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Geospatial Analysis of Tree Species for Ecological Economics

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Abstract. Ecological economics requires spatial, biotic, and abiotic data, to be analyzed for management decision-making. The *Tachigali Subvelutina,* popularly known as *charcoaler,* is a promising tree species in Brazilian economy to energetic plantation. The *charcoaler* can be used as an energy source (production of firewood and charcoal), lumber and plump (making fence posts, pillars, construction and packaging), pulp and paper, landscaping and reforestation to recover, and environmental restoration. The aim of this study is to geospatial analyze the potential species distribution of *Tachigali Subvelutina* to determine areas for reintroduction, and to discover potential areas of conservation and forest management. Results presented five rules that best represented the six physical environment themes of the study.

Keywords: ecological economics, economic systems, business intelligence, management information systems, sustainable management.

1. Introduction

The Ecological Economics seeks to understand the economy and its interaction with the environment from the physical and ecological principles. The perception of resource allocation problems and how they should be treated promotes the unification of biophysical basis of ecological and economic systems as interdependent, co-evolutionary categories. In this study, we model the potential distribution of tree species from Amazon to support studies for the conservation and the reintroduction of species, besides to evaluate theoretical approaches to bio-geographic processes [1].

The use of geographic data, structured in geographic databases, and manipulated by geographic information systems, recognised a large amount of data to be pre-processed, explored and analysed, using many geo-visualization[1] techniques and tools. Along with, data mining techniques were applied in order to discover interesting rules and patterns. Geographical data correspond to a reference dimension (location) directly related to the real geographical world, such as satellite images, maps, environmental data collected in the field, cadastral inventories, and numerical models of land [2]. Spatial databases are collections of geo-referenced data, handled by Geographic Information System (GIS). GIS are computer systems capable of capturing, modelling, storing, retrieving, manipulating, analysing, and presenting spatial data [3]. Data mining denotes various processes aiming to explore large databases, in order to extract knowledge by recognizing patterns and relationships among variables, obtained by reliable techniques and validated by their statistical expression [4].

The Amazon has an important role in the planet's carbon cycle, and a great influence on climate change. The impacts of human activities on Amazon ecosystems include the effects of deforestation, logging, burning, and fires. Regarding the Tocantins River basin, an affluent of Amazon River, a reduction of 16.75% of the native vegetation was estimated during the period of 1990-2007. This area is rapidly changing the

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[1] Geovisualization integrates approaches from visualization in scientific computing (ViSC), cartography, image analysis, information visualization, exploratory data analysis (EDA), and geographic information systems (GISystems) to provide theory, methods, and tools for visual exploration [5].

process of native cover, depending on population and economic growth registered in Tocantins State for the last two decades.

While the process of deforestation has partly promoted an expansion of regional economy, nonetheless, for the Tocantins River basin, this process has been resulted in eradication or reduction of plant and animal species, affecting negatively the biodiversity of the region. Moreover, the social community suffer the damage due to the non-use of the economic potential from these species. A case example in regional terms can be given by the species *Tachigali Subvelutina*, popularly known as *charcoaler*, traditionally used as stakes in construction, also as charcoal, and urban landscaping. This charcoal tree is a promising species in the economics of energetic plantations.

This work has the purpose to model the potential geographic distribution of the *Tachigali Subvelutina* species in the Sub-basin of Tocantins River. The aim is to determine areas for reintroduction of the *Tachigali Subvelutina* species and to discover potential areas of conservation and forest management. The understanding of the relationships between vegetation and environmental variables is significant to estimate the impacts of *charcoaler* distribution and productivity.

2. Methods

The study area consists of a stretch of two irregular polygons of Tocantins river basin, located in the north region of Brazil, between latitudes 08°00'00" S and 11°00'0" S, and from longitude 48°54'41,360" W and 47°27'11,395" W, Figure 1. Its area covers 26,536.5 square kilometers, and has a circumference of about 1,226,084 meters. The anthropized area corresponds to 10,045.4 km^2. Tocantins River flows to the mouth of Amazonia River.

