

BLUEPRINT PROJECT FOR SUSTAINABLE LANDSCAPES

Multiscale analysis of land covers for the Zona Bananera municipality, department of Magdalena, Colombia

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Abstract

Assessing environmental and social sustainability at the landscape level poses significant challenges related to the availability of accurate cultural, economic, and ecological information. In this sector, decision-making must take this intersectional information into account to develop management strategies that enhance the sustainability of the territory, prevent detrimental actions to ecosystem services, and defend against poor socioeconomic management of a region.

To obtain key information in planning and land use planning processes, it is important to generate accurate spatial data associated with land cover and/or land use. This data is crucial to create monitoring and follow-up indicators of socio-ecological sustainability, as well as define actions that enroll different actors to work towards the sustainable management of said territory-landscape. This report aims to give an approximation on how to obtain land cover maps at different cartographic scales with aims to facilitate the analysis of information and ultimately evaluate which scale and method combinations offer the best balance between precision of data generated and resources invested.

The document describes the identification and classification processes of land covers through two methodologies:

1. Through visual interpretation on screen and
2. By supervised interpretation from automated classification algorithms.

A comparison was made between the land cover classification scales at a scale of 1:5,000, 1:25,000 and 1:100,000.

The results of this comparative analysis between land cover classification methods made it possible to identify the advantages and disadvantages of each, helping to inform a final guide to achieving sustainability of landscape-territories at different scales.

Methodological, multi-scale analysis for obtaining land covers within two study windows: the municipality of Zona Bananera, department of Magdalena, Colombia

In the project titled "Optimization and Evaluation of Landscape Sustainability: Development of an Evaluation Framework and Pilot Phase in the Municipality of Zona Bananera, Magdalena, Colombia", the generation of thematic cartography has been identified as a key component to a successful project. For land cover and use in the defined areas of interest, evaluating the ecological and territorial conditions present in the agricultural landscape is crucial, especially when coupled with high intensity land use.

The main objective is to evaluate and compare two classification methods and their role in generating accurate land cover information from medium resolution satellite images (scales 1:5,000 - 1:25,000 and 1:100,000). Also, as an added value to the study, different land cover analysis methods are reviewed through unsupervised classification algorithms to display respective strengths and weaknesses.

This document presents a variety of available geographic services and their coverage information from various satellite image classifications. The following chapter presents a supervised classification analysis from an algorithm using Random Forest, followed by the results associated with the visual interpretation of Corine Land Cover methodology. Coverage at a 1:25,000 scale for the defined study window areas is analyzed using the tools of unsupervised classification, supervised classification, and visual interpretation on screen. Additionally, comparisons between the scales are interpreted using visual, on-screen methodologies.

Geoservices available with information on land covers through unsupervised classification algorithms

Obtaining information on the current state of land cover is an essential aspect for the planning and management of a territory at a landscape scale. This information is crucial for monitoring since the current coverage metrics allow for future comparisons. By recording landscape coverage data, the evaluation of a site's development and evolution becomes much more accessible, even extending towards the region's socio-cultural and economic aspects. Therefore, in any part of the country or countries where you plan to implement a landscape assessment and planning, it is important to consider the availability of satellite images and accompanying classification measures.

The main geoservices available at the international or national level typically define coverage information automatically. This automatic definition, also referred to as an unsupervised definition, means the classifications are made using maximum likelihood statistical algorithms,

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neural networks and/or decision trees which classify the pixels by reflectance ranges. This unsupervised method is not supplemented by on-the-ground verification of forest cover.

Geoservice Global Forest Change - High-Resolution Global Maps of 21st-Century Forest Cover Change (Hansen et al, 2011).

Professor Dr. Hansen ¹, from the University of Maryland in the United States, published his work based on the exploration and analysis of landsat images with spatial resolution of 30 meters for the entire planet in 2013. This input presents the forest gains and losses between the years 2000 to 2012 and the last update of its geovisor, with associated data collected between 2000 and 2019. For more information on the methods in which this geoservice operates, you can consult the following access link (<https://earthenginepartners.appspot.com/science-2013-global-forest>). Additionally, the coverage classification code is also available on the Google Earth platform engine.

