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Apoio: PRPPG/PROAPUPEC
| Jataí-GO | n.12 | jan-jun/2009 |
ISSN 1679-9860

GEOMORPHOLOGICAL MAPPING OF THE CLARO AND BOIS RIVERS DRAINAGE BASIN USING TECHNIQUES OF REMOTE SENSING AND GEOPROCESSING

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Abstract

The aim of this study is the application of techniques of remote sensing and geoprocessing as auxiliary tools in geomorphological studies. It was used as model of study mapping the geomorphological units of the Rio Claro and Rio dos Bois, both in the basin located in the right margin of the Araguaia River, state of Goiás. It was used interferometric images of the Shuttle Radar Topography Mission (SRTM), applied for an area of 123.276 km² of the drainage of the Claro and Bois Rivers, whose geomorphological features was mapped in a scale of 1:100.000. It was identified and characterized denudational geomorphological features, the SRAIVC1, SRAIVC2, SRAIIB-RT, SRAIIIA, HB-ED, ZER, MC; and agradational geomorphological features, alluvial belts, and unit association with lake systems.

Key words: geomorphology, remote sensing, SRTM, Claro and Bois Rivers.

Resumo

MAPEAMENTO GEOMORFOLÓGICO DA BACIA HIDROGRÁFICA DOS RIOS CLARO E DOS BOIS UTILIZANDO TÉCNICAS DE SENSORIAMENTO REMOTO E GEOPROCESSAMENTO

O objetivo deste estudo é a aplicação de técnicas de sensoriamento remoto e geoprocessamento como ferramentas auxiliares em estudos geomorfológicos. Foi utilizado como modelo de estudo o mapeamento das unidades geomorfológicas do rio Claro e rio dos Bois, ambos na mesma bacia hidrográfica localizada na margem direita do rio Araguaia, Estado de Goiás. Foram utilizadas imagens interferométricas da Shuttle Radar Topography Mission (SRTM), aplicadas numa área

Artigo recebido para publicação em 05 de Outubro de 2008;
Artigo aprovado para publicação em 03 de Abril de 2009

de 123.276 km² da bacia de drenagem dos rios Claro e Bois, cujas características geomorfológicas foram mapeadas na escala 1:100.000. Foram identificadas e caracterizadas unidades geomorfológicas denudacionais, SRAIVC1, SRAIVC2, SRAIIB-RT, SRAIIIA, HB-ED, ZER e MC; e unidades geomorfológicas agradacionais, faixa aluvial (FA), e unidade associada a sistemas lacustres.
Palavras-chave: geomorfologia, sensoriamento remoto, SRTM, rios Claro e dos Bois.

1. Introduction

The present study is a morphogenetic interpretation of geomorphological units through the remote sensing techniques, using interferometric images of the Shuttle Radar Topography Mission (SRTM). The range view of these sensors is lateral in relation to the ground surface and has been successfully used since 1960´s for analysis of natural resources (SABINS, 1996). Called RADAR - Radio Detecting and Ranging (detect and measure distances using radio waves). The main importance of this sensor is its independence from the solar interactions on the ground (active sensor), because of its own energy to identify targets on the terrestrial surface. This characteristic of the RADAR make it very useful when operating in adverse weather conditions.

The SRTM data are part of this set of radar images, but have a different way of mapping when compared to previous sensors. In 2000 the sensors of SRTM was attached to a 60 meters mast on the Endeavour space shuttle, in order to obtain a global topographic data. The different positions between these sensors (Band C / X) and its degree of tilt (angle of sight) allows the calculation of the elevation surface, a technique that produce interferometric images. The procedure to create interferometric images is similar to the principle of stereoscopy and allows obtaining a digital elevation model (MDE). These images have three spatial dimensions, latitude, longitude and altitude (x, y, z) and it is not necessary generate curves level for the extraction of topographic products, such as slope, hypsometric and roughness (FARR and KOBRICK , 2000; RABUS et al, 2003). Because of these utilities, the use of SRTM images has become very common in many studies, like topographical analysis in geology, hydrology, geomorphology and ecology (CARVALHO and LATRUBESSE, 2004; SABINS, 1996; ALVES and CARVALHO, 2007; CARVALHO and Bayer, 2008; CARVALHO and RAMIREZ, 2008).

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2. Study Area

The interpretation of the geomorphological units was done using two rivers as examples of study, the Claro and Bois Rivers, both in the State of Goiás. The reason for studying these two rivers together is because they are considered as belonging to the same river system, by the Brasilian Geological Service (CPRM). The drainage basin of these two rivers, together, has an area of 123.276 km², located in the right margin of the Araguaia River, on the transition point of up to middle fluvial plain (Figure 1). Compared to the Bois River, the Claro has great volume of water and a more developed fluvial plain. The main deposits the basin of both rivers are gnaisses, granites and amphibolites in the upper basin, and sands, gravels and conglomerates in the middle and lower basin. The Claro River is developed on the Regional Planation Surface IVC1 (SRAIVC1 – *Superfície Regional de Aplainamento*), running SE-NW, interspersed by hills with medium and strong dissected relief.

