



Physiographic characterization to determine erodibility and its relationship with meteorological drought in soils of La Ponderosa farm, Municipality of Monterrey, Casanare - Colombia

Caracterización fisiográfica, para determinar la erodabilidad y su relación con la sequía meteorológica, en suelos de la finca La Ponderosa, Municipio de Monterrey, Casanare - Colombia

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Ricardo Antonio Tobón-Rojas.

*Master's Degree. Minuto de Dios University Corporation- UNIMINUTO. Zipaquirá, Colombia.
ricardo.tobon@uniminuto.edu, <https://orcid.org/0000-0002-2157-1414>*

Liliana Figueroa-Del Castillo.

*Master's degree. El Bosque University. Bogotá - Colombia.
lfigueroa@unbosque.edu.co <https://orcid.org/0000-0003-2326-6904>*

Javier Leonardo Romero-Fernandez

*Master's degree. Universidad El Bosque Bogota, Colombia,
jlromero@unbosque.edu.co <https://orcid.org/0000-0001-5045-114X>*

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ABSTRACT

The purpose of this article is to approach the environmental problems that have been generated in recent years in the entire department of Casanare, through the strong summers and droughts, becoming a threat to the water sources and soils in this area. Therefore, the development of this research seeks to relate the threat of meteorological drought with geomorphological and physiographic parameters, especially the slopes present on the Ponderosa farm, to determine the areas susceptible to erodability. Using GIS - geographic information system tools, six zones or "paddocks" were determined in which slope ranges were classified between 0 and 10, with zero being the least and 10 being the greatest. In the paddocks called 2, 3, 4 and 6, the areas with the highest ranges, between 6 and 10, were identified, indicating steep to steep slopes, these being the most susceptible to mass movements, runoff and therefore erodability. These factors identified in the present investigation, directly influence the sustainability of the productive activities of the farm such as livestock and in some sections, palm crops.

Keywords: Threat due drought, Erodability, GIS, Sustainability, Casanare.

RESUMEN

El presente artículo tiene como finalidad abordar la problemática ambiental que se ha generado durante los últimos años en el departamento de Casanare – Colombia, en especial en el municipio de Monterrey, producto de los fuertes veranos y sequías, convirtiéndose en una amenaza para las fuentes hídricas y los suelos de esta zona. Por lo tanto, el desarrollo de esta investigación busca relacionar la amenaza por sequía meteorológica con parámetros geomorfológicos y fisiográficos, en especial las pendientes, presentes en la finca la Ponderosa, para determinar las zonas susceptibles a erodabilidad. Mediante la utilización de herramientas de sistemas de información geográfica SIG, se determinaron seis zonas o "potreros" en los cuales se clasificaron rangos de pendientes entre 0 y 10, siendo cero la menor y 10 la mayor. En los potreros denominados 2, 3, 4 y 6 se identificaron las zonas con mayores rangos, entre 6 y 10, indicando pendientes abruptas a escarpadas, siendo estas las más susceptibles a movimientos en masa, escorrentía y por ende a erodabilidad. Estos factores identificados en la presente investigación, influyen de manera directa en la sostenibilidad de las actividades productivas de la finca como lo son la ganadería y en algunos apartes, los cultivos de palma.

Palabras clave: Amenaza por sequía, Erodabilidad, SIG, Sostenibilidad, Casanare.

INTRODUCTION

During the last decade, the drought experienced in the department of Casanare has left about 250,000 hectares of green savannahs full of water and animals, now turned into a desert and causing the death of different species such as cattle, chigüiros, babillas, fish, etc. (Palacio & Rodríguez, 2014), the above in relation to the inadequate management of water resources, indiscriminate deforestation of the natural forest, expansion of the agricultural frontier, overgrazing, change in land use, and oil activity (CDGRD, 2012).

At this point, hazard is related to the danger that means the possible occurrence of a physical phenomenon of natural, technological or man-made origin that can manifest itself at a site and during a predetermined exposure time. Technically, it is expressed as the probability of exceeding a level of occurrence of an event with a level of severity at a specific site and during a period of time; for this reason, in most cases, hazard assessment is carried out by combining probabilistic analysis with analysis of the physical behavior of the generating source, using information on events that have occurred in the past and modeling with some degree of approximation to the physical systems involved (Cardona, 1993).

