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Use of Geoprocessing in Identification of Areas Suitable for the Implementation of Center Pivot Irrigation in the District of Mossurrize, in Republic of Mozambique

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Abstract

With population growth, there is an increase in the demand for food, making irrigation an important technology for this purpose. Therefore, planning, and technical knowledge of environmental variables are essential for the implementation of irrigation, facilitated by geoprocessing techniques, which can help in decision-making, mainly due to the ability and ease of working large areas. The objective of this study is to analyze areas with potential for the implementation of a center pivot irrigation system in the district of Mossurrize. The analysis was carried out using geoprocessing tools through QGIS 2.3.20.0 and ArcGIS software. The methodology considers the combined analysis of different information plans to generate a synthesis map. The information plan variables were reclassified with weights from 1 to 9, demonstrating the influence of each element on the considered phenomenon. Then the variable maps were submitted to weighted analysis. The tools for spatial analysis through geoprocessing proved to be efficient in the manipulation and integration of the data used to identify and quantify the areas suitable for the implantation of a center pivot irrigation system and may be a viable alternative for decision making.

Keywords: *Applied Geoprocessing, Multicriteria Analysis, Irrigated Agriculture, Agricultural Fitness*

1. Introduction

The increase in world population makes it necessary to expand the supply of food and jobs to guarantee the quality of life. This implies greater water needs, land use and occupation pressure, and energy supply (Silva, 2015). One of humanity's greatest challenges in this century is to ensure food and environmental security for a world population that, in 2030, will be approximately 8.3 billion people. In order for this challenge to be overcome without provoking conflicts over water use, alternatives must be sought to reconcile the increase in food production with available water resources (Rodrigues et al., 2007).

New trends reflect a reduction in surface irrigation and an increase in center pivot and spot irrigation (Mantovani et al, 2007; Christofidis, 2006). Center pivot irrigation has several advantages: labor savings, high productivity (Bernardo et al., 2008), possibility of complete automation of the system, it can be applied to a wide range of crops, including grain, vegetables, coffee, forage, and grasses (Jacinto, 2001).

Given the importance of irrigation for agricultural production, the identification of suitable areas for the implementation of irrigation systems is fundamental in the development process of Brazilian agriculture (Ayers and Westcot, 1994). In view of this, the use of geographic information systems in agriculture has proven to be an important tool in the design and development of activities, as it is possible to create in a practical and less costly way, databases and cartographic documents, such as thematic maps that can serve as basis for the development of an activity (Carvalho et al, 2005), such as the identification of suitable areas for the introduction of irrigation systems. In view of the tools presented in geoprocessing, the weighting method is considered one of the most efficient methods for decision making, being applied in works related to agriculture and natural resource management (Barros et al, 2007).

Given the above, the objective of this study was to analyze areas with potential for the implementation of a center pivot irrigation system using geoprocessing tools.

2. Material And Methods

The study area corresponds to the district of Mossurize (Figure 1), located in the western region of the province of Manica. The district is bounded to the north by the district of Sussundenga, its entire western extent is limited by the Republic of Zimbabwe, to the south and east by the district of Machaze, to the northeast by the district of Chibabava (sofala). The district headquarters is located at coordinates 20.450022° S and 32.821993° E, with a territorial area of 5,096 km², with a tropical climate. The district has a total population of 195,400 inhabitants (inhabitant km²) (MAE, 2005).

