Procedia
Environmental Science, Engineering and Management
http://www.procedia-esem.eu

Procedia Environmental Science, Engineering and Management **8** (2021) (2) 601-606

Environmental Innovations: Advances in Engineering, Technology and Management, EIAETM, 19th-23rd October, 2020

GIS IN COLOMBIAN POST-CONFLICT LAND USE PLANNING*

Hernán Granda-Rodriguez[1], Jenny Patricia-Vanegas[1], Daniel Robledo-Buitrago[1], John Jairo Castañeda[1], Edier Fernando Ávila-Vélez[1], Miguel A. De Luque-Villa[1,2]**

[1]Universidad de Cundinamarca, Fusagasugá ,Colombia
[2]Pontificia Universidad Javeriana, Bogotá D.C, Colombia

Abstract

This research collected and interpreted geographic and temporal data on changes in land use coverage in order to improve sustainable development and land use planning in Silvania, Colombia. This study was carried out in the municipality of Silvania, Colombia where a spatio-temporal land cover change analysis was carried out for the years 1994 to 2018. Photointerpretation of satellite images was done with ArcGIS 10.5, following the Corine Land Cover methodology. In the last 20 years in the municipality of Silvania, land use changed from Forest and semi-nature areas; only 6% was lost. These changes were not significant when compared to other areas in Colombia where deforestation has increased after armed conflict ended. Armed conflict in Silvania may have, to some extent, prevented an accelerated rate of deforestation. Strategic planning is urgently needed in this municipality with the help of different technological tools, such as GIS, that are important for land use planning because they facilitate the understanding and analysis of information related to the territory.

Keywords: Colombian post-conflict, GIS, land cover change, Silvania, ZOMAC

1. Introduction

Colombia is the country that has been most affected country by the armed conflict in Latin America, where armed groups and drug dealers converge, resulting in generating displacement in the rural areas (Turriago Rojas, 2016). This historic displacement made it possible to increase agricultural and livestock uses, transforming natural ecosystems into fragmented landscapes and altering the functionality, stability and dynamics of the country's

* Selection and peer-review under responsibility of the EIAETM
** Corresponding author: mdeluque@ucundinamarca.edu.co

ecosystems. Currently, Colombia has a wide variety of ecosystems with great diversity, making it the second most biodiverse country worldwide. However, activities such as land usurpation, changes in local regulations on land use, investments in logging and burning and the need to connect historically isolated towns have threatened these ecosystems.

This historical displacement made it possible to increase the agricultural and livestock frontier, transforming natural ecosystems into fragmented landscapes, altering the functionality, stability and dynamics of all the country's ecosystems. Currently, Colombia is characterized by having a wide variety of ecosystems that make up a great diversity, being considered the second most biodiverse country at worldwide, but activities such as usurpation of lands, changes in local regulations on land use, investments to carry out logging and burning and the need Establishing connectivity between historically isolated towns, has caused their ecosystems to be in the category of threats.

In 2016, the peace agreement was signed with FARC guerrillas, wherein the Zones Most Affected by the Conflict (ZOMAC) were created, made up of 344 cities, which prioritized the advancement of productivity issues. environmental sustainability and justice for victims. Likewise, the ZOMACs must adjust their Territorial Development Plans (PDT) in terms of peacebuilding and environmental protection. However, identifying environmental problems in these territories is not easy, especially because of human-environment conflicts. This problem affects the well-being of the community because it does not contemplate sustainable land use planning. For this reason, it is necessary to establish an investigative baseline that develops strategies for the prevention and mitigation of land deterioration. Tools such as geographic information systems (GIS) are very useful in the diagnosis of sustainability and ordering of development plans in terms of land use, availability of natural resources, agricultural production and environmental risks, when aiming to adapt to climate change (Palacios Bermúdez, 2015).

Land cover changes have become a priority for local governments when formulating forest protection policies and land planning (Moncada Rasmussen, 2010). GIS technologies are widely used in landscape studies at different scales because they have the ability to adapt information from the Earth's surface by spatially extracting georeferenced data to build accurate models (De Luque et al., 2019).

GIS technological solutions visualize geographic information, generating an interpretive framework for understanding and analyzing information related to a specific territory (Alonso Sarría, 2006). The adoption of GIS in the socio-environmental context has made it possible to correlate geographic data with hydrological, meteorological, demographic, cadastre management, and vegetation, soil and air quality, among others. Although the use of GIS in Colombia is not a novelty since government departments and agencies have built robust visualizations, use in supporting new research topics and problems related to informed political decision-making has not yet been explored.

