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Indirect quantitative-qualitative pedologic geomorphic characterization in sub-basin of 7th order of the middle São Francisco watershed – northern Minas Gerais state

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Abstract

The characterization presented in this study aims to identify and map the different types of pedogeomorphic units found in a 7th order, the Pandeiros river basin, in the upper São Francisco River (1st order basin), located in the North of Minas Gerais State. A general panoramic view of the geodiversity is presented, since the Pedogeomorphic Maps allow a visualization of the spatial distribution of the main pedogeomorphic classes, providing important information for various purposes, such as teaching, research and land-use planning. These Maps are relevant specifically for the territorial planning, even without providing data of the local use and occupation because they have strategic information for the understanding and evaluation of the landscape dynamics in region, offering subsidies to the understandings of the processes, phenomena and behaviors of the physical environment related to the different forms of interference of human actions. The Maps also provide support for environmental assessments that have been applied to identify, characterize and monitor trends in environmental aspects.

Keywords: geology, geomorphology, pedology, relations of associativity between geo-systems.

1. Introduction

The quantified relationships between rocks, geomorphology (geoforms), soils, and surface formations are a fundamental contribution to prove the pertinence of morphogenesis and pedogenesis processes in land-use decisions (Martins Junior, 2014). They should also be useful for future mapping and other field studies, as they allow for probable indirect inferences from the relationships between rocks, soils and geoforms, applicable to agricultural projects and plantation studies for the production of biomass for bioenergy in a manner compatible with the grounds.

With this consideration, the basic meaning attributed to the calculations is the use of the pedo-geomorphic, pedo-lithographic and litho-geomorphic indices as the proper variables when classifying large watersheds, as a whole, or of the same large sub-basins in order to obtain homogeneous areas by measurable geosystem variables (Martins Junior, 2008). In this article we aim to describe these indices. This study is part of two research groups: 'Environmental Geosciences' and 'Integrated Solutions in Ecology Energy Economic and Management', both associated to the National Council for Scientific and Technological Development (*Conselho Nacional de Desenvolvimento Científico e Tecnológico* - CNPq).

Study area

The study area, shown in Figure 1, is inserted in the Pandeiros basin - UPGRH / SF9 in the Northern Region of Minas Gerais - which, according to Development Company of the São Francisco and Parnaíba Valleys (Companhia de Desenvolvimento dos Vales do São Francisco e do Parnaíba – CODEVASF, 2013), stands out for its mineral, agricultural and Eucalyptus forestry, but where the use of native forest with an economic production intention would be better.

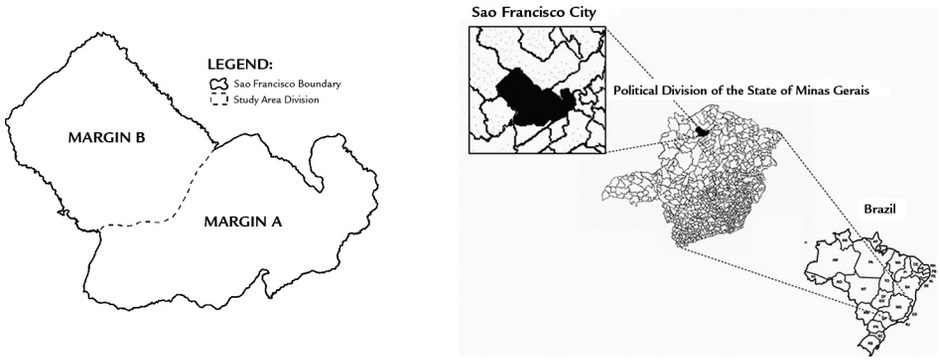


Figure 1
Location of São Francisco downtown.