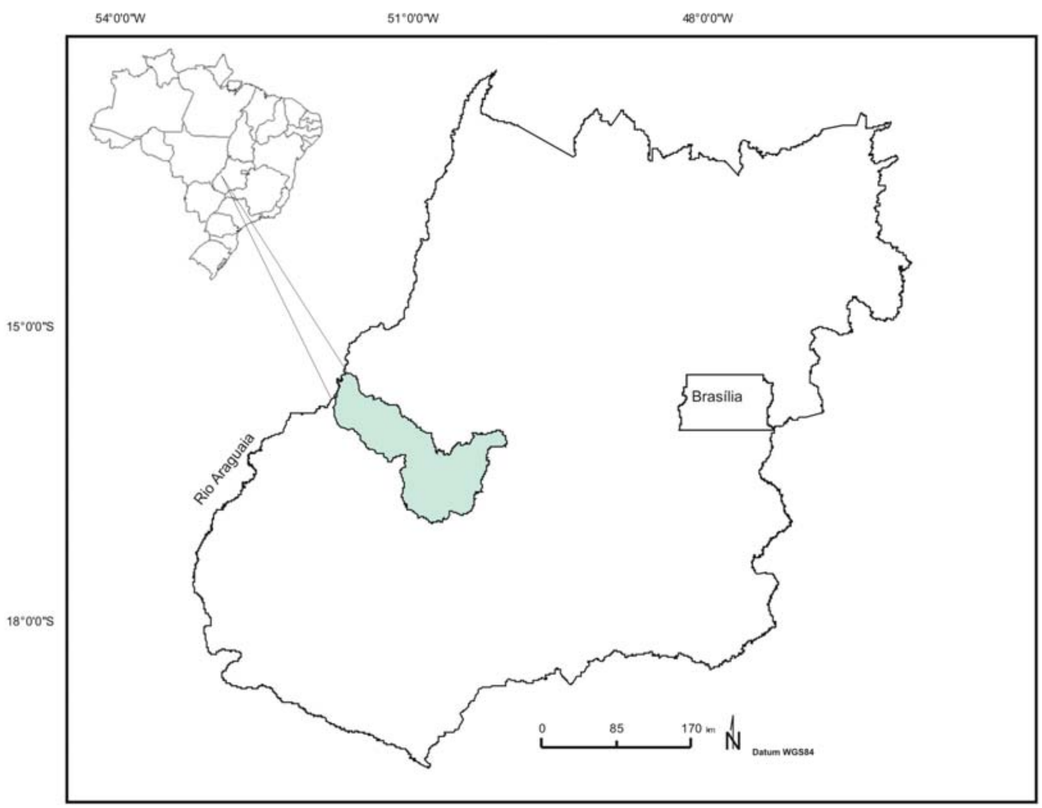

Figura 1 – Location of the Claro-Bois drainage basin, highlighted in blue in the Center-West of Goiás.

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The geomorphological units of the drainage of both rivers, Claro and Bois, characterized as Regional Planation Surface (*SRA – Superfície Regional de Aplainamento*), are the most important representative units of the Goiás region. This SRA is compartmentalized in four surfaces (SRA I, SRA II, SRA III and SRA IV) with different altimetric intervals, mainly associated with Hills (MC – *Morros e Colinas*), folded structure like Hogbacks (HB-ED – Hogback-*Estrutura Dobrada*), Tablet Relief (RT – *Relevo Tabuliforme*). These surfaces were arisen by denudation and planning morphological process of the landscape (LATRUBESSE and CARVALHO, 2006).

The primary streams of the drainage of the rivers Claro and Bois drains, in its upper basin, a relief with medium and strong dissected landscape, terrains with folded structures (hills) in the form of "hogback", and higher surfaces, such as SRAIIB-RT (surface with shape of Tablet Relief) and SRAIIIA. The altimetric variations in the upper basin are approximately between 280 to 800 meters. The lithology is composed mainly by sandstones in the upper basin, ortognaisses and schists (*Aquidauana* Formation, granite-gneiss complex, and Sequence metavulcano-sedimentary). In the middle and lower drainage the basin is formed mainly by granites, sandstone and deposits of sand and gravel (post-tectonic formations). The soils in the upper basin are argisols and cambisols; in the middle and lower basin are mainly oxisols and argisols. The feature of the land uses across the basin is mainly annual pasture and agriculture.

3. Methods

The data for geomorphological interpretations were obtained from primary observations in field, interpretation of maps and use of specific computer programs for geoprocessing and remote sensing. The field work was realized in April 2008, in order to obtain the visual geomorphological features of the drainage area of the Claro and Bois Rivers. During the excursions it was take the ground control points (GCP´s) to identify relief patterns, like the morphological contacts between different units and the lithological composition.

The mapping of the geomorphological units was delineated by manual and automated remote sensing techniques (CARVALHO and BAYER, 2008), using interferometric images of Shuttle Radar Topography Mission (SRTM). The primary data was the geomorphological map of

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Goiás (1:250.000 scale). For the interpretation of Claro-Bois drainage basin, was necessary a reinterpretation in scale 1:100.000, new adjustments have been made in the units on the map 1:250.000 (State of Goiás), which remained with the same legends, however, significant spatial adjustments were made in the units. ENVI 4.0 and ArcGIS 9.2 software were used for delineation and interpretation of the geomorphological units. The images were obtained from US Geological Survey's - EROS Data Center [seamless.usgs.gov] and Landsat 7 ETM+ images from GeoCover [zulu.ssc.nasa.gov/mrsid].

