Soil-vegetation relationships in savanna landscapes of the Serra da Canastra Plateau, Minas Gerais, Brazil

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Abstract
This work aimed to define the relationship between soil distribution and the savanna physiognomies of the "Cerrado" in the Serra da Canastra plateau landscapes. The chemical and physical analysis identified the following soils: Dystric Leptosols, Dystric Cambisols, Dystric Plinthosols, Alumic Gleysols, Rhodic Ferralsols and Xanthic Ferralsols. The endmembers relate to variation between the Photosynthetic Vegetation (PV) and Non Photosynthetic Vegetation (NPV): Hydromorphic Vegetation, Wooded Savanna, Shrub Savanna, Grassland and Rock Outcrops. In the Serra da Canastra Plateau, water-logging in soils, such as Dystric Plinthosols and Alumic Gleysols where Hydromorphic Vegetation develops, were observed. Local well drained soils classified as Rhodic Ferralsols occur on a flat relief where Wooded Savanna is observed. The Dystric Leptosols are on the edge of the plateau, connecting rock outcrops.

Key Words
Soil Classification, Savanna Physiognomies, Cerrado, Serra da Canastra plateau.

Introduction
The Brazilian savanna, known as "Cerrado", covers approximately 2,000,000 km² (around 23% of Brazil), with high diversity of species occurring in different types of soils and geologic formation (Eiten 1972; Ribeiro and Walter 1998; Silva *et al*. 2006). Unfortunately, this biome was considered a hotspot of biodiversity due to the high diversity, high species endemism and high threat level caused by the human activities (Myers *et al.* 2000). In the last decades the agriculture expansion intensely exploited this biome and about 40% of the original area has already been converted in unnatural land cover (Sano *et al.* 2001; Ab' Saber 2003).

The diversity of physiognomies has been related to edaphic characteristics, namely the presence of nutrients and the high level of exchanged aluminum in the soil (Haridasan 2000). In addition, the physiognomies have been related to relief, topography variation (Oliveira Filho *et al.* 1989, 1995), water dynamic in the soil (Furley 1996) and geomorphologic aspect (Felfili 1998). The knowledge derived from such studies is essential for the design of conservation strategies.

A sample of this diversity is the Serra da Canastra, located in the Southeast region of Brazil (between 20º00´ and 20º30´ South latitude and 46º15´ W and 47º00´ West longitude). However, there is a lack of detailed spatial information, which is a result of the difficulties and costs involved in mapping the ecological diversity of such heterogeneous region. Remote Sensing and Geographic Information System (GIS) are valuable tools to reach a fast and efficient monitoring phenology and change detection (Yu *et al.* 2003).
This work aimed to define the relationship between soil distribution and the savanna physiognomies of the "Cerrado" in the Serra da Canastra plateau landscapes.

Methods
Soil identification and classification
In this work 250 samples of soil (120 cm depth) were collected in the accessible area of the Serra da Canastra plateau; helicopter flights were taken in order to reach the inaccessible areas and observe the savanna physiognomies and relief changes.

The samples were submitted to chemical and physics analysis to determinate the following parameters: pH in H_2O and in KCl, aluminium (Al), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), hydrogen +aluminium (H+Al), organic matter (OM) and the proportion of sand, clay and silt according Embapa (1997). The Bases and Aluminium saturations, Cation Exchange Capacity (CEC) and ΔpH were obtained from those parameters.

Endmember detection and Spectral Classification

Data from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) atmospherically-corrected (Thome *et al*. 1998) were acquired for the spectral classification of the *"Cerrado"* physiognomies. The endmembers detection was proposed by Bordman and Kruse (1994) according to the following stages: i) spectral reduction based on the Minimum Noise Fraction (MNF); ii) spatial reduction using Pixel Purity Index (PPI); iii) n-D Visualization and manual identification of endmembers. The Spectral Correlation Mapper (SCM) was applied for the spectral classification based on the endmembers.

Results

According to chemical and physical analysis, five classes of soil were identified in the Serra da Canastra plateau: Ferralsols, Cambisols, Plinthosols, Gleysols and Leptosols (Table 1).