Regional geology

The study area is located in the transition zone between the Mountain Range do Espinhaço (to the east) and the São Francisco River (to the west). In geotectonic terms the region is inserted in the transition zone between the São Francisco Craton and the Araçuaí Folded Range. The cratonic zone, in the definition of Almeida (1977), consists of a platform area whose foundation was consolidated in pre-Brasilian times, thus serving as an anchor for the folding bands established in Brasiliano times. Alkmim et. al. (1993, p. 50) perfected this concept, and the craton was "understood as a feature of the Upper NeoProterozoic, that is, shaped by the Brasilian tectonic event, although it has consolidated as a segment of the continental lithosphere since the Archean Eon."

The Araçuaí Range corresponds to the western portion of South America of the Araçuaí Orogen - Western Congo, as part of the Brasiliano - Pan African orogenic system. According to Pedrosa-Soares *et al.*, there was a (1) continental rift stage with an important contribution of glaciogenic sedimentation (1.0-0.9 GY), (2) the development of a passive margin (800 MY), and (3) with the closing of this ocean basin, the generation of a magmatic arc (625-570 MY). In this conception, the Espinhaço Range is excluded from this domain, which, however, is included in the same context by other authors (Almeida, 1977; Uhlein *et al.*, 1986, 1998). Souza (1985) recognized four major tectonogeological units in the region, (1) Intrachatonic rift (MesoProterozoic); (2) Marine epicontinental basin (NeoProterozoic); (3) Synclise basin (Mesozoic); (4) Final superimposed cover (Cenozoic). These geotectonic units respectively correspond to the following lithostratigraphic units: (1) Supergroup Espinhaço; (2) São Francisco Supergroup; (3) Areado Group; (4) Cenozoic deposits.

2. Methodology

In order to better organize the study in question, the municipality of São Francisco was divided into two relatively equal parts, considering as a natural parameter of separation the São Francisco River itself, whereby Margin A was denominated as the portion of land located to the southeast (right) of B, with B being the specific location of this study, which is the portion of lands located to the northwest (left), as shown in Figure 1.The B portion was evaluated by Teixeira (2016, unpublished data), as the part of the municipality most degraded from the point of view of the loss of original vegetation (Cerrado), this being the sub-basin of 7th order focus of this study.

Thus, for the accomplishment of this research the following data and information were used:

- Geological Map provided by the Economic Development Company of the State of Minas Gerais (CODEMIG - Year: 2014), scale1: 100,000.
- Pedological map provided by RURALMINAS (Year: 2003), scale 1: 250,000.
- Geomorphological map provided by RURALMINAS (Year: 2003), scale 1: 250,000.
- Vector Data with Municipal Limits ceded by Brazilian Institute of Geography and Statistics (IBGE).

In this way, geological, geomorphological and pedological maps "fused" together to form the Pedo-Geomorphic, Litho-Geomorphic and Pedo-Lithographic maps. From these, all areas of the geosystem variables (rocks, soils, geoforms) that were related to the total area of the study sub-basin were extracted. The indexes can be obtained from the overlaying relationships between rocks, soils and geoforms in such a way as to make these relationships perceptible for their importance in the topographic organization of the sub-basin and the relationships of interest for agricultural, forestry and pastoralism as well as mitigation actions. Thus, all the Pedo-Geomorphic, Litho-Geomorphic and Pedo-Lithographic indexes of interest are obtained.

3. Results

For the situation exposed in this study, the environmental conditions between rocks / geoforms / soils for this river basin should be described by the spatial relationships between them.

Main specific lithostratigraphic characterization

These data are extracted from the cartography for the study site with regional geoscientific information in the CODEMIG database (2014).

Q2a (Cenozoic - Quaternary) - Alluvial deposits along the large river channels, extending through their floodplains with kilometeric width; Are composed of gravel, sand in various granulometries and clay banks; The deposits are unconsolidated and have a metric thickness up to a maximum of 10 meters. (It occurs in 11.90% of

the area of interest)

NQdi (Cenozoic - Neogene / Quarenary) - Alluvial deposits arranged on terraces a little above the level of the most recent alluviums, generally sandy and not very clayey and with levels of gravel, with a thickness of about 5 meters (occurring in 41.18% of the area of interest), which are common in the upper parts, mainly on the edges of the sandstone plains, and which also cover the flat relief indistinctly.

