y de condiciones más favorables para la satisfacción de la demanda de un terreno y casa propia entre las familias puneñas y migrantes hacia esta ciudad lacustre, por lo que este estudio muestra el crecimiento del suelo edificado entre los años 2004 y 2018 para determinar la tendencia y tasa media de crecimiento al 2025 utilizando métodos de teledetección y S.I.G en el manejo del territorio, teniendo como resultado que el suelo edificado en el C.P. de Jayllihuaya crece de forma exponencial-polinómica de segundo orden con una tasa de crecimiento promedio de 16.37% anual, lo que significa que para el 2025 se prevé que el suelo edificado será de 61.55 Ha que es el doble en comparación a las 30.19 Ha del 2018, lo que implica que el centro poblado de Jayllihuaya estará dentro de 6 años ocupada casi en su totalidad, lo que alerta a las autoridades y gestores del territorio a tomar las medidas necesarias.

Palabras clave: Crecimiento urbano, firmas espectrales y SIG

Introducción

In the City of Puno, the developable area is increasingly scarce and there is little space left to build, and an area of accessible urban expansion and good conditions is the Jayllihuaya Village Center, however the demand of young families to have their own home has encouraged the construction sector in the city of Puno, as this sector in recent years has grown and in 2017 registered 2.20% of the increase in the national GDP (CAPECO, 2018; Fernandez & Dominguez, 2019). Which is reflected in the day to a life of the city of Puno, Alto Puno, and C.P. of Jayllihuaya, new constructions, extensions, and remodeling of buildings which even makes us presume that some official figures fall short of reality, instead INEI (2018) indicates that the average annual growth rate of the population of Puno in the period 2007-2017 was -0.8% which could indicate that the population explosion is slowing down in Puno, but already the demand for ownership housing is high and the growth of

built-up land is inevitable and hardly controllable (Alvarado et al., 2018; Monzo & Membrado-Tena, 2019).

Therefore, the objective of this research is to find the area of built-up land in the Jayllihuaya population center between 2004 and 2018 through remote sensing techniques with multi-temporal satellite images and G.I.S. that help us to determine the trend and average rate of growth of built-up land for this area of urban expansion of Puno to 2025 and thus be able to have an accurate reading of what awaits this Jayllihuaya town center in just 6 years and also seeks to be reference research for urban development plans to take the necessary actions and measures for the properly balanced growth of the city of Puno.

Methodology

The parent research on which this article is based comes from Picone and Linares (2014), whose article is entitled *Propuesta metodológica para la extracción y análisis de densidades urbanas mediante teledetección y SIG. Case study: Tandil city, Argentina*, where we are presented with a methodology based on the use of remote sensing and classification types in the recognition of land use through satellite images, where the scene is chosen (study area) and the pre-processing is performed (choice of suitable images), and then make the procedure of the extraction of thematic information (supervised classification with spectral signatures) to subsequently interpret the classes (land use), where it is concluded that this methodology could extract built-up urban areas where it is recommended to use satellite images of the best possible resolution, which is applied in this study.

Likewise Calderon et al (2018), in their study "Change in vegetation cover and land use from 2000 to 2009 in Morelos, Mexico", were to evaluate trends and Spatio-temporal changes in land use using remote sensing techniques between two time periods, In this case, the areas of land cover were determined using the supervised classification technique with the maximum likelihood algorithm in ArcMap 10 using LANDSAT multispectral satellite images, and then a comparison was made in areas of the two periods, where it was concluded that the use of remote sensing and GIS allows estimating the magnitude of changes in the territories.

We also consulted the work of Macedo, Pajares, and Santos (2010), entitled "Unsupervised classification with color images of the land cover", where remote sensing work is done on land use in the La Sabana river basin, Mexico, using the methodology of unsupervised classification only with RGB composition images, which represents the natural color where the procedure was to make a pre-processing, unsupervised classification of color images