Table 1. Soil classification, chemical and physics analysis. Cation Exchange Capacity (CEC), Organic Matter (OM), Bases Saturation (V) and Aluminium Saturation (M)

Soils	Depth	Sand 2 – 0,2 mm	Sand 0,2 - 0,05 mm	Silt 0,05 – 0,002 mm	Clay <0,002 mm	Silt/Clay	pH		ΔpH	Al	Ca	Mg	K	H+Al	CEC	OM	V	M
							H_2O	KCl		(cmolc dm³)							g.kg^{-1}	
	(cm)	g.kg-1																
FRro	0-30	50	20	150	780	0,19	4,24	4,08	-0,16	0,79	0	1,06	0,11	11,76	12,93	43,4	90,32	403,54
	30-90	40	30	140	790	0,18	4,44	4,47	0,03	0,18	0	0,18	0,03	7,98	8,19	29,3	25,73	460,63
	90-120	40	30	110	820	0,13	4,64	5,12	0,48	0,08	0	0,19	0,01	5,94	6,14	19,4	31,81	290,77
FRxa	0-20	60	390	150	400	0,38	4,78	3,89	-0,89	2,44	0,16	0,23	0,15	6,16	6,70	22,5	80,77	818,44
	20-40	60	370	140	430	0,33	4,92	4,06	-0,86	0,87	0,03	0,21	0,08	4,40	4,72	14,6	68,71	728,27
	40-60	110	350	120	420	0,29	5,38	4,81	-0,57	0,08	0,03	0,32	0,06	1,60	2,01	8,6	202,56	164,47
CMdy	0-20	20	60	140	780	0,18	4,80	4,30	-0,50	0,32	0,26	0,04	0,06	8,08	8,36	28,5	33,97	529,71
	20-40	180	120	180	520	0,35	5,21	5,09	-0,12	0,08	0,24	0,08	0,01	4,76	4,93	18,0	35,03	316,43
LPdy	0-20	180	530	230	60	3,83	4,91	3,96	-0,95	1,31	0,32	0,07	0,08	6,04	6,51	29,0	71,76	737,23
PLdy	0-20	100	50	220	630	0,35	5,26	4,93	-0,33	0,34	0,31	0,14	0,12	8,78	9,35	40,8	61,01	373,42
	20-40	100	50	220	630	0,35	5,55	5,61	0,06	0,05	0,07	0,36	0,06	5,14	5,63	32,6	86,45	93,21
	40-60	160	60	730	50	4,60	5,67	4,12	-1,55	0,00	0,08	0,19	0,03	2,68	2,98	22,3	100,13	0,00
Glau	0-20	80	500	210	210	1,00	4,98	3,97	-1,01	2,54	0,03	0,47	0,09	17,95	17,95	160,4	32,99	810,90
	20-40	120	470	230	180	1,28	5,01	4,16	-0,85	2,13	0,03	0,21	0,04	13,58	13,58	81,1	20,51	884,38

These classes (Table 1) showed relation to four Savanna physiognomies and outcrop rocks, according to endmembers detection (Figure 1). These endmembers express the proportion of chlorophyll and photosynthesis activity of vegetation from Photosynthetically Vegetation (PV) to Non Photosynthetically Vegetation (NPV) and their variations (Figure 1).

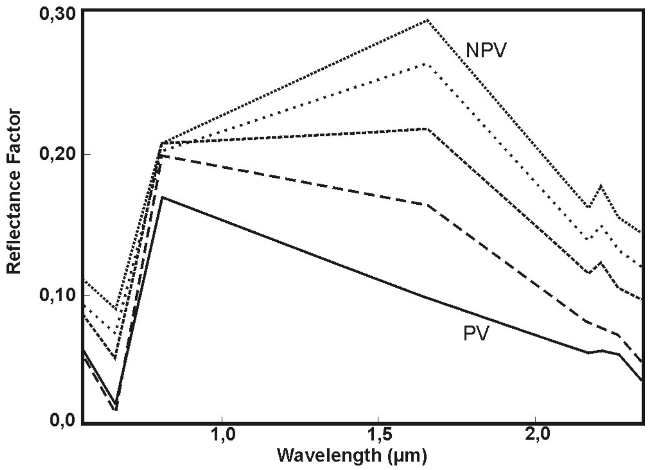

Figure 1. Endmembers detection of the vegetation from ASTER data, where NPV (Non Photosynthetical Vegetation) represents the outcrops and the PV (Photosynthetic Vegetation) represents the Hydromorphic Vegetation; between them, the graphic shows the savanna formations grassland, shrub and wooded savanna, respectively from up to bottom.