According to the Colombia Risk Atlas reveals latent disasters that drought originates through a deficit of rainfall over an extended period of time, resulting in a shortage of water for some activity or sector. Its impacts are due to the interaction between the natural event (less rainfall than expected) and the demand for water supply, a situation that in many cases is exacerbated by human activities.

Due to the growing inclusion of this phenomenon, in Colombia "The national action plan to combat desertification and drought in Colombia" (2005) was born as a main objective, to advance actions against land degradation, desertification and mitigation of the effects of drought, as well as for the sustainable management of the ecosystems of dry areas, from the application of practical measures that allow preventing, stopping and reverting such degrading processes and contributing to the sustainable development of the affected areas (Minambiente, 2005). The above, through methods and the use of geographic information systems where drought can be calculated, allowing the development of more detailed spatial-temporal analysis in order to define the severity, frequency and distribution of droughts at different scales, where exposure and vulnerability are integrated to provide information on the possible economic, environmental or social consequences generated by drought.

The urgency that has arisen at the national level and mainly in the department of Casanare to provide alternatives that help mitigate the negative effects that originate at the environmental, social and economic level in relation to drought in this territory cannot be ignored. In this sense, the present project is proposed through the use of different tools, among them the GIS that allow identifying the diverse impacts that are generated in the soil produced by meteorological droughts, by means of a spatial and statistical analysis, as well as

geological, geomorphological and physiographic analyses, with the purpose of designing strategies that allow determining the scope of this threat by drought on the soil of the farm La Ponderosa.

Based on the above, the impacts and repercussions generated by phenomena such as meteorological drought, which are potentiated by geographic and physiographic conditions and anthropic activities, causing an economic, social and environmental effect, were reflected in the development of the project carried out at the La Ponderosa farm in the municipality of Monterrey, Casanare.

MATERIALS AND METHODS

For the development of this research, a bibliographic review was carried out, with which international, national and local references were analyzed. Thanks to these theoretical references, the research was delimited and focused in order to comply with the objectives set out in the research. Through the studies entitled "General Study of Soils and Land Zoning in the Department of Casanare" (IGAC, 2014) and "Annexes of the Explanatory Memory of the Zoning of the Susceptibility and Relative Threat by Movements in Mass scale 1:100.000 plate 230 - Monterrey" (SGC, 2013), the physiographic aspects were determined, including the characterization of the main geological units, through a lithological description of the different types of rocks present in the analyzed area, followed by the identification of how the geomorphology is constituted in the study area through its geostructures, morphological landscape and slope.

By means of GIS software - ArcGIS, the slope ranges present in the study area were calculated using a georeferenced image of the study area and its respective delimitations in raster format, then the Spatial Analyst Tools tool was used, then the Surface window and finally by clicking on the Slope window.

Finally, for the geographic characterization, the respective visit was made to analyze the topography of the terrain to obtain information on its condition. According to the information obtained, the current state of the study area was represented by means of the free software Google Earth.

RESULTS

In order to obtain the results, the study conducted by the IGAC (2014) entitled "General Study of Soils and Land Zoning, Department of Casanare. Scale 1:100,000", identifying the physiographic and geographic characteristics of the study area, for which the following information was characterized.

Physiographic and Geographic Characteristics

1. Location. The representative area for the present study was the La Ponderosa farm, which is located southwest of the municipality of Monterrey - Casanare, on the foothills of the plains, in the Tierra Grata district, 11 kilometers from the urban center, at the coordinates $4^{\circ} 51' 37.2366''$ North Latitude and $-72^{\circ} 56' 12.3246''$ West Longitude, it has an area of 733,000 m², where it limits in North direction with the farm El Portal, in South and West direction with the farm Venecia and in East direction with the farm Las Palmeras. The farm is divided into six pastures that are used for cattle raising (Figure 1).

