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# DISTRIBUTION OF LAND COVER AND LAND USE IN THE TUMBILLÁN MICRO-BASIN, PROVINCE OF JAÉN THROUGH THE USE OF GOOGLE EARTH ENGINE

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## ABSTRACT

*This research was carried out in the Tumbillán micro-basin, province of Jaén, Cajamarca, with the aim of determining land cover and use (LUC) for the year 2024. The Google Earth Engine (GEE) platform was used as the main tool for geospatial information processing, complemented by the open source programs QGIS and RStudio. The classification was carried out using the Random Forest (RF) algorithm, recognized for its high accuracy in LUC analysis, and was based on the Corine Land Cover (CLC) classification legend. In 2024, seven types of land cover and use were identified: areas with no or little vegetation (1103 ha), shrub/herbaceous vegetation (822.2 ha), permanent crops (749.2 ha), low open forest (639.7 ha), pastures (207.3 ha), transitional crops (112.2 ha) and discontinuous urban fabric (65.1 ha). The results showed that the largest proportion of the territory is occupied by areas with no or little vegetation (29.8%), followed by shrub/herbaceous vegetation (22.2%) and permanent crops (20.3%). The implications of land cover are related to the water capture and infiltration capacity offered by each type of cover. Protected soils, such as those with forests, conserve biodiversity better and are less susceptible to erosion, while soils with low cover are more prone to erosion and accelerated deterioration, especially during rainfall.*

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**KEYWORDS:** Land Cover, Land Use, Google Earth Engine, Corine Land Cover, Microwatershed.

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## 1. INTRODUCTION

Cover and use of the soil, is expressed through the description of the different forms of vegetation cover and land uses; the purpose is to make known the different types of use at a given time and the way in which the use of its resources has been developed, without taking into account their potential or future use; that is, it allows us to know the effective use of the territory in its different landscape units and the way in which the use of the natural resources of soil, water and vegetation has been developed (Alcántara, 2011).

In recent years, the sub-basin of the Jaénstream has been rapidly intervened by anthropic activity, causing severe impacts on the production of ecosystem services, such as water production, soil protection, carbon sequestration, and other services that it generates for society and the environment.

The sub-basin of the Jaénstream has an area of approximately 35400 ha. In it there are dry and cloud forests with high biodiversity, which are of vital importance in the cyclical maintenance of water that sustains the capture, storage and headwaters of streams that when joined together form the Jaénstream (Provincial Municipality of Jaén, 2012).

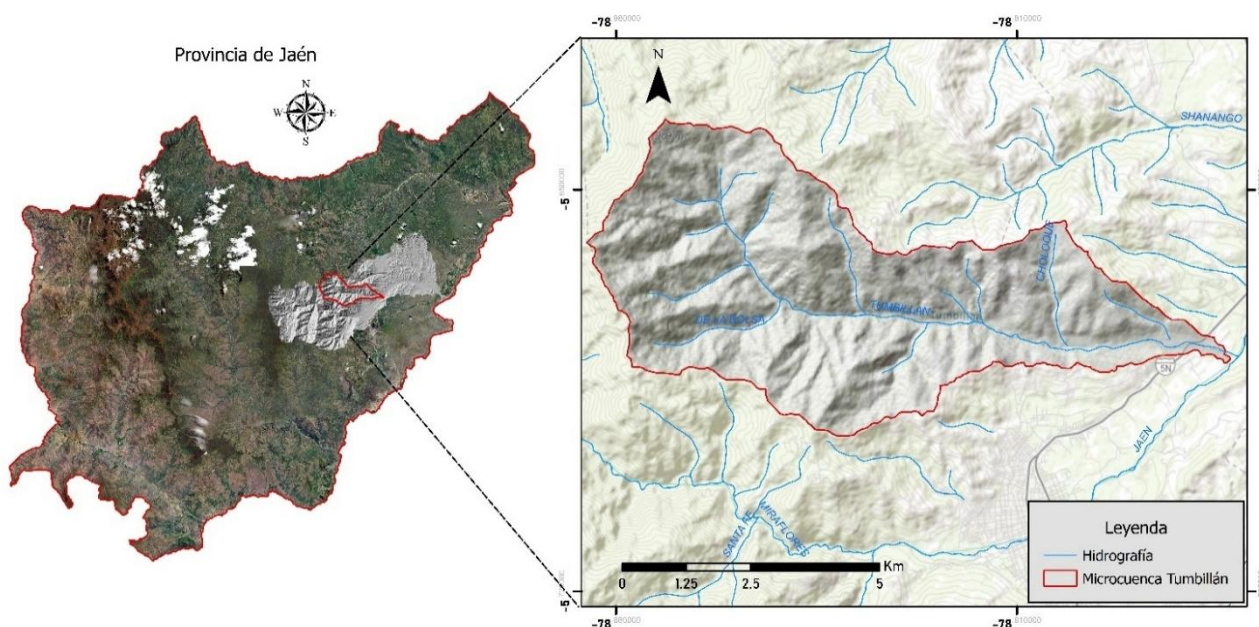
Previously, studies carried out by Ato & Gonzales (2019) determined coverage in the Amojú basin for the year 2019, finding in the Tumbillán micro-basin a