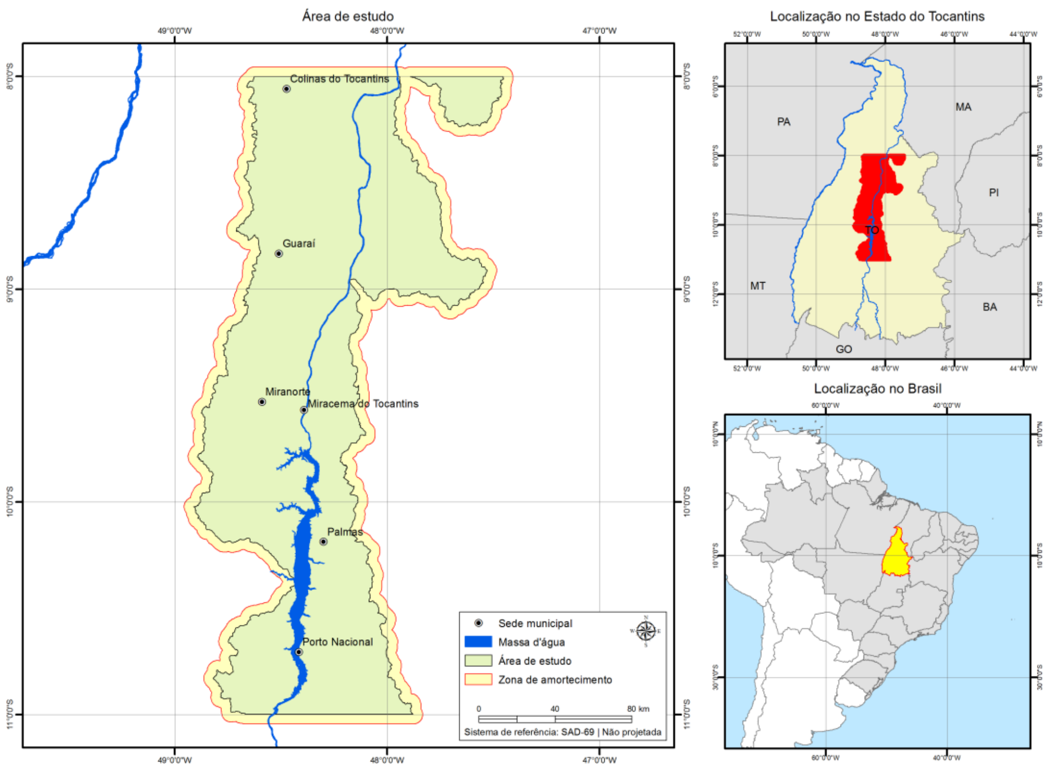

Fig. 1: Study field

2.1. Geo-processing

The geospatial themes of physical environment of this study include: geology (rocks), hydrogeology, geomorphology (relief), pedology (soil), declivity, erodibility, hypsometry, hydrology, and vegetation.

The geological and geomorphology data were originated from the Settlement Project of the Amazon Protection System Databases[2], scale 1: 250,000, WGS84[3] reference system. The geospatial vector data of this project were obtained from the original drafts, interpreted in 1: 250,000 scale, from surveys of natural resources conducted by Radam and Radambrasil[4] projects. Thereafter, these data were reinterpreted with the support of semi-controlled mosaics Radar (1972) and Landsat TM-5 (2001) images, information of other institutions, and fieldwork.

The information plan of hypsometry (altitude) was generated from the polygonising of level contours of Continuous Digital Cartographic Base of Tocantins State, using geographic information system of ESRI / ArcGIS 9.3[5]. This product was obtained in 1: 100,000 scale.

The information plan of potential erodibility soil was obtained through the establishment and digital manipulation of declivity classes and the erosive potential of the soil. The plan considered the interpretation of the following sources:

a) Topographic charters of IBGE and DSG, 1: 250,000 scale.
b) Draft pages of thematic interpretation from soil, geology and geomorphology, 1: 250,000 scale.
c) Multispectral images of Landsat TM in bands: 3, 4 and 5; 1: 250,000 scale (1996).
d) Semi-controlled radar mosaics of images, 1: 250,000 scale, by Radam and Radambrasil projects.
e) Reports of pedology, geomorphology, and geology, by Radam and Radambrasil projects.
f) Geo-environmental Map of the State of Tocantins, 1: 1,000,000 scale, produced by the staff of Geosciences Division of the Midwest, department of Geosciences (CGD), IBGE (Digeo-CO / DGC / IBGE), in 1995.