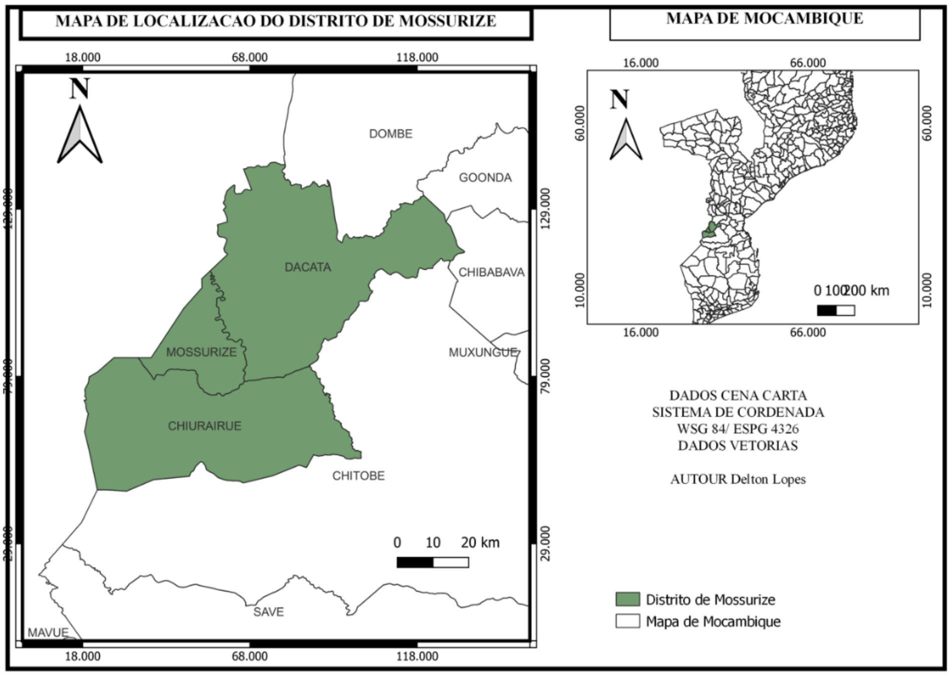

Figure 1: Location of the study area

Source: Authors, 2021.

Analysis of Factors

This study was carried out with the help of free software QGIS 3.20.0 and ArcGIS to manipulate vector data such as points, lines, and polygons in addition to raster data. In the multicriteria analysis for decision making, four variables were considered, which are prerequisites to make pivot irrigation feasible. Central, namely, land use and occupation, distance from the water body, land slope and soil classes (Barros et al., 2020).

Land use and occupation

The mapping of land use and occupation is an essential practice for understanding landscape transformations, which makes it possible to acquire information that will serve as subsidies for the assessment of environmental support capacity. Thus helping to direct conservation management, with the aim of reducing impacts on the environment (SANTOS; SANTOS, 2010).

Therefore, the mapping of land use and occupation was obtained through visual interpretation of RGB (Red, Green, Blue) images from LANDSAT 8 dated July 29, 2020, with a spatial resolution of 30 cm.

Each use class found in the mosaic was vectorized in the form of polygons and classified according to their characteristics through the Plugins SCP by the k-made method in an unsupervised classification according to figure 2.

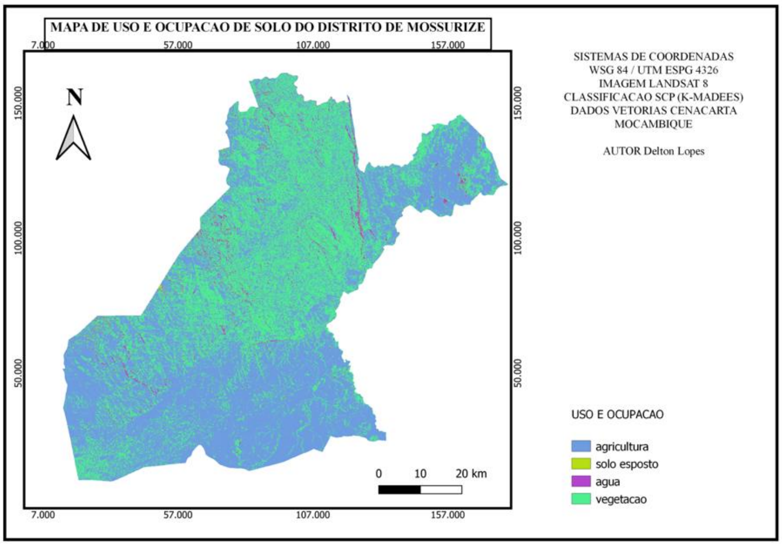

Figure 2: Map of land use and occupation in the District of Mossurize

Source: Authors, 2021.

Soil Classes

The vector spatial data of the soil classes were obtained through a shapefile file on the Cenacarta Moçambique platform. The vector data were cut with the Mossurize Administrative boundary, which presented the soil classes of Argisols, Oxisols, Cambisols, Neosols and Arrenosols, according to the FAO classification, available in the table of attributes of the referenced layer. Oxisols have good depth, medium and clayey texture, vary from strongly to well drained, as shown in Figure 3. Cambisols cover mineral soils with variable characteristics, but always have medium to fine texture, with small depth and high content of primary minerals. Neosols are soils with little pedogenetic development, consisting of mineral material or organic material less than 20 cm thick, with a sandy texture and the presence of gravel (Embrapa, 2013).