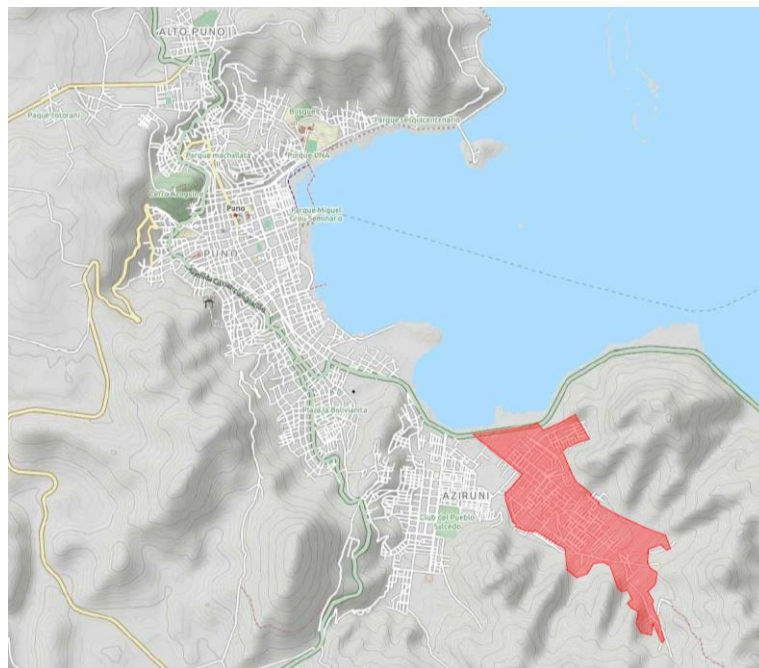
and accuracy assessment, where in the pre-processing stage using the algorithm of Otsu (1979) discard those images that have the optimal threshold of illumination in the RGB bands (Red, Green, Blue) so that the classification can be processed as best as possible. Where it is concluded that the pre-processing of images under the concept of optimal threshold, allows us to identify up to 9 classes of land cover with 95% accuracy, calculated by fuzzy error matrix, which gives us light to discard those images overexposed and with values in the bands very high lows estimating the magnitude of changes in the territories.

Results

Growth of built-up land between 2004 - 2018. After collecting high-resolution satellite images of 1.8m² per pixel coming from google earth between the years 2004-2018, images from the years 2005, 2006, 2009 and 2015 were pre-processed and discarded, because they were not within the optimal threshold (Otsu, 1979), then images from the years 2004, 2011, 2012, 2013, 2014 were used, 2016, 2017 and 2018, with which the study area was delimited, which is the area recognized as Jayllihuaya, polygon compiled from the 2013 cadastral plan, where the urban allotments of Aziruni I, II, III are located, a study area that has an extension of 345.01 Ha, which is shown in Figure 01.

Figure 01

Jayllihuaya study area in the city of Puno.