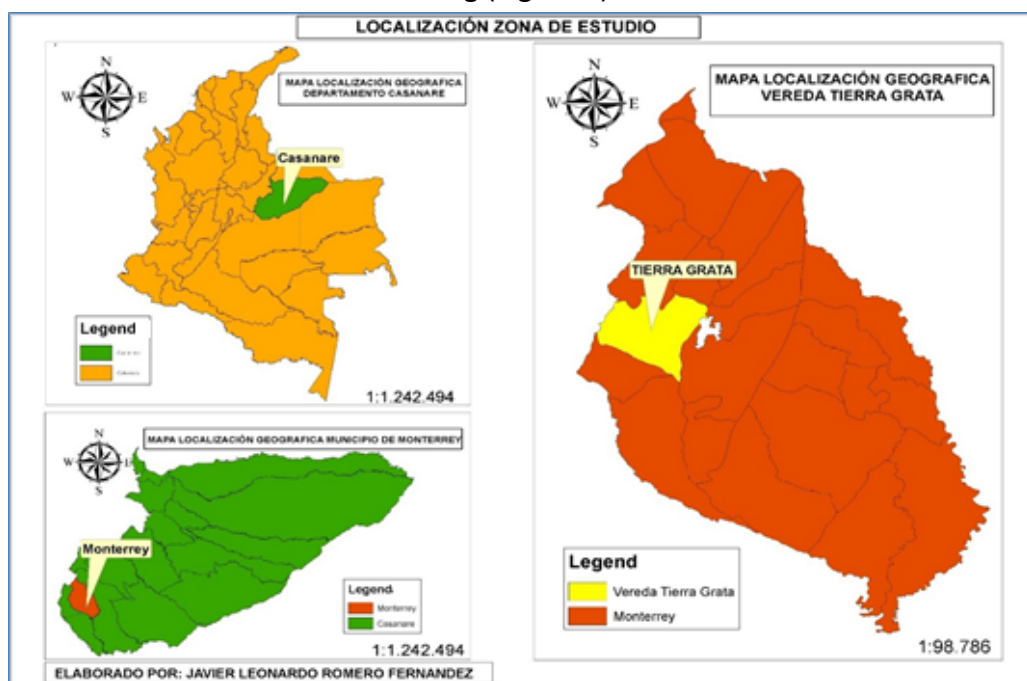


Figure 11 . Location map of the study area. (Figuerola, Romero, Tobón, 2019).

2. Geology. Two large zones with geological characteristics were identified: the first corresponds to the mountainous zone and is located to the northwest of the department; and the second corresponds to the piedmont and the flat zone, which is commonly known as the eastern plains.

In the first region, sedimentary rocks outcrop with ages ranging from the early Cretaceous to the Quaternary. The second region, which represents approximately 88% of the departmental area, is made up of the piedmont and plain zone and consists of alluvial, alluvial-torrential and fluvio-glacial deposits accumulated during the Pleistocene and Holocene, which form fans, cones, terraces and plains, on which eolian materials were deposited later.

Based on the above information, in the geological aspect of the study area, a lithological description was made of the main rock units presented below in relation to their geological period:

Cretaceous

- **Fómeque Formation.** It is made up of gray mudstones intercalated with marls, siltstones and limestone lenses, dark gray to black in color; there are frequent intercalations of quartz sandstones, micaceous, fine-grained, light gray, deposited in a shallow marine sedimentation environment of shallow waters. Its outcrop is located in small strips in the divisions of the Túa river.

- **Une Formation.** It is made up of three groups: a basal group that consists of solid quartz sandstone of white color and fine to medium grain; towards the middle part, the sandstone becomes conglomeratic and towards the top there is clayey sandstone of reddish color and fine to medium grain. The middle group is made up of dark gray mudstones, with thin intercalations of quartz sandstone, reddish in color, fine grained, well sorted and in strata up to 1 m. And an upper group, made up of white quartz sandstone, fine to medium grained, with quartz pebbles up to 5 cm in diameter. The sedimentation environment of the formation corresponds to a coastal environment with deltaic influence, which is why it resembles the Fómeque formation formed on the middle slopes of the Túa river.