mosaic of pastures, crops, and natural spaces. In this sub-basin, the Tumbillán micro-basin only has 3698.7 ha; which means 10.5% of the Jaén sub-basin. The migration of people, especially farmers in fragile areas of the upper part of the sub-basin, has caused serious negative impacts on the ecosystem, endangering water production for the life of the water and other environmental services it generates (MPJ, 2012).

## 2. MATERIALS AND METHODS

### *Study area.*

The micro-basin of the Tumbillán creek has a total area of 3689 ha and is located in the province of Jaén, comprising part of the districts of Jaén and Las Pirias (Figure 1). In its lower part it has slight slopes no greater than 15°, while in the middle and headwaters it has steep slopes with undulating landscapes and a severely fragmented forest ecosystem. Hydrographically, this micro-basin belongs to the sub-basin of the Quebrada Jaén, which in turn integrates the Alto Marañón III inter-basin (Regional Government of Cajamarca, 2014). The Tumbillán creek is an important tributary of the Jaén Creek, which joins it in the lower part of this sub-basin, specifically in the town of "Yanuyacu", where it is used for the irrigation of hundreds of hectares of agricultural crops.



*Figure 1: Location of the study area.*

### *Delimitation of the micro-basin*

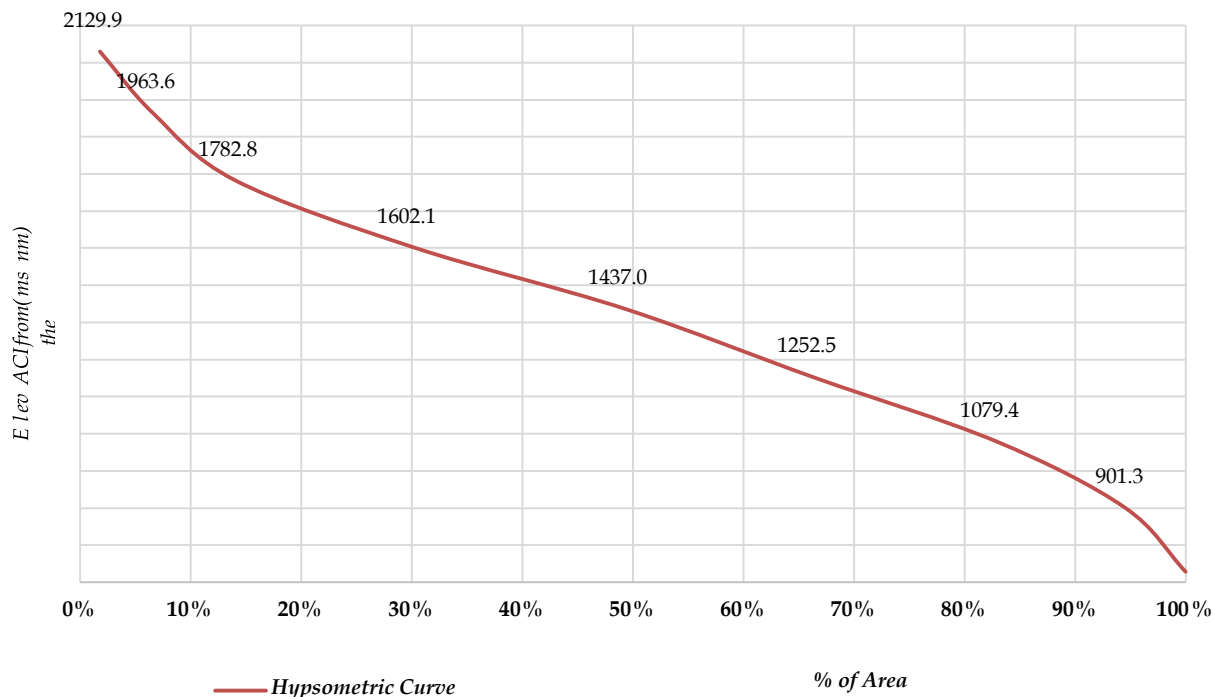
This process was carried out using the free software SAGA GIS, using as the main input a DEM