This research compiled and interpreted geographic and temporal data on land use cover changes to articulate the process of diagnosis of sustainable integral development and land use planning in Silvania.

2. Material and methods

2.1. Study area

The study focused on the municipality of Silvania in the Department of Cundinamarca, as shown in Fig. 1., located in the south west of Cundinamarca near to the University of Cundinamarca. It has a population of 22.020 in an area of 163 km² and has undergone multiple socioeconomic transformations in recent. The extrajudicial actions of groups and clashes with public forces have transformed land use and changed the social composition, eroding the well-being of the population and affecting biodiversity throughout

the territory. Three municipalities in the region, Cabrera, Viotá and Silvania, were designated as ZOMAC. Since 2018, they have included peace building in municipal planning.

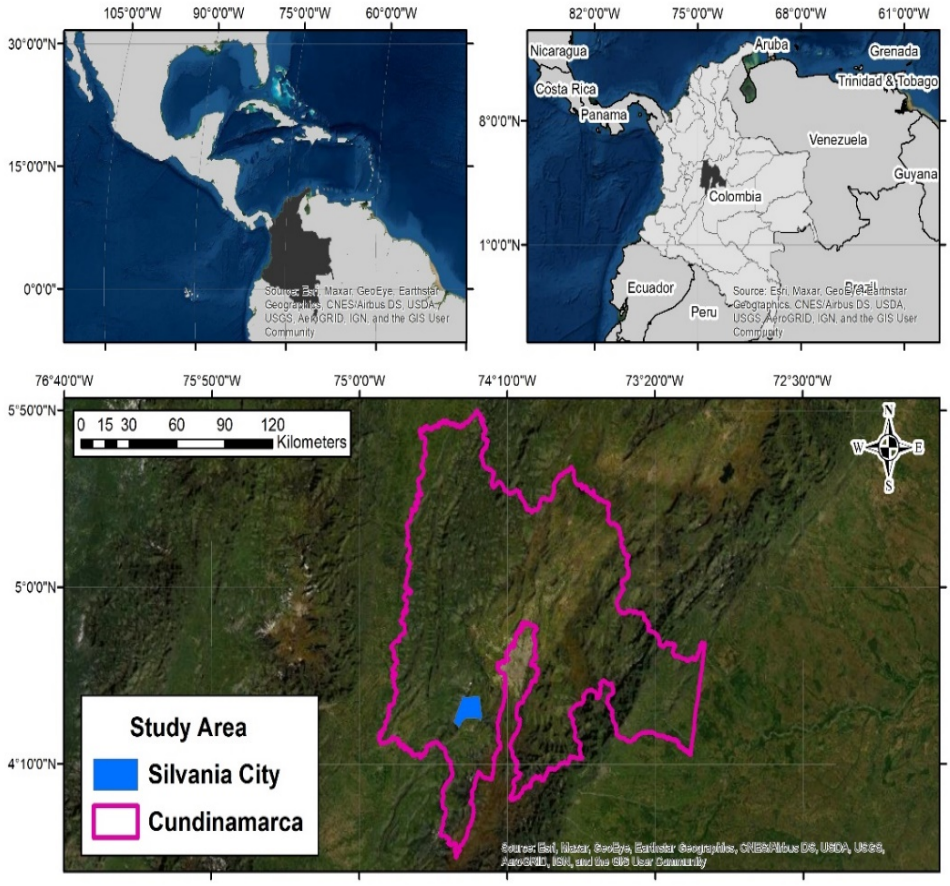

Fig. 1. Study area, Silvania, Cundinamarca, Colombia

2.2. Land cover classification

Planetscope images, acquired on March 22, 1994 and February 02, 2019, were used for the land cover classification. Planetscope has 4 spectral bands: Blue 455 -515 nm, Green 500 - 590 nm, Red 590 - 670 nm, NIR 1 780 - 860 nm and 3 m spatial resolution.

The photointerpretation of the satellite images was done with ArcGIS 10.5, following the Corine Land Cover methodology adapted for Colombia-CLCC. The acquired satellite images were treated with radiometric corrections using ENVI 5.3 (Aguilar Arias et al., 2015) in order to obtain measurements consistent with the characteristics of the Earth's surface and higher level results (Chander et al., 2009).