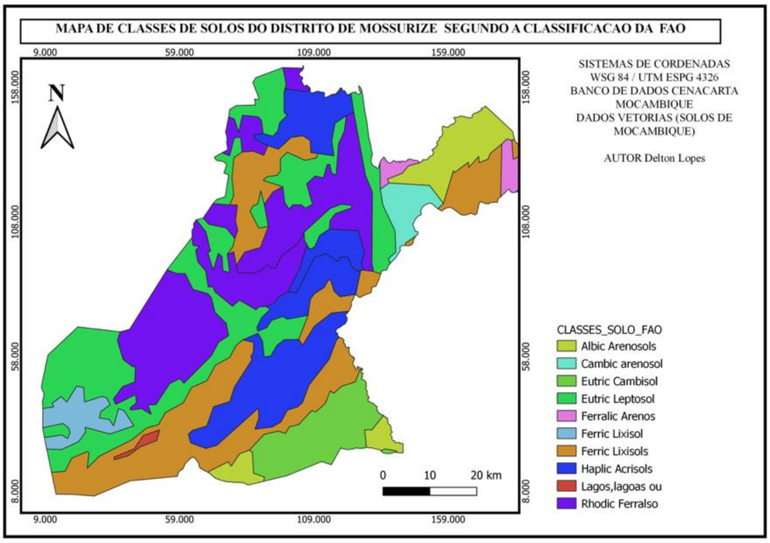

Figure 3: Soil class Maps of Mossurize District According to FAO Classification

Source: Authors, 2021.

Based on the information described, the soil classes were reclassified through the attribute table with values corresponding to the degree of importance, where the weights were assigned according to the most favorable characteristics for agriculture in a general context. The next procedure was to transform the vector file into a raster file. **Table 1** presents the soil classes, characteristics and weights referring to suitability for irrigation.

Table 1: soil classes, characteristics and weights referring to suitability for irrigation

Attributes	Characteristics	Weight (9-1)
Latosol	Ripe, deep, structured, well drained.	9
Cambisol	Shallow, stony, high mineral content	6
Clayey	well drained, and water infiltration capacity	5
Sandy	high concentration of sand, little	2
Neossolos	shallow, stony, high, low	1
Plinthosol	low ripened petric	1

Adapted from (Lima et al, 2013)

Land slope

The slope map was generated from the SRTM mission (Shuttle Radar Topography Mission). The data were acquired by the Geographical Database of Mozambique (Cenacarta Mozambique). After acquiring the scene, the coordinate reference system was changed to WGS 84 EPSG:4326. In sequence, the slope classes (%) were extracted with the Slope tool in QGIS according to figure 4.