With this Global Forest Change service, the classification of the coverage is separated into two categories: forest and non-forest. These distinctions are made from training data that allows the statistical classification model to be calibrated from spectral bands 3, 4, 5 and 7. However, Hansen clearly recognizes that the classification system may present some inconsistencies according to the different remote sensors from Landsat. Likewise, it should be noted that a complete validation of the data has not been carried out with the results obtained with Land Images Satellite 8.

To analyze this geoservice, a search was made for the classification of deforestation by temporalities, in which a strong deforestation was identified for the study area in Zona Bananera for the 2018 period. According to Figure 1, the coverage information carried out at the national level by Ideam ², showed that within this period and region, high levels of deforestation allowed for the establishment of banana and oil palm coverage to be established in more than 80% of the territory. This transition happened 30 or more years ago.

¹Hansen, MC, PV Potapov, R. Moore, M. Hancher, SA Turubanova, A. Tyukavina, D. Thau, SV Stehman, SJ Goetz, TR Loveland, A. Kommareddy, A. Egorov, L. Chini, CO Justice, and JRG Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342 (November 15): 850–53. Data available online from: <http://earthenginepartners.appspot.com/science-2013-global-forest>.

²Ideam: Institute of Hydrology, Meteorology and Environmental Studies, Subdirectorate of Ecosystems and environmental information; non-forest forest maps for Colombia at a scale of 1:100,000.

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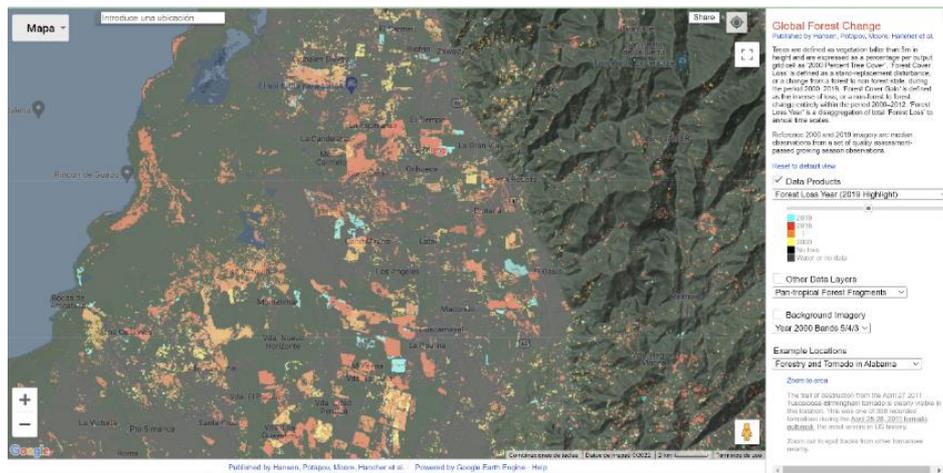


FIGURE 1. CLASSIFICATION OF COVERAGE BY DEFORESTATION BETWEEN THE PERIODS 2000 TO 2019 ACCORDING TO THE ALGORITHM BUILT BY HANSEN ET AL, 2019.

In conclusion, it can be stated that Hansen's deforestation model is an interesting tool for global analyses, however the identification of land covers is limited to two classes (Forest and Non-Forest). The classification method used does not allow for discriminating and differentiating losses/changes in land use between Banana and oil palm coverage, which can generate inaccuracies for decision-making at the regional and local scale.

