Artículo Científico

Assessing the spatial distribution of cultivated pastures in the Brazilian savanna

E. E. Sano, A. O. Barcellos, and *H. S. Bezerra**

Introduction

According to Zimmer and Corrêa (1993) most of the regional or state level data about the total area of pastures in Brazil are unreliable. Consequently, the few published data about their spatial distribution are also inaccurate. This is the case of the Brazilian savanna, which covers more than 208 million hectares in the central part of Brazil. On the other hand, information regarding the area and the spatial distribution of pastures in Brazil are essential for meat and milk yield prediction, as well as for pasture degradation monitoring and reclamation, among others.

Numerous research have shown that satellite-based remote sensing is a powerful tool to map pasture lands. For instance, Assad et al. (1988) reported significant differences in the spectral response of *Brachiaria humidicola*, *B. decumbens*, *B. ruziziensis,* and *Andropogon gayanus* over the near-infrared wavelengths (700-1050 nm). These types of pastures are commonly found in the Cerrado. Gomide and Assad (1990), using Landsat/TM imagery, identified areas with *A. gayanus* over three municipalities from central Brazil.

Despite the potential of remotely sensed data, the high number of scenes necessary to cover the entire Brazilian savanna makes their use time demanding and costly. For example, it is necessary 177 scenes of Landsat/TM satellite to cover the whole Brazil's tropical savanna region (each TM image corresponds to a polygon of 185 km x 185 km in the terrain). A promising alternative is the use of the Agricultural Census data which is regularly published by the Brazilian Institute for Geography and Statistics (IBGE).

This paper focuses on the area calculation and the spatial distribution analyses of cultivated pastures in the Brazilian savanna, based on the data published in the 1995-96 census and on a Geographical Information System (GIS) technology.

Background information

The Brazilian savanna, nationally known as Cerrado, covers an area of approximately 208 million hectares in the central part of the country. It is an upland, species-rich vegetation with more than 450 vascular species per hectare (Eiten, 1993). There are three layers of vegetation: grassland, shrubland, and woodland. The variations in their proportion are the basis for classifying different types of Cerrado: savanna grassland, shrub savanna, wooded savanna, etc. The soils are acid (pH between 4.0 to 5.5), with high aluminum saturation. The dominant soil unit corresponds to Oxisols (> 45% of its surface) (Adamoli et al., 1986). Average temperature is fairly uniform (around 23 °C all over the year) and there is a well-defined dry and wet seasons, from May to September and from October to April, respectively. The annual average precipitation varies from 1000 to 2000 mm, depending upon the region.

Cerrado covers the entire State of Goiás, as well as part of the following states: Bahia, Ceará, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará, Piauí, and Tocantins. The following neighbor ecosystems influence the Cerrado core area: the Amazon rainfall forest in the north and northwest, the semiarid Caatinga in the northeast, the Atlantic rainfall forest in the south and southeast, and the Pantanal wetland in the southwest (Figure 1).

Until the mid-60's, the Brazilian savanna was mostly exploited for subsistence agriculture and beef cattle ranching (Spehar and Souza, 1994). Since then, the construction of Brasília, the country's capital city, the relatively low land prices, the federal government subsidies, and the attractive prices for commodities favored an intensive Cerrado's land occupation. The fastest livestock growth in this region happened in the 70's: more than 100% increase from 1970 to 1980, against an average increase of 15% in the other regions

* Researchers, Empresa Brasileira de Pesquisa Agropecuária, Centro de Pesquisa dos Cerrados (Embrapa/CPAC), BR-020 Km 18, Caixa Postal 08223, 73301-970 Planaltina, DF, Brazil. E-mail: sano@cpac.embrapa.br

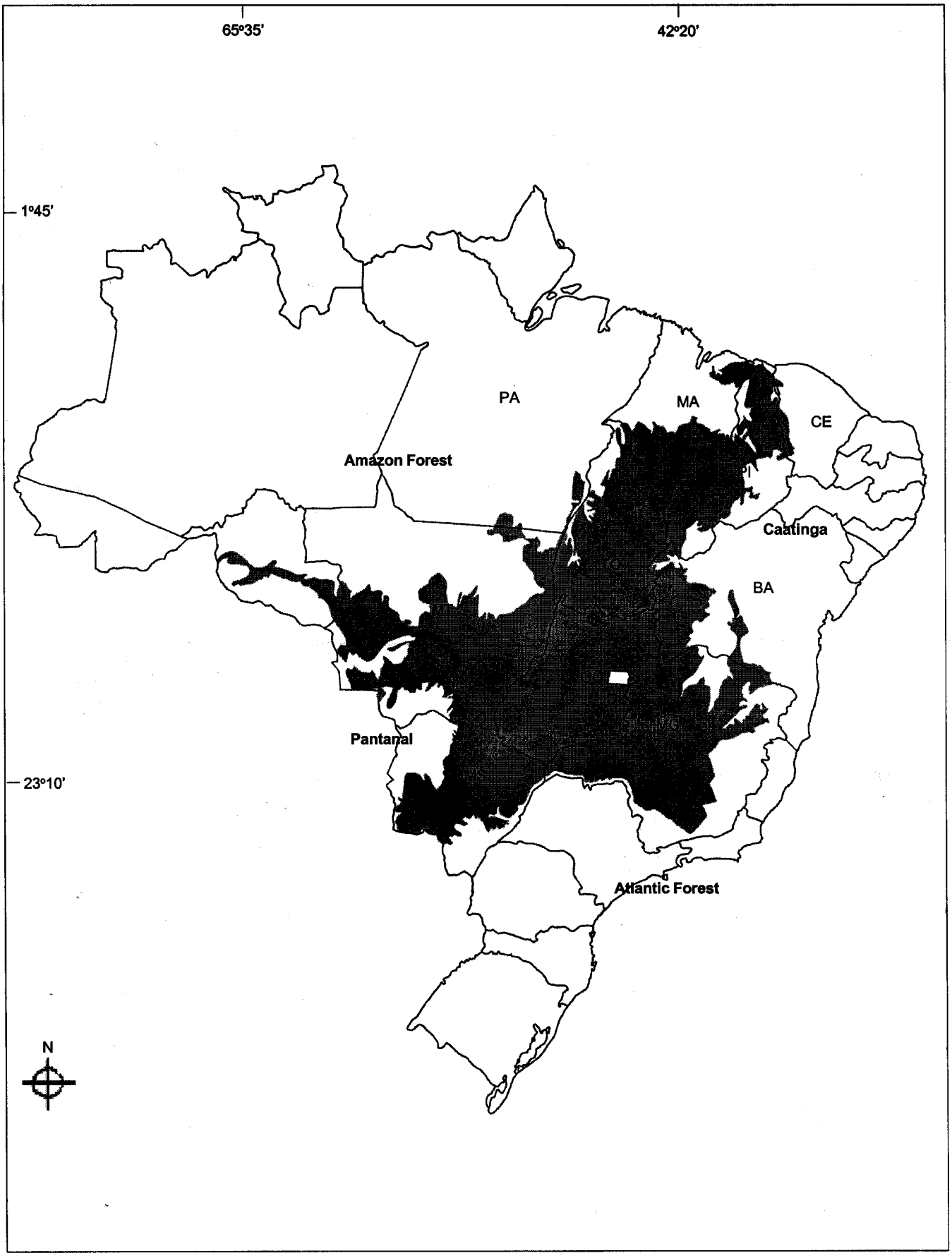

Figure 1. *Cerrado's boundary map.*

of the country (IBGE, 1984). Currently, about 40% of the Brazilian cattle population are in the Cerrado (Barcellos, 1996; Carvalho et al., 1990).

