Lithology and land use and land cover maps improved to support soil mapping

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Abstract. *Soil-landscape correlations are used to produce and interpret digital soil maps. This study aims to present a methodology for obtaining and preparing environmental covariates related to soil formation (lithology) and transformation (land use/land cover) to support digital soil mapping in Rio de Janeiro state, Brazil. Maps provided by the Geological Survey of Brazil and the MapBiomas Project were used. Lithology and land use/land cover classes, respectively, were merged according to class similarity and soil-landscape correlation. The derived maps have fewer classes and better correlation with soil formation and transformation, and thus, are ready to be used to produce and interpret soil spatial patterns in Rio de Janeiro state.*

1. Introduction

The Earth is a closed and cyclic system. Transformations that occur in it are derived from the constant interaction between its biotic and abiotic components (Martins et al., 2003). Soils are examples of natural components that evolve from the interaction among covariates such as: parent material (lithology), climate, organisms and relief, overtime (Soil Science Division Staff, 2017).

In the recent decades, geotechnologies have been increasingly used to optimize studies of landscape elements related to soil attributes (Moore et al., 1993; Vasques et al., 2016). At the same time, researches on environmental and sustainability issues reveal thegreat importance of soil use and management to mitigate climate change, since soils havegreat potential to sequester carbon, an element associated with the formation of greenhouse gases (Machado, 2005), and to store water and nutrients.

In this context, obtaining and studying geospatial information related to soil formation and transformation helps to understand global dynamics and their impacts on sustainability. Above all, geospatial data serve as covariates for the generation and interpretation of digital soil maps (McBratney et al., 2003; Vasques et al., 2016).

2. Objectives

The purpose is to present a methodology for obtaining and preparing maps of environmental raster covariates for digital soil mapping in Rio de Janeiro state, Brazil, namely lithology and land use/land cover, related to soil formation and transformation, respectively.

3. Materials and Methods

3.1 Preprocessing

The environmental covariates explored in this research were: lithology, and land use/land cover. The software used was ArcMap v.10.7.1 (ESRI, Redlands, USA). In order to adjust the spatial reference of the dataset, all maps were reprojected to Lambert Conical and Conformal projection system.

The lithology data was obtained from the Geological and Mineral Resources Map of Rio de Janeiro State, scale 1:400.000, produced by the Brazilian Geological Survey in shapefile format, and available at the link < https://rigeo.sgb.gov.br/handle/doc/18458 > (Heilbron et al., 2016). The vector map was converted to raster with an output cell size of 30 m.

The land use/land cover data was obtained from the Land Use/Land Cover Map of 2016 produced by the MapBiomas Project in raster format with a cell size of 30 m (MapBiomas, 2016). The image was obtained following the instructions at item 5 of the "MapBiomas Collections" page, accessed at the link <https://brasil.mapbiomas.org/colecoes-mapbiomas>, using a Toolkit on the Google Earth Engine platform.

3.2 Class merging

Some lithology and land use/land cover classes were merged with other classes, respectively, in order to reduce the number of classes, as well as increase their correlation with soil types, enabling their use as covariates for digital soil mapping in the Rio de Janeiro state. The similarity between classes and their theoretical correlation with soil types were considered as a criterion for merging.

Lithology classes were merged based on the columns "LITOTIPO1" and "LITOTIPO2" and saved in a new column called "Litotipo". The mineralogical composition and the rock types (igneous, metamorphic or sedimentary), rock groups and unconsolidated sediment types were considered as criteria for merging.

The classes present in the land use/land cover map were merged based on their detailed description available at the link < https://mapbiomas-br-site.s3.amazonaws.com/downloads/Legenda_Cole%C3%A7%C3%A3o_7_-_Descri%C3%A7%C3%A3o_Detalhada_-_PDF_PT.pdf >. The 22 original land use/land cover classes (column "uso_cobert") were rearranged into 12 classes in a new column ("uso_cob1"), based on similarities of the environment, including wetlands, environments with sandy soils, agricultural areas and built-up and barren areas.

4. Results

4.1 Lithology and land use/land cover types

Lithology classes were rearranged into 9 lithotype classes (Table 1), while landuse/land cover classes were merged into 12 classes (Table 2).

Table 1. Name and description of the rearranged lithotype classes.