of the study area, it was delimited taking as an exit point the mouth of the Tumbillán creek in the Jaén ravine. The result of this processing was a polygon-

type shapefile file with the perimeter of the micro-watershed, this same file was imported into the "assets" section on the GEE platform and used as a

clipping mask for the Sentinel 2 satellite image of the year 2024. The hypsometric curve of the micro-basin is shown below:

*Hypsometric curve of the micro-basin*



**Data collection**

It was made from the Copernicus data catalogue on the GEE platform, this dataset is publicly accessible (Tsfaye et al., 2024). A date range filter was used that included the months of September to December 2024 due to low rainfall and consequently cleaner cloud images

(Takaku et al., 2014) found that the use of a DEM is essential in classification, and its use can increase the final accuracy of classification. Therefore, it was incorporated as an auxiliary variable to processing. This incorporation was made from the data catalog of "ALOS DSM: Global 30m v3.2" in GEE, and was used to generate the topographic indices (Tadono et al, 2014).

**Tile Preprocessing**

The pixels with the presence of cloud cover were removed from the image thanks to GEE's "cloud mask" function, and finally a composite image was obtained for the year 2024 by applying the "median" function on the same platform. A radiometric and atmospheric correction was subsequently performed. The selection of Sentinel 2 products was mainly based on having a spatial resolution of up to 10

meters, a temporal resolution of 6 days and free access (Berra et al., 2024).

**Processing and obtaining spectral indices and topographic variables**

The spectral indices were calculated from the satellite image obtained previously, these were: Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Improved Vegetation Index (EVI) and the Soil-Adjusted Difference Vegetation Index (SAVI), this processing was carried out in GEE (Huang et al., 2021).

The auxiliary variables used in this study were slope and elevation, and were obtained from a DEM from the data catalog of "ALOS DSM: Global 30m v3.2" in GEE (Takaku et al., 2014).

**Sampling areas**

They were taken in the field from visits made in the months of September to December 2024, as a result seven types of land use were identified, which are: Areas with no or little vegetation, shrub/herbaceous vegetation, permanent crops, low open forest, pastures, transitory crops and

discontinuous urban fabric. These areas were georeferenced with a GPS device and later incorporated as sampling areas to the GEE platform. After that, areas were uniformly identified in inaccessible areas with the help of an optical image from Google Earth Pro, so that the sample is representative and ensures accurate results at the time of classification. In total, 189 areas were collected both in the field and through Google Earth Pro.

**Image classification**

The Random Forest algorithm was used for classification (Breiman, 2001) which is one of the most used and best precision classifiers incorporated into the GEE platform. Parameters such as the number of decision trees were adjusted, which in this case were 70.