The beef cattle system in this region is generally extensive, that is, large farms where total area averages 1800 ha (Costa et al., 1986), with low inputs of working capital. The major cultivated pasture belongs to the generum *Brachiaria*. About 80% of annual forage production occurs during the wet season and the maintenance practices are restricted to shrub removal by using rotavators and/or fires (Costa, 1998).

Methods

The basis for this study was the 1995-96 agricultural census published by IBGE (1998). In this census, questionnaires were applied to farmers in field campaigns conducted from August 1995 through July 1996. The complete dataset is constituted by 26 reports. We analyzed the following volumes: Bahia (n. 15); Ceará (n. 9); Distrito Federal (n. 26); Goiás (n. 25); Maranhão (n. 7); Mato Grosso (n. 24); Mato Grosso do Sul (n. 23); Minas Gerais (n. 16); Pará (n. 5); Piauí (n. 8); and Tocantins (n. 6). All information regarding cultivated pastures were extracted from CD-ROMs enclosed in each report. However, most of the census data can also be obtained through the Internet (www.sidra.ibge.gov.br).

The data extracted from the census were: name of municipality, location (latitude and longitude coordinate system), area of municipality (km^2), and cultivated pasture areas (hectares). Dividing the cultivated pasture area by the municipality area, we derived the percent of municipality covered by this type of land use. For spatial distribution analysis purpose, these percent values were classified into five categories: <10%, 10%-20%, 20%-30%, 30%-40%, and > 40%.

Because all states of central Brazil, except Goiás, are only partially covered by Cerrado, as stated early in this paper, each municipality was also classified in 'Cerrado' and 'Non-Cerrado'. It was labeled as 'Cerrado' if more than 50% of its total area was covered by the Cerrado physiognomies. If the value was less than 50%, then it was labeled as 'Non-Cerrado'. The public domain, Brazilian GIS software named SPRING (Sistema de Processamento de Informações Georreferenciadas), developed by the National Space Research Institute (INPE) (Câmara et al., 1996) was used to obtain such classification. The input products were the Cerrado's boundary map and the Brazil's municipality boundary map. The unpublished 1:1,000,000 scale Cerrado's boundary map was digitized in the Embrapa's GIS and Remote Sensing facility in Brasília, Federal District. The raster format municipality map of Brazil corresponded to the existing municipalities in 1997 (IBGE, 1999). Only those municipalities labeled as 'Cerrado' were considered in the area calculation and spatial distribution analyses.

Results

Table 1 shows an example of tabular product obtained by overlaying the Cerrado's boundary map, the Brazil's municipality map and the IBGE's agricultural census data in the SPRING software package. The example corresponds to the State of Mato Grosso do Sul and includes only the municipalities with more than 50% of their area originally covered by Cerrado. Similar tables, not included in this article because of the space limitation, were also derived for other states total or partially covered by Cerrado.

Table 2 shows a summary of the GIS data integration. The total area of cultivated pastures in the Brazilian Cerrado region was 49,462,136 ha. About 20% of this ecosystem is currently occupied by cultivated pastures. At state level, Goiás presented the largest area (hectares) with 14,150,900, followed by Mato Grosso do Sul (11,970,463), Mato Grosso (8,884,790), Minas Gerais (8,181,043), and Tocantins (3,658,357). These states make 94.7% of the total area of cultivated pastures in the study region.

The spatial variation analysis of the density of cultivated pastures in the whole Cerrado region (Figure 2) indicates that the largest concentration of pastures for cattle exploitation are mainly in the eastern Mato Grosso do Sul and western Goiás. These states present more than 40% of their Cerrado's related land surface under cultivated pastures (Table 2). Such predominance of pastures can be attributed to the presence of good slaughtering and storage facilities, reasonable transportation network, and favorable climate and topographical conditions in these states. On the other hand, the eastern part of the Cerrado presents the lowest cultivated pasture densities, mainly due to the dry climate conditions. Many municipalities in Minas Gerais and Mato Grosso also present low density because of the strong competition from annual crops, mainly soybean and corn.

Figure 3 shows that most municipalities of Mato Grosso do Sul (42, from a total of 45) present more than 40% of their area with cultivated pastures. According to IBGE (1998), this is the current state presenting the largest livestock in Brazil. Two municipalities (Inocência and Paranaíba) even present more than 70% of cultivated pasture coverage (Table 1).

Table 1. **Tabular data of Mato Grosso do Sul, obtained by integrating the Cerrado's map, the Brazil's municipality map, and the agricultural census data. Municipalities with less than 50% of their area covered by Cerrado were not included.**