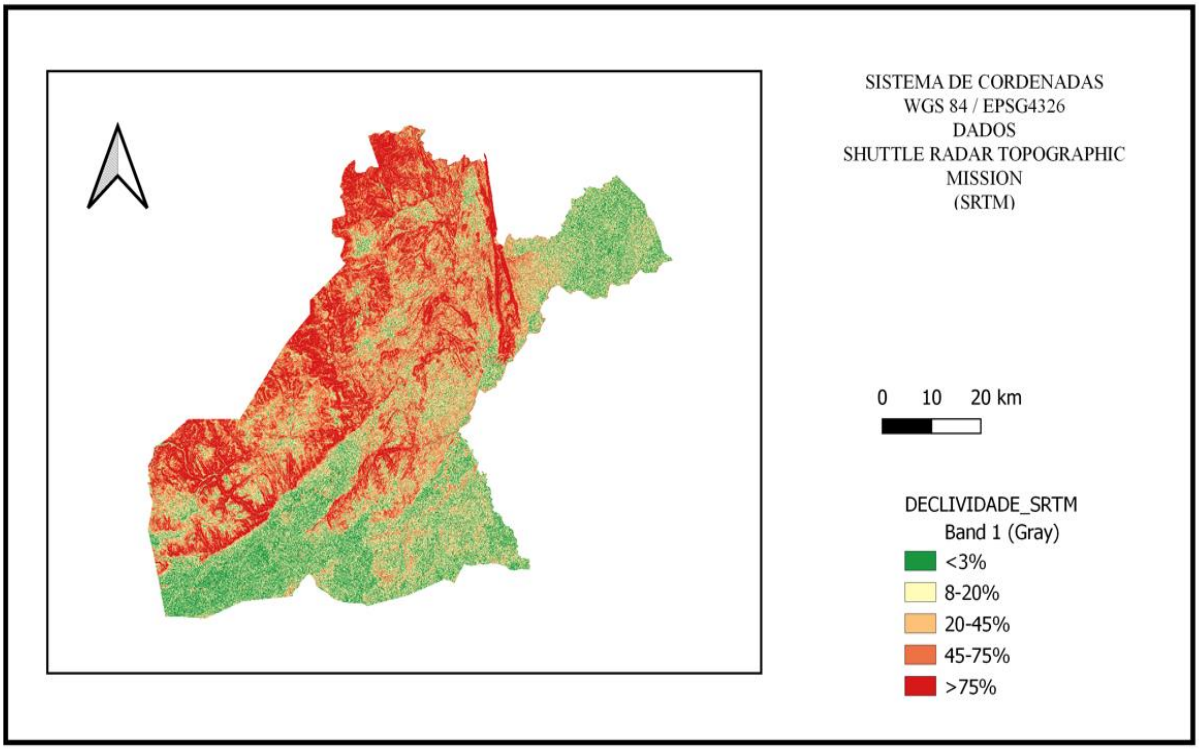

Figure 4: Slope map was generated from the SRTM mission

Source: Authors, 2021

To assign weights, reclassification was performed using the r. Reclass tool in QGIS, inserting the rule in figure 6.

0.0000 thru 3.0000 = 9 optimal (0-3%)

8,0001 thru 20,0000 = 6 Good (8-20%)

20,0001 thru 45,0000 = 4 Average (20-45%)

45,0001 thru 75,0000 = 3 Bad (45-75%)

End = terrible (> 75%

Table 2: Attributes for suitability, slope intervals and weights for slope classes.

Attributes	Slope	Weight (9-1)
Great	0-3%	9
Good	8-20%	6
Average	20-45%	4
Bad	45-75%	3
Poor Quality	>75%	1

Distance from the water body

For the course distance from the body of water, with the help of ArcGIS a buffer was generated with a distance of 200 meters (Figure 5). the study area showing its rivers. According to studies carried out, the distances to water bodies are related to the cost of implementing the irrigation system via central pivot, because the further away, the more expensive the cost with motor pumps and pipes (Martins et al., 2015). With this, it is possible to estimate the distances of the watercourse before the land under analysis, because the closer to the hydrographic network, the easier the access to water. According to Lima et al. (2013), hydrographic distance classes refer to regions subdivided according to their distance from a water body, where water for irrigation can be captured.

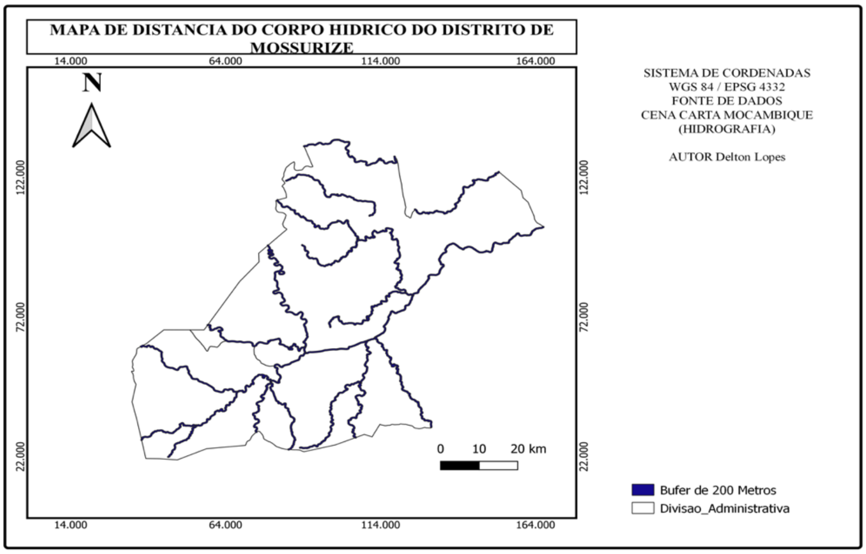

Figure 5: Distance Map of the Water Body of the District of Mossurize

Source: Authors, 2021

Aptitude map

The aptitude map for center pivot irrigation was generated in a QGIS environment using multicriteria analysis, which allows the combined analysis of different variables to generate a synthesis map. In this procedure, the degree of pertinence of each information plan and each of its caption components was used to construct the final result.

The mathematics used was the simple weighted average between the weights and grades of each variable, following the methodology proposed by Moura et al. (2007) and employed by Silva et al. (2014). Each element of the information plan received a weight that represents the degree of influence on the suitability of the area for installing irrigation. Higher grades represent areas with good aptitude, lower grades represent areas with poor aptitude. The layers of soil classes, terrain slope and distance from the water body were crossed using the QGIS raster calculator through the weighted analysis of each element.