The NPV (Figure 1) represents the outcrops rocks and the PV, the Hydromorphic Vegetation (Gallery Forest and Humid Grassland). Between the NPV and PV, the endmembers detection encompasses the savanna formations encountered in the Serra da Canastra plateau, representing from the dominant herbaceous stratum

(Grassland and Shrub Savanna) to the woody dominated stratum (Wooded Savanna).
The Grassland is associated to Dystric Leptosols, Dystric Cambisols, Dystric Plinthosols, Alumic Gleysols. The Dystric Leptosols are located on the edge of the plateau from wavy to strong-wavy relief, bordering the rock outcrops with sandy texture owing to the presence of quartzite parent material. Dystric Cambisols are enclosed to the rock outcrops and could be associated to Shrub Savanna in a soft-wavy relief (Figure 2).

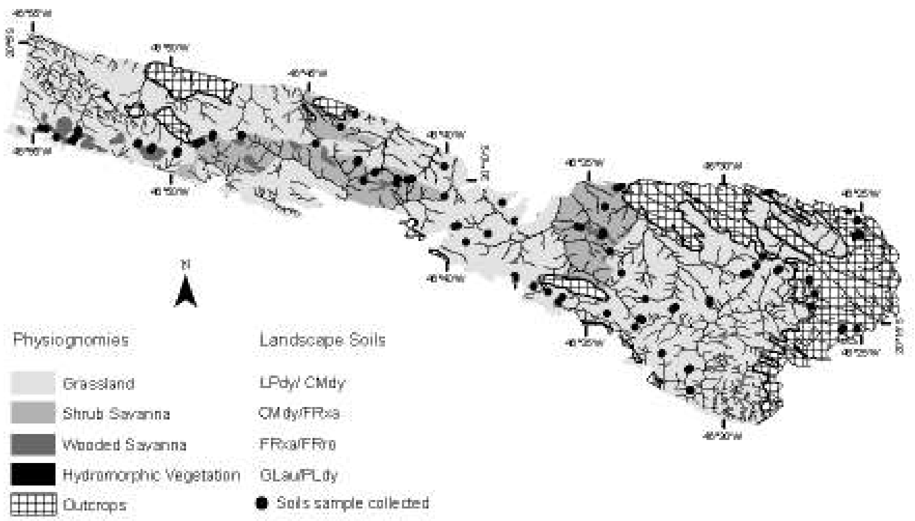

Figure 2. Map of physiognomies related to soil distribution in the Serra da Canastra plateau.

The Serra da Canastra plateau is a synform structure where the origin of soil parent material is heavy clay and likely to be low water permeability. The presence of water-logging soils could be related with this structure control (Valeriano 1995, Liversovskii 1976) which allows the development of Dystric Plinthosols and Alumic Gleysols, in which the occurrence of Hydromorphic Vegetation is observed. Furthermore, the Humid Grassland is associated to Dystric Plinthosols, as well as Gallery Forest to Alumic Gleysols, with high levels of OM and 884,38 g/kg of exchanged aluminum.

On the other hand, the Rhodic Ferralsols are soils of well-drained places on a flat, relief, followed by Xanthic Ferralsols (Macedo 1987). These soils are heavy clay and derived from phyllites, where the occurrence of Wooded Savanna and Shrub Savanna is observed on a flat relief, owing to the soil morphologic structure and depth.

Conclusion

Four physiognomies of “Cerrado” and rock outcrops have been separated by the endmenbers detection and spectral classification. The variation between the Photosynthetic Vegetation (PV) and Non Photosynthetic Vegetation (NPV) corresponded the Hydromorphic Vegetation, Grassland, Shrub Savanna, Wodded Savanna and rock outcrops. In each vegetation environment, the soil classification changed, as well. On the region of rock outcrops, the Dystric Leptosols have been associated with grassland. The water influence is related to Alumic Gleysols and Dystric Plinthosols. These water-logging soils are related to humid grassland and Gallery Forest. Deep weathered soils as Rhodic Ferralsols and Xanthic Ferralsols related to Wooded Savanna and Shrub Savanna were observed. These soils are associated with flat relief and soft-wavy relief. Dystric Cambisols are located in transition areas between grassland and shrub Savanna and between rock outcrops and Shrub Savanna.

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