International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-10, Issue-2; Feb, 2023
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.102.16

River Area Restriction Method Based on Geoprocessing and Voronoi Polygons

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Received: 11 Jan 2023,
Receive in revised form:13 Feb 2023,
Accepted: 20 Feb 2023,
Available online: 28 Feb 2023

***Keywords*— Voronoi Edges, Medial Axis, Graphs, Multicriteria, Decision-making.**

Abstract*— *The routing of power distribution and transmission lines is an important step to bring energy and modernize the lives of the population. The process involves complex multiple criteria decision-making. The area of interest must be carefully modeled in weighted and restricted areas based on geospatial data. This paper brings a methodology based on geoprocessing and Voronoi polygons to obtain one of the most important restricted areas in energy distribution lines, the rivers. Rivers are areas that should be avoided when their width exceeds the maximum distance between poles. The methodology consists in generate Voronoi edges from which the medial axis and the width of each point of the river are obtained. Then, a buffer is placed in each vertex of the river higher than a threshold. The result to the case study brings a restricted area of rivers of the State of Parana to help decision-makers in routing distribution energy lines with more assertiveness.

I. INTRODUCTION

The transmission and distribution of energy is an important aspect of modern society, enabling the distribution of electricity to homes and businesses. However, the process of selecting the best transmission and distribution routes involves complex decision-making, which can be aided by using multicriteria decision analysis**.**

One of the steps in the planning of transmission and distribution energy lines is to identify features and build the land surface models of the study area. Therefore, many variables need to be considered in this planning and multicriteria analysis is an effective tool for addressing the complex decision-making involved this theme.

In the literature, researchers have proposed methodologies based on multicriteria decision analysis (MCDA) and Geographic Information Systems (GIS).

Monteiro [4] uses MCDA to analyze multiples geographic criteria to model the surface. Applying economic and environmental variables, the author proposes new electric distribution lines in different scenarios. Another author [6] models and weight different geographic criteria, obtaining costs and restrictions matrices to use with least cost path algorithms, resulting in new layouts of distribution lines.

The goal of this article is to provide a framework for decision-makers to evaluate and select restrictive areas of rivers to best routing of transmission and distribution energy lines.

II. MULTICRITERIA DECISION ANALYSIS

The mentioned studies used similar weighting and ranking MCDA methodologies. GIS based AHP and hybrid MCDA, in which the first approach is to weight the criteria with classic AHP and after, rank the data using GIS approaches.

A GIS Based MCDA Site Selection Framework [1] is built in 5 phases: data acquisition, weighting method, ranking method, combine both methods and calculate consistencies. In the weighting method, the criteria are divided in weighted and restricted data, processed and standardized to be combined into matrices of costs and restrictions.

III. RESTRICTED AREAS

A difficult item to model in distribution energy lines routing are the geographic areas where the distribution lines cannot be constructed and must be avoided. So, geospatial data to indicate restricted areas have to be emphasized. Table 1 brings restricted areas.

Table 1. Restricted criteria

Restricted criteria
Rivers and lakes
Airfields
Heliports
Transmission lines pole
Chemical Plant

Fonte: The authors.

Rivers and lakes can be crossed by distribution lines according to its physical width and the maximum distance between poles. To identify the distance of distribution line poles is necessary to know the distribution energy line topology. While the physical width of a river is measured through its geospatial data.

The methodologies applied to obtain the diameter of a river automatically to a long distance are not known by the authors. However, there are many to obtain the medial axis. Karimipour [3] uses a Voronoi-based medial axis extraction algorithm to watershed delineation. Voronoi polygons are an associated set of regions around points in the Euclidean plane, the region is classified closer to one of the vertices than to any other vertices. The edges are classified in three groups: inner Voronoi edges, outer Voronoi edges and mixed Voronoi edges.

Also, two well-known plug-ins for GIS free software are HCMGIS and Geometric Attributes. HCMGIS has tools to access open data, batch converter, projections, geometry processing and field calculation utilities [2]. Geometric attributes are a set of tools for calculating attributes along the centerline including width, deviation, transects, shape, sinuosity, and adjacency [5].

