

# Geomorphology and habitat diversity in the Pantanal

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(With 4 figures)

## Abstract

The present study deals with the inter-relations in the relief which forms the Bacia do Alto Rio Paraguay (BAP) in mid-west Brazil. The overall aim is to discuss the relationship between relief forms and the biodiversity of the Pantanal. The BAP is a natural environmental system with contrasts in two of the compartments on which it is formed: the plateau, the most elevated compartment, highly transformed by human activities, and the plain which forms the Pantanal, which is more preserved and less transformed in relation to productive activities. The analysis was performed based on publications with a geomorphologic focus, examining the different relief units of the BAP and the dynamics of the revealing processes of landscape change which the Pantanal has undergone since the end of the Pleistocene.

*Keywords:* Pantanal geomorphology, biodiversity, relief.

## Geomorfologia e a biodiversidade no Pantanal

### Resumo

O presente estudo tem como objetivo abordar a inter-relação entre os compartimentos do relevo brasileiro que compõem a Bacia do Alto Paraguai - BAP, para discutir as formas de relevo e a biodiversidade do Pantanal. A abordagem fundamenta-se na compreensão das diferentes formas do terreno, associando ao fato que a BAP é um sistema ambiental natural que tem contrastes nos dois compartimentos que a compõem: o planalto, o compartimento mais elevado, fortemente transformado por atividades humanas; e a planície, que constitui o Pantanal mato-grossense, mais conservada e pouco transformada, quanto ao uso com atividades produtivas. A análise foi realizada a partir de publicações com enfoques geomorfológicos, abordando as diferentes unidades do relevo da BAP e o entendimento da dinâmica dos processos reveladores de que o Pantanal passa desde o fim do Pleistoceno, com processos de mudanças da paisagem.

*Palavras-chave:* geomorfologia do Pantanal, biodiversidade, relevo.

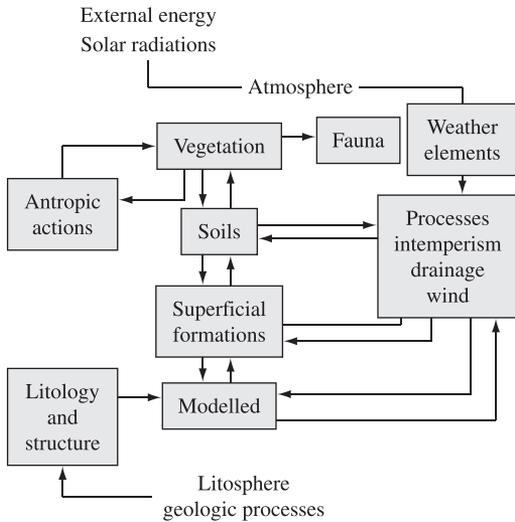
### 1. Introduction

Biodiversity itself is a relatively recent term, and it has only recently been studied in relation to other areas of scientific knowledge, such as geomorphology. There have been few studies on the biodiversity of the Pantanal Mato-Grossense which deal with the relief forms at the interface of the abiotic, biotic and anthropic components of its complex environmental system (Franco and Pinheiro, 1982; Silva, 1984; Ross, 1990; Ab'Saber, 1996; Alho and Gonçalves, 2005).

The spatial arrangement of the relief forms is considered an important variable for understanding the diversity of the landscapes and one of the indicators of the dynamic balance in the protection of biodiversity.

Since relief is the result of endogenous and exogenous forces, including climatic and tectonic factors, it helps to explain the distribution, diversity, extinction and performance of living beings on the earth's surface (Silva, 1984).

The definition of geomorphologic units is based on the supposition that the planet is the result of the interaction between living beings and the physical-geographical environment. This is illustrated in the works of Tricart (1972), in the form of a matrix. While the morphogenetic processes modify the surface of the Earth they generate instability and harm the multiple and fragile balances towards which the systems incline, connected by a chain of interdependences, such as that shown in Figure 1.



**Figure 1.** Flow chart elaborated based on Tricart's conception (1972).

In the Tricartian matrix the models are situated at the interface of abiotic, biotic and anthropic components. Tricart considered that an eco-dynamic unit is characterised by a certain dynamic of the environment and has repercussions on biosynthesis.