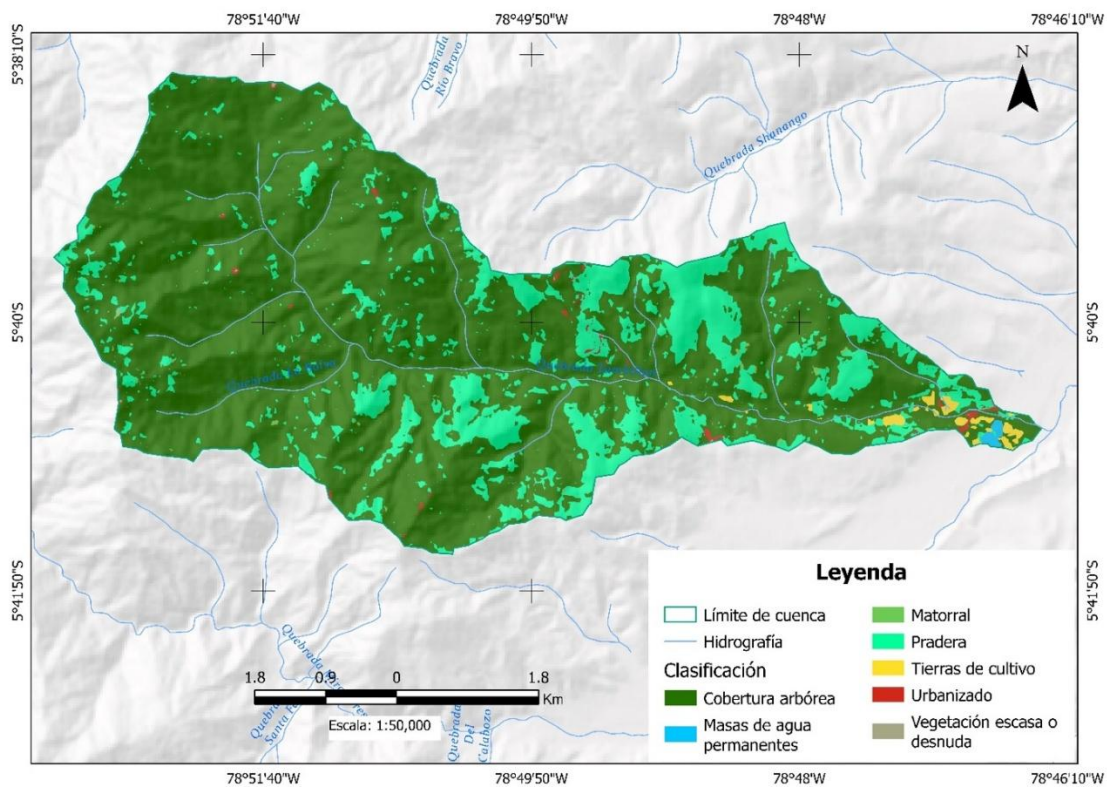
Of the data collected, 70% was used for training and 30% for validation.

**Comparison of the map obtained with the WorldCover 10 m 2021 map of the European Space Agency (ESA)**

ESA's WorldCover 10 m 2021 product provides a global land cover map for the year 2021 with a spatial resolution of 10 metres, based on data from Sentinel-1 and Sentinel-2. This product includes 11 classes of land cover and was generated within the framework of ESA's WorldCover project, which is part of ESA's 5th Earth Observation Coverage Programme (EOEP-5) (Zanaga et al., 2022).

To access the ESA map, the GEE data catalog (<https://developers.google.com/earth-engine/datasets?hl=es-419>) was used, using the "clip" function, a LUC cutout was made for the study micro-basin, the quantification and final design of the ESA LUC map was carried out in the QGIS software.

The comparison between both maps was made based on the quantified coverage results.



**Figure 2: Distribution of LUC in the Tumbillán micro-basin by ESA 2021.**  
Source: Prepared with data from ESA's WorldCover.

**3. RESULTS**

The results of the LUC classification are shown in a quantified way in the following table:

**Table 1: Quantification of LUC in the Tumbillán micro-basin year 2024.**

No	Coverage	Area (ha)	Occupancy rate (%)
1	Permanent crops	749.2	20.3

2	Discontinuous urban fabric	65.1	1.8
3	Pastures	207.3	5.6
4	Shrub/herbaceous vegetation	822.2	22.2
5	Areas with little or no vegetation	1103.0	29.8
6	Low open forest	639.7	17.3
7	Transitional crops	112.2	3.0
Total		3698.7	100.0