IV. FRAMEWORK TO OBTAIN THE RESTRICTED AREA

The methodology proposed in this paper is to obtain the restricted area of rivers from a buffer of the Voronoi polygon medial axis and edges. However, a series of steps must be applied during the process. For this, it was developed with the use of programming in Python by the IDE PyCharm. The methodology consists of 10 steps:

1. Segment the river polygon.
2. Densify the vertices of the polygon and equalize their distance.
3. Generate Voronoi polygons.
4. Transform from polygons to lines.
5. Break the lines.
6. Delete the lines that are not touching the river polygon and are outside of it, keeping only the polygon edge lines and the medial axis line inside the polygon.
7. Extract the medial axis line that are inside and not touching the river polygon using graphs.
8. Extract the vertices of the medial axis line.
9. Back to Voronoi polygon edge lines, the diameter of the lines is the diameter of the river in that vertex, take the diameter and save to its current vertex;
10. Generate a buffer in the vertices extracted with its diameter value only if the diameter is higher than the maximum distance between poles allowed to the energy line topology.

V. CASE STUDY: STATE OF PARANA, BRAZIL

Parana, one of the 26 states of Brazil located in the southern region of the country, has an area of 199,298.982 square kilometers and boasts a diverse hydrological landscape, including numerous bodies of water and other hydrological features (Figure 1).

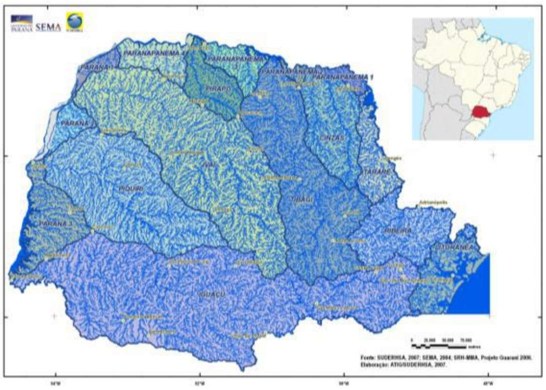

Fig.1 – Hydrographic Basins of the State of Paraná

Source: Adapted from SUDERHSA (2007)

The vector data containing surface river networks for the state of Paraná is available from the Instituto de Águas e Terra (IAT). This data was produced by SUDERHSA [7] and includes detailed information on river morphology, water flow, and other hydrological features.

Applying the methodology, first (a) the vector data was segmented into nine grids, in Figure 2 are viewed of the grids zoomed. Then, (b) the vertices were densified and equalized each 15 meters of all river's polygons. With the polygons densified the Voronoi tool was applied (c), generating a polygon to each vertex, Figure 3. The Voronoi polygons were converted to lines (d) and the lines were broken (e). The lines that were not touching the river polygon and were outside of it were deleted (f), with only the polygon edge lines and the medial axis kept Figure 4. The medial axis line was extracted (g) using graphs with threshold of 10 meters from the lines inside and not touching the river polygon Figure 5. The medial axis line was converted into vertices (h). Back to Voronoi polygon edge lines, its diameter is the diameter of the river in that region, so the diameter value of the edge was saved into the medial axis vertex touching it (i). Lastly, a buffer of the medial axis vertices with its diameter value was generated (j), only if the diameter is higher than the maximum distance between poles allowed to the energy line topology, in this case 30 meters Figure 6. The results obtained to the state of Parana in Figure 7, shows all the restrictions to the state based on the maximum width of the rivers.

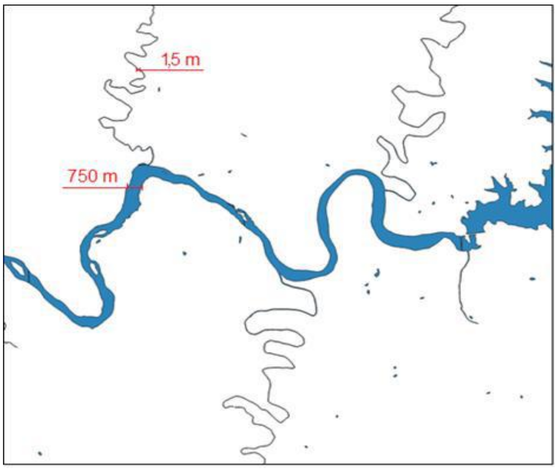

Fig.2 – Grid zoomed

Source: The authors.