Name	Description
Carbonate and calcisilicate rocks	Carbonate rocks or groups of rocks containing at least 1/4 of carbonate and calcisilicate rocks, with one of the lithotypes as the first element of the set (it was considered that the first element is the predominant lithotype in that polygon).
Clastic sedimentary rocks	Sedimentary rocks, mostly from "Sand bars" type deposits in interlocking river systems, alluvial fan systems, mud flow deposits and sand bars.
Clayey unconsolidated sediments	Swamp and mangrove deposits, where the clay fraction naturally predominates.
Mafic and ultramafic rocks	Rocks of mafic or ultramafic composition or groups of rocks that contain ultramafic as the first or second element of the set (e.g., norite, gabbro, gondite, amphibolite, meta-ultramaphyte).
Micaceous quartzofeldspathic rocks	Igneous and metamorphic rocks with high mica content (e.g., biotite granite, muscovite gneiss, garnet-biotite gneiss).
Quartzofeldspathic rocks	Rocks or groups of rocks in which the majority have an acidic/intermediate granitic/tonalitic composition, represented by either igneous (e.g., granite, enderbite, charnokite, diorite, tonalite, trachyte, syenite)or metamorphic rocks (e.g., gneiss).
Quartz-rich rocks	Rocks rich in quartz (e.g., quartzite) or groups of rockswhose first element is a quartz-rich rock (with the exception of quartzite and meta-chert associated with marble).
Sandy unconsolidated sediments	Coastal, ancient beaches and eolic, alluvial or anthropogenic deposits with a predominance of sand or coarser fractions.
Unconsolidated sediments	Colluvium and materials from fluvial-marine deposits with no predominance of any textural fraction.

Table 2. Name and description of the rearranged land use/land cover classes.

Name	Description
Agriculture	"Soy", "Coffee", "Cane" and "Other Temporary Crops"
Built-up and barren	"Urbanized Area", "Mining" and "Other Non-Vegetated Areas"
Beach, dune and sandbank	"Beach, Dune and Sand Spot", "Wooded Sandbank Vegetation" and "Herbaceous Sandbank Vegetation"
Forest	"Forest Formation"
Forest plantation	"Forest Plantation"
Pasture and agriculture mosaic	"Mosaic of Uses"
Other non-forest	"Other Non-Forest Formations"

formations	
Pasture	“Pasture”
Rocky outcrop	“Rocky Outcrop”
River, lake and ocean	“River, Lake and Ocean” and “Aquaculture”
Savanna	“Savanna Formation”
Wetland and mangrove	“Mangrove”, “Wetland” and “Hypersaline Tidal Flat”

4.1 Lithology and land use/land cover maps

From the lithotype map generated for the Rio de Janeiro state (Figure 1), the majority (approximately 53,4%) of the state comprises Quartzofeldspathic rocks and Micaceous quartzofeldspathic rocks, i.e., mostly igneous or metamorphic rocks of intermediate/acid composition, which are widespread throughout the state territory.

Mafic and ultramafic rocks (~9,9%) and Carbonate and calcisilicate rocks (~5,5%) are interspersed in NE-SW belts, mainly in the northern portion of the state. Quartz-rich rocks (~6,2%) are concentrated in the central-east part of the state, mainly associated to Quartzofeldspathic rocks and Mafic and ultramafic rocks.