3. Results and discussion

Fig. 2 shows the land cover changes during the study period. The forest land cover change in Silvania was not significant when compared to other areas in Colombia, decreasing over the last 20 years by only 6% (Fig. 2). Some of these forest patches were

replaced by artificial territories and agricultural areas; a major land change was observed in northeastern Silvania.

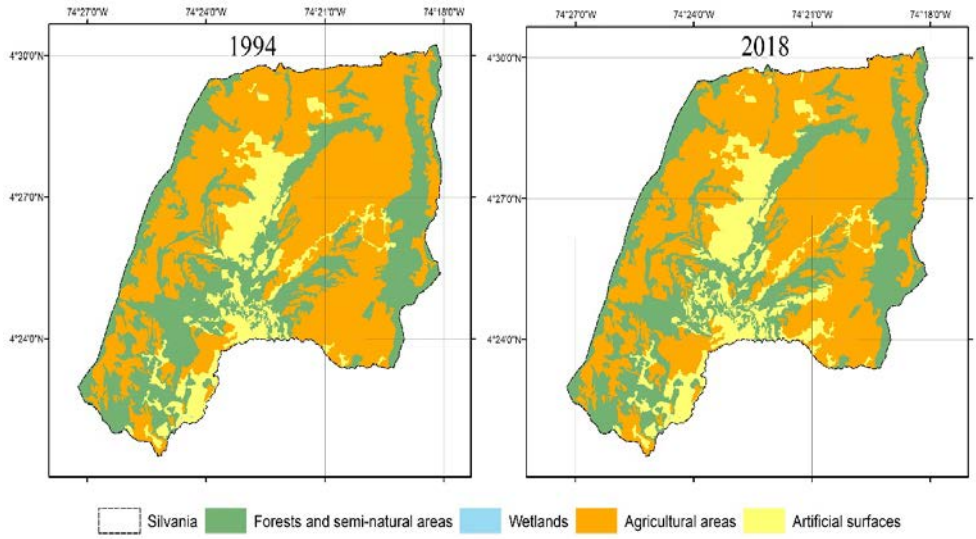

Fig. 2. Silvania Land cover maps for the years 1994 and 2019

Table 1 shows the land cover percentages for 1994 to 2019. The spatio-temporal trend for land cover from 1985 to 2018 showed a loss of forest and semi-natural area (316 ha) as a result of an increase in agricultural (22 ha) and artificial territories (338 ha). Silvania has a fundamentally agricultural economy thanks to the high fertility of the soil in this area. In addition, this city is an alternative center of production and food supply for the country's capital. Likewise, artificial territories have grown because of the demand for urbanized areas by the population.

Table 1. Silvania Land cover change

Land Cover	***Year***		***Land cover change %***
	1984	***2018***	
Artificial territories	1980 (ha)	2317 (ha)	17 %
Agricultural territories	8768 (ha)	8746 (ha)	0.25 %
Forest and semi-natural areas	5539 (ha)	5224 (ha)	6%
Wetlands	2 (ha)	2 (ha)	0

Geographic information systems (GIS) and remote sensing were used to assess, monitor and follow-up on land use and coverage in the municipality of Silvania from 1994 to 2018. Where the loss of forests and natural areas was no more than 6%, insignificant when compared to other Colombian areas where the rate of deforestation has been quite accelerated or areas such as protected areas that, after the Colombian peace agreement with the Revolutionary Armed Forces of Colombia (FARC), have seen a dramatic and very significant increase in the rate of deforestation, including their buffer zones (Clerici et al., 2020). This loss of forest land

cover in the country is due to illegal human activities that alter the characteristics of the ecosystems, diminishing ecosystem services and affecting food security.

For this reason, identifying agricultural territories and conserving forest areas are essential to maintaining food security given the growing demand for food and climate change. Management of depleted water resources through improved irrigation and storage systems, together with flood or drought resistant crop varieties, can contribute to sustainable agricultural practices and maintain food security (Karthikeyan et al., 2020). For example, Forests and semi-natural areas in Silvania provide important cover for water infiltration, capture and accumulation, generating spongy soils with a high capacity for regulating the moisture content produced by a moss mattress, which forms a sponge that retains water in times of rain and progressively releases it in times of drought, feeding aqueducts in seasons of scarcity and providing regulation and supply ecosystem services. If food security is to be guaranteed in the municipalities most affected by Colombia's internal conflict (ZOMAC), such as Silvania, GIS tools are an important component of land use planning. GIS are technological solutions that visualize geographic information with a potential to generate an interpretative framework for understanding and analyzing information related to a specific territory. This geospatial tool can be used with the free and real time information from social, environmental, and biological components in the municipality of Silvania, which public institutions, universities, and citizens can access. Difficulties in territorial management and planning in Colombia include the lack of transparency and low access to information for the public and officials from different areas of the public sector. The gaps between major and intermediate cities and municipalities tend to impede the access to open data the design of platforms, the quality and traceability of information, and the digitalization and accessibility of strategies.