The main product to the mapping, as a raster format, were the interferometric images from SRTM, knowing as SRTM images, SRTM data or SRTM DEMs, with 90 meter of spatial resolution. To a better delineation of the topographic aspects, it was made a spatial resize by pixel size, using the nearest neighbor method of the ENVI program (Figure 2). Was used an unsupervised classification, Isodata method, to automated delineation of major surfaces and relief structures, like hills. The products generated from SRTM data to topographic analysis were:

i) Shaded-relief: important for descriptions of lithologic contacts and structural features. The perspective of the relief, through the simulations of different angles of illuminations, gave the shadow of the relief, giving the impression of concavity and convexity, allowing the identification of structural features, lithologic contacts, erosion zones, hills, and other geomorphological features of the study area.

ii) Density-slice (hypsometry): important to identify differentiated baselines. The hypsometric map was generated by slicing the image, composed by altimetric classes. This routine allowed the identifications of the differentiated relief baselines. These baselines are equivalent to the Regional Planation Surfaces (*Superfícies Regionais de Aplainamento* - SRA). This procedure also allowed mapping the Retreated Erosion Zones (*Zonas de Erosão Recuante*). The intervals were defined in accordance with field data, literature and shaded images interpretations.

iii) Topographic profile: Important to identify variations in the topography. This technique was useful in the present study, because: i) allowed the identification of precise limits between the SRA and ZER, ii) allowed to visualize the variations (irregularities) of the relief from different geomorphologic units, and iii) allowed to draw the topographic profiles of the paths traveled in field. The topographic profile were chosen based in two criteria: i) by the its

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geomorphologic representativeness, cutting different units, ii) by the possibility of follow them along the main paths traveled during the field work, allowing the ready identification of each point identified in field.

The interpretation of the agradational units was possible through ETM+ (Landsat 7) images, which allowed the visualization of the lake systems (*sistemas lacustres*) and the drainage basin of the Claro and Bois Rivers.

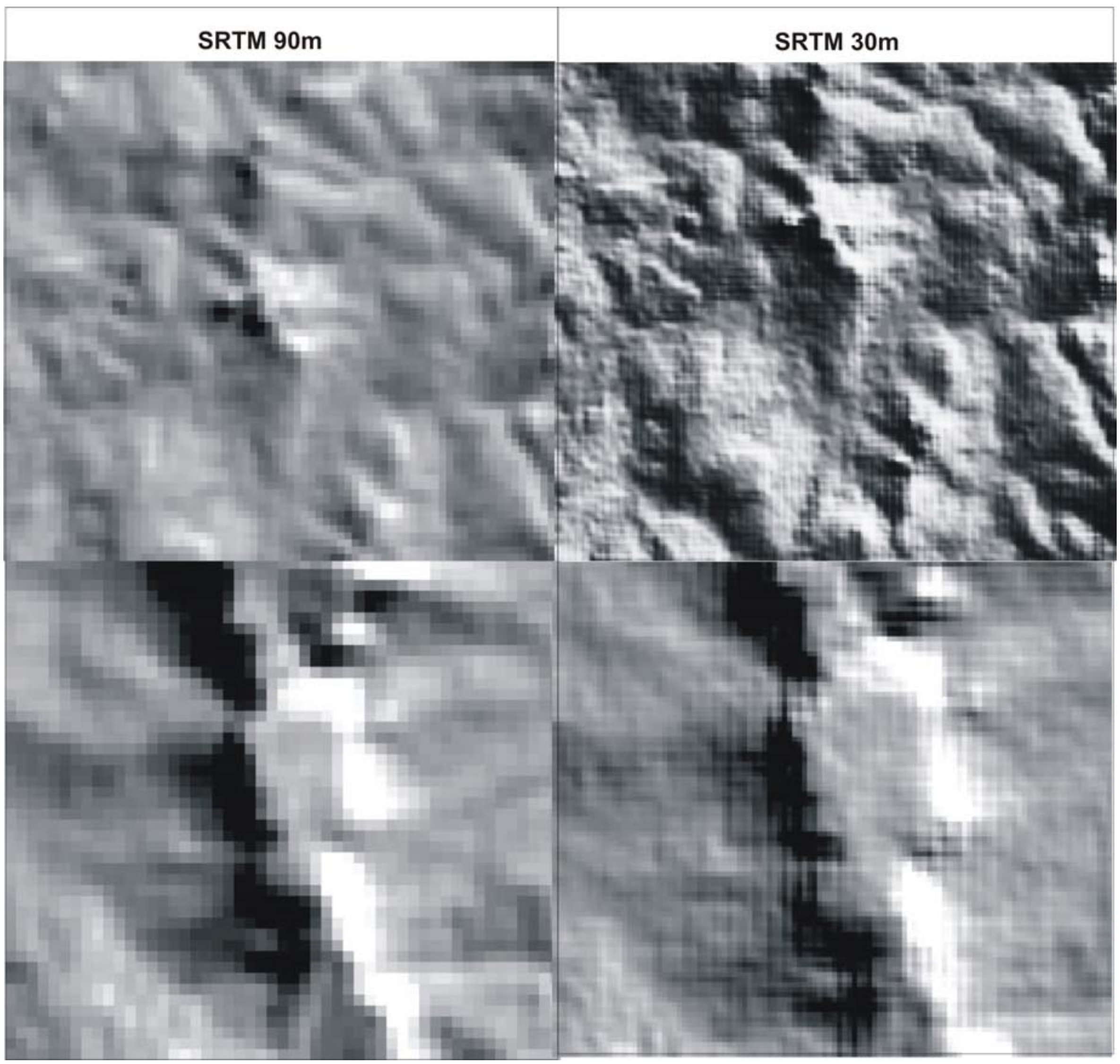

Figure 2 – Interpolation of the images SRTM from 90 meters to 30 meters, showing how better is seeing the limits of slopes and roughness of the relief.