Municipality	Latitude (South)	Longitude (West)	Area of municipality (km^2)	Area of cultivated pasture (ha)	% of municipality with cultivated pasture	Class
Água Clara	20°26'52"	52°52'40"	11,031	609,077	55.2	5
Alcinópolis	18°19'26"	53°42'21"	4400	223,867	50.9	5
Anastácio	20°29'02"	55°48'25"	2949	133,051	45.1	5
Antônio João	22°11'27"	55°56'52"	1144	59,599	52.1	5
Aparecida do Taboão	20°05'13"	51°05'38"	2750	178,427	64.9	5
Bandeirantes	19°55'04"	54°21'50"	3116	187,597	60.2	5
Bela Vista	22°06'32"	56°31'15"	4895	227,328	46.4	5
Bodoquena	20°32'20"	56°42'54"	2507	125,245	50.0	5
Bonito	21°07'15"	56°28'55"	4934	271,496	55.0	5
Brasilândia	21°15'21"	52°02'13"	5806	359,528	61.9	5
Camapuã	19°31'51"	54°02'38"	10,758	594,879	55.3	5
Campo Grande	20°26'34"	54°38'45"	8096	492,960	60.9	5
Caracol	22°00'50"	57°01'26"	2939	129,396	44.0	5
Cassilândia	19°06'46"	51°44'02"	3650	250,285	68.6	5
Chapadão do Sul	18°47'38"	52°37'22"	3851	179,738	46.7	5
Corguinho	19°49'55"	54°49'44"	2641	164,339	62.2	5
Costa Rica	18°32'38"	53°07'44"	5723	335,635	58.6	5
Coxim	18°30'25"	54°45'36"	6410	320,277	50.0	5
Dois Irmãos do Buriti	20°40'48"	55°17'45"	2345	118,831	50.7	5
Dourados	22°13'15"	54°48'21"	4086	193,819	47.4	5
Guia Lopes da Laguna	21°27'28"	56°06'50"	1210	69,914	57.8	5
Inocência	19°43'33"	51°55'48"	5776	404,202	70.0	5
Jaraguari	20°08'31"	54°23'56"	2913	184,935	63.5	5
Jardim	21°28'48"	56°08'16"	2202	127,251	57.8	5
Maracaju	21°36'50"	55°10'04"	5299	257,892	48.7	5
Miranda	20°14'27"	56°22'40"	5479	190,604	34.8	4
Nioaque	21°08'06"	55°49'48"	3924	206,195	52.6	5
Nova Alvorada do Sul	21°27'57"	54°23'02"	4019	193,819	48.2	5
Nova Andradina	22°13'58"	53°20'34"	4776	325,051	68.1	5
Paranaíba	19°40'37"	51°11'27"	5408	399,792	73.9	5
Pedro Gomes	18°06'03"	54°33'07"	3651	217,341	59.5	5
Ponta Porã	22°32'09"	55°43'33"	5329	257,925	48.4	5
Porto Murtinho	21°41'56"	57°52'58"	17,735	429,045	24.2	3
Ribas do Rio Pardo	20°26'34"	53°45'32"	17,309	960,657	55.5	5
Rio Brilhante	21°48'07"	54°32'45"	3988	179,341	45.0	5
Rio Negro	19°26'56"	54°59'13"	1818	85,920	47.3	5
Rio Verde de Mato Grosso	18°55'04"	54°50'38"	8152	315,439	38.7	4
Rochedo	19°57'10"	54°53'34"	1561	82,320	52.7	5
Santa Rita do Pardo	21°18'10"	52°49'51"	6142	376,129	61.2	5
São Gabriel do Oeste	19°23'42"	54°33'57"	3854	169,293	43.9	5
Selviria	20°22'01"	51°25'08"	3259	209,121	64.2	5
Sidrolândia	20°55'55"	54°57'39"	5286	266,913	50.5	5
Sonora	17°34'37"	54°45'28"	4076	205,024	50.3	5
Terenos	20°26'31"	54°51'36"	2841	186,318	65.6	5
Tres Lagoas	20°45'03"	51°40'40"	10,207	660,803	64.7	5

Table 2. **Total area and percent of state covered with cultivated pastures. The values refer only to the Cerrado's area of each state.**

State	Cultivated pastures	
	Area (ha)	Cover (%)
Ceará	6732	0.9
Federal District	62,443	10.7
Pará	226,825	38.9
Piauí	286,503	2.2
Rondônia	520,817	19.7
Bahia	740,551	6.9
Maranhão	772,712	6.5
Tocantins	3,658,357	16.1
Minas Gerais	8,181,043	23.3
Mato Grosso	8,884,790	23.2
Mato Grosso do Sul	11,970,463	52.0
Goiás	14,150,900	42.5
Total	49,462,136	—
Average	—	20.2

About 60% of the Goiás municipalities also present more than 40% of their area covered by cultivated pastures (Figure 4). In the northeastern part of the state, we can point out Divinópolis de Goiás, a single municipality in the region presenting an intensive pasture plantation and meat production. The economical activity in the northern Goiás is still based on meat production (IBGE, 1998), but in the southern part, particularly in the municipalities of Montividiu, Rio Verde, Santa Helena de Goiás, and Turvelândia, there is a strong competition from grain production. Cropping in these municipalites is highly technified, with good crop planting and harvesting machineries and adequate storage and market infrastructures.

According to IBGE (1998), Mato Grosso was the state which experienced the largest increase in area with cultivated pastures during the past 10 years in Brazil. This increase happened mainly around Rondonópolis (Figure 5), because of a good road system and a number of storage facilities. Figure 6 highlights two important pasture production regions of Minas Gerais: the eastern part of the state and the north of Montes Claros municipality. Contrasting with other states, where pastures are mostly used for meat production, Minas Gerais is also an important milk producer (IBGE, 1998).

In Tocantins, most of the cultivated pastures are concentrated along the Belém-Brasília interstate highway, especially near Gurupi city (Figure 7). Maranhão and Bahia present a relatively low density of cultivated pastures (Figures 8 and 9), partially because of an intensive use of native pastures (IBGE, 1998) and because of significant cropping areas, especially in the southern Maranhão, near Balsas, and in the western Bahia, near Barreiras. The maps and the spatial distribution analyses of cultivated pastures from Ceará, Federal District, Pará, and Piauí were not presented in this study because they represent less than 2.5% of the Cerrado's cultivated pastures.

Concluding remarks

This study clearly demonstrated the GIS capability to determine the area and to assess the spatial distribution of cultivated pastures in the Brazilian savanna in an effective way. The method can be used for area calculation and spatial analyses of other land uses in different ecosystems or regions in Brazil.

Considering the 10-year repeat time between each agricultural census in Brazil, an alternative technique is necessary to be developed to quantify and monitor pasture areas in meantime. An approach can be the combination of remote sensing and agricultural census data. Using thematic maps similar to those produced in this study, it is possible to select areas with high pasture densities for remote sensing data acquisition. This will reduce costs as well as processing and interpretation times. A promising remote sensing product for pasture mapping over large areas will be the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, which operates at 250 m spatial resolution, 36 spectral bands, and 1-2 day temporal resolution.

Resumen

En el estudio se calculó el área cultivada con pasturas y su distribución espacial en la región del Cerrado brasileño. Para el efecto, las áreas de campo cultivadas con pasturas en cada municipio de la región, que fueron obtenidas en el censo agrícola 1995-96, se integraron con los mapas de los mismos municipios obtenidos mediante sistemas de información geográfica (SIG). Los resultados indicaron que el área total cultivada con pasturas en la región de Cerrado era de 49,462,136 ha. Las mayores áreas se encontraban en la parte suroeste, principalmente en los estados de Mato Grosso do Sul, Goiás y Mato Grosso.