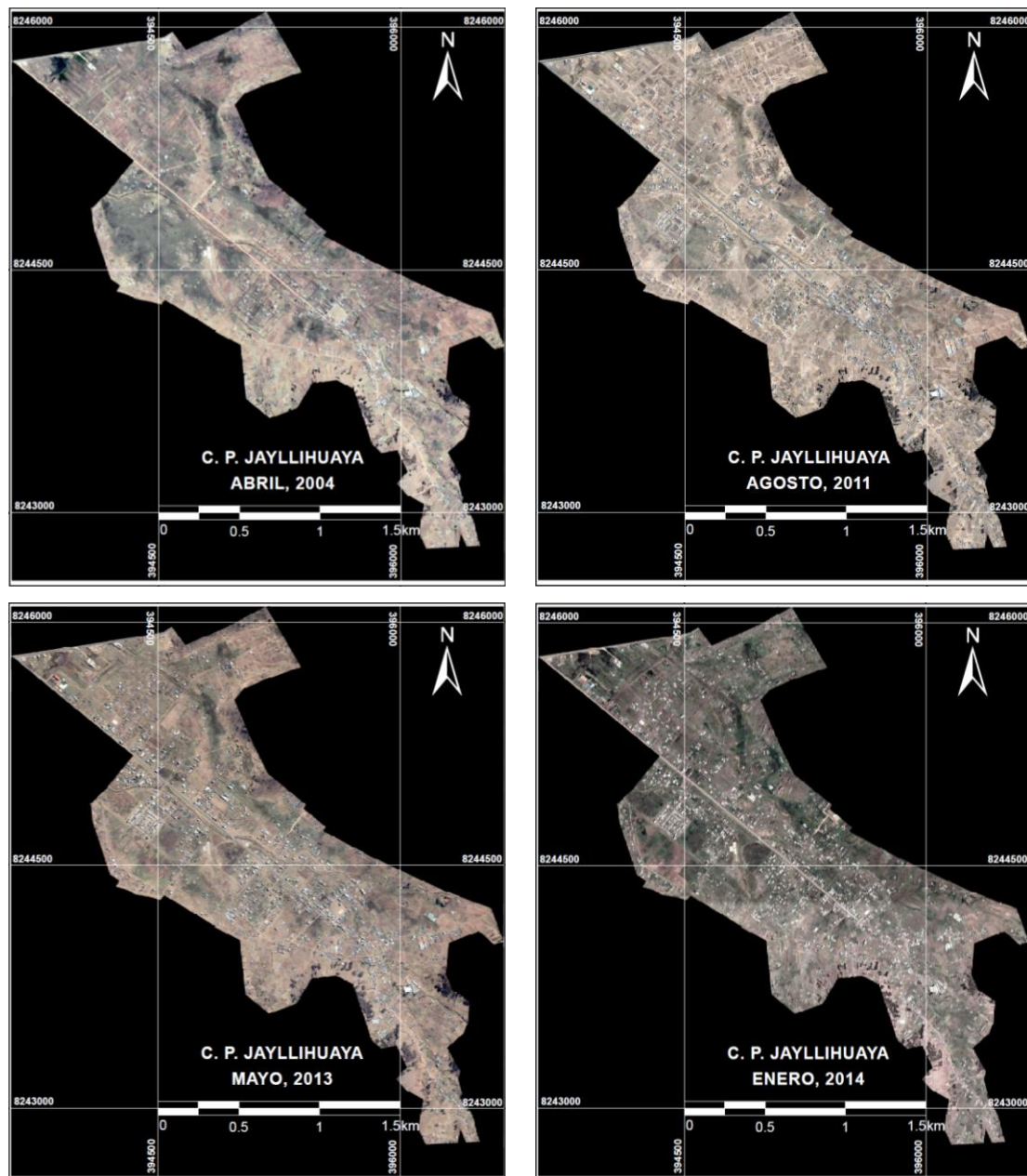


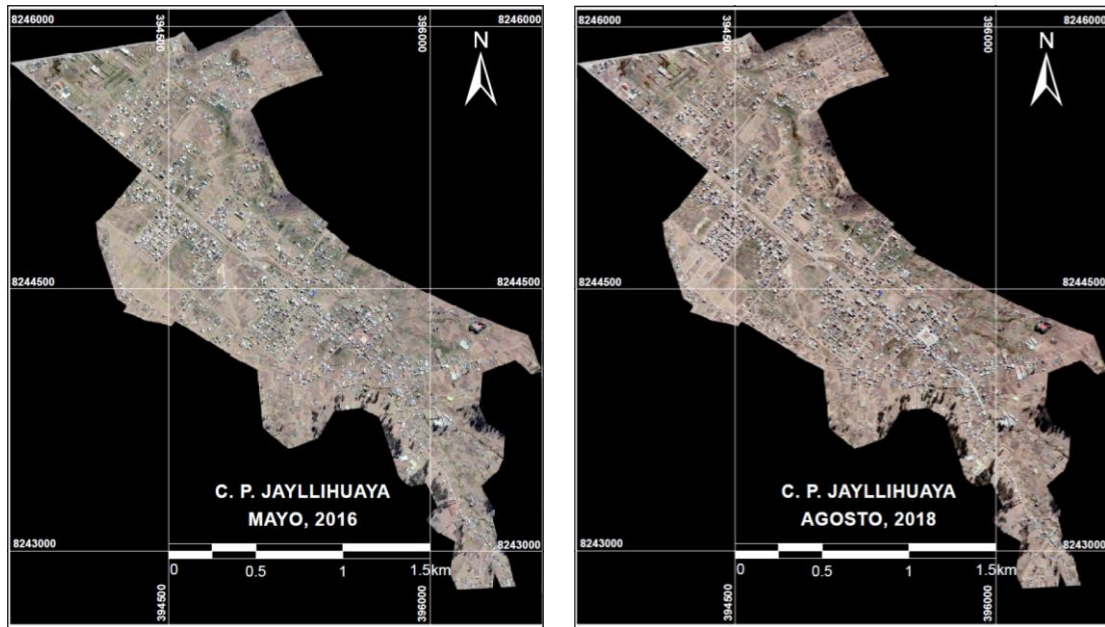
Source: OpenStreetMap - Puno cadastral map 2013.