This tool is useful in areas of humid tropical forests and areas of forests such as the Amazon, where deforestation processes are easily detected by the Hansen algorithm, but doubts remain when there are coverages with spectral similarity to that of forests elsewhere. This happened to be the case with oil palm and banana coverage for the municipality of Zona Bananera. In other words, ***the Hansen Global Forest Change service is not functional for landscapes dominated by crops such as palm and banana.***

Land Cover Geoservices on the Global Forest Watch Platform

Like the previous case, the Global Forest Watch platform also uses satellite images. A platform called Base Sat is used to perform the classification of land covers and similarly, the platform uses the classification algorithms developed by Hansen in much of its findings. The platform takes Hansen's Forest and non-forest classifications one step further by integrating them with other indicators such as the density of cover and altitude ranges of trees, which employs information from Lidar sensors.

The classifications of land cover for Zona Bananera on the platform were reviewed, where two temporalities of coverage analysis are highlighted, one for the year 2000 and the other for the year 2010. According to this information, the statistics for the two windows of analysis were generated resulting in data that shows ***54% of the area categorized as tree cover,*** as shown in Figure 2.

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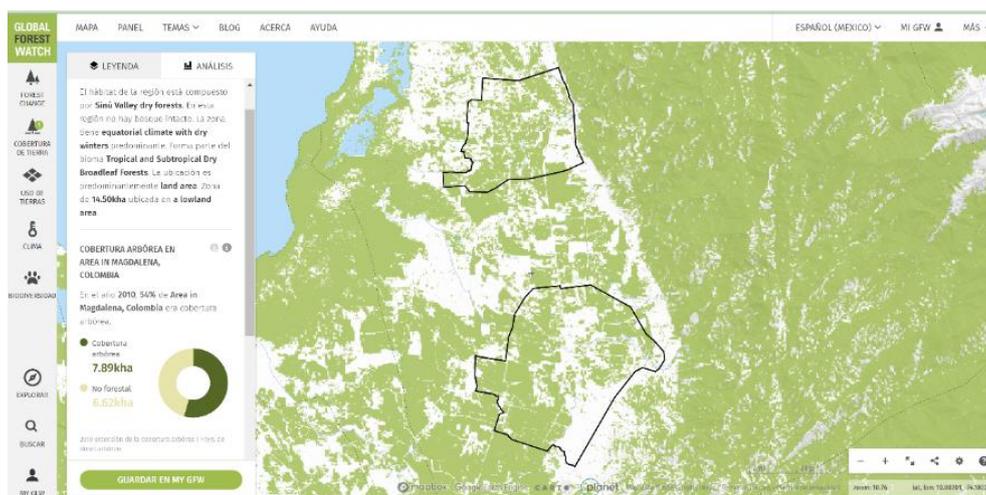


FIGURE 2. TREE COVERAGE PRESENT FOR THE YEAR 2010 ACCORDING TO A COVERAGE GREATER THAN 75% DENSITY AND FOR THE TWO WINDOWS UNDER STUDY IN THE MUNICIPALITY OF ZONA BANANERA.

Based on the coverage information present in the two windows being studied, combined with the historical process and land use in the areas that appear with tree cover, we can see that, these **are areas defined by oil palm crops and banana plantations**. Therefore, we infer that in this geoservice, agricultural crops are interpreted as if they were a natural or semi-natural tree cover. **The foregoing is affirmed based on the previous studies carried out for the two windows at a scale of 1:5,000 and the corroboration in the field, where it was observed that in the southern zone of the two windows there are palm plantations established more than 15 years ago and no forests that Global Forest Watch suggests.**

Both above geoservices described display difficulties in obtaining accurate information at local scales for both international and national classification algorithms. These geoservices generate inputs that can be considered useful for large-scale analyses, but in terms of landscapes at the municipal level, with smaller study windows and analysis units, the information has the risk of presenting confusion and misrepresenting agricultural coverage and identified forest cover.

Sentinel EO Browser Platform Geo Services Hub

This service is provided by the European space agency (ESA) through its Sentinel Program HUB and uses satellite images with a spatial resolution of 10 meters. Therefore, its resolution presents information with greater detail, reaching scales of 1:25,000. Figure 3 shows the 1:25,000 scale, carried out using the Corine Land Cover methodology, and the 1:5,000 scale, produced by the same method. This example allows us to observe the level of detail that can be obtained with submetric satellite images and a spatial resolution of 5 to 10 meters.