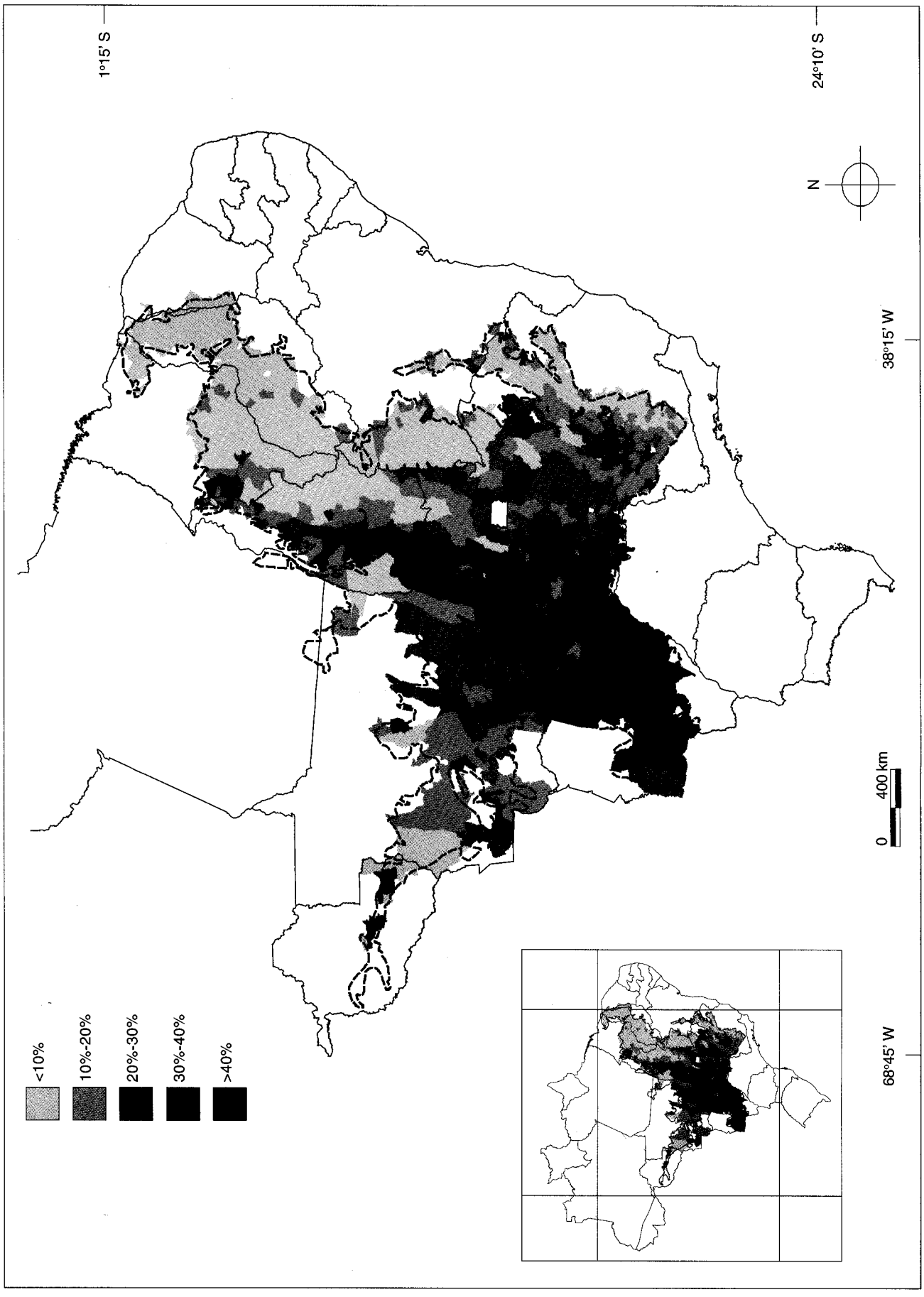

Figure 2. *Spatial distribution of cultivated pastures in the Brazilian Cerrado region. Values in the legend indicate the percent of the total area with cultivated pastures in each municipality.*

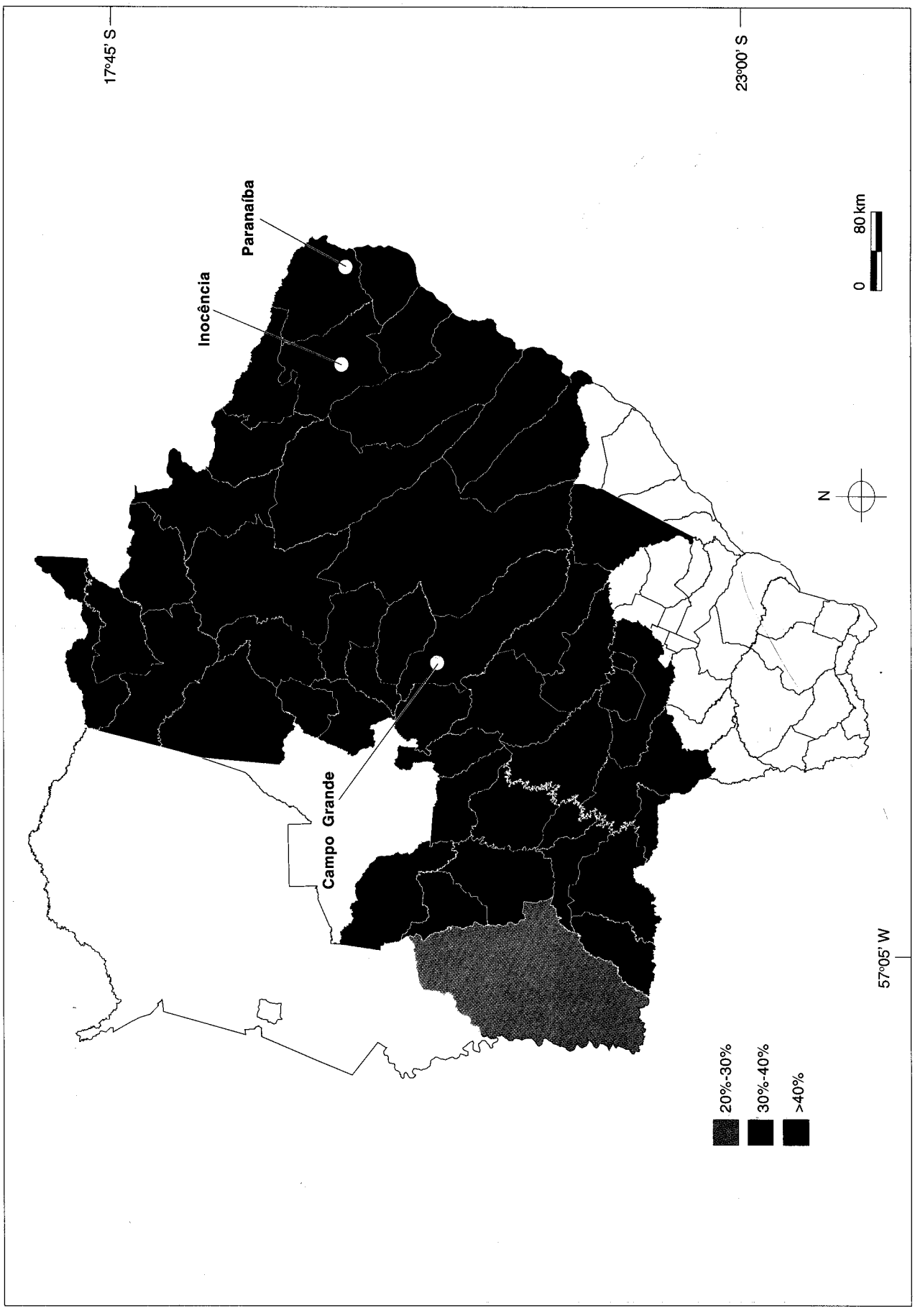

Figure 3. *Spatial distribution of cultivated pastures in the Cerrado's area of Mato Grosso do Sul State. Values in the legend indicate the percent of the total area with cultivated pastures in each municipality.*