Paleogene

- **El Limbo Clay Formation.** The formation is made up of gray to greenish-gray claystones and mudstones, with intercalations of yellowish-white quartz sandstones, medium to coarse grained, stratified in banks 1 to 5 m thick; and with the presence of coal mantles. According to its stratigraphic sequence, it is interpreted that the formation was deposited in a marshy to marine lagoon environment, outcropping in the form of elongated strips in the upper part of the Rio Túa basin.

Quaternary

- **Colluvial-alluvial deposits.** Corresponds to sedimentation units that form colluvial-alluvial cones, terraces and piedmont alluvial fans, which are predominantly made up of sandstone blocks and pebbles in a matrix that varies from sandy to clast-supported, sometimes with lenticular intercalations of sandstones and reddish siltstones. These deposits of colluvial, colluvio-alluvial, alluvial and/or alluvial-torrential origin are quite dissected and in some cases tilted by the active tectonics of the region. This type of sedimentation is found in large proportions throughout the La Ponderosa farm, mainly along the banks of the El Tigre and Ranchería streams.

Alluvial Deposits. These are alluvial accumulations from the Pleistocene and Holocene, which occupy the braided and meandering valleys of the main rivers of Casanare, and the alluvial plain inherited from the Eastern Plains. These deposits are made up of well-sorted and

rounded cobbles, with block sizes up to gravel; layers of very coarse-grained sands; and fine materials such as silts and clays in the floodplains. According to SGC (2009) the most representative alluvial deposits are found in the project study area.

Geomorphology

- **Geostructures.** The department of Casanare is currently divided by two major geostructures: the Andean mountain range and the eastern plains sedimentation megabasin. The study area is located within the sedimentation basin geostructure, since it is delimited by two watersheds, Caño El tigre and Ranchería Creek, which are part of the Túa River basin.

- **Morphological Landscape.** The Ponderosa farm has a piedmont landscape, which extends along the eastern slope of the eastern mountain range, formed by the sedimentation of materials transported from the higher elevations to the lower, more open areas. It comprises flat, gently sloping surfaces with gradients between 3% and 12%. The piedmont deposits generally constitute the record of alluvial and alluvial-torrential events that descend from the mountain range towards the Orinoco plain.

5. Delimitation Through the respective field visit and analysis using the free software Google Earth, the area of the La ponderosa farm was delimited (Figure 2), which is defined by two rivers, which are the El Tigre stream located to the west and the Ranchería Creek to the east of the farm. These two streams belong to the Túa River basin.



Figure 22 . La Ponderosa farm. (Figueroa, Romero, Tobón, 2019).

Caño El tigre is connected to paddocks 1 and 6 of the farm, which is used as a drinking trough for the cattle in this area. According to the inhabitants of the farm, this stream used to be larger and more abundant, but due to the strong summers from January to April of this year, it was used as a watering place for the cattle that live in this area.

year, did not recover as I expected them to, because of this I could not get the water for a fish farm, which generated me another economic income apart from cattle fattening (Vaca, 2018). According to the above commentary and the field visit, the impact generated by the drought phenomenon was reflected in the high temperatures, generating a considerable reduction of the water sources and therefore affecting the soils of the La Ponderosa farm.

On the other hand, the Ranchería stream is located to the east of the farm where it is connected to paddocks 2, 3 and 4, in the same way that the El Tigre stream is used as a watering place for the animals of the Ranchería type.

Equine and bovine.

The respective field visit showed that this river has a large extension of gallery forest on the banks of its course. On the other hand, the pastures of Finca La Ponderosa are divided by a creek that originates from the El Tigre River, where it was identified that this creek produces a dragging of material from the pastures, generating the formation of moderately inclined reliefs.

It should be noted that, with the delimitation of the farm, it was possible to describe the sequence "slope-erodability-weather drought", giving relevance to the processes that affect the sustainability of the farm.

6. Slopes. Through GIS processing the value of the slopes was calculated, as shown in Figure 3, determining that the reddish and orange shades reflect slope ranges between 6 and 10, which indicate that they are steep slopes (classification 4) to steep (classification 5) being more susceptible to mass movements and dragging of material (SGC, 2015), these are located mainly on the banks of the Tigre River, the Ranchería Creek, in paddocks 2, 3, 4 and 6.