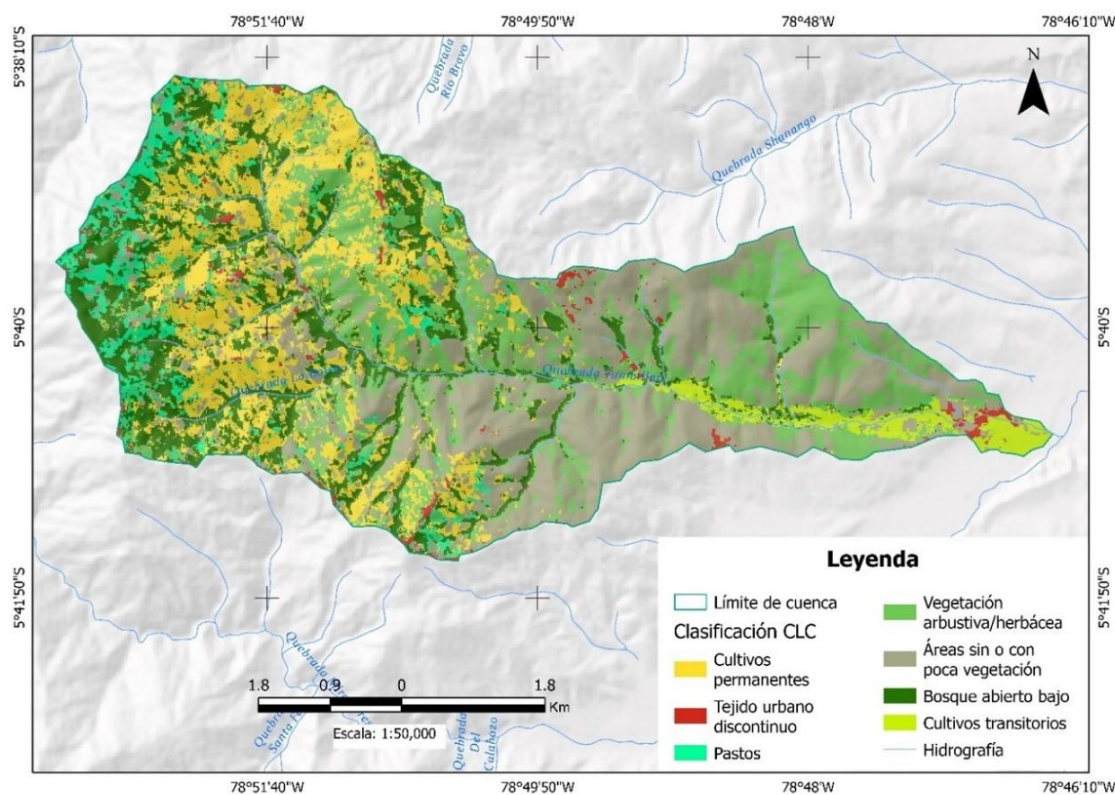
The results of the LUC quantification of ESA's WorldCover map are shown in the table below:

**Table 2: Quantification of LUC in the Tumbillán micro-basin According to the ESA in 2021.**

No.	Coverage	Area (ha)	Occupancy rate (%)
1	Prairie	668.6	18.1
2	Urbanized	13.7	0.4
3	Tree cover	2976.9	80.5
4	Scrub	10.3	0.3
5	Sparse or bare vegetation	1.3	0.03
6	Farmland	21.7	0.6
7	Permanent bodies of water	5.8	0.2
Total		3698.3	100.0

The spatial distribution of LUC in the micro-basin shows small remnants of low open forest distributed mostly in the middle and upper parts of the micro-basin, the deterioration in this specific ecosystem is due to the great progress of the expansion of agricultural lands and the establishment of pastures for livestock purposes. In addition, the map shows the spaces occupied by permanent crops throughout

the upper part of the micro-basin, these crops would not represent serious risks only if they were complemented with agroforestry systems; however, in the field trip it was found that a large part of them are monocultures. On the other hand, areas with no or little vegetation are distributed throughout the lower part of the micro-basin and occupy most of the territory. The full distribution map is shown below:



**Figure 2: Distribution of LUC in the Tumbillán 2024 micro-basin.**

**Permanent crops**

This space is considerable in the micro-basin and

includes the upper and middle part; 749.2 ha was determined, which means 20.3% of the total territory.

In this space, it was possible to determine the presence of agroforestry systems, among which coffee (*Coffea arabica*) associated with guaba, coffee associated with eucalyptus (*Eucalyptus globulus*), coffee associated with pine (*Pinus sp*), coffee associated with banana (*Musa paradisiaca*) stand out. In addition, the presence of coffee monocultures.

### **Discontinuous urban fabric**

This part is made up of small spaces covered by houses that are mostly located in the hamlets and population centers. In the micro-basin, the towns of El Arenal, Tumbillán, Alto Vista Alegre, El Laurel, Peña Blanca, El Limón and San Miguel occupy the urban fabric.

In this study, 65.1 ha of this space were obtained, occupying 1.8 % of the total area of the micro-basin.

### **Pastures**

The pastures extend on both banks of the Tumbillán stream, near the forests and affecting the forests mainly in the upper part of the micro-basin.

The pastures that were determined were mostly kikuyo, sweet grass, purple grass, and natural pastures that are installed after the slash and burn of the forests.