The use of one method or another will depend on the objective of the project or territorial planning of the landscape that is going to be carried out, either

- Property scale/window, with actions directly involving property owners or Communal Action Boards of the villages, or

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- With a regional municipal vision, in which general recommendations are provided and actions are delegated to property owners.

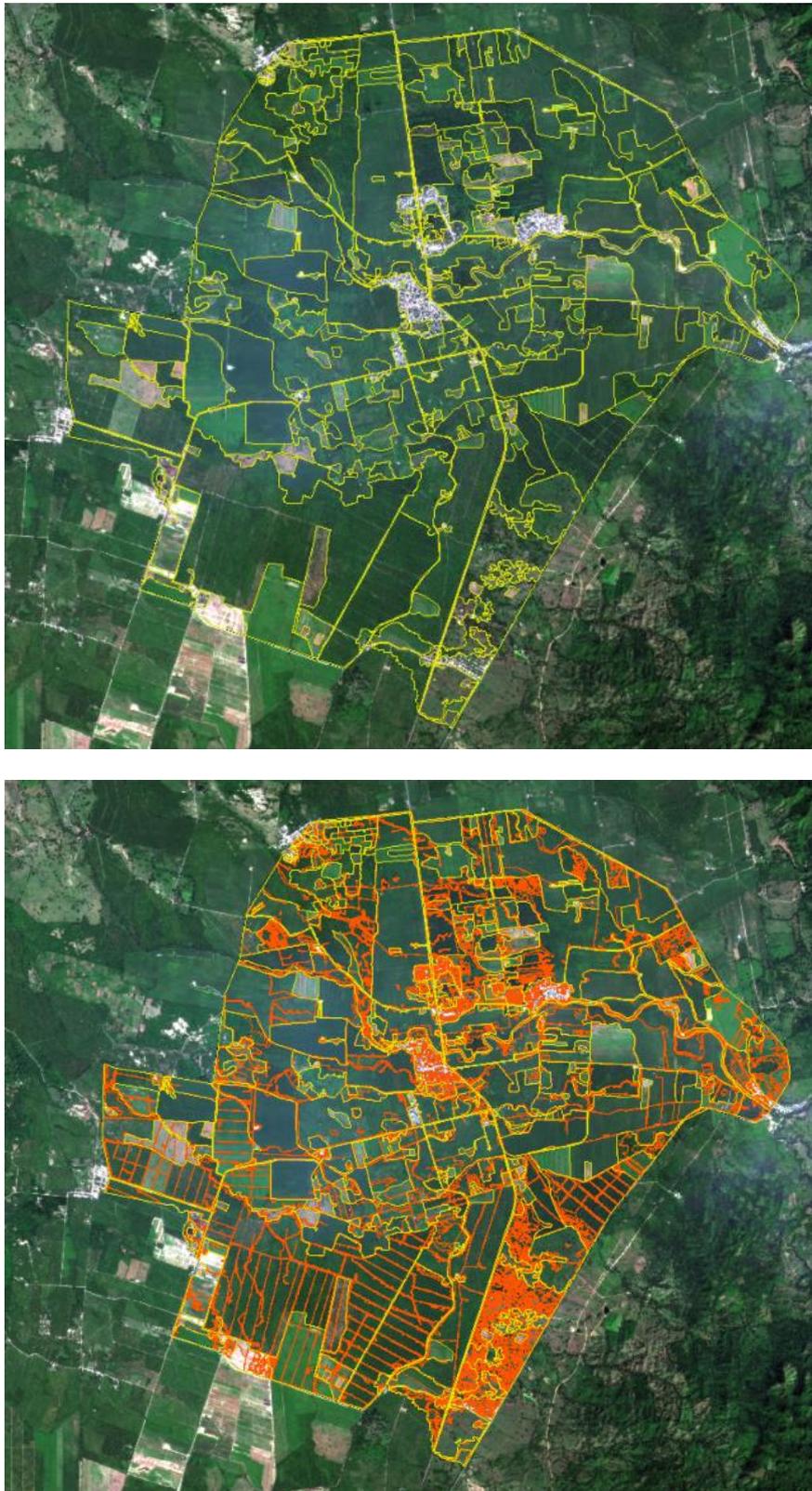


FIGURE 3. COMPARATIVE LEVEL OF DETAIL IN THE INTERPRETATION AT THE 1:5,000 SCALE (LEFT IMAGE) AND THE 1:25,000 SCALE (RIGHT IMAGE IN RED).

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Obtaining three coverage scales through visual interpretation and Corine Land Cover methodology for the regions under study allowed us to identify the main differences in the detail and precision within the land covers. In turn, the comparison of the information with the supervised classification method showed considerable differences between the data of one method with respect to the other (Figure 4).

In relation to the supervised classification method, when contrasted with the other scales, it was possible to identify that this method allows for obtaining data per pixel (4.7 meters), generating a high level of detail in the coverage description. However, this can make it difficult to homogenize continuous coverage, as in the case of oil palm where there may be areas of pasture or roads that disrupt labeling by the management production system.