The watershed information plan contains the 30 major river basins of the river systems from Tocantins and Araguaia rivers. This product was created within the agro-ecological zoning project with support from topographic charts of DSG[6]/IBGE[7], 1: 250,000 scale (generating a digital elevation model from level contours), and satellite images from the National Department of Water and Power (DNAEE)[8]. Later, we refined this information by the support of Continuous Digital Cartographic Base, and CBERS2 and Landsat 5 satellite images, 1: 100,000 scale. After all, the limits of the river systems from Araguaia and Tocantins rivers were revised.

The information plan of phyto-ecological regions was produced in 1: 100,000 scale. The data was obtained from the geographic database by mapping the phyto-ecological regions, and the Forest Inventory of Tocantins State[9]. The information plan was generated from digital image processing techniques of Landsat MSS-2 (1973), TM Landsat-5 (1990, 2005 and 2007), and CBERS-2B (2008 and 2009). The digital elevation model of SRTM supported the visual interpretation, besides geology maps, like topography and soils. In this way, we could identify the phyto-ecological regions and their vegetation types. The plot units were mapped according to the terminology of the Brazilian Vegetation Technician manual[10], and the official

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[2] Amazon Protection System (SIPAM). Database of Sipam - State Center of Tocantins members. Population of Amazon Databases. Legal Amazon - State of Tocantins. Brasília: Presidency / Civil House / Operations and Management Center of the Amazonian Protection System (Censipam), 2004. DVD-ROM. (Thematic vector and tabular data structured in scale 1: 250,000).

[3] WGS 84 - World Geodetic System - is a Conventional Terrestrial Reference System (CTRS), which means that the observations made are reduced to the same time, eliminating the effect of pole movement in certain coordinates.

[4] The Federal Government through the Ministry of Mines and Energy conducted the Radam and Radambrasil projects in the 1970s and 1980. The current surface of Tocantins State covers six pages, published in the series Survey of Natural Resources. The pages namely: (i) SC.23.Rio San Francisco and SC.24 Aracaju - volume 1, 1973; (ii) SB. Teresina and part of SB.24 Leaf Jaguaribe - Volume 2, 1973; (iii) SB.Araguaia and part of the leaf SC.22 Tocantins - volume 4, 1974; (iv) SC.22 Tocantins - Volume 22, 1981; (v) SD.22 Goiás - Volume 25, 1981; and (vi) SD. 23 Brasilia - Volume 29, 1982.

[5] This information plan was generated in 2012 through the GIS Laboratory of SEPLAN, and integrates the Geographic Database of Tocantins. However, it has not been published.

[6] Division of Geographic Service - Brazilian Army.

[7] Brazilian Institute of Geography and Statistics.

[8] Currently, the National Water Agency (ANA) and the National Electric Energy Agency (ANEEL) assumed DNAEE competencies.

[9] Department of Planning and Modernization of Public Management (SEPLAN). Department of Research and ecological zoning. Division of Ecological-Economic Zoning (DZE). Geographic Database Mapping of the phyto-ecological regions and Tocantins Forest Inventory. version 1. Palmas, SEPLAN / DZE, 2013. DVD-ROM. (Thematic vector data structured in 1: 100,000 scale).

[10] Fundação Instituto Brasileiro de Geografia e Estatística (IBGE). Manual técnico da Vegetação Brasileira. Rio de Janeiro: IBGE, 1992, 92p.

classification of phyto-physiognomy from the *Cerrado* biome. To identify the plot units we used information obtained from activities of the forest inventory, botany collection, and the mapping of vegetation carried out between September 2008 and August 2011.

2.2. Data mining

The first stage consisted of evaluating data mining objectives in agreement with our data set, which was constructed in order to achieve the purpose of the work. The exploratory research of Tachigali Subvelutina species may include an understanding of the relationships between the vegetation and the environmental variables in order to determine areas for reintroduction, conservation, and forest management. In this case, the data mining of potential geographic distribution of Tachigali Subvelutina should identify the relationships between biotic and abiotic factors.

Apriori, an association rule algorithm, is capable to find patterns among data properties, by the identification of unknown relationships between them. The association rule has the form A -> B, where A, called the antecedent, and B, called the consequent are sets of items or transactions, and the rule can be read as: the attribute A often implies B. To evaluate the generated rules we used some measures of interest: the most used are well established, such as support and confidence in the work of [6]. The authors [7] performed a survey of other metrics and suggested strategies for selecting appropriate measures for certain areas and requirements.