Studies by Ross (2006) have been based on a combination of information about natural vegetation, lithology, relief forms, soils, climate and biogeography. These have culminated in the mapping of the territorial macrospace in Brazil, which also show the different types of land use by society.

The Ross classification (2006) was built on this integrated view. Ross's analysis of the BAP places the plateau in the category of savannah that has been highly transformed by economic activities. In contrast, the plain where the Pantanal Mato-Grossense lies is placed in the slightly transformed group of natural environmental systems, such as the fluvial plains of Araguaia and Guaporé and some marine plains.

The Pantanal Mato-Grossense is a natural system presenting a great diversity in flora and fauna. Even though it is occupied by human activities, the Pantanal presents low transformation intensity in the natural vegetation cover caused by productive activities such as farming and mining. However, it has undergone very strong impacts from other activities. The two main threats are the uncontrolled use of soil in the areas surrounding the Pantanal plain, which are drier and flood free; and the consequences of deforestation on the plateau. The latter is a result of many development plans for Central Brazil, none of which considered the natural connection between the high and low parts of the region (Conservação Internacional, 2009).

The plateau is also intensively used for agriculture and cattle breeding. Human occupation is less invasive in the natural vegetation cover of the plains. On the plateau

region the natural cover represents 42% of the total territory and on the plain the percentage is 87% (Conservação Internacional, 2009); Abdon et al., 2007).

Alho (2008, p. 958) provides an analysis of the key factors that have impacted the Pantanal's ecosystems:

The present landscape arrangement and natural ecosystems are the result of three factors: 1) geological changes occurring since the Quaternary, which probably influenced the drainage patterns of the region; 2) the pronounced differences in annual cycles of wet and dry seasons plus exceptional periods of long flooding or droughts causing retraction or expansion of the Pantanal, thus, a phenomena related to greater or lesser primary productivity and ecological succession and 3) areas related to human intervention such as pastures, artificial ponds or introduced trees near the ranch houses.

Assine (2003) and Mercante et al. (2007). indicate the existence of complex processes of change in the landscape of the Pantanal, resulting from the sedimentary dynamic in alluvial fans. In these fan regions the landscape changes continuously because of sedimentation and by avulsion processes. These cause changes in the river beds, such as those occurring in the Taquari River.

The Pantanal is a highly changeable quaternary sedimentary plain. Its understanding is vital to projects for use and occupation, as well as conservation and preservation, and needs to be based on interdisciplinary knowledge (Ab'Saber, 1988; Alho and Gonçalves, 2005; Assine et al., 2008; Mercante and Paiva, 2009; Mercante and Santos, 2009). This study is placed within this context, in order to identify aspects of relief forms which are important to the biodiversity of the Pantanal Mato-Grossense. First we examine the relationship between plateau and plain by classifying the compartments and cartography of the relief units. Next, we describe different relief forms in the Pantanal, with special attention to the formation of fluvial fans. Last, some conceptual lessons will be highlighted in order to detail the innumerable landscape features that characterise the region's relief and shelter its rich biodiversity.