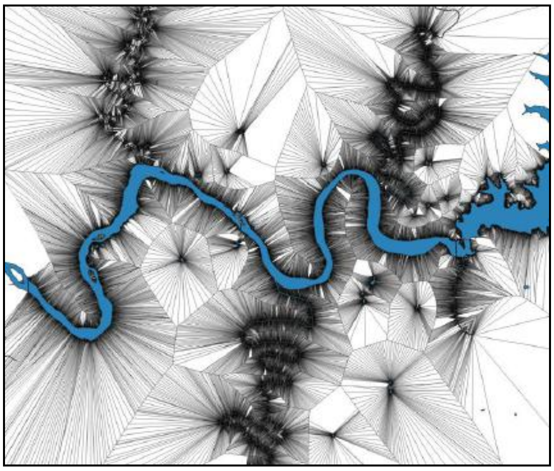

Fig.3 – River polygon + Voronoi polygons

Source: The authors.

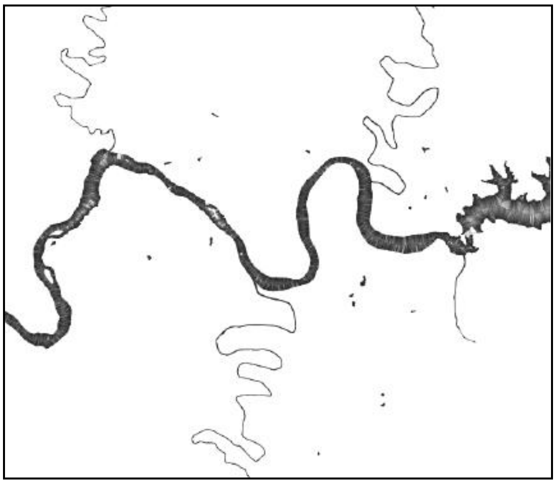

Fig.4 – Voronoi edges

Source: The authors.

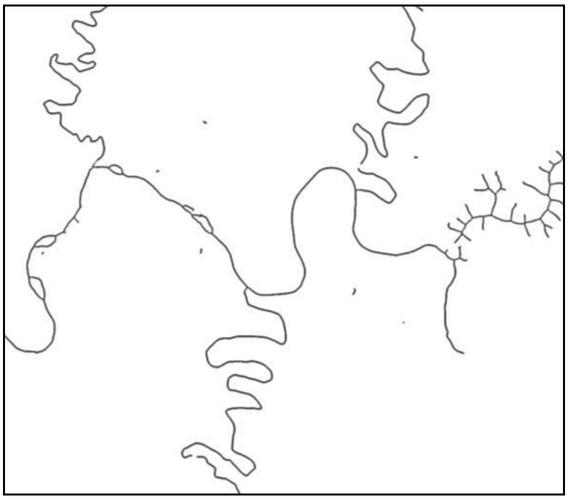

Figure 5 – Medial axis

Source: The authors.

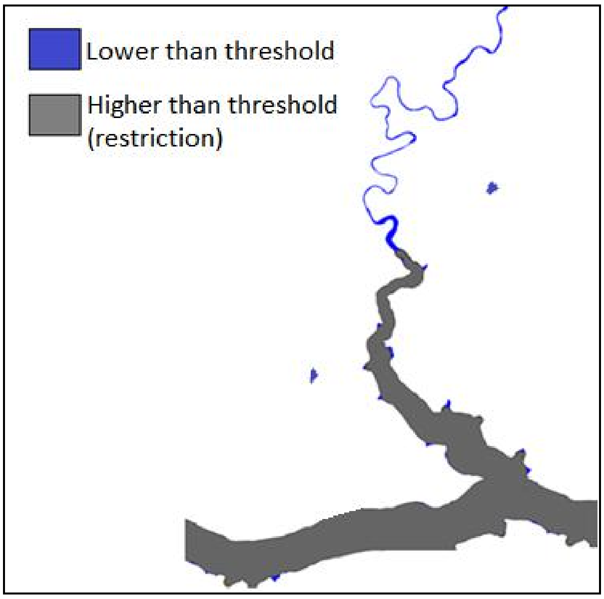

Fig.6 – River restriction buffer

Source: The authors.