- Support: The support of a rule is defined as the fraction of the items, which satisfy the set A and B of the rule.
- Confidence: It is a measure of the strength of support to the rules and corresponds to statistical significance. The probability of the rule in finding B so that B also contain A;
- Lift: Used to find dependencies, it indicates how much more common it becomes B when A occurs. It can vary between 0 and ∞.

3. Results and Discussion

The association rules as an exploratory technique generated rules describing the most relevant patterns found in the selected data. These patterns represent the possible combinations of variables occurring with a particular frequency, composed by antecedent and consequent. The antecedent contains a subset of attributes and their values, and the consequent has a subset of attributes resulted of the antecedent.

In this work, the purpose for generating association rules was to discover patterns of potential areas where the *Tachigali Subvelutina* specie occurred. Therefore, the antecedent is composed by abiotic factors of the environment, and the consequent by the biotic factor of *Tachigali Subvelutina* specie. For the data association, we selected out six spatial themes of physical geology to be analysed: geomorphology, erodibility, water body away, soils up to the 2nd level of classification, and the vegetation.

The procedure give us a total of more than 1,000 association rules with many different relations. However, we only selected five classification rules that best represented the six physical environment themes where *Tachigali Subvelutina* species were found as consequent. The five classification rules were selected based on their confidence indices and by the quantity of compound attributes. The selected instances represent a total of 274 individuals of *Tachigali Subvelutina* specie which were occasionally found in the 98 plots, 147,000 m2, of the collected field.

Each rule has different levels of physical themes enrolled and their interpretation, e.g., rule 508, Table 1:

Table 1. Interpretation of rule 508.

Enrolled Attributes	**Geology, Geomorphology, Pedology (Soil), Erodibility, Hypsometry (altitude), and Hydrology (distance from water bodies)**
Rule Denotation	Geol_Let=Dp Geom_Simb=Dt Erod_Clas=Muito_forte CotaFisico=400 Dist_Agua=400 EB_Nivel_2=FFc ==> Acronimo=Scle pani
Rule Interpretation	If geology is from Pimenteiras formation, and geomorphology has structural tabular surface composed by dissecting processes; and erodibility with shallow and very shallow soils, with presence of rock outcroppings, predominant relief ranging from hilly to steep, and slopes greater

	than or equal to 45%. Quota of altitude between 300 and 400 meters, with a distance from water bodies from 400 to 500 meters; and the soil composed by concretionary Petric Plinthosols; then there is the presence of the *Tachigali Subvelutina* specie.

The five best rules composition of the abiotic variables for reintroduction, and potential areas for conservation and forest management are shown in Figure 2.