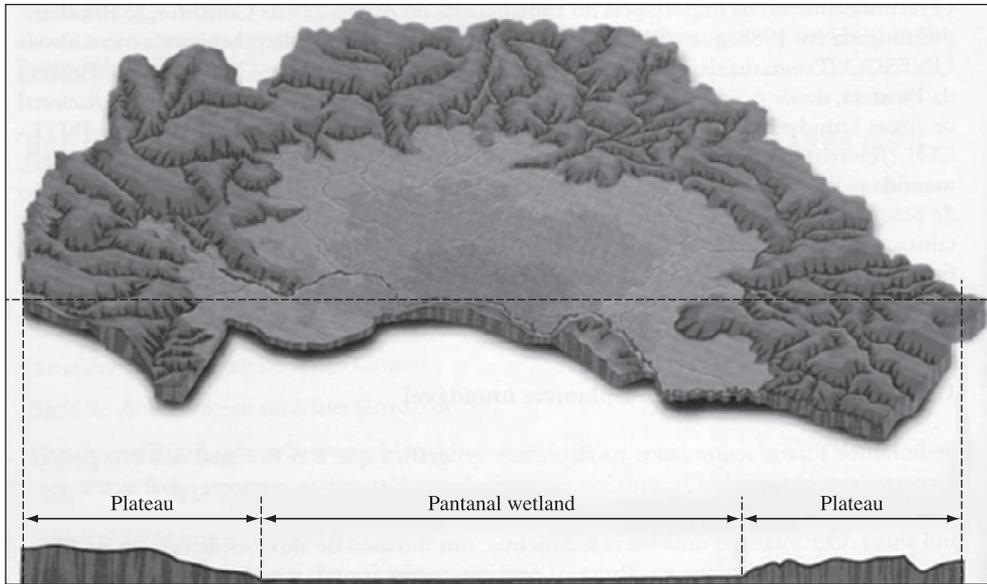
## 2. Study Area

The Pantanal, located between parallels 15° and 20° S and meridians 55° and 59° W, is a vast low flat plain. It features a depositional tract of sandy sediments derived from the plateaus of sedimentary basins, forming huge alluvial fans and lacustrine and fluvial environments. Accumulation areas are geomorphologically highlighted on the plain with seasonal floods and other areas of fluvio-lacustrine accumulation.

The Pantanal Mato-Grossense has worldwide value and is recognised as the world's largest continuous inland wetland. It ranges in altitude from 100 to 150 m, presents flat relief, and lies within a significant geological unit known as the Bacia do Alto Paraguay (BAP) (Figure 2).

## 3. Procedures

We analyse texts and cartographic examples, integrating methodological focus based on the idea that relief forms are



**Figure 2.** Illustration of the diagram block showing aerial view from West and the flat texture representing the unit of the Pantanal flats and the Pantanal itself and the remaining wrinkled texture representing the surrounding plateau. The inferior part of the illustration shows the topographic profile elaborated from north to south axis starting with the high parts of the plateau followed by the depressed part of the flat and finishing on the plateaus of the extreme south. Adapted from Alho and Gonçalves (2005).

direct and permanent products of the interactions between internal and external energy flows. The methodology used in this study is based on a literature review of publications presenting mappings of the different geomorphologic compartments of the BAP, where we can find the plain and the marshlands of the Paraguay River, known as the Pantanal Mato-Grossense.

The concepts of Ross (2006) have been adopted for the generation of the BAP map, highlighting the relief macroforms of the surrounding plateau and including the Pantanal Mato-Grossense plain. Ross (2006) provides the basis to understand that the Pantanal Mato-Grossense is an active sedimentary basin being filled by a considerable layer of sediments that come from the surrounding plateau. He demonstrates that the plain and the marshland are natural environmental systems which have undergone little transformation, taking into account information on the characteristics of natural vegetation, geology, geomorphology, pedology, climate and biogeography.

In order to understand the sedimentary processes the studies by Tricart (1972, 1982) were used. These are based on the premise that geomorphologic evolution generates differentiation in the relief units. On the Pantanal Plain, in particular, the sedimentary dynamics involves the formation of alluvial fans.

#### 4. Discussion

Relief, as one of the components of the natural environment, presents a great diversity of shapes. These

shapes are important for all living beings, which need a physical support, or biotopic.

The relief of the Bacia do Alto Paraguai is marked by the contrast between the plain which is the Pantanal, with areas ranging from 50 to 150 m above sea level, and the elevated lands of the plateau (200 to 1,200 m above sea level).