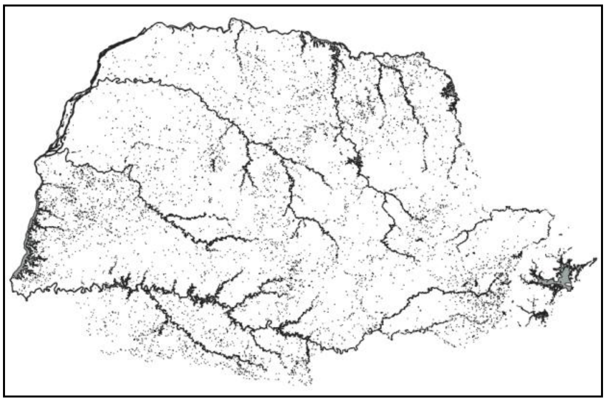

Fig.7 – Buffer in rivers wider than 30 meters in the State of Parana, restricted to build distribution lines with threshold of 30 meters.

Source: The authors.

VI. CONCLUSION

This article sought to highlight the problems of distribution network expansion and its restrictions. A solution proposal was presented as a framework using geoprocessing methods to obtain the restricted area. The case study results to the state of Parana, Brazil, showed a promising solution that can contribute to obtain the restrictions of rivers by different, helping decision-makers in distribution energy lines routing.

A good estimate of the restricted area of a river is highly related to the quality of the geospatial data used, so the data is very important in the methodology.

The code and the data applied in this paper are available on demand.

ACKNOWLEDGEMENTS

The authors would like to thank the National Electric Energy Agency (ANEEL) and Copel Energy Distribution Company for funding the R&D project ANEEL PD-02866-0509/2019 "UAV E IA AS SUBSIDIES FOR AUTOMATIC GENERATION OF OPTIMAL LD TRAINING", as well as the contribution of other Lactec researchers involved in this project.

REFERENCES

[1] Chiarani, E., Antunes, A.F.B., Drago, D., Oening, A.P. & Paschoalotto, L.A.C. 2022, 'Optimal Site Selection using Geographical Information System (GIS) Based Multicriteria Decision Analysis (MCDA): A case study to Concentrated Solar Power Plants (CSP) in Brazil', Anuário do Instituto de Geociências, 46:48188. https://doi.org/10.11137/1982-3908_2023_46_48188

[2] HCMIGIS (2023). QGIS Plug-in. Version 23.2.1. Disponível em: <https://plugins.qgis.org/plugins/HCMGIS/>

[3] Karimipour, Farid & Ghandehari, Mehran & Ledoux, Hugo. (2013). Watershed Delineation from the Medial Axis of River Networks. Computers & Geosciences. 59. 132-147. 10.1016/j.cageo.2013.06.004. Diponível em: <https://www.researchgate.net/publication/254084470_Watershed_Delineation_from_the_Medial_Axis_of_River_Networks>

[4] Monteiro et al. 2005. Compromise Seeking for Power Line Path Selection Based on Economic and Environmental Corridors. IEEE Transactions on Power Systems. 20(3), p1422–1430. https://doi.org/10.1109/TPWRS.2005.852149.

[5] Nyberg, B., Buckley, S.J., Howell, J.A., Nanson, R.A., (2015). Geometric attribute and shape characterization of modern depositional elements: A quantitative GIS method for empirical analysis, Computers & Geosciences, Vo. 82, 2015, p. 191-204. Disponível em: <https://plugins.qgis.org/plugins/geometric_attributes/>

[6] Santos et al. 2019. Optimizing routing and tower spotting of electricity transmission lines: An integration of geographical data and engineering aspects into decision-making. Electric Power Systems Research. 176 (2019) 105953.

[7] SUDERHSA, 2007. Mapas e dados espaciais. Disponível em: <https://www.iat.pr.gov.br/Pagina/Mapas-e-Dados-Espaciais>