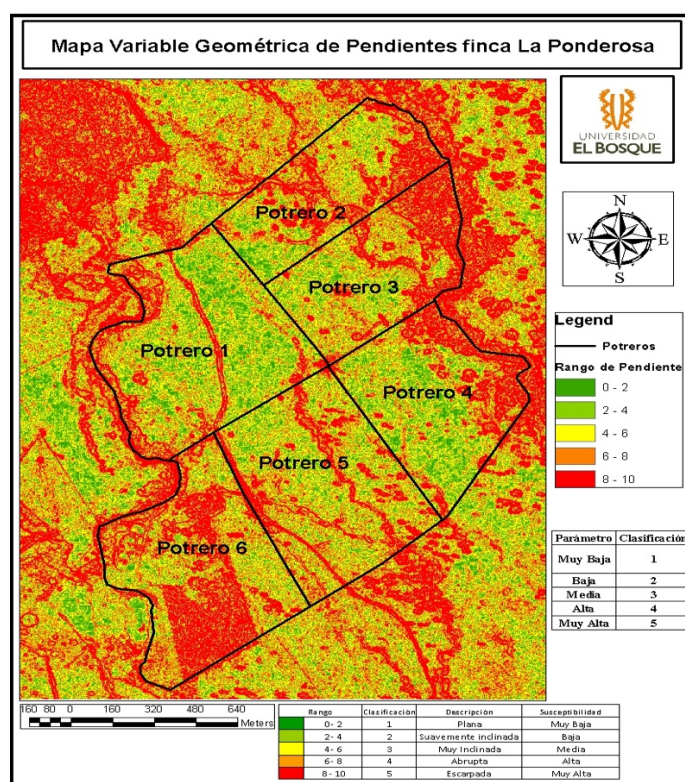


Figure 33 . Geometric Slope Variable Map Finca La ponderosa. (Figueroa, Romero, Tobón, 2019).

The areas with the lowest slope range are located in the center of the farm, in paddocks 1 and 5, and to a lesser extent, in paddocks 3 and 4, where the green and yellow shades reflect slope ranges between 0 and 6. This is characterized by a flat to very steep relief.

The relief of the farm is characterized mainly by gently sloping and steep slopes, by the length of its slopes and its geofoms associated with denudation processes, this being a determining factor in establishing the susceptibility to erodibility of the study area, which is classified between high and very high.

The slopes established between ranges 6 and 10, generate an intensification of runoff, producing an increase in its volume, decreasing moisture retention and infiltration in the soil, increasing susceptibility to erodibility in the area of interest and therefore will be the sectors most affected by the threat of meteorological drought in the region.

The results of this study show the current state of the threat due to meteorological drought, a phenomenon that will continue to directly affect the soil and water matrices in the study region, evident in the slope ranges and susceptibility to erodibility obtained. Likewise, GIS tools are a support in the recognition and identification of physiographic and geographic indicators that allow determining the impact on sustainability, represented in productive activities, in this case, pastures and livestock, at a socioeconomic and environmental level, being these data viable to be extrapolated to the department of Casanare and other regions of the Colombian Orinoquia.

CONCLUSIONS

According to the results obtained, the following conclusions can be drawn: The geographic and physiographic characterization, the division of the farm area into zones or "paddocks" was established, characterizing the regions with slope ranges between 6 and 10 (classification 4 and 5), where paddocks 2, 3, 4 and 6 are the most affected by the presence of abrupt to steep slopes. Likewise, paddocks 1 and 3 have areas with slope ranges between 0 and 6 (classification 1 to 3), described as flat, gently sloping and very steep, relevant information to identify the range of slopes, susceptibility to erodibility and threats due to meteorological drought. The characterization of the rock units that make up the different piedmont geofoms in the region of the municipality of Monterrey, and especially the region where the Ponderosa farm is located, contributes to the creation of a relief with different degrees of slopes, which directly influences the processes of runoff and infiltration, generating areas with a higher degree of susceptibility to erodibility. The use of geographic information systems, especially ArcGIS software, contributed to establish the geomorphological and physiographic relationships of the study area, for decision making in the prevention and mitigation of the threat of meteorological droughts, generating knowledge on the sustainable management of the economic activities developed in the La Ponderosa farm.

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