##### 4.1. Classification and relief units

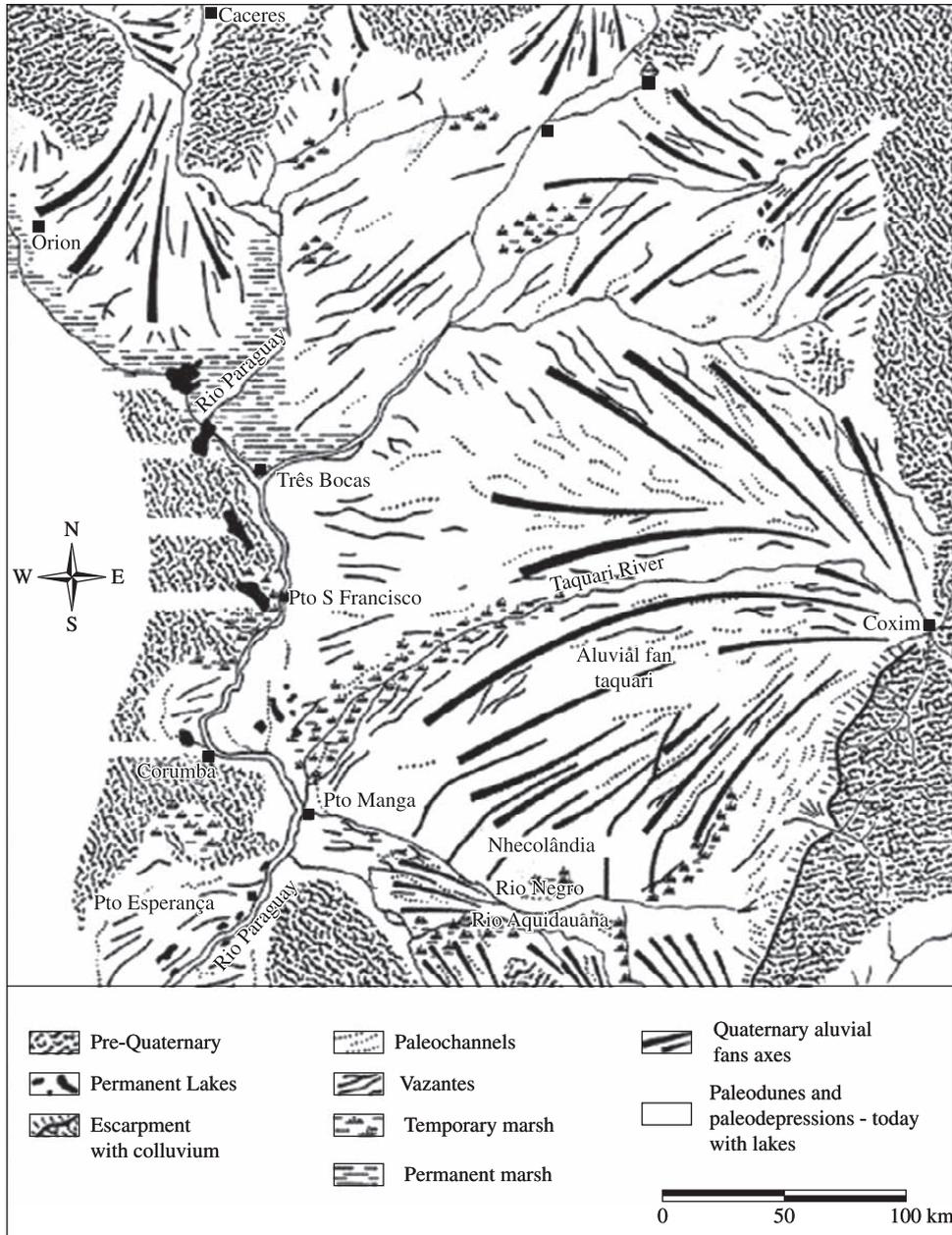
According to the classification of the geomorphologic units of Brazil elaborated by Ross (2006) the plain and the Pantanal of the River Paraguay are surrounded to the east, northeast, south and southeast by macroforms of Brazilian relief (Figure 3).

In the cartographic synthesis with the different geomorphologic units of the macroforms of Brazilian relief, the plain and the Pantanal of the Paraguay River, as mapped and denominated by Ross (2006), are one large unit considered a slightly transformed environment despite being occupied by human activities.

The data and information presented in Table 1 reveal one of the important aspects of the Bacia do Alto Paraguai, which are the relief macroforms which surround the plain and the Pantanal of the Paraguay River. These geomorphologic units are important in order to understand the existing complexity in the processes of accumulation and the fluvial processes on the plain.

##### 4.2. The plain and the Pantanal of the Paraguay River

The plain represented in Figure 3 as a large white area presents low intensity of transformation of the



**Figure 3.** It is shown in the cartographic product about the geomorphology of Pantanal, elaborated by Tricart, the design of the alluvial fans, and the observations about the geomorphologic partitioning.

natural vegetation cover by interventions of productive activities, such as extensive cattle breeding, subsistence agriculture, fishing, mining and timber extraction. In these less transformed environments the natural conditions are highly diversified, and mosaic plant cover is formed. There are various types of words, also highlighted on the map: on the wetlands, the fluvial dykes and the uplands known as “cordilheiras”. All these environments are extremely rich in fauna and flora and have been used for many different human activities.