4. Conclusions

The Forest and semi-natural area land cover change was not significant over the last 20 years, a positive significance for biodiversity conservation, possible because Silvania, an area affected by the Colombian armed conflict, did not venture into remote areas, which would have caused deforestation. However, after the demobilization of the Colombian guerrillas, areas such as the Amazon, Choco and Caquetá have presented an unprecedented high rate of deforestation. For this reason, Silvania wishes to avoid these environmental conflicts, which requires sustainable development of the landscape matrix in order to mitigate the impact of socioeconomic activities on the natural habitat, along with tools such as geographic information systems that monitor these changes. Special emphasis should be placed on monitoring the positive delta seen in the average area of the forest patch and the semi-natural covers, which should be corroborated with an assumption of an upward trend scenario.

Acknowledgements

The community and the Mayor's Office of Silvania are thanked for support in the field activities and the services provided. This research was supported by funding from the Universidad de Cundinamarca, Gobernación de Cundinamarca and MinCiencias Colombia BIO program Project “Herramienta geoespacial para la construcción del diagnóstico socioambiental del Plan de Desarrollo Territorial del municipio de Silvania –Cundinamarca” 63546. This funding was provided by the Science, Technology and Innovation Fund of the General Royalties System, administered by the "Francisco José de Caldas" National Financing Fund for Science, Technology and Innovation.

References

Aguilar Arias H., Mora Zamora R., Vargas Bolaños C., (2015), Atmospheric correction methodology for Aster, Rapideye, Spot 2 and Landsat 8 images with Envi Flaash module software, (in Spanish), *Revista Geográfica de América Central*, **2**. DOI: 10.15359/rgac.2-53.2.

Alonso Sarría F., (2006), *Geographic information systems*, (in Spanish), University of Murcia, Murcia, Spain, On line at: https://www.um.es/geograf/sigmur/sigpdf/temario.pdf.

Chander G., Markham B.L., Helder D.L., (2009), Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors, *Remote Sensing of Environment*, **113**, 893-903. DOI: 10.1016/j.rse.2009.01.007.

Clerici N., Armenteras D., Kareiva P., Botero R., Ramírez-Delgado J.P., Forero-Medina G., Ochoa J., Pedraza C., Schneider L., Lora C., Gómez C., Linares M., Hirashiki C., Biggs D., (2020), Deforestation in Colombian protected areas increased during post-conflict periods, *Scientific Reports*, **10**, 1-10. DOI: 10.1038/s41598-020-61861-y.

De Luque M.A., Pérez Y.P., Rodríguez Y.A., Jiménez Rodríguez C., (2019), Analysis of the forest fragmentation process: methodologies oriented in the use of geographic information systems and landscape metrics, (in Spanish), *Ciencias agropecuarias*, **5**, 32-41. DOI: 10.36436/24223484.193.

Karthikeyan L., Chawla I., Mishra A.K., (2020), A review of remote sensing applications in agriculture for food security: Crop growth and yield, irrigation, and crop losses, *Journal of Hydrology*, **586**, 124905. DOI: 10.1016/j.jhydrol.2020.124905.

Moncada Rasmussen D.M., (2010), Spatio-temporal analysis of oak forests (Quercus humboldtii Bonpl.) change and its relationship with pottery at Aguabuena (Ráquira-Boyacá), (in Spanish), *Colombia Forestal*, **13**, 275-298.

Palacios Bermúdez E., (2015), *Multitemporal analysis in the forested coverage of the northern area of the Chocó department 1990-2014*, MSc Thesis, (in Spanish), University of Manizales, Manizales, Colombia, On line at: https://ridum.umanizales.edu.co/xmlui/handle/20.500.12746/2459.

Turriago Rojas D.G., (2016), Peace Process in Colombia: the Road to Reconciliation?, (in Spanish), *Actualidades Pedagógicas*, 159-178. DOI: 10.19052/ap.3827.