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4. Results and Discussion

Figures 3 – 4 show the geomorphologic units identified in the study area: SRAIIIA, SRAIIB-RT, SRAIVC2, SRAIVC1, MC, Fluvial Plain, HB-ED and Alluvial Belt (*Faixa Aluvial*). Table 1 show the correlation of the geomorphologic units identified by RADAMBRASIL (non morphogenetic classification) with the current map of the Claro and Bois Rivers, made in this study (with a morphogenetic classification).

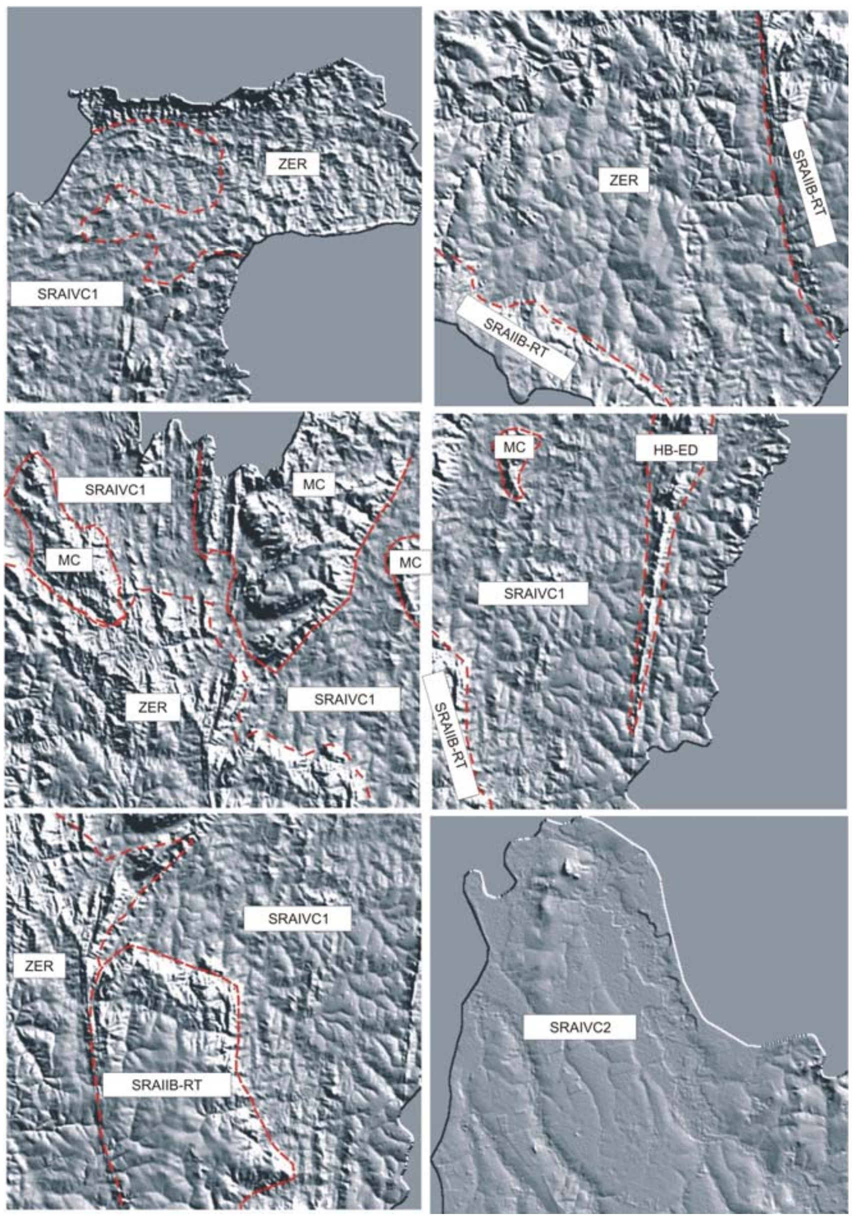

Figure 3 – Examples of the geomorphological units mapped in the drainage basin of the rivers Claro and Bois.