Based on the interpretation of orbital images available in the 1980s, Tricart (1982) mapped the main areas of past action of eolic processes and used cartography to present the alluvial fans of the Pantanal, whose distributary pattern of the rivers were highlighted by the fluvial paleochannels.

The author also analysed geomorphological conditions in the areas with lagoons. He considered that these regions, nowadays occupied by innumerable circular and semi-circular lagoons like those present in the Nhecolândia Pantanal, are a relic of non-active alluvial fans.

**Table 1.** Geomorphologic units in the surrounding of Pantanal Mato-Grossense, based on Ross classification (2006). Adapted from Ross (2006).

<b>Paraná basin plateau and lowlands</b>			
<b>Relief forms</b>	<b>Altitude(m)</b>	<b>Litology</b>	<b>Soils</b>
Ample hills with convex summits – mid-north.	400 - 700	Sandstones	Red-yellow-sandy latosoils
Chapadas – flat surfaces on the North-Northeast Patamares and structural scarps associated to hills and mound-hills with convex summits.	700 - 800	Sandstones associated with clayish detritical covering	Sandy-red claysoils
Scarps on the edges	500 - 1,400	Basalts, diabases and rhyolite.	Clayish red latosoils Nitosoil cambic soils, litolic
<b>Alto Paraguai Plateau and residual elevations</b>			
Elongated elevations on anticlinal crystals – synclinal – mountainous relief	600 - 800	Calcareous silicified sandstone	Litolic neosoil
Valleys and closed anticlinal depressions	300 - 400	Shales	Cambic neosoil
Ample synclinal valleys	200 - 300	arkose	Rocky outcrops
Intermountain depressions			Red claysoils
<b>Bodoquena Plateau</b>			
Surfaces of hills with convex summits, fragments with flat summits	600 - 900	Migmatite, gneisses, amphybolite, quartzite, carbonatic rocks and granites	Red claysoils Litolic neosoil
<b>Cuiabana Depression</b>			
Vast mound-hills with slightly carved valleys	150 - 400	Metasandstones – phyllite – quartzite	Red-yellow plintosoils and claysoils
Small asymmetrical crests			
<b>Alto Paraguai-Guaporé Depression</b>			
Vast mound-hills with flat summits, slightly carved valleys	150 - 250	Shales	Quartzarenic neosoils
Fluvial plains		Arkose - inconsolidated sandy sendiments	Yellow Latosoils
<b>Miranda Depression</b>			
Vast mound-hills with flat summits	150 - 200	Metasandstones, phyllite, quartzitos, limestone	Red-yellow claysoils
Not too deep valleys			