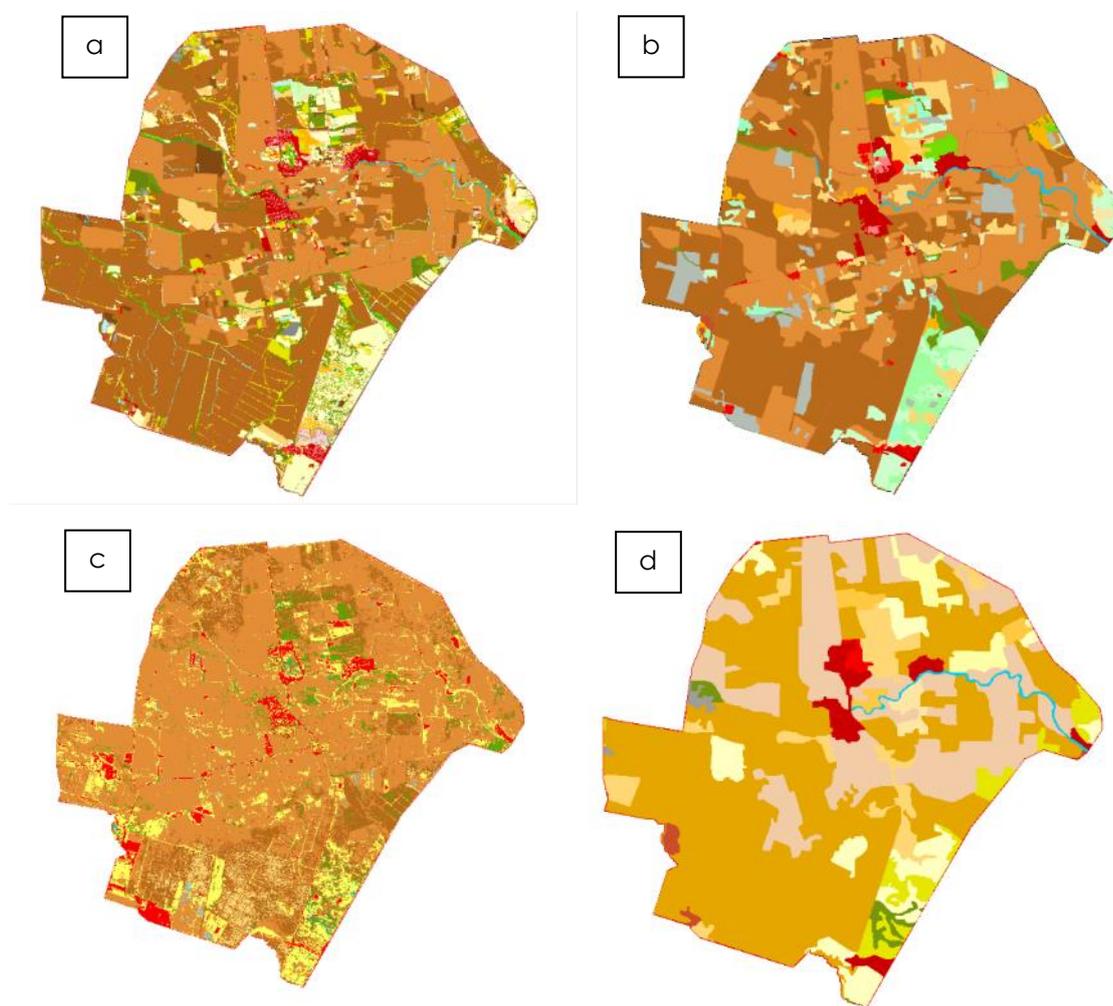


FIGURE 4. COMPARISON OF LAND COVERS OBTAINED BY THE DIFFERENT SCALES OF ANALYSIS AND CLASSIFICATION METHOD: A. CLC VISUAL METHOD SCALE 1:5,000 – GREATER PRECISION AND DETAIL B. CLC VISUAL METHOD SCALE 1:125,000 C. SUPERVISED CLASSIFICATION METHOD AND SCALE 1:25,000 AND D. CLC VISUAL CLASSIFICATION METHOD AT A SCALE OF 1:100,000 – IDEAM 2018.

The 1:5,000 scale (Figure 4a) presents the highest degree of precision and thematic accuracy, ratified with the verification carried out in the field. With an outstanding level of detail, this scale presents the largest number of coverage classes.

In relation to the 1:25,000 scale (Figure 4b), information on internal roads in productive areas, some green areas associated with the main rivers, detail of some green areas inside urban areas, and secondary vegetation with living fences can be identified in the perimeters of some properties or farms.

On the 1:100,000 scale (Figure 4d), taken as the national reference for the study carried out by Ideam for the year 2018, a strong generalization of the types of coverage can be observed. However, its information and degree of detail is inadequate and insufficient for planning decisions at the local level.

Table 6 compares the main coverages for each scale of information obtained. To facilitate the analysis of the results, the detailed coverages from visual methodology were homologated to be able to compare them with the number of classes obtained in the supervised classification.