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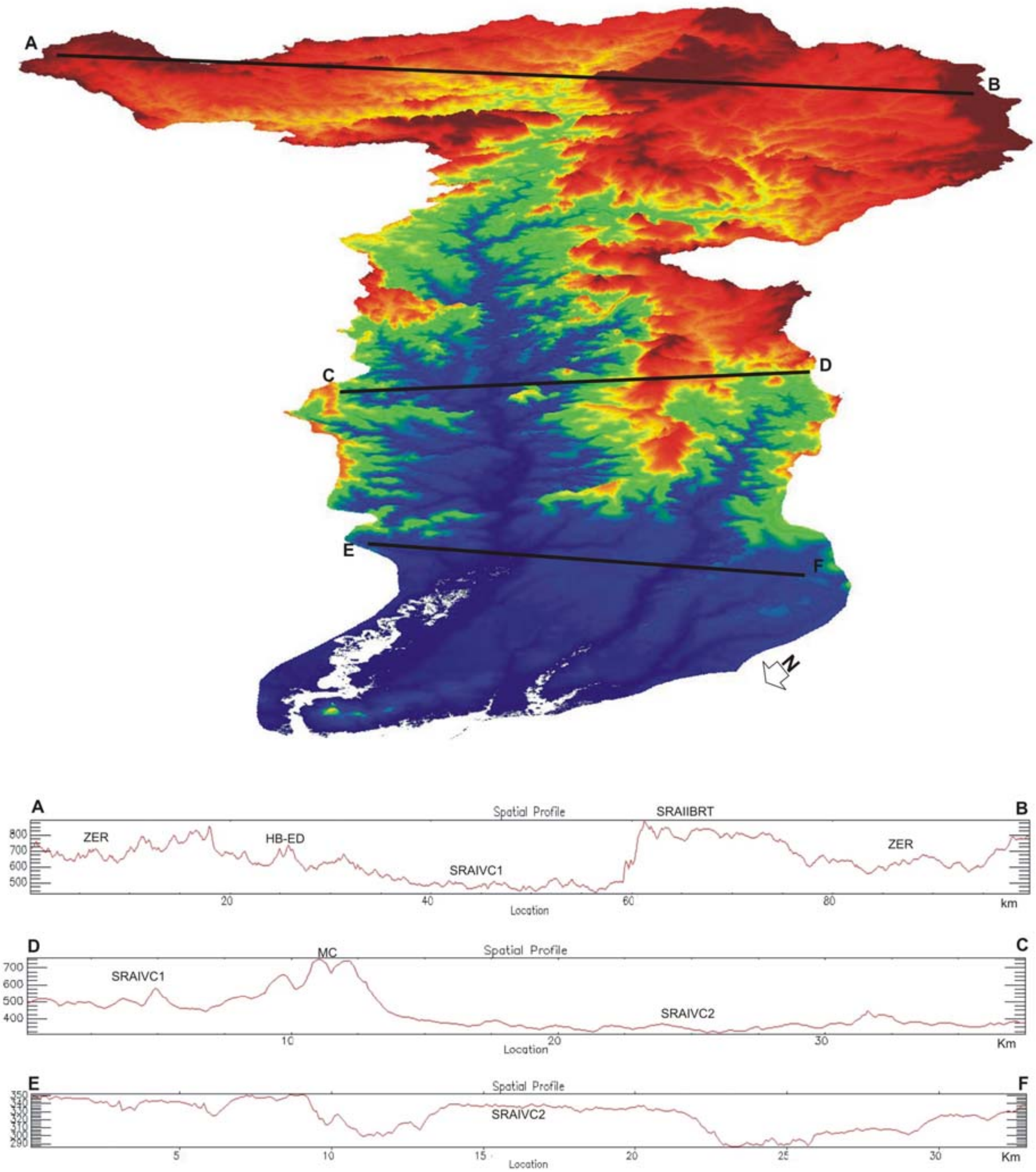

Figura 4 – Claro and Bois River drainage basin. The topographic profiles detach the geomorphologic units and its variations. Remark the dissected degree from the profile A-B to E-F, which is gradually reducing. The profile E-F shows the well developed valleys of the unit SRAIVC2 and a smooth profile.

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Table 1 – Rivers Claro and Bois, correlation of the geomorphologic units, RADAMBRASIL and this study.

Radambrasil (MAMEDE et al., 1981)	Current map, this study.
Lower Plateau of Goiânia (*Planalto Rebaixado de Goiânia*)	SRAIVC1 / ZER
Higher Plateau of Tocantins-Parnaíba (*Planalto Alto Tocantins-Paranáiba*)	MC / HB-ED
Septentrional Plateau of the Paraná Basin (*Planalto Setentrional da Bacia do Paraná*)	SRAIIB-RT / ZER
Depression of Araguaia (*Depressão do Araguaia*)	SRAIVC2 / SRAIVC1/Fluvial Plain/Alluvial Belt

4.1. Description of the mapped geomorphologic units

Regional Planation Surfaces - SRAIVC1 and SRAIVC2

The planation surface IVC is developed in the region drained by the Araguaia drainage basin. This surface IVC has the lowest altimetry quotas of the state of Goiás (250-450 m). The relief is well developed and sub-divided in two sectors (IVC1 e IVC2). The SRAIVC1 has morphology more rugged and is developed on granite-gneisses rocks (southeast of the drainage basin), biotites (center), sandstones and conglomerates (center-north). The SRAIVC2 show a lower dissected index and is associated with lakes of the Araguaia River plain. This surface is also associated with the Claro and Bois Rivers plain and with lower areas (depressions), which are situated outside the fluvial plain. In some regions the sedimentary rocks (sandstones) are overlapping by detritus laterite coverage, which actually is a transit alluvium of the erosion surface that suffered a strong laterite process as an iron crust (duricrost). The dismantling of the rusty crust formed by iron oxides and hydroxides has generated on this unit a mosaic of rounded lakes (lake systems) in the depression of the Araguaia River (SRAIVC2). This unit takes place on sand, silt, and small sandstone package, mainly in the range of transition from IVC1 to IVC2.

Regional Planation Surface IIB Tablet Relief - SRAIIB-RT

This surface is well developed in the southwest sector of the State of Goiás, in the geologic Province of the Paraná Basin. In relation to the Claro and Bois Rivers drainage basin, the SRAIIB-RT is represented by the Septentrional Plateau of the Paraná Basin. The SRAIIB-RT is characterized by forming a flat relief in the top (tablet relief) or "*chapadões*" (brasilian popular term), generated on sedimentary rocks, like sandstone and silts, whose main structural feature are the layers in horizontal strata.