With the delimitation, we proceeded to georeferenced in the UTM WGS 84 datum of the 19S zone, and then cut the satellite images to the study area (Figure 02) for the proper quantification of the occupation of the built-up land through the supervised classification, where it was restricted to have only one class (built-up land), this process was done for all the years mentioned.

Figure 02

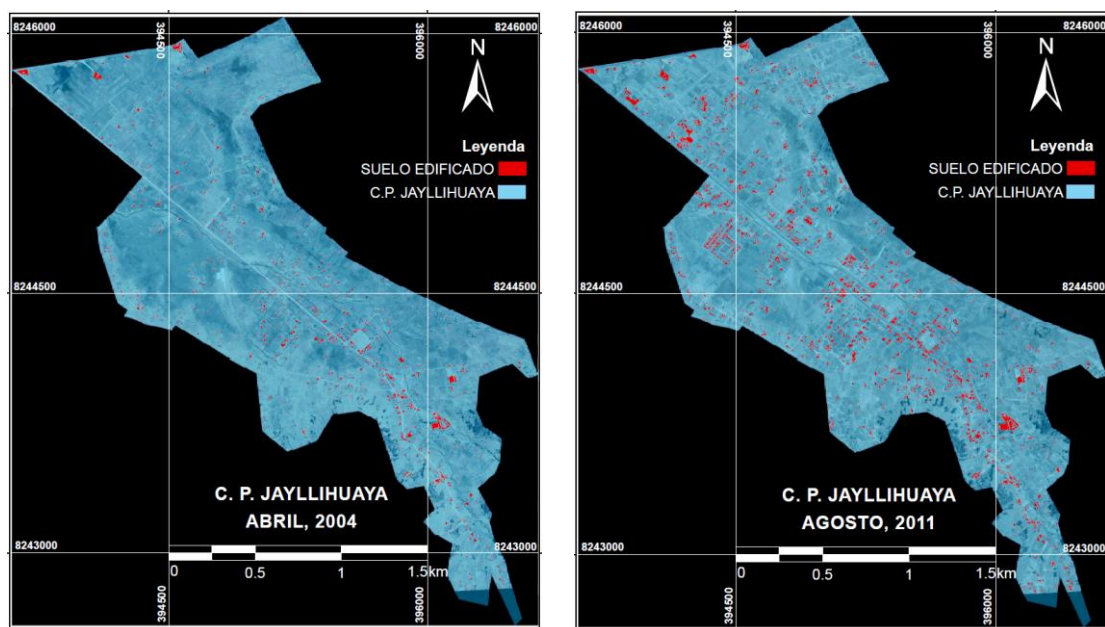
2004-2018 time intervals of C.P. Jayllihuaya.