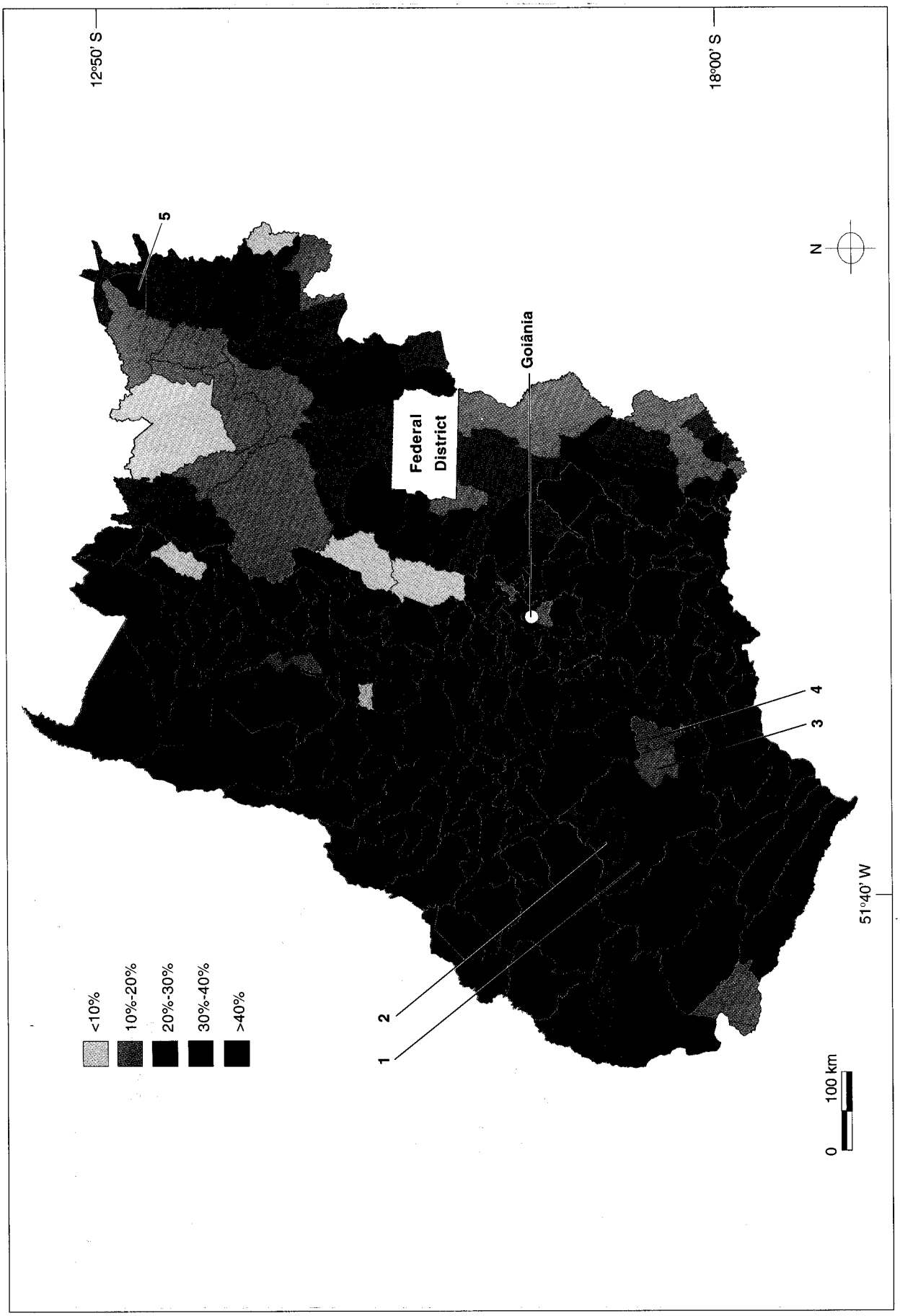

Figure 4. *Spatial distribution of cultivated pastures in the Goiás State. Values in the legend indicate the percent of the total area with cultivated pastures in each municipality. Municipalities with strong competitive crop production: Rio Verde (1), Montividiu (2), Santa Helena de Goiás (3), and Turvelândia (4). Municipality with intensive meat and milk production: Divinópolis de Goiás (5).*