Regional Planation Surface IIIA - SRAIIIA

In the map can be seen that this unit is developed in a range directed SW-NE in the central portion of the State of Goiás and in the northwest edge of the Paraná Basin, penetrating as erosive recessed within the basin, producing cliffs that reach hundred of meters high. This unit, known as Higher Plateau of Tocantins-Parnaíba (*Planalto Alto do Tocantins-Paranaíba*), show positive features in the form of low hills, hills and domes (*serras baixas, colinas e domos*), formed by granites, schists, amphibolites and gneisses.

Zone of Retreated Erosion - ZER

The areas identified as Zone of Retreated Erosion (Zona de Erosão Recuante – ZER) represents the evolutionary stage between two areas of regional planning. It is an active unit that is being dissected by the drainage, so that the old plain is eroded (retreated), leading a new regional surface planning in a lower quota. The degree of development of the ZER varies depending of the lithologic features of the unit that is been eroded. When the ZER is associate to large drainage basins, then this unit may extend over large areas, with significant retreats. In other conditions this unit is limited to the front/slope of “chapadões” (a free face with scarp crests), as in the case of the SRAIIB-RT in direct contact with the SRAIVC1 (Figure 5). As one unit ZER develops, a landscape of hills (MC – *morros e colinas*) may be formed, leading the testimony hills of the old eroded relief, known as Inselbergs (*morros testemunhos*).

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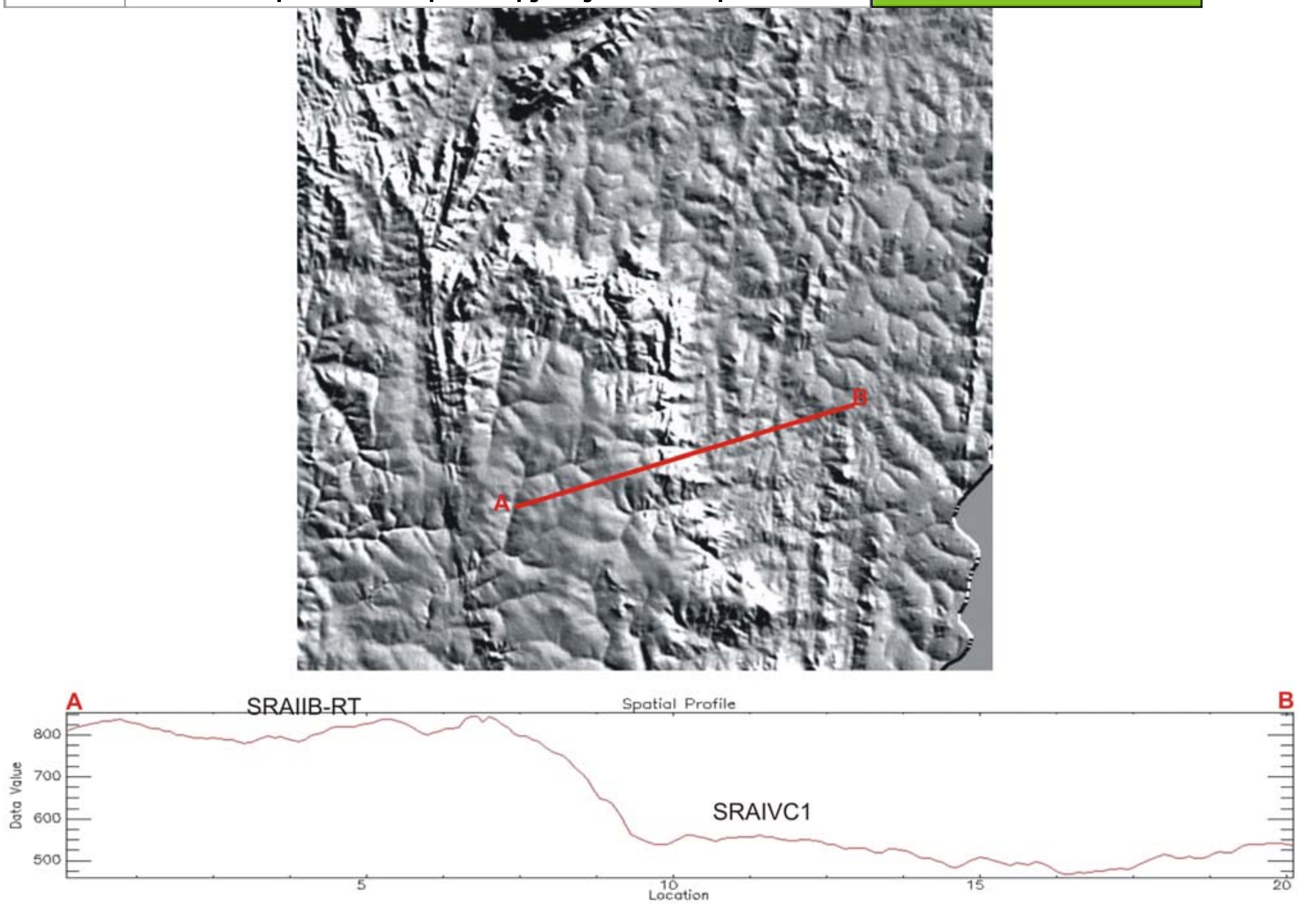

Figure 5 – Direct contact (free face with scarp crests) of the SRAIIB-RT with the SRAIVC1. Note that in the topographic profile A-B do not exist a ZER.