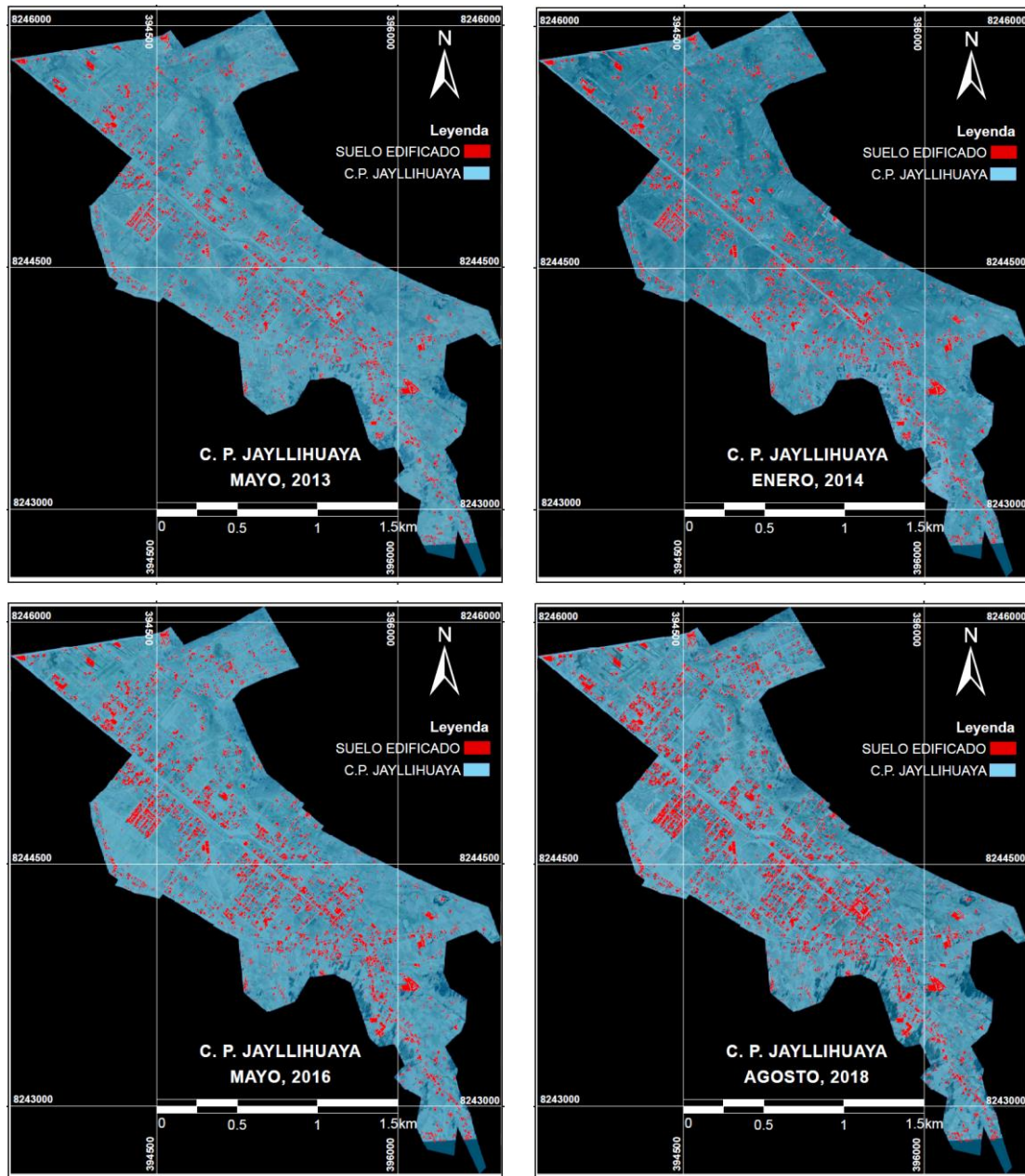




The supervised classification allowed us to see that in 2004 the extension of the building was 4.21Ha, which represents 6.48% of the approximate buildable area, according to the urban parameters of the R2 zoning (MPP, 2012), which was growing over the years until reaching 46.53% of the buildable area in August 2018, which is already representative, since, in the span of 14 years, the built-up land has grown by 40% of the total buildable area, which can be evidenced in Figure 03.

Figure 03
Land built between 2004 -2018: C.P. Jayllihuaya.





The areas of built-up land with its growth rate are shown in Table 01, where it is found that with 2004, the built-up land is 7.16 times more extensive in 2018, an alarming figure, since the growth rates were only slowed down somewhat between the period 2016 - 2017, having an average growth rate between 2004 and 2018 of 16.37%, which highly exceeds that mentioned by CAPECO, this shows that in the city of Puno, not necessarily the poverty rates reflect reality because the population that demands a habitable space has the economic conditions to build and generate urban expansion in the city of Puno and specifically in the populated center of Jayllihuaya, likewise it is expected that the INEI data, will be reflected in a few years in their data of deceleration of population growth, thus being able to give a respite to the indiscriminate and exponential growth of the built-up urban hull.