Pastures occupy 207.3 hectares. which is 5.6% of the total area of the micro-basin.

### **Shrub/Herbaceous vegetation**

This space is made up of species characteristic of the Marañón dry forest. These spaces have not presented a significant intervention of their areas to date, one of the factors is the unproductive soil it has; in addition, some limitations such as low rainfall.

This space contains 822.2 ha, which means 22.2% of the micro-watershed.

### **Areas with little or no vegetation**

These spaces were found in the lower part of the

micro-basin, generally caused by the scarcity of precipitation and also by the intervention of the hand of man in order to extend the urban area. These spaces withstand forest fires almost every year in the summer months, occupying 1103 ha of territory, which means almost a third of the micro-basin.

### **Low open forest**

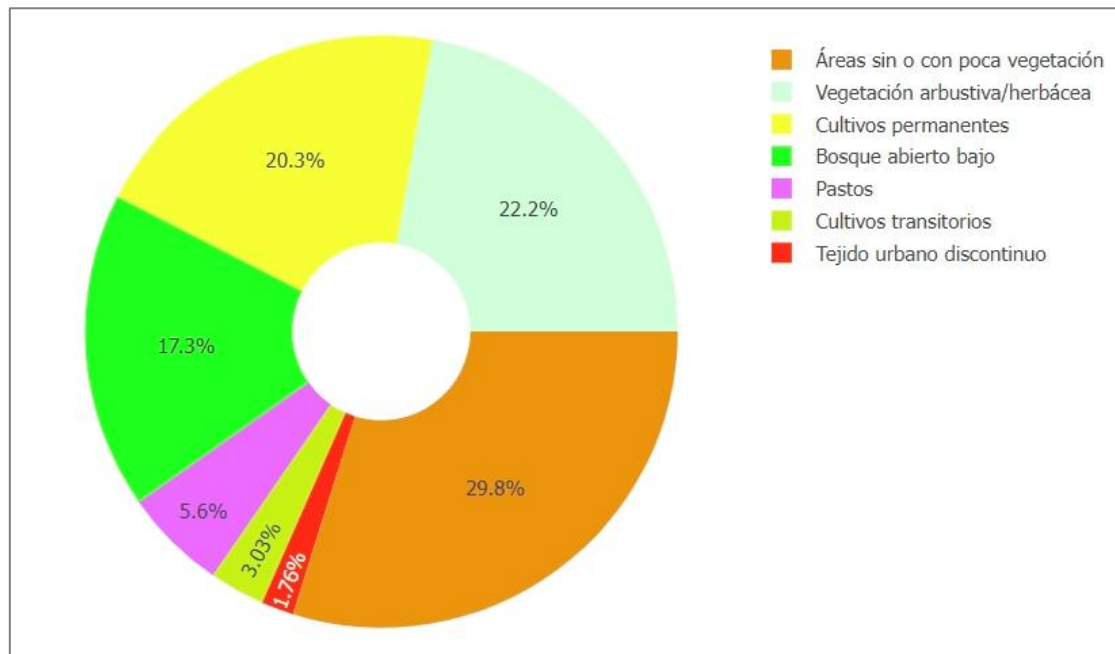
This space is made up of all the wooded areas inside the micro-basin. The number of hectares that resulted from the classification was 639.7 ha, which means 17.3% of the micro-basin, mostly relicts. The forests are found in the middle and upper parts in a fragmented way and in other cases associated with purmas and intervened areas.

The species that were found in this space as mentioned by Marcelo et al (2010) are: Balsa (*Ochroma pyramidale*), Cetic (*Cercopia Palmata*), Acerillo (*Aspidosperma polyneuron*), Matico (*Buddleja globosa*), Morero (*Maclura tinctoria*), Lishina (*Jacquinia mucronata*), Ingas, Palo de agua, Chilcas and Cujaca.

In the lower part of the micro-basin we find relicts of forest, composed mostly of species such as Faique (*Acacia macracantha*), Llangua (*Cybistax antisyphilitica*), Iguaguana (*Cordia iguaguana*), Guayacán (*Tabebuia chrysantha*); in smaller quantities it was possible to observe species of Catahua (*Hura crepitans*), Tunsho (*Ceiba insignis*) Booby bird (*Tessaria integrifolia*), Higuierilla (*Ricinus communis*), Cat's Claw (*Senegalia riparia*), Carob (*Prosopis juliflora*), and Cherry (*Muntingia calabura*) on the banks of the ravine (Marcelo et al., 2010).