3. Results and Discussion

Before any decision-making in the agricultural and environmental environment, efficient planning is necessary, analyzing whether a particular practice is really essential. This also refers to the implementation of an irrigation system, where one must first investigate whether there is a need to irrigate the crop in question, whether it is feasible to implement an irrigation system, whether the area has adequate conditions and, above all, whether the source of water present on site is sufficient to meet the water needs of the system and the crop.

Figure 6 shows the analyzes of the individual maps. The same figure shows the occurrence of Oxisols with characteristics such as being very deep and well drained, predominant in most areas of the district, followed by clayey and camisoles. Oxisols have good capacity for agricultural exploitation and mechanization, their composition is predominantly kaolinite-type clay, these particles are responsible for the structural characteristic of the soil (FAO, 2007). For the study area, the type of soil did not present a limitation for agricultural suitability.

Areas with greater slopes and intense agricultural operations may present some problems, such as soil compaction, reduced permeability and, consequently, increased surface runoff. Areas with a slope above 8% were found close to drainage channels and smoothed areas occurring in almost every area of the district. In the reclassified values of slope, classes of good and medium suitability were observed, some areas closer to the drainage channels resulted in less smoothed areas, but not compromising the implantation of the systems in these places. For Landau et al. (2014) smoother areas facilitate mechanization, indicating these areas for the expansion of irrigated agriculture.

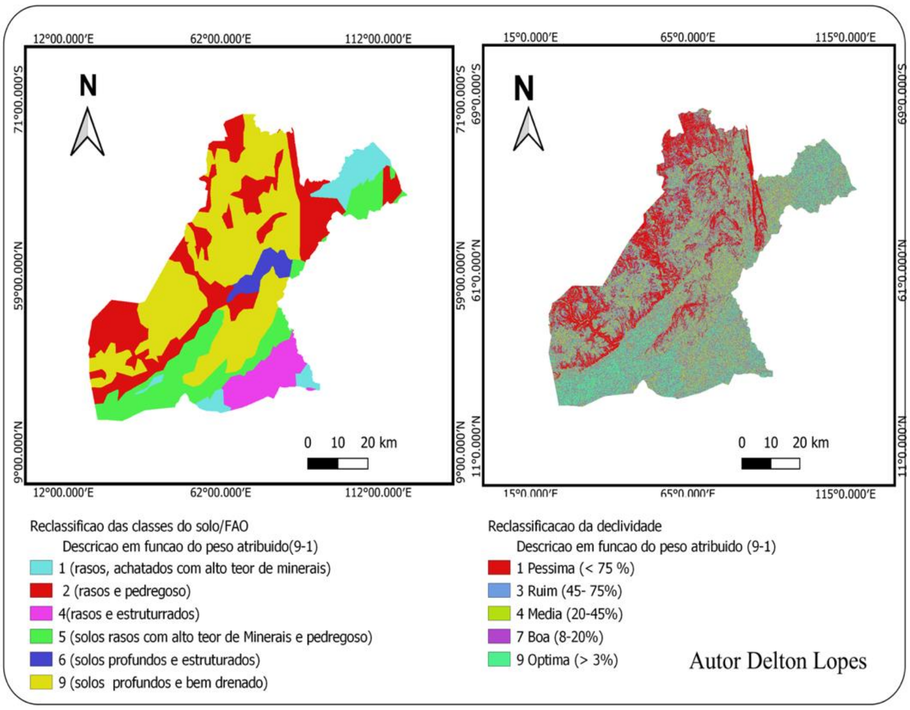

Figure 6: Map of reclassification of soil classes and slope in the Mossurize region.

Source: Author, 2021

The distances from the drainage channels reduced the aptitude to the north of the district, the distances are related to the increase in the cost of piping, in addition to influencing the sizing of the pumping system, gradually increasing the cost of implanting the irrigation system, therefore these areas will have less aptitude for long distances. In general, the municipality had few areas with poor suitability for irrigation. It was possible to observe in the study that from the buffer of 200 meters generated it is possible to dimension the area after it is known that the cost of implantation of the central pivot system is directly related to the costs with piping, dimensioning of the pumping system, consequently reducing the aptitude for large distances (Gomes et al., 2017).