Table 01

Built-up land and average growth rate of the Jayllihuaya P.C. 2004 - 2018

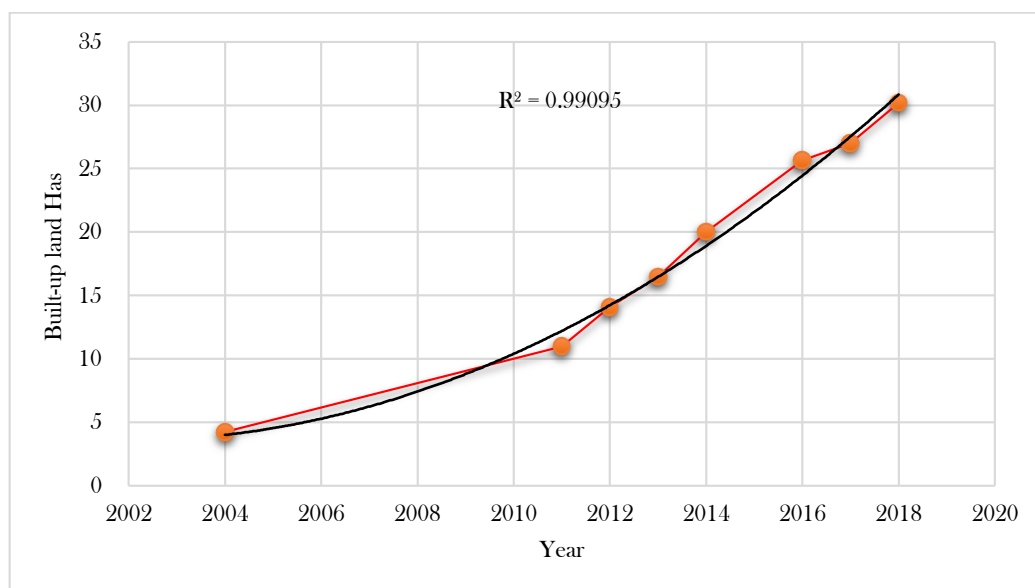
Year	Built-in land (Ha)	Average growth rate
2004	4.21	
2011	10.98	14.67%
2012	14.08	28.20%
2013	16.46	16.88%
2014	20.03	21.69%
2016	25.65	13.17%
2017	27.00	5.27%
2018	30.19	11.81%

As shown in Figure 04, there is an almost perfect relationship with an exponential-polynomial equation of second order, which is the equation that allows showing the trend and thus being able to determine the area of built-up land by 2025, which is the following equation 1, where y is area of built-up land and x is desired prediction year.

$$y = 0.10639x^2 - 425.98179x + 426409.18932 \quad \dots(1)$$

Figure 04

Trend of built-up land between 2004 -2018: C.P. Jayllihuaya.



Note: Red line is the occupied area; black line is the polynomial prediction of the occupied area.

Therefore, by 2025, it is estimated that the built-up land area will be 61.55 Ha, with the maximum approximate built-up area being 64.87 Ha according to urban parameters, which means that by 2025, the extension of the Jayllihuaya Public Housing Project will have only 3.32 Ha of free buildable land according to the projection.

Remote sensing techniques and GIS applications are undoubtedly a new world to be discovered and introduced in the field of urbanism and territorial planning as stated by Calderon et al (2018), however, care must be taken when choosing satellite images according to the scale and extent of work, likewise, the pre-processing is very important because this reduces the margins of error in the results, and make predictions more accurate and reliable, This is why it is the task of the researcher in this field to select the information before generating any process in the field of GIS. By using the methodology of Macedo, Pajares, and Santos (2010), it was possible to have more certainty about the considerations to be taken to extract the information from RGB satellite images that are available on the Internet.

Conclusions

The study predicted that by 2025, the area of built-up land will be 64.87 Ha, which is almost the limit for building according to the current urban parameters given by the Provincial Municipality of Puno, where it indicates that in the R2 zone the free area should be 40%. Although the immediate causes of built-up land expansion were not analyzed, it was clearly determined that growth is predicted with a second order polynomial trend (exponential), with an average growth between 2004 and 2018 of 16.37%, which is very high considering that Puno is considered a poverty zone. Finally, G.I.S. and remote sensing are a key weapon for the correct interpretation and prediction of both urban and rural territories.

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