### **Transitional crops**

They are located in the lower part of the micro-basin, on the banks of the Tumbillán creek because they require water for their production, in this space were found crops such as: arróz, corn, cassava, sweet potato, arracacha, vegetables and various plantations also established in horticultural gardens. This space covers 112.2 ha, representing 3% of the total area of the micro-basin.



**Figure 4: Percentage of LUC occupancy in the Tumbillán micro-basin.**

The micro-watershed gives us to understand that it is in the phase of maturity; that is, it is in balance. In addition, it will not present erosion of great significance in the soils and interior environments of the same.

In addition, we can interpret that it has a steep slope in the upper part ranging from 1800 to 2243 m.a.s.l. While in the middle part the slope tends to decrease slightly to 1000 meters of altitude; At the bottom, the slope increases slightly again to the lowest point, which is at 624 m.a.s.l.

#### 4. DISCUSSION

The Tumbillán micro-watershed plays a crucial role both ecologically and socially. Its importance lies in being a vital resource for the agricultural irrigation of hundreds of hectares, in addition to housing fragments of forest ecosystems that contribute to biodiversity. However, the fragmentation and deterioration of these ecosystems, especially in the middle and upper parts of the micro-watershed, underscore the urgent need to implement effective conservation strategies.

One of the main factors driving the deterioration of these ecosystems is the expansion of agricultural land and pastures for livestock purposes. Despite the immediate economic benefit, this practice poses a significant risk to the sustainability of the micro-watershed. It would be prudent to encourage the use of agroforestry systems as an intermediate solution, combining agricultural production with ecosystem conservation. For example, permanent crops, which occupy 20.3% of the micro-watershed, could be

complemented with strategies such as the association of coffee with native tree species, which would improve the sustainability and resilience of these areas.

The use of advanced technologies such as SAGA GIS and Google Earth Engine (GEE) was instrumental in this study, allowing the delimitation of the micro-watershed, processing satellite images and calculating key spectral indices. This approach not only ensures accuracy in the results, but also opens doors for the application of similar methodologies in other areas with conservation problems. However, it is crucial to continue exploring how to improve these tools for more detailed and representative maps.

The comparison between the land cover map obtained for 2024 and ESA's WorldCover 10m 2021 map highlighted the importance of having up-to-date data. Despite the usefulness of ESA's global map, the local map generated in this study offers a higher level of detail and specificity to understand the current dynamics of the micro-watershed.

Finally, the results emphasize the need for sustainable management of the identified areas. Forest remnants, which constitute 17.3% of the micro-watershed, should be a priority in conservation programs, while areas with no or little vegetation, which cover almost a third of the territory, could be the object of reforestation strategies. Promoting responsible agricultural practices and establishing protected areas are essential steps to ensure the ecological and social integrity of the micro-watershed.

## 5. CONCLUSIONS

The LUC map for the Tumbillán micro-basin was elaborated, obtaining the following percentage results: Areas with no or little vegetation with 29.8%, shrub/herbaceous vegetation with 22.2%, permanent crops with 20.3%, low open forest with 17.3%, pastures 5.6%, transitory crops and discontinuous urban fabric with 3.03% and 1.76% respectively. With which it is concluded that the occupation of LUC in the Tumbillán micro-basin is generally by soils without or with little vegetation, followed by shrub/herbaceous vegetation and permanent crops.

According to the WorldCover map of the year 2021 prepared by the ESA, the Tumbillán micro-basin has a tree cover of 80.5%, followed by grassland with 18.1%, in a smaller proportion are Cropland, Urbanized, Scrubland, Permanent water bodies and Bare soil or with scarce vegetation with 0.6%, 0.4%,

0.3%, 0.2% and 0.03% respectively.

Human activities, especially agricultural and livestock expansion, have contributed significantly to the fragmentation of forested relicts, highlighting the need to implement sustainable strategies, such as agroforestry systems, to reduce negative environmental impacts.

The use of technological tools such as SAGA GIS and Google Earth Engine allowed a precise delimitation and detailed analysis of land use and cover, demonstrating the potential of these platforms for environmental management studies.

It is essential to promote sustainable land management, which includes the recovery of key ecosystems, the promotion of responsible agricultural practices and the conservation of natural resources to ensure the ecological balance and well-being of local communities.

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