K2up (Mesozoic - Cretaceous - Urucuia Group - Posse Formation) - It consists of sandstones of varying colors, usually in red tones, poorly selected and, as a rule, silicified; The best steep outcrops of cliffs; The thickness is estimated at 60 meters (Occurs in 19.24% of the area of interest).

K1a (Mesozoic - Cretaceous - Urucuia Group - Areado Group) - This is the lower level of the group, but is poorly represented by outcrops; In a few exposures, it is possible to see banks of clayey white sandstones interspersed with fine levels of a greenish silicon where the rock has a possible volcanic contribution; Sometimes there are silicified kernels, the thickness varies between 30 and 50 meters; The outcrops are, as a rule, covered by white sand produced by the intemperic disintegration of the rock; Lateritic shells exist in isolated sites (Occurs in 25.21% of the area of interest).

CPsf (Paleozoic - Caboniferous / Permian - Santa Fé Group) - Red diamonds, red shales with dropstones, microlaminated, red or locally green shales with pebbles and dripping blocks. Red clay matrix conglomerate, with pebbles and limestone blocks rounded to sub-angles of the Sete Lagoas Formation (Occurs in 1.50% of the area of interest).

NP2sl (Proterozoic - Neoproterozoic / Ediacariano - Bambuí Group - Sete Lagoas Formation) - Calcarenites, calcilutites and intercalated intraformational calcirrudites, forming a set of carbonate sediments with an average thickness of five meters, being able to reach locally at 15 meters. They always appear in depressions of the Archean basement, with an area of occurrence in drainage bottoms. The carbonaceous rocks show light gray to dark gray coloration and localized occurrences of cross strata of the hummocky type, columnar stromatolites and aragonite pseudomorphs (Occurs in 0.88% of the area of interest).

Pedological characterization

Ca11 – Cambi soil A + Littoral soils A (Occurs in 10.19% of the area of interest). AQa2 - Quartz sands + Yellow Red Latosol (Occurs in 16.97% of the area of interest). AQa4 - Quartz sands closed phase + Hydromorphic quartz sands (Occurs in 62.56% of the area of interest). Ae3 - Eutrophic Alluvial Soils A + Indiscriminate Planosols + Indiscriminate Hydromorphic Soils (Occurs in 9.76% of the area of interest). HQa - Hydromorphic Quartz Sands (Occurs in 0.10% of the area of interest). Ra2 - Littoral Soils A + Cambisol A (Occurred in 0.39% of the area of interest).

Geomorphological characterization

The most common geomorphological typologies found in the study area are: a) pedimentation; B) planing; C) river dissection; D) fluvial surfacing and dissection; E) river accumulation; F) fluvial deposition and g) exudation. Table 1 shows the predominance of the relief forms existing within each geomorphological typology for the locality of interest (Table 1).

Table 1
Geomorphological characterization of the studied site (Margin B).

Tipology	Prevalence of Relief Forms - Occurrence (%)												
	sa	pf	tf2	tf1	c	ptrv	rv	ve	str	so	kv	cv	krv
a)	-	-	-	-	-	-	-	-	14.91	-	-	-	-
b)	66.26	-	-	-	-	-	-	-	-	-	-	-	-
c)	-	-	-	-	2.45	-	1.87	-	-	-	0.20	3.40	0.08
d)	-	-	-	-	-	1.73	-	-	-	0.65	-	-	-
e)	-	4.61	-	-	-	-	-	-	-	-	-	-	-
f)	-	-	2.69	0.30	-	-	-	-	-	-	-	-	-
g)	-	-	-	-	-	-	-	0.79	-	-	-	-	-