Hills (Morros e Colinas) - MC

As the ZER progresses and the retreat of the hillside evolve, the hills (*morros* and *Colinas*-MC) can be identified in a more disconnected way in front of the hillside (ZER). The hills stand out on an area of regional extension at a lower elevation. Large areas of hills are remnants of resistant lithology to erosion that have been preserved as the SRA (regional planation surface) evolved. In many occasions the hills appear with a strong structural control (folded structures formed by metamorphic rocks with well marked structures). In other occasions, smaller associations of hills constitute typical testimonies (Inselbergs) that stand out over the planed surface, like the hill called “Morro do Engenho” located in the Araguaia River fluvial plain, mouth of the Claro River.

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Hogbacks - Folded Structures – HB-ED

The tectonics of folding affects different groups of pre-Cambrian rocks. Maybe the most striking feature is the association of hills forming the hogbacks (HB) and structural crests. In this study there is a particular feature of HB near Sanclerlândia city, State of Goiás, in the eastern limit along the road GO-070. This positive feature folded is formed by metamorphic rocks, like schists and amphibolites, belonging to a folded unit of Serra Dourada (a hogback structure) (Figure 6).

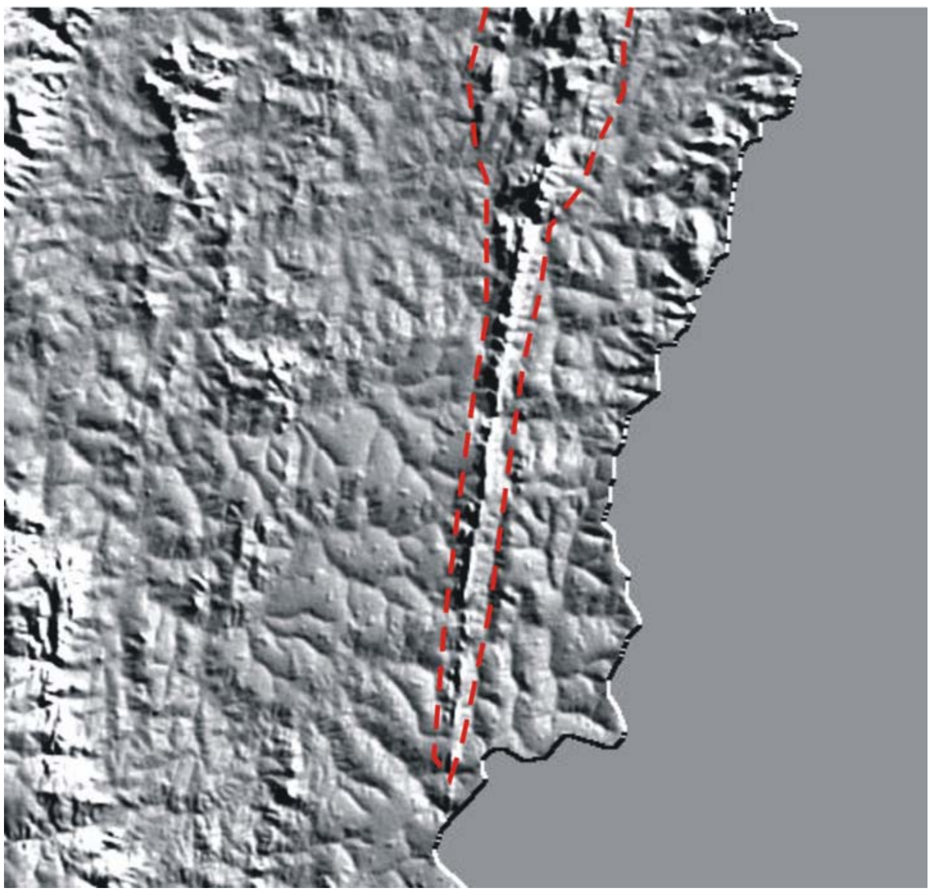

Figure 6 – The structure HB-ED – dotted - in contact with the SRAIVC1. This unit is part of the Serra Dourada hogback system.

Figure 7 shows the final result of the mapping proposed in the present study. It is the geomorphologic map of the Claro and Bois Rivers drainage basin, interpreted in the scale of

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1:100.000. The portion studied is the right margin of the Araguaia River, in the transition between the high and medium course of this river, where the rivers Claro and Bois are tributaries.