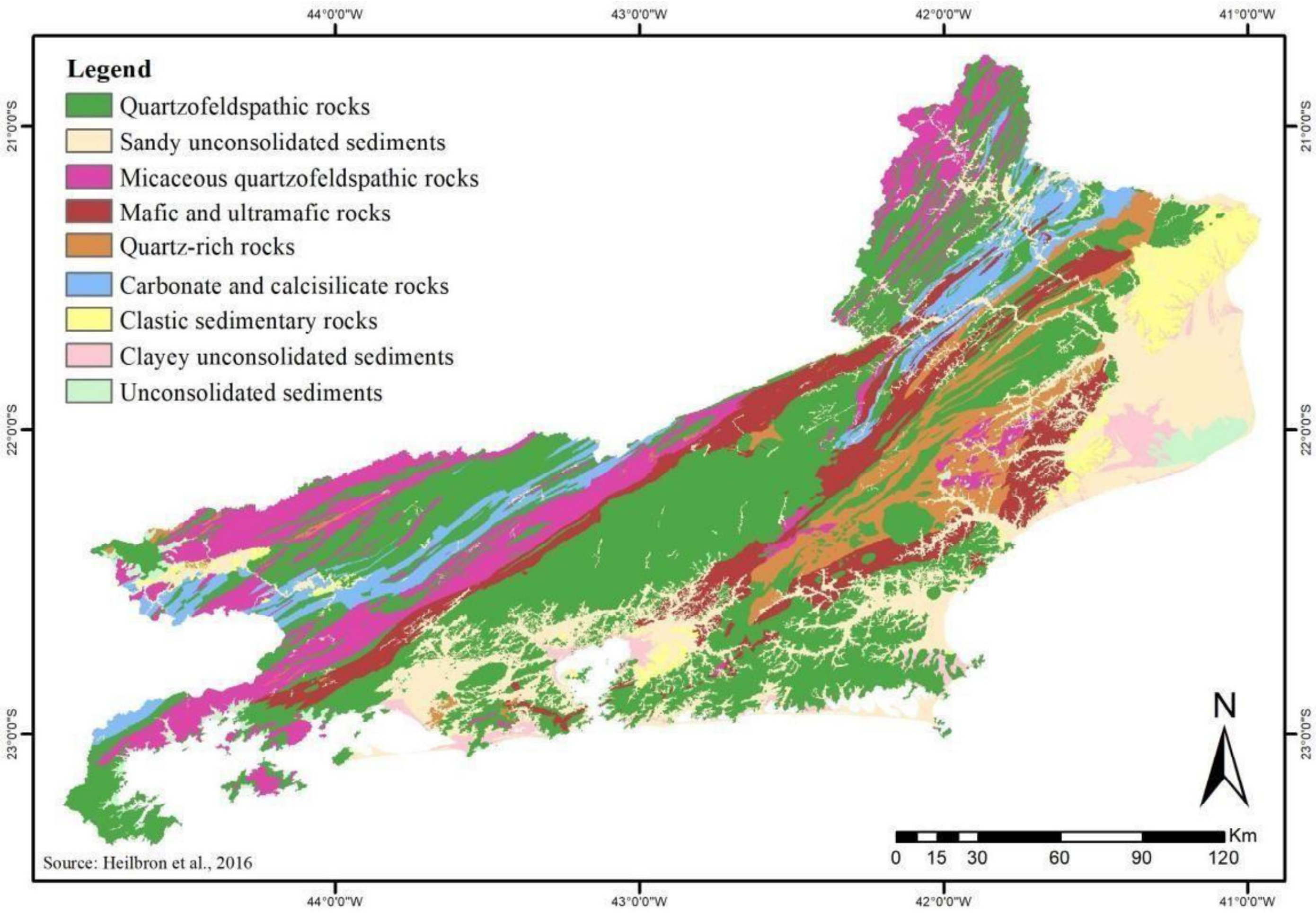

Figure 1. Map of Lithotypes of the Rio de Janeiro State, adapted from the Geological and Mineral Resources Map of Rio de Janeiro State (Heilbron et al., 2016).

Clastic sedimentary rocks (~3,4%), Unconsolidated sediments (~1,4%), Sandy unconsolidated sediments (~17,9%) and Clayey unconsolidated sediments (~2,3%) are located mainly in the plains and lowlands along the coastal zone, and the Sandy unconsolidated sediments extend inland around drainage channels.

From the land use/land cover map (Figure 2), adapted from the MapBiomas Project Land Use/Land Cover Map of 2016 (MapBiomas, 2016), most of the state territory is occupied by pasture (~41,9%) that is spread out across the state, followed by forested areas (29,3%) that are concentrated in the preserved areas with higher altitudes across the *Serra do Mar* (central part) and *Serra da Mantiqueira* (extreme northwest) mountain ranges.