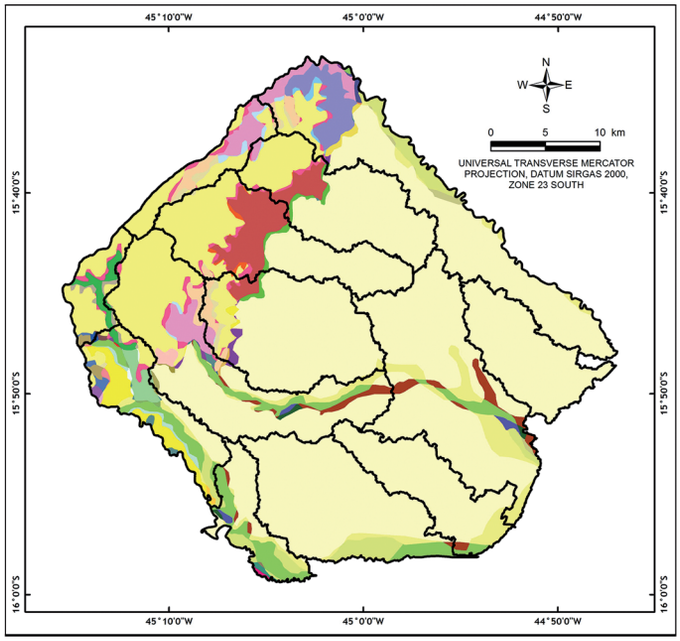
Pedo-geomorphic indices

The pedo-geomorphic indices, presented in Table 2, are of particular interest to agriculture in a regional view where the most striking features must be recorded.

Table 2
Pedo-Geomorphic Characterization of the study site (Margin B).

Soils	Occurrence % of Geoform with Soils												
	Tipology de Geoforms												
	c	ptrv	rv	str	ve	sa	kv	cv	so	pf	krv	tf1	tf2	
Ae3	Índex (%)	1.1	7.9	1.1	0.2	0.8	1.4	-	-	1.3	0.8	-	-	-
AQa2		1.4	0.8	2.8	81	1.1	7.9	1.1	0.8	0.2	1.3	0.13	-	-
AQa4		-	0.2	0.06	0.3	-	96	0.04	0.6	0.09	1.7	-	0.2	0.3
Ca11		21	14	11	12	6	1.4	-	28	5	0.4	-	-	-
HQa		-	-	-	-	-	35	-	-	-	8	-	-	56
Ra2		-	-	40	32	-	12	-	-	-	1	15	-	-

Figure 2 shows the spatial distribution of the Pedo-Geomorphic elements of the evaluated locality inserted in the municipality of São Francisco - Northern Minas Gerais.



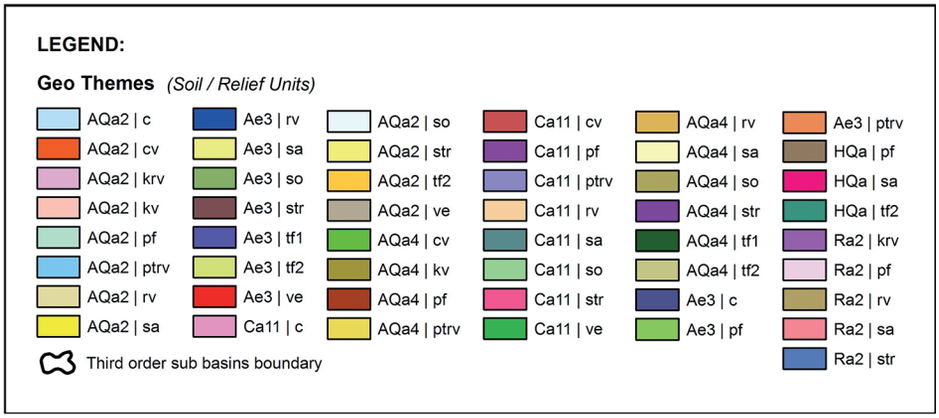


Figure 2
Map of the Pedo-Geomorphic aspects of the region of interest.

The meanings of the acronyms can be found in CODEMIG (2014) and RURAL MINAS (2003).