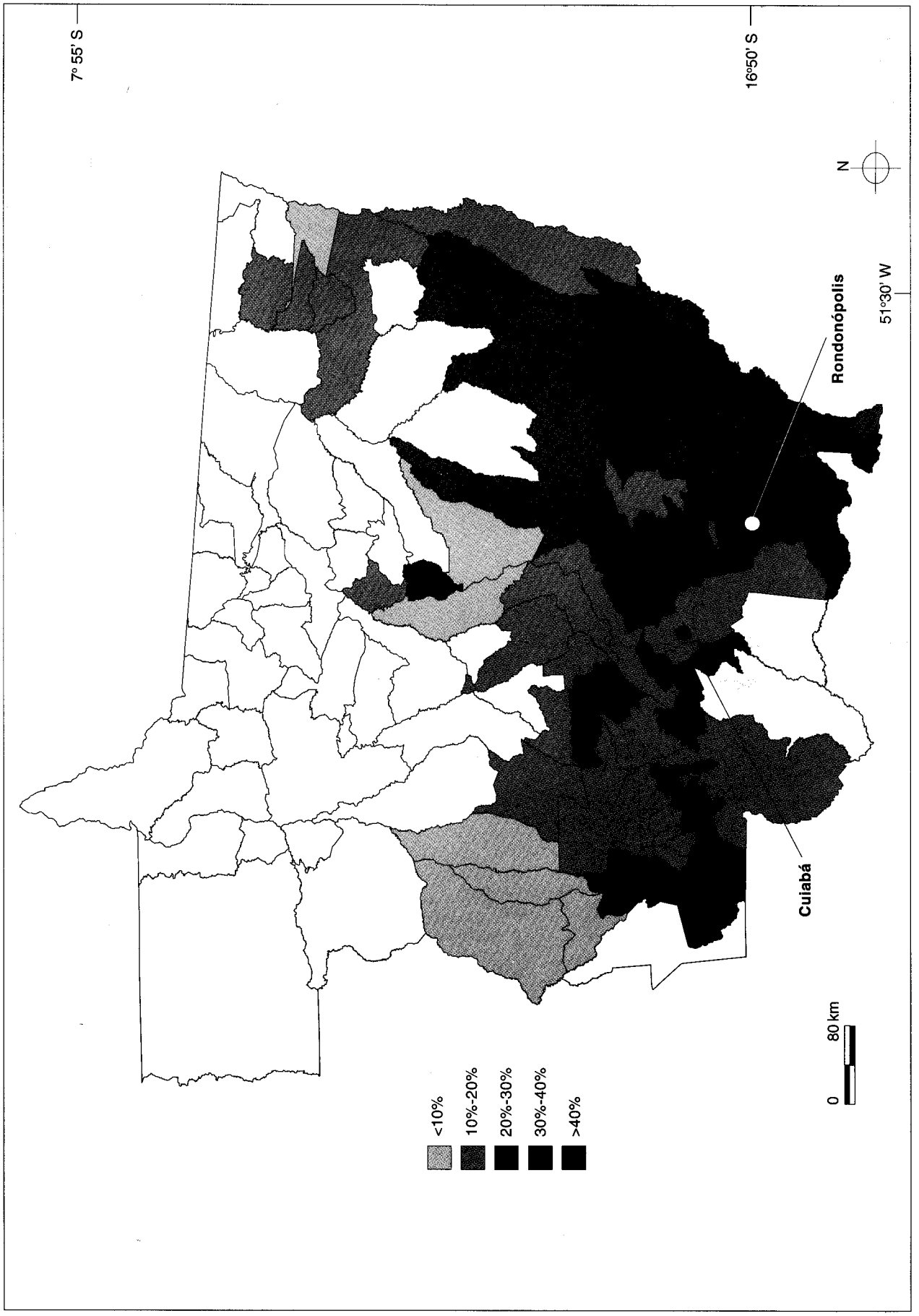

Figure 5. *Spatial distribution of cultivated pastures in the Cerrado's area of Mato Grosso State. Values in the legend indicate the percent of the total area with cultivated pastures in each municipality. The most important meat production area in the state is in Rondonópolis and neighborhood.*

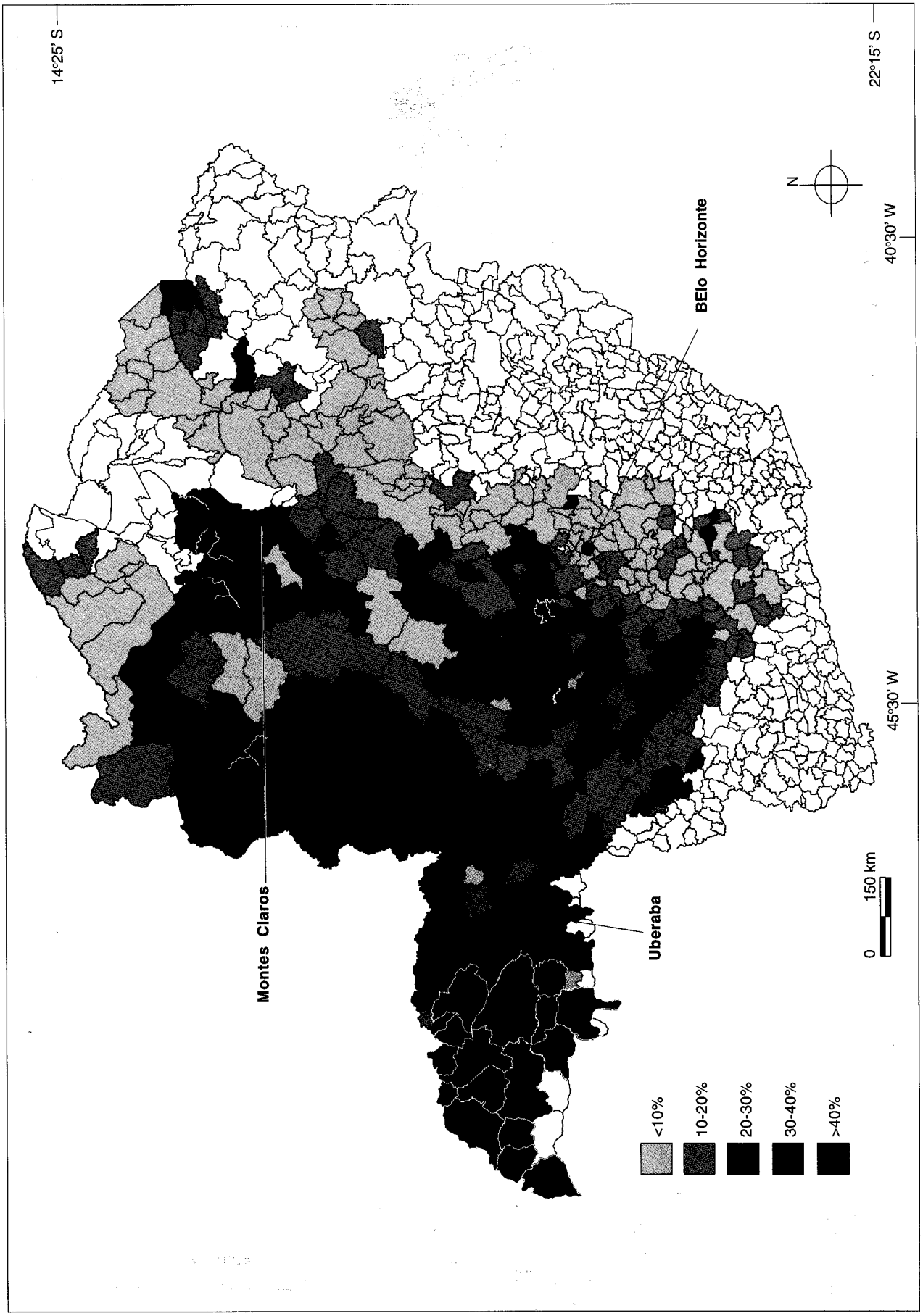

Figure 6. *Spatial distribution of cultivated pastures in the Cerrado's area of Minas Gerais State. Values in the legend indicate the percent of the total area with cultivated pastures in each municipality. The most important meat production regions are in the western part of the state and near Montes Claros.*