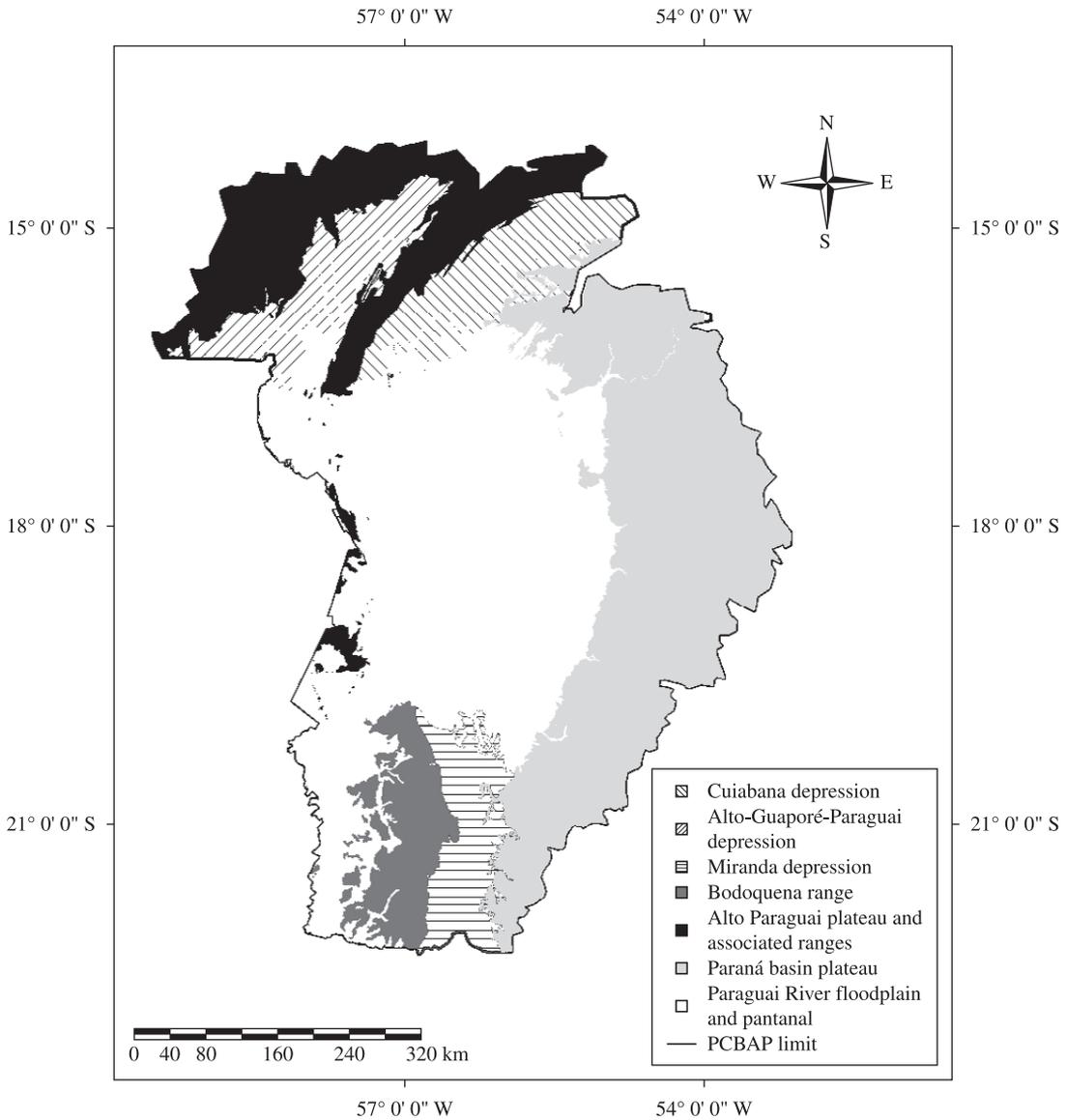
On Tricart's (1982) map, it is important to highlight the outline of several alluvial fans, of which the largest is known as the Taquari Mega-fan (Figure 4).

The plains and the Paraguay River Pantanal cover a vast surface with extremely flat topography and altitudes ranging from 80 m near the Paraguay River to 150 m in higher areas. They present a complex hydrographic network of rivers originating from the surrounding scarps, running through narrow alluvial plains subject to seasonal floods with permanent flooded areas. All rivers originating in the east, northeast, south and southeast coalesce on the left riverbank of Alto Paraguay.

Due to different flooding patterns these areas have been denominated according to flood accumulation areas and plains. These areas are traditionally known as "Pantanais Mato-Grossenses" or Pantanal sub-regions.

Those units are denominated "pantanais" (swamps) due to frequent flooding by superficial waters. However, this name is inappropriate as the region does not present swamps as a whole. The plains are identified according to different genetic formation processes, such as fluvial plains (linked to the Paraguay River and its affluents) and fluvio-lacustrine plains (in interfluvial positions among the rivers of the basin).

The flood areas are directly related to the topographic variations and to the kind of soil which characterises the behaviour of superficial and sub superficial waters. From this, low, average and high flood areas are known, positioned in different ways in relation to the main axis of local drainage. The altitude varies between 150 and 180 m further from the drainage axis, but areas near drainage lie at below 100 m altitude. This is also the case at the confluences of



**Figure 4.** BAP map presenting the macroforms of the relief of the surrounding plateau and the plain of the Pantanal Mato-Grossense.

the main fluvial courses, with variable flooding periods ranging from three to four months in weak flooding areas up to nine months in strong flooding areas; there are also areas which remain flooded all year long.