Litho-geomorphic indices

The litho-geomorphic indexes, presented in Table 3.

Occurrence% of Geoform on Rocks

Rocks	Tipology of Geoforms													
	c	ptrv	rv	str	ve	sa	kv	cv	so	pf	krv	tf1	tf2	
Q2a	Índex (%)	4.0	>>0.2	>0.2	2.0		68.0	-	-		12	-	-	14.0
NQdi		-	-	-	>>0.2	-	90.7	-	-	0.3	6.0	>>0.2	1.0	2.0
K2up		7.0	2.0	8.0	62.8	3.0	6.0	>>0.2	10.0	0.2	1.0	-	-	-
K1a		2.0	5.0	1.0	6.0	0.5	74.0	1.0	2.0	2.0	2.0	0.25	0.25	-
CPfs		1.0	-	5.0	61.5	6.0	15.0	0.5	-	8.0		3.0	-	-
NP2sl		19.0	21.0	-	5.0	-	43.0	1.0	-	1.0	9.0	1.0		>>0.2
NP3sh		-	-	-	-	-	100	-	-	-	-	-	-	-

Table 3
Litho-Geomorphic characterization of the site studied (Margin B).

The litho-geomorphic indexes are important variables to be used for the classification of sub-basins in homogeneous areas. Rock / geoform relationships are important for both geotechnics and agriculture, the construction of highways, railways, waterways, hydroelectric power stations and other engineering works.

Figure 3 shows the spatial distribution in the terrain of the Litho-Geomorphic conditioners of the studied place located within the municipality of São Francisco - Norte de Minas Gerais.

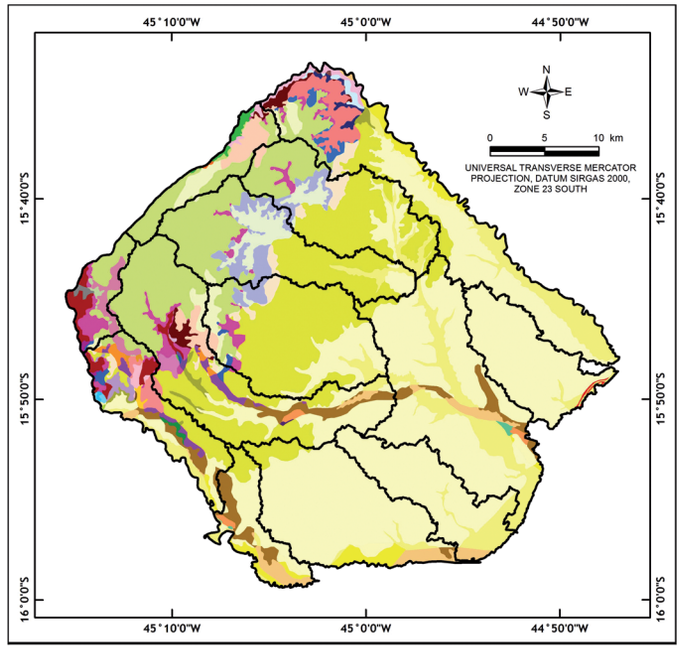


Figure 3
Map of the Litho-Geomorphic aspects of the region of interest.

The meanings of the acronyms can be found in CODEMIG (2014) and RURAL MINAS (2003).