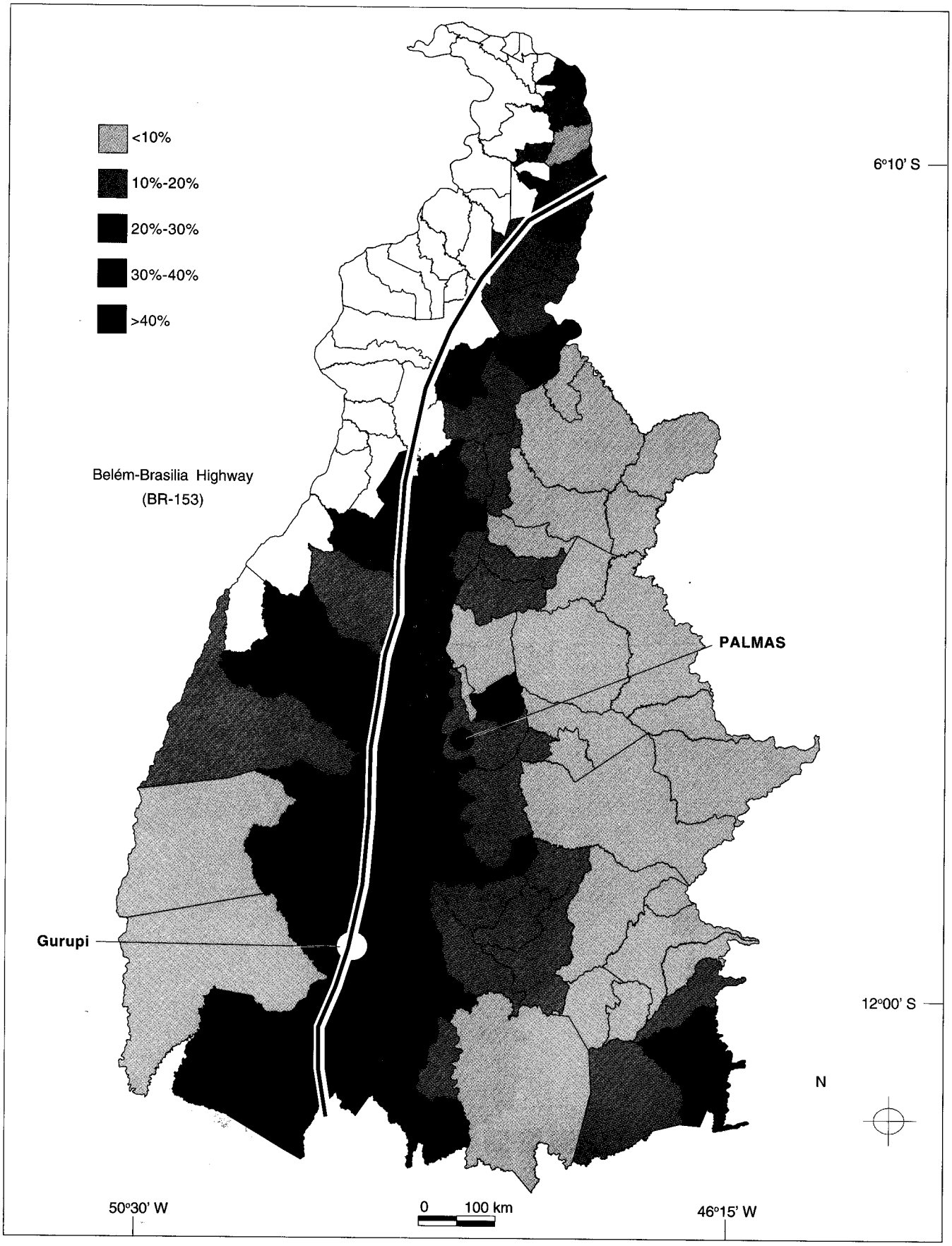

Figure 7. *Spatial distribution of cultivated pastures in the Cerrado's area of Tocantins State. Values in the legend indicate the percent of the total area with cultivated pastures in each municipality.*

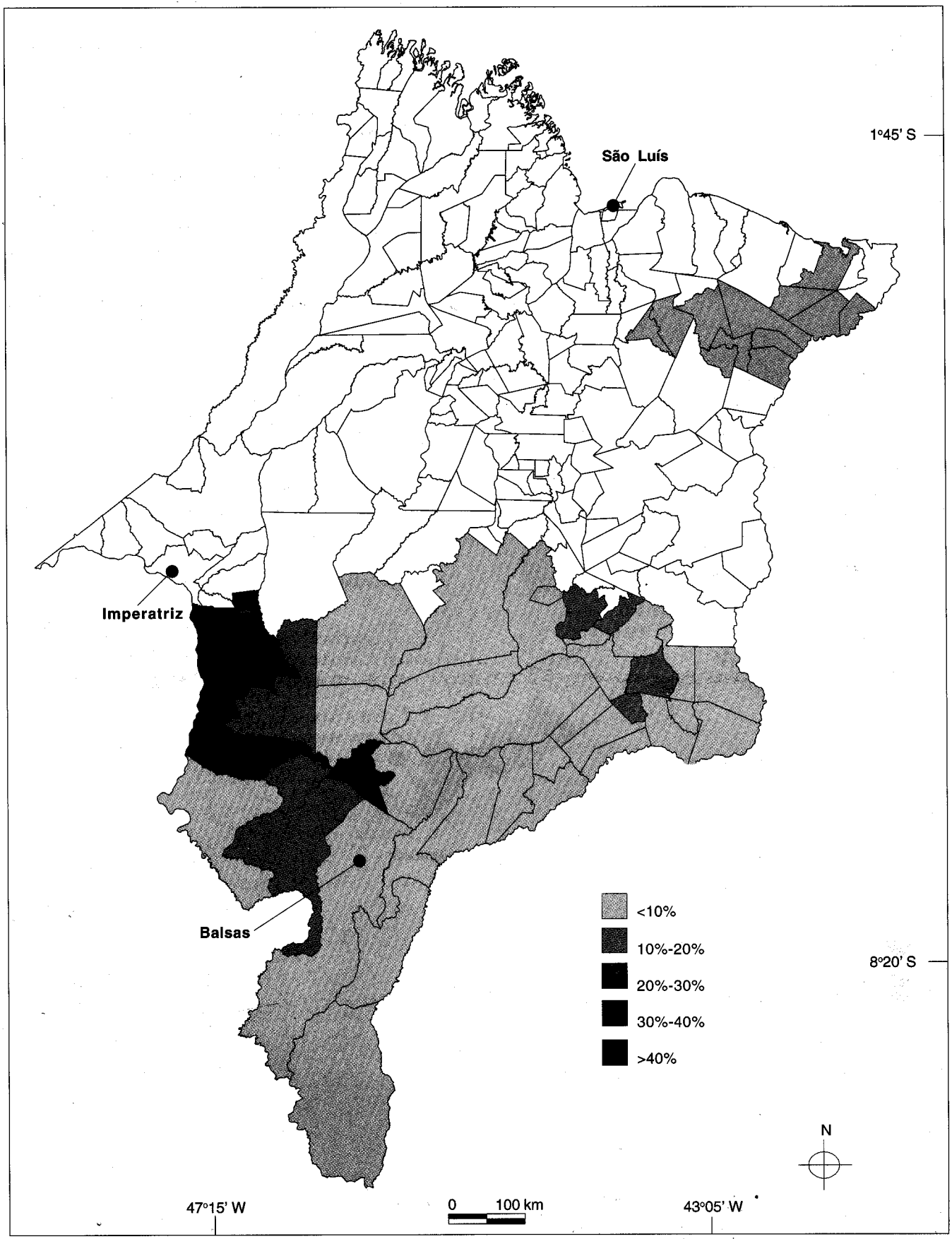

Figure 8. *Spatial distribution of cultivated pastures in the Cerrado's area of Maranhão State. Values in the legend indicate the percent of the total area with cultivated pastures in each municipality. There is a development pole in the southern part of Imperatriz.*