The main results show:

1. The overestimation of banana cover in the supervised classification with respect to the visual classification Corine Land Cover;
2. In relation to the same scale 1:25,000, a difference of 14.6% is observed and with respect to the scale of greater detail (1:5,000) where a difference of 23.36% is identified. As compared to the more general scale of 1:100,000, this difference is maintained.

TABLE 1. COMPARISON OF GENERAL COVERAGE FOR THE TWO COVERAGE CLASSIFICATION METHODS AND THE THREE ANALYSIS SCALES PERFORMED FOR THE WINDOWS UNDER ANALYSIS.

COBERTURAS GENERALES	Clasificación supervisada Segmentación 1:25.000		Clasificación CLC Visual 1:25.000		Clasificación CLC Visual 1:5.000		Clasificación CLC Visual 1:100.000	
	Hectáreas	Porcentaje	Hectáreas	Porcentaje	Hectareas	Porcentaje	Hectareas	Porcentaje
Coberturas de la tierra								
Agua	20,8	0,14%	131,760728	0,91%	133,0	0,92%	52,7	0,36%
Areas_urbanas_suelo_desnudo	549,9	3,79%	1095,484745	7,55%	672,9	4,64%	464,6	3,20%
Banano	9116,9	62,87%	6997,69525	48,26%	5729,6	39,51%	5645,9	38,93%
Bosque	531,8	3,67%	280,750844	1,94%	793,3	5,47%	92,7	0,64%
Mosaicos pastos cultivos espacios naturales	356,4	2,46%	1030,528508	7,11%	501,5	3,46%	1257,4	8,67%
Palma	2244,8	15,48%	3859,014365	26,61%	4553,2	31,40%	5625,6	38,79%
Pastos	1637,1	11,29%	1070,823441	7,38%	1701,3	11,73%	1083,6	7,47%
Zonas pantanosas	43,8	0,30%	0	0,00%	0,0	0,00%	0,0	0,00%
Total general	14501,4	100,00%						