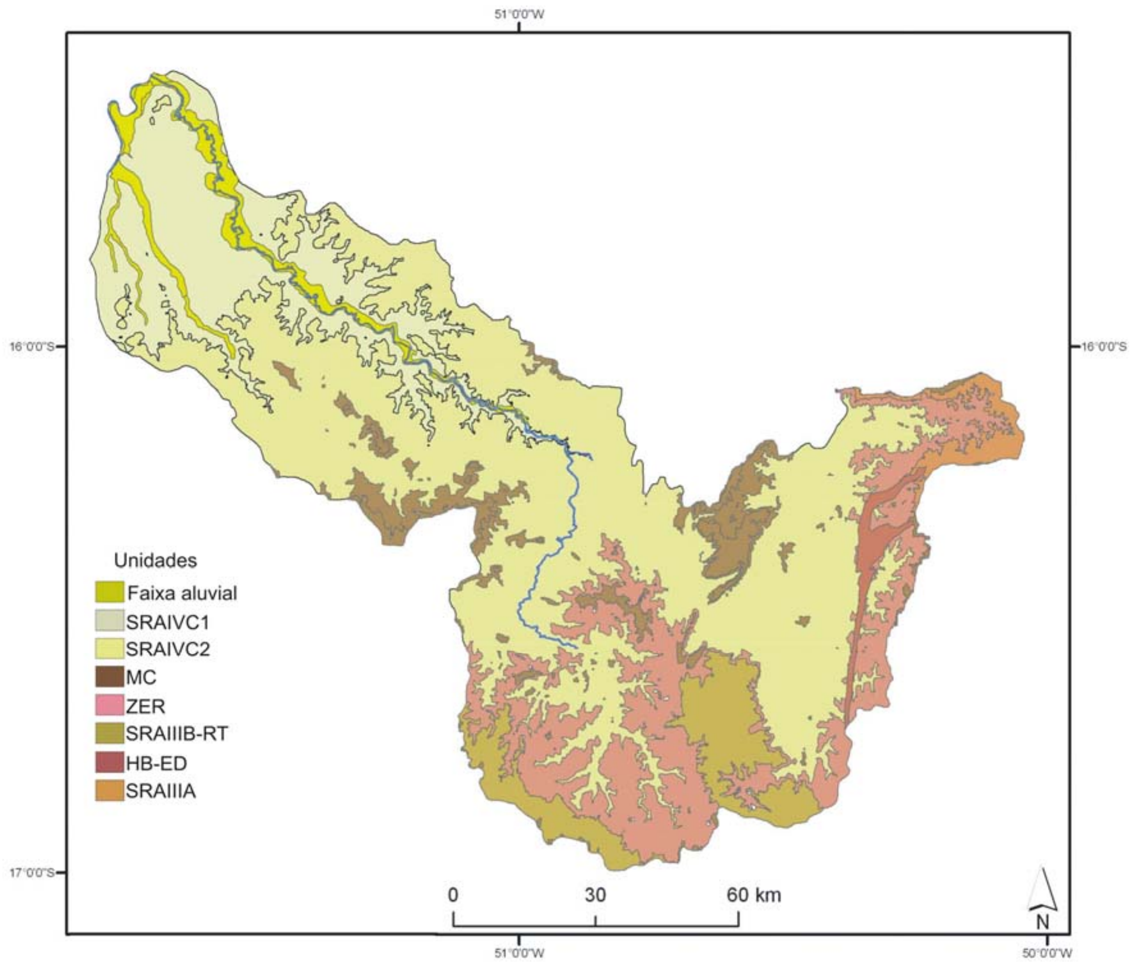

Figure 7 – Geomorphologic map of the Claro and Bois Rivers, tributaries of the right margin of the Araguaia River.

5. Conclusion

The SRTM images were a very useful tool for this study, highlighting the topographic features of the relief, which are very important for identification and mapping the different denudational units, using a morphogenetic classification. The SRTM images also enabled to make a good correlation with the geologic map and show its robustness as a tool for the ongoing studies, where I make correlations with vegetation, land uses and geomorphology of the State of Goiás. These studies aims to identify, for example, units of vegetation linked to geomorphology, I porpoise the term "Phytogeomorphology" to be used - becouse have a conotation more linked to structural aspects of the vegetation in association with the morphological process of the units of relief - and not a simple spatialization like "Phytogeography". The Landsat 7 images were very useful to identify the aggradacional units, like the river plains, lake systems and alluvial belts. These images allow fine interpretations of the alluvial belts, which are important for studies on paleoenvironments.

It become clear from this study that in some geomorphological interpretations, depending on the spatial scale we should be careful in utilize some products for data extraction, such as the use of topographic maps or images from passive sensors, for analysis of drainage system, because in general there is no correspondence of the reality of the regions. Therefore, the MDE interpretations of the drainage promote better results, because these interferometric images provide a tridimentional data of relief, showing for example, the dissected valleys for map the drainage systems. Some other examples of studies are useful for identifications and interpretations of the diversity of the topographic profiles of the Araguaia region, such as descriptions of the longitudinal profile of the Araguaia River in its medium course, and the topographic transverse profile of this river (CARVALHO e LATRUBESSE, 2004).

The declivity and hypsometric maps generated in this present study enabled the detections of the topographical differences that exist in the Claro and Bois drainage basin and its relations with the existing geomorphological units. The preparation of the MDT images in 3D perspectives is a base that can be used in many geological and geomorphological studies, providing a vision in various angles of the spatial morphological aspects of the study site. Is important know, that the MDEs from SRTM data are in relation of topographical surface, not of terrain level, such as topographic charts.

The general conclusion is that the increased technology of geographical information system in the last decade allowed a much better understanding of the environment. The data can be crossed in various ways optimizing the extractions of the regional information of the landscape and use of land for management plan and sustainability. In this way we can expect for more advanced geoprocessing and remote sensing techniques that will enable us to refine our geomorphological studies, like the ongoing project of the German Aerospace Center (DLR) called TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurements). This project will provide DEMs more accurate as than SRTM data. The technique is similar as the SRTM project, DEMs generated by interferometric images (If-SAR) mapped by X-band. The new project of DLR consist in two satellites flying in orbit formation (twins satellite constellation), TanDEM-X and TerraSAR-X, that will provide DEMs with an accuracy of less 2 meters, forming a high-precision radar by interferometry.

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