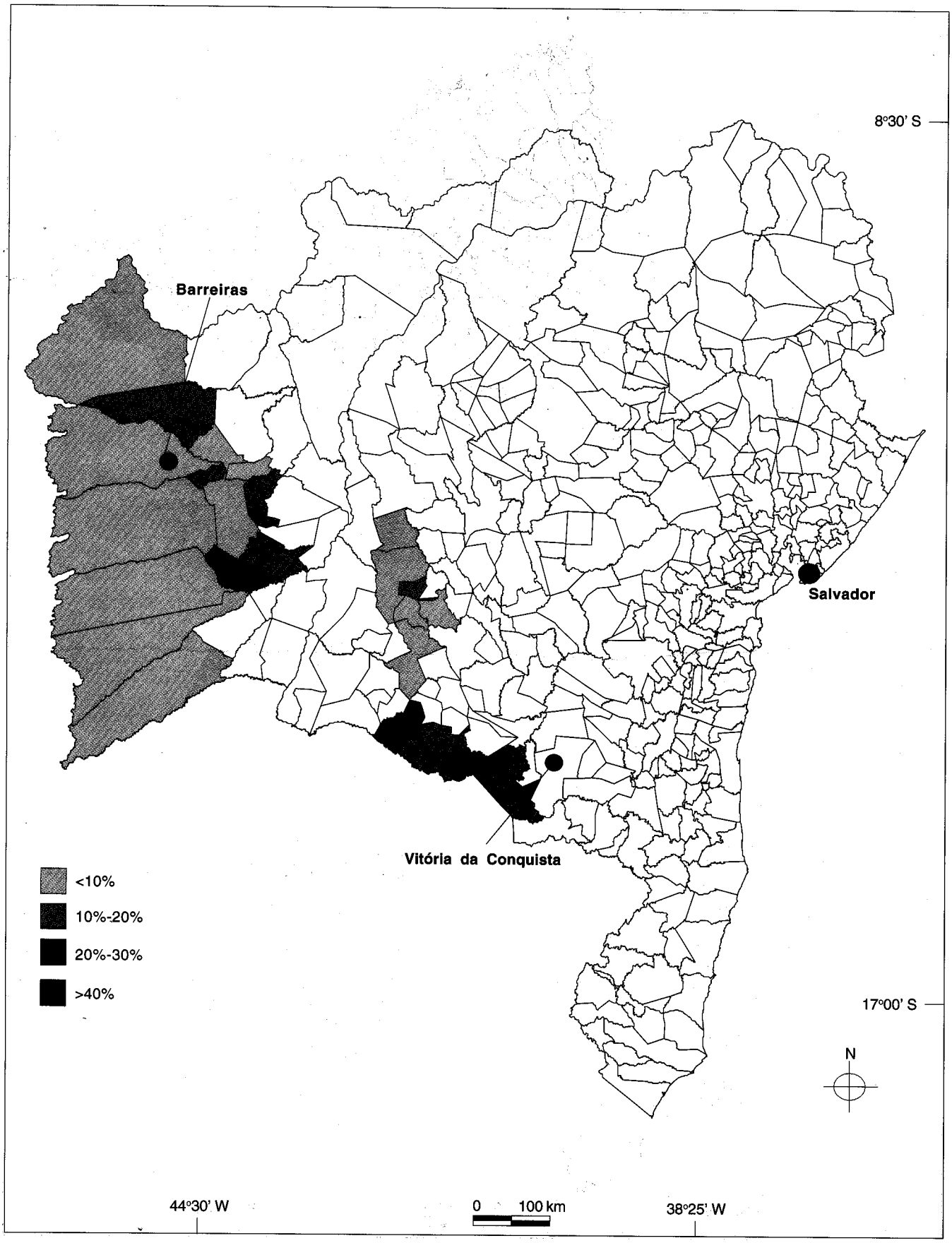

Figure 9. *Spatial distribution of cultivated pastures in the Cerrado's area of Bahia State. Values in the legend indicate the percent of total area with cultivated pastures in each municipality.*

References

Adámoli, J.; Macedo, J.; and Madeira Netto, J. 1986. Caracterização da região dos Cerrados. In: Goedert, W. J. (ed.). Solos dos Cerrados: Tecnologias e estratégias de manejo. EMBRAPA-CPAC, Planaltina, DF. p. 33-74. (In Portuguese.)

Assad, E. D.; Macedo, J.; and Moreira, L. 1988. Estudo da mobilidade da fronteira agrícola no município de Silvânia-GO. In: Quinto Simpósio Brasileiro de Sensoriamento Remoto. Natal, RN, October 10-15. Anais. INPE, Natal. vol. 2, p. 430-436.

Barcellos, A. O. 1996. Sistemas extensivos e semi-intensivos de produção: Pecuária bovina de corte nos Cerrados. In: International Symposium on Tropical Savannas. 1. Brasília, DF. Biodiversidade e produção sustentável de alimentos e fibras nos Cerrados. Anais. EMBRAPA-CPAC, Planaltina. p. 130-136.

Câmara, G.; Souza, R. C.; Freitas, U. M.; and Garrido, J. 1996. SPRING: Integrating remote sensing and GIS by object-oriented data modelling. Computer & Graphics 20(3):395-403.

Carvalho, S. I.; Vilela, L.; Spain, J. M.; and Karia, C. T. 1990. Recuperação de pastagens degradadas de *Brachiaria decumbens* cv. Basilik na região dos Cerrados. Pasturas Tropicales 12(2):24-28.

Costa, F. P. 1998. Farmer's objectives and their relationship with the phenomenon of pasture degradation in central Brazil. Ph.D. thesis, University of Reading. 198 p.

_____; Pacheco, J. A.; Corrêa, E. S.; and Arruda, Z. J. 1986. Estimativa do custo de produção da carne bovina para a região centro-oeste. Comunicado técnico 30. EMBRAPA-CNPGC, Campo Grande, MS.

Eiten, G. 1993. Vegetação do Cerrado. In: Pinto, M. N. (ed.). Cerrado: Caracterização, ocupação e perspectivas. 2nd edition. Editora Universidade de Brasília, Brasília, DF. p. 17-73.

Gomide, C. C. and Assad, E. D. 1990. Avaliação da distribuição do *Andropogon gayanus* cv. Planaltina utilizando imagens de satélites TM-Landsat em áreas de Cerrado. Pasturas Tropicales 12(3):2-6.

IBGE (Instituto Brasileiro de Geografía e Estatistica). 1984. Censo agropecuário de 1980. Rio de Janeiro.

_____. 1998. Censo agropecuário de 1995/1996. Rio de Janeiro.

_____. 1999. Malha municipal digital do Brasil. Situação em 1997. Rio de Janeiro (CD-ROM).

Spehar, C. R. and Souza, P. I. 1994. Developing sustainable cropping systems for the Brazilian savannas. In: Kang, B.; Akobundu, I. O.; Manyong, V. M.; Carsky, R. J.; Saninga, N.; and Kueneman, E. A. (eds.). Moist savannas of Africa: Potentials and constraints for crop production. IITA/FAO Workshop. Proceedings. IITA/FAO, Cotonou, Benín. p. 325-356.

Zimmer, A. H. and Corrêa, E. S. 1993. A pecuária nacional, uma pecuária de pasto? In: Paulino, V. T. et al. (orgs.). Encontro sobre recuperação de pastagens. Instituto de Zootecnia, Nova Odessa, SP. p. 1-25.