- **Oil palm cultivation:** an underestimation of the area can be identified with supervised classification, that is, less area of this coverage is identified with respect to the visual interpretation. It is observed that for the same scale of 1:25,000 in the supervised classification method, the percentage is 15.48% of the analysis windows in this coverage and for the Corine Land Cover method an estimated percentage of 26.61%, resulting in a difference of approximately 11.13%. Compared with other scales, such as the more detailed or precise scale of 1:5,000, a difference of 4.7% can be seen, this may be due mainly to changes in land use and conversion of areas to banana crops.

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- **Natural coverage associated with forests:** shrublands, secondary vegetation or green areas, can be identified in Table 1. The natural coverage obtained through supervised classification is 3.67% while the same scale from the Corine Land Cover method is observed at 1.94%. For this situation, it is observed that the supervised classification method details the forest units and therefore has a greater accuracy in labeling the study area; The foregoing is noted, considering that the 1:5,000 scale relates to 5.47% in forest coverage and semi-natural areas. For forests and natural areas in general scales such as 1:100,000, little or no presence of these natural covers (0.64%) is identified.

As a final part of the analysis, below (Table 7), the main characteristics and results obtained for the different coverage interpretation methods and scales are listed:

TABLE 2. MAIN CHARACTERISTICS AND RESULTS FOR THE CLASSIFICATION METHODS ANALYZED AND THE DIFFERENT SCALES OF ANALYSIS OBTAINED INFORMATION ON LAND COVER FOR THE WINDOWS UNDER STUDY

Characteristic	Scale 1:5,000: visual interpretation, CLC method	Scale 1:25,000: visual interpretation, CLC method	Scale 1:25,000 Supervised classification	Scale 1:100,000: visual interpretation, CLC method
Minimum mapping unit	Defined unit of 1,000 square meters with coverage separation at the highest level and with the creation of new coverage categories for greater thematic accuracy.	Minimum unit of 1.5 hectares, where the roads and small constructions or continuous or discontinuous urban fabric are not detailed, likewise it is not possible to differentiate the semi-natural covers such as live fences, high or low secondary vegetation and small relicts of forests present in the area. Riverbanks.	Minimum unit per pixel (4.7 meters for Planet Scope) is approximately 25 square meters, however this can create <i>salt and pepper effects</i> with mixing between layers. High level of detail and precision for coverages that present a high contrast and when there are no similar coverages in the area to be classified.	Minimum mapping unit of 25 ha and 5 ha for artificialized areas. It is a national and regional analysis classification; therefore, it does not allow a high level of detail in the identification of coverage at a window or farm scale.
Thematic accuracy of coverage	High precision by using images with submetric spatial resolution (in centimeters). Level of coverage separation with greater precision and delineation. Requires field verification for some coverages.	From medium to high thematic precision, it can mask or generalize some coverage that may be important for a local analysis, such as secondary vegetation, alternate and secondary roads, urban green, drainage or small rivers, canals, and construction or discontinuous urban fabric.	The number of thematic classes is limited; therefore, some coverage may fall into a single category; for example, roads and urban areas or palm crops and mixed agricultural areas. Its spatial accuracy is high, but it can generate noise due to very small units inserted in large coverages.	It has adequate and good thematic accuracy for homogeneous and large-scale coverage, but it is limited in specifying small coverage and small-scale land uses.
Execution times	250 hours	120 hours	60 hours	60 hours
Number of coverage classes	42 classes	27 classes	8 classes	18 classes