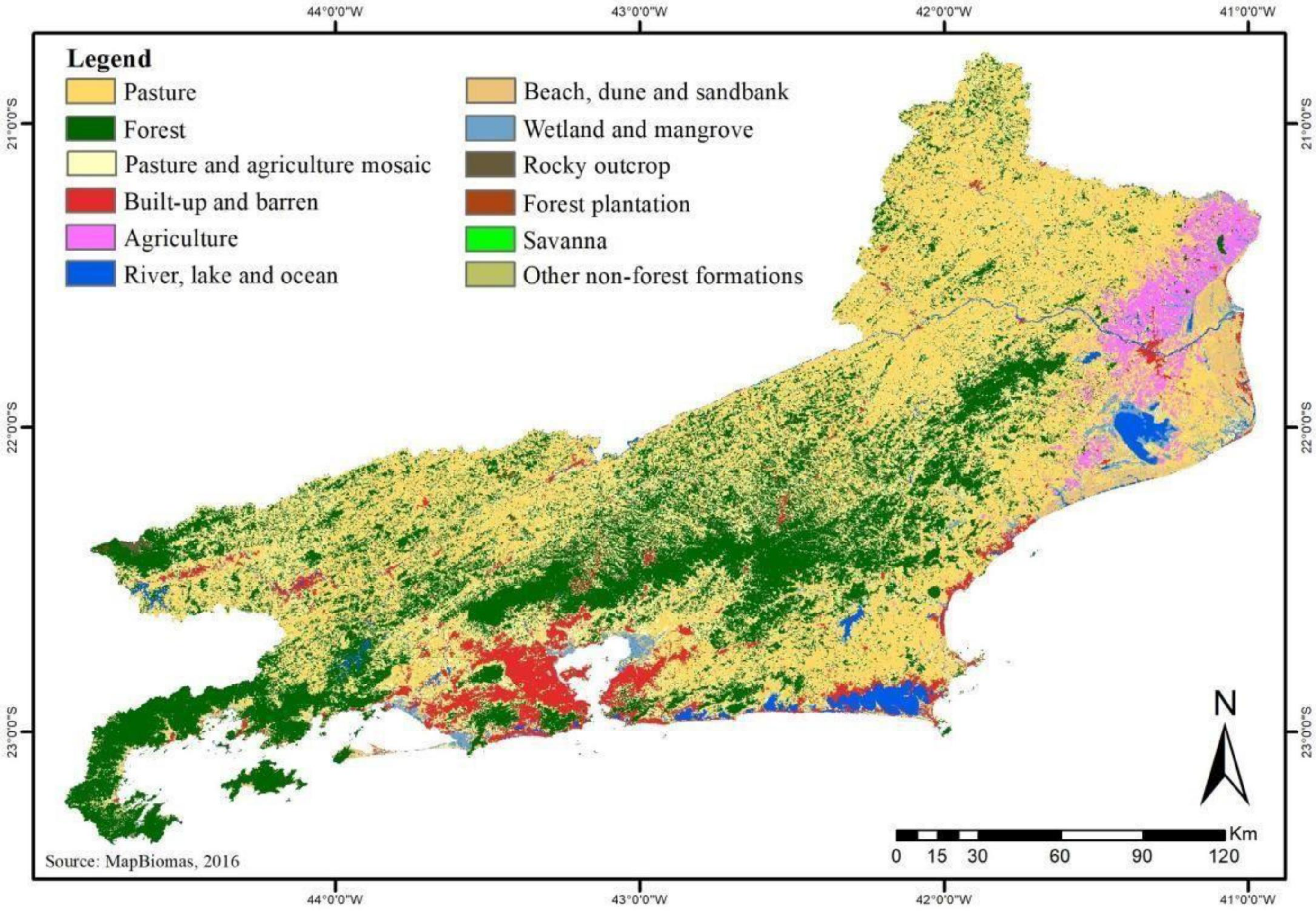

Figure 2. Map of Land Use/Land Cover in 2016 for the Rio de Janeiro State, adapted from the 7.1 collection of the MapBiomas Project (MapBiomas, 2016).

Agriculture (~2,7%) is mainly concentrated in the eastern part of the state, close to the border with Espírito Santo state. Despite the emphasis given to soybean, coffee and sugarcane crops in the MapBiomas map, most agricultural areas in Rio de Janeiro belong to the “Other Temporary Crops” class, which refer to other annual short/medium cycle crops, including maize, beans, vegetable, and other crops.

Built-up and barren areas (~5,3%) are concentrated at the more densely populated area in the southern part of the state, where the city of Rio de Janeiro, the state capital, and the surrounding metropolitan area are located. These areas are very close or adjacent to sensitive areas such as mangroves and sandbanks, which are protected by law.

5. Conclusions

The lithotype map shows a predominance of granitic or gneissic parent rocks that lead to more acidic and clayey soils. Sedimentary lithology concentrates in the coastal region and derives either more clayey or more sandy soils, depending on the texture of the parent sediment (lithology).

The land use/land cover map shows the predominance of pasture and forested areas in the Rio de Janeiro state. While the first acts more intensely on the soil dynamics,either increasing (e.g., improved pasture) or decreasing (e.g., degraded pasture) soil organic matter and fertility, the latter preserves soil characteristics that are closer to pristine conditions.

The methods used in the study produced novel and up-to-date lithology and land use/land cover geospatial data at a detailed spatial resolution (30 m) to support digital soil mapping and other initiatives in the Rio de Janeiro state. However, only the lithology and land use/land cover covariates partially explain the formation and dynamics of soils and their chemical and physical attributes. Thus, other environmental raster covariates, for instance, related to relief (e.g., slope, curvature), climate (e.g., precipitation, temperature)and organism activity (e.g., biomass content), must be included to improve digital soil mapping in the state.

6. References

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