Pedo-lithographic indices

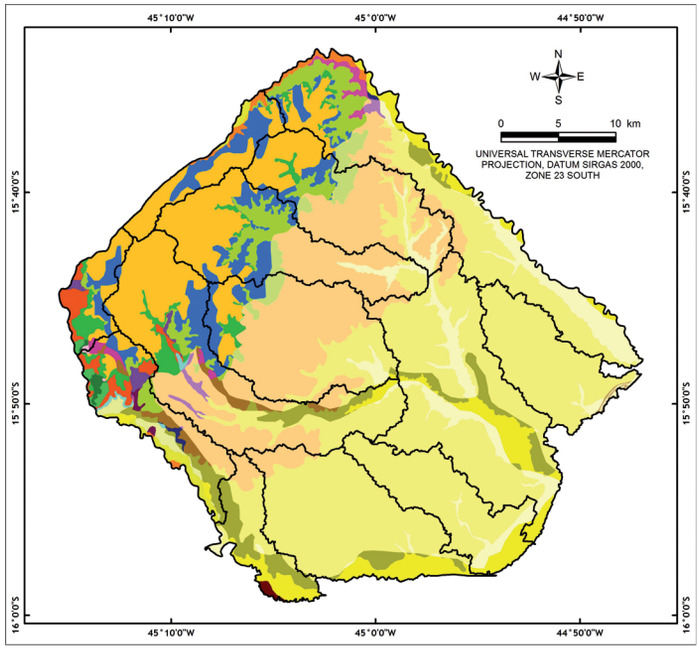
The pedo-lithographic indexes, presented in Table 4, are important variables to be used to classify sub-basins in homogeneous areas. These rocks / soil relationships are also important for both geotechnics and agriculture, in this case associated with the soil suitability chart.

Occurrence % of Lithology on Soils

Soils		Lithographic typology						
		Q2a	NQdi	K2up	K1a	CPfs	NP2sl	NP3sh
Ae3	Index (%)	49.0	40.0	2.0	8.0	-	1.0	-
AQa2		4.0	3.0	75.0	11.0	6.0	1.0	-
AQa4		9.0	57.8	2.0	30.0	-	1.0	0.2
Ca11		6.0	1.0	52.0	35.0	3.0	3.0	-
HQa		100	-	-	-	-	-	-
Ra2		-	-	8.0	39	52	1.0	-

Table 4
Pedo-Litographic Characterization of the site studied (Margin B).

Figure 4 shows the pedo-lithographic elements spatially distributed over the study area evaluated in the municipality of São Francisco – Northern Minas Gerais.



LEGEND:

Geo Themes *Soil / Lithology*

AQa2 | CPsf	AQa2 | Q2a	AQa4 | NP3sh	Ae3 | NP2sl	Ca11 | K1a	HQa | Q2a
AQa2 | K1a	AQa4 | CPsf	AQa4 | NQdi	Ae3 | NP2spl	Ca11 | K2up	Ra2 | CPsf
AQa2 | K2up	AQa4 | K1a	AQa4 | Q2a	Ae3 | NQdi	Ca11 | NP2sl	Ra2 | K1a
AQa2 | NP2sl	AQa4 | K2up	Ae3 | K1a	Ae3 | Q2a	Ca11 | NQdi	Ra2 | K2up
AQa2 | NQdi	AQa4 | NP2sl	Ae3 | K2up	Ca11 | CPsf	Ca11 | Q2a	Ra2 | NP2sl

Third order sub basins boundary

Figure 4
Map of
Pedo-Lithographic aspects of the region.

The meanings of the acronyms can be found in CODEMIG (2014) and RURAL MINAS (2003).

4. Conclusions

With the characterizations established in this study, it is possible to develop the necessary steps to articulate a land-use adaptation program or rather a mitigation program according to previous results.

Thus, land-use orientation procedures in very busy areas have the appearance of being a fundamental way of inducing a more appropriate spatial planning between the basin conservation aspects and the future sustainability of all types of activities (rural and non-rural).

This is one of the levels of studies that follows the series of studies that allow the planning of the Territorial Planning and from this study, the following subjects can be extracted:

1 - the relative importance of soil types in a region (rocky soils, rare soils, more unstable soils) that serves as a basis for the analysis of land-use capacity, is used for the study of soil suitability,

2 - allows to be part of a multivariable system to study the land-use decision-making process.

3 - It will be used for analyzes of rural properties with a view to specific uses in agricultural projects,

4 - It will serve to subsidize the determination of the use of good agricultural practices in order to maintain the conservation of the soils even in cases of low conditions of utilization of the same.

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