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Conclusions

- The **geoservices consulted** present coverage classification alternatives in an unsupervised manner from satellite images that allow thematic mapping at scales of 1:100,000 and 1:25,000. The analysis obtained from these geoservices may be of interest for international, national, or regional planning. However, it presents **high limitations in thematic precision and accuracy in productive and agricultural areas**. There is evidence suggesting a need to perform a treatment on satellite images to carry out a supervised classification (visual interpretation) on screen to give greater thematic accuracy of the information associated with land covers.
- Geoservices are useful for consulting and downloading satellite images, but in terms of unsupervised classification analyses available on these platforms, they will mainly serve to carry out a quick and preliminary evaluation to make decisions about downloading information and subsequent processing in specialized software.
- To evaluate a landscape and its territorial context at a local scale implies a high limitation of access to satellite image sources with high spatial resolution. Therefore, there can be a strong limitation to obtaining local scale data. However, the Google Earth Pro platform provides high-resolution images that can be downloaded, but their timing or date of image capture must also be evaluated.
- Medium to high spatial resolution images from the Sentinel and Planet Scope platforms are an alternative to evaluate the landscape at a scale of 1:25,000. However, the possibilities of detailing precise information at the farm level may be limited and therefore limit the ability to evaluate the various coverages at the farm level.
- The 1:100,000 scale presents reliable information for decision making at a regional, departmental, and national scale. The information is valuable for evaluating the main cover classes, but it does not facilitate a detailed analysis of the landscape conditions at a local and/or farm scale.
- The supervised classification method at the 1:25,000 scale presents similar detail to the 1:5,000 scale of the visual method. However, there is a proven misrepresentation of coverage classes and therefore, its reliability is low in the differentiation of coverages. Likewise, they differ between the number of cover classes identified in the 1:5,000 scale and the 1:25,000 scale.
- Visual classification using the Corine Land Cover method, at a scale of 1:25,000, presents greater thematic accuracy within coverage classifications in contrast to the supervised classification. However, this scale does not break down coverage of small extensions less than 1.5 hectares. Therefore, coverage containing secondary roads, live fences, remnant natural vegetation in small areas, among other typologies, are omitted. This observation must be considered according to the objective and scope of the desired spatial analysis.
- The 1:5,000 scale is the one with the greatest precision and differentiation of thematic classes. Consequently, it presents more information for decision-making at the farm and municipal scale, as well as allowing detailed planning and evaluation of attributes or indicators associated with the management of green areas within farms or properties. The above is valid when a project seeks to obtain detailed information for plot scales or windows. Its main limitation to keep in mind are the costs for purchasing satellite images and the time it takes to obtain an interpretation of the coverage.

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- In general, if the measurement of the sustainability of the landscape-territory is considered beyond the unique and specific coverage analysis (that is, this coverage analysis is used as an element within a comprehensive analysis of the territory), it must be associated with spatial data. Quantitative and qualitative methods must be identified at local scales for the environmental, economic, social, and cultural dimensions as well. It would be easier for local actors to identify with said territory to ensure proper understanding of the region. The information from the coverage analysis can be utilized by these local actors and decision-makers in coordination with one another. Important aspects within the projects will serve to improve the sustainability of the landscape with inclusion criteria that is sustainable in the long term with an assignment of responsibilities according to the roles and scope of each actor.

Recommendations for the final Blueprint system for replica

As a suggestion and note for other similar studies in the future, it is ideal to consider an intermediate scale of 1:10,000 to provide more details of the coverage to decision makers at the local level and invest less time than that implemented for the 1:5,000 scale with similar results but less detail on some coverages.

Due to the inaccuracy and errors presented, the use of any publicly available geoservice data is not advised.

For the Blueprint version for future replicas, it is recommended:

1. Regarding use of time; if resources are limited: the supervised classification
 2. If greater coverage accuracy is required, as is necessary for landscapes dominated by agricultural uses: visual classification with field verification.
- Scale of all municipalities for land use planning objectives: 1:25,000
 - Windows with a specific focus defined by local actors or project managers: 1:5,000.