The aptitude map was generated with the result of 4 grouped classes named by the aptitude characteristics: Bad, Bad, medium, good, excellent, the grouping represents the integration of the layers, the areas were limited when there is a great relative difference between the values of the data from each information plane. Figure 7 shows the aptitude map for the installation of center pivot irrigation, and in this figure the areas with pivots installed in the region in 2017 can be seen.

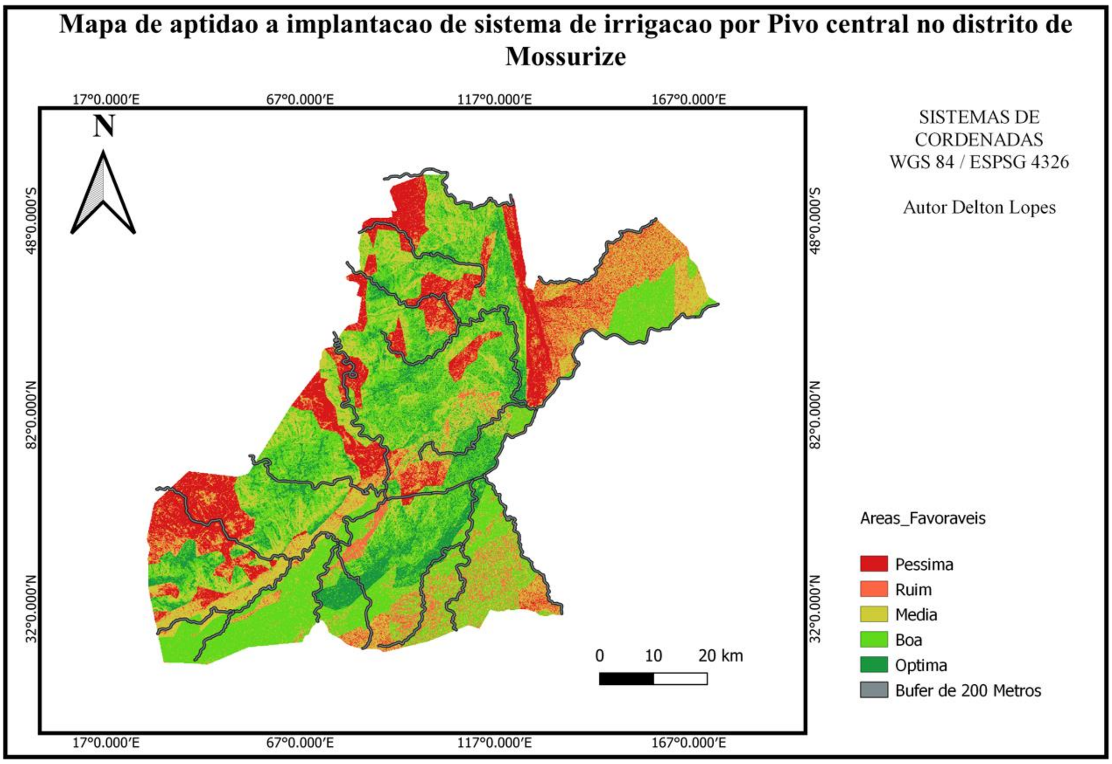

Figure 7: Map of suitability for center pivot irrigation installation in Mossurize district

Source: Authors, 2021

The district presented favorable conditions, represented by 89.29% of the lands with aptitude 0ptima and 9.35% as good. Being justified by the low slope and the presence of Oxisols and high density of surface channels. Martins et al. (2015) observe the high aptitude for irrigation in areas with smooth slopes and with the presence of Latosol in the municipality of Paracatu - MG, with similar characteristics to this study. In areas classified as medium and poor suitability, natural vegetation areas and urban areas represent 0.23% and 1.12% for medium and poor suitability. In the study by Martins et al., (2015) identified areas above 30% slope and predominance of Neo sols for areas of medium and poor suitability, Lima et al. (2013) also observed that slope and soil factors limited some areas in the municipality of Unai - MG. The limitation of soils and slope were not significant for the municipality of Santa Helena de Goiás - GO.

4. Conclusion

It is concluded that the Mossurize district has great aptitude for the implementation of center pivot irrigation systems. The information from raster and vector data manipulated in QSIG and ArcGIS software enabled the generation of information that can help in decision-making regarding the implementation of central pivots in the District of Mossurize. The spatial analysis tools through GIS proved to be efficient in the manipulation and integration of the data used for identification and quantification of the suitable and unsuitable areas for the implantation of a center pivot irrigation system, being able to be a viable alternative for studies of suitability for irrigation.

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