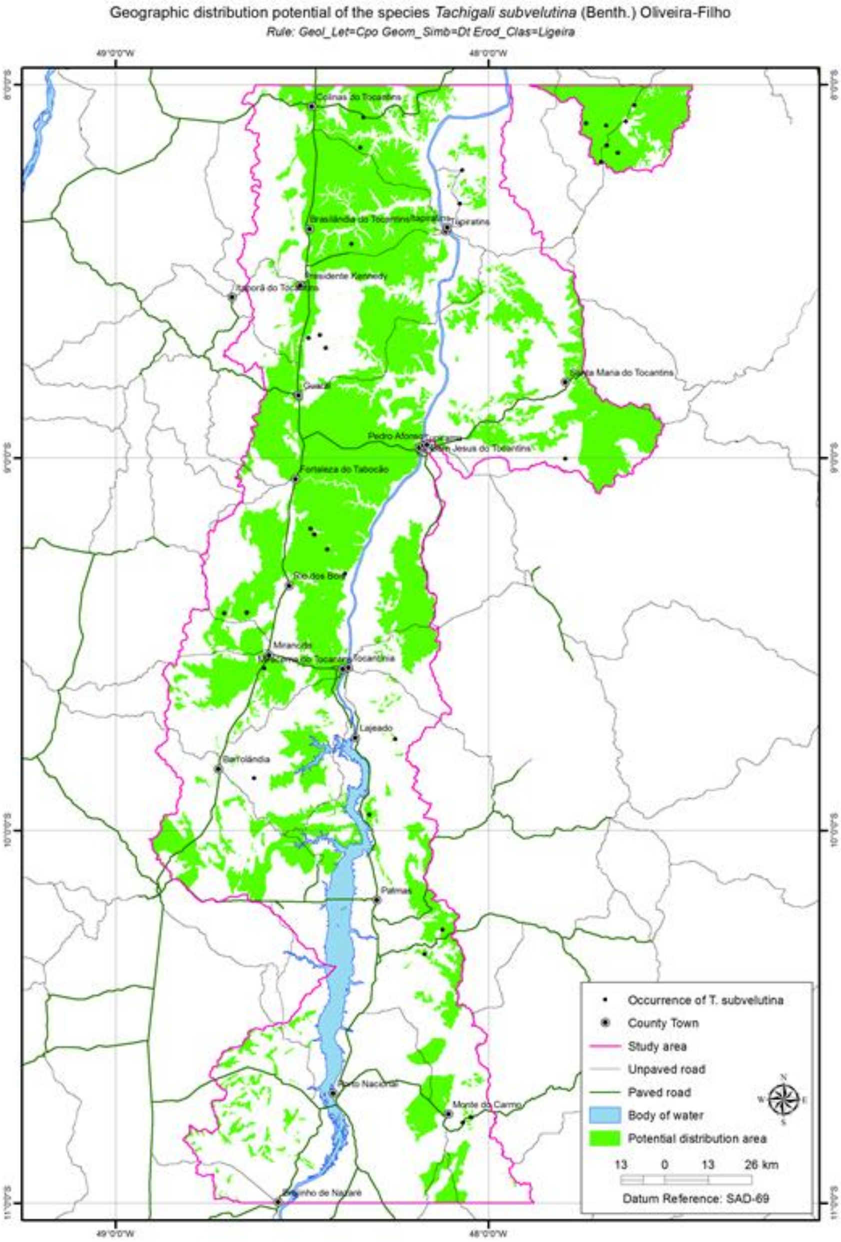

Fig. 2: The composition of the five rules. These compound rules represent 9,538.83 km ²of the study field, with 3,512.31 km ²of human occupation.

1) Geol_Let=Dp Geom_Simb=Dt Erod_Clas=Muito forte

Geology is from Pimenteiras formation; geomorphology has structural tabular surface composed by dissecting processes; erodibility with shallow and very shallow soils, presence of rock outcroppings, predominant relief ranging from hilly to steep, and slopes greater than or equal to 45%.

2) Geom_Simb=Dt Erod_Clas=Ligeira CotaFisico=200

Geomorphology has structural tabular surface composed by dissecting processes; erodibility with soils ranging from well to strongly drained occurring in smooth relief (predominance slopes between 3-8%); and topographic elevation of 200 meters.

3) Geom_Simb=Dt CotaFisico=200 EB_Nivel_2=RQo

Geomorphology has structural tabular surface composed by dissecting processes; topographic elevation of 200 meters; soil with presence of órticos quartizic neossolos.

4) Geol_Let=Dp Geom_Simb=Dt EB_Nivel_2=FFc

Geology is from Pimenteiras formation; geomorphology has structural tabular surface composed by dissecting processes; soil with presence of concretionary Petric Plinthosols.

5) Geol_Let=Cpo Geom_Simb=Dt Erod_Clas=Ligeira

Geology is from Poty formation; geomorphology has structural tabular surface composed by dissecting processes; erodibility with soils ranging from well to strongly drained occurring in smooth relief (predominance slopes between 3-8%).

4. Conclusion

In this work, we developed a geospatial mining analysis for the potential distribution of *Tachigali Subvelutina* species, with the aim to determine areas for reintroduction and to discover potential areas of conservation and forest management. To perform this purpose, we collected and manipulated geospatial themes of physical environment including geology (rocks), hydrogeology, geomorphology (relief), pedology (soil), declivity, erodibility, hypsometry, hydrology, and the vegetation.

The procedure give us five rules that best represented the six physical environment themes where *Tachigali Subvelutina* species were found as consequent, selected based on their confidence indices and by the quantity of compound attributes. The five rules could represent 78.10% of occurrences of the *Tachigali Subvelutina* species, inside 35.94% of the geospatial study field. These results indicate the potential use of the integration between data mining and geo-visualization in discovering potential distribution of species.

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