The flooded areas are modelled on recent sediment deposits along the valleys characterised by the presence of marginal dams, sandy bars, islands and circular and semi-circular shaped lagoons. Some features in these areas are identified by the following regional names:

- baias: small depressions in the terrain presenting different forms (circular, semicircular or irregular), which may contain water. They may or may not be covered by aquatic species of plants;
- cordilleras: ridges of firm terrain, locally denominated "cordilheiras". The term "cordilheira" is used for the innumerable marginal paleodykes or clay ridges, which are usually unflooded, ranging from one to three metres above the field levels and which cover strips of the terrain (on average longer than they are wide). These are preferred areas for the location of cattle ranches, and are very much used as a refuge for "swamp" livestock and by the regional fauna during the flood season;
- vazantes: vast elongated depressions located between the "cordilheiras" which serve as fluvial courses up to many kilometres long and which

may be intermittent or perennial, or may connect bays or streams;

- d) corixos: channels with temporary or perennial drainage which connect adjacent baias or even bigger water courses. They are more powerfully erosive than the “vazantes” (presenting more excavated beds which are usually narrower and deeper).
- e) capões or caapões: islands of trees usually in an area located from 0.3 to 30 m above the field. It is slightly hilly, measuring from five to one hundred metres in diameter, where the vegetation becomes denser and the trees are from many different species of flora in the savannah.
- f) *oxbow lakes*: these lakes are on the banks of many rivers and have a significant role in the freshwater biodiversity as they are reproduction and feeding sites for many species. They may present high connectivity with the original system (the river) due to the relief, distance and the magnitude of the flood rhythm. They are often known as baias.
- g) fluvial avulsion: fluvial avulsion starts with the breaking of marginal dykes and sedimentation on adjacent low areas which become flooded during flooding seasons. The breaks in marginal dykes are known by the communities in the Pantanal as “arrombados”. During the floods part of the water starts to flow towards the flood plain through the “arrombado” and the channel may split, originating a distributary channel. In case the new distributary channel becomes the main channel, which usually implies abandonment of the old channel, leading to a drastic change in the river course; and
- h) fluvial plains: These are the various strips of land where sediments accumulate. This is a result of the surface drainage difficulties along practically all the watercourses of the Paraguay River and its main tributaries which flow down the plateau towards the plain, such as the rivers Bento Gomes, Cuiabá, São Lourenço, Itiquira, Taquari, Negro, Aquidauana, Miranda, Nabileque and Apa.

Many factors must be considered when analysing how exogenous processes act on the fluvial plains, in the superficial drainage of water (speed, discharge and kinds of flow), subterranean infiltration and drainage, time of residence of the water in the system, water table fluctuation, kinds of transport of the sediments (channelled or spread flow), deposit of sediments on the riverbed, sedimentary processes on the flood plains, avulsion and divergence of the channels.

The processes of deposition and erosion are constant. This is highlighted by the migration and abandonment of the beds, by the formation of marginal dykes, changes in channels by avulsion processes and the breaks known as arrombados. These processes of alterations in the landscape are intense in the alluvial fan of the River Taquari (Mercante et. al., 2007).

The fluvio-lacustrine plains correspond to the deposits of the marginal areas in the lagoons in the hydrodynamic processes of flooding and “vazantes” where they vary in the quality of the carried sediments.

It is important to mention the hills scattered along isolated areas of the plain, which are usually round and from 150 to 200 m high on average. During the flooding season they stand out in the flooded areas like islands covered in vegetation. The hills located on the west side are not part of the plain, but are eroded areas of the Amolar Mountains.

## 5. Final Considerations

Despite offering generic data and being more classificatory for BAP units, the analysis of published articles makes it possible, by means of the conceptions adopted by their authors, to relate geomorphologic dynamics and relief forms with the biodiversity of the plain and the Pantanal of the Paraguay River, i.e., the Pantanal Mato-Grossense.

The approach made it possible to reach some conclusions:

- 1) The landscape of the Pantanal has become a symbol for biodiversity and environmental challenge with a double mission: to enrich the biodiversity and not allow the degradation of Pantanal with predatory and inadequate uses.
- 2) The Pantanal is definitely a complex and heterogeneous space cell inland in the South American continent and in order to establish biodiversity conservation and recovery strategies the link with its geomorphology is indispensable.
- 3) The Pantanal Mato-Grossense is a natural system which has been slightly transformed by human action and at the same time a fragile microcosm of rich biodiversity against the threat of turning into an environmental system that is highly degraded and modified by human actions.
- 4) Its geomorphologic evolution process, which has been going on for thousands of years with a sedimentary dynamic on the alluvial fans, is continuously changing due to the alterations in accumulation and deposit of sediments as well as due to the dynamics of its drainage system.
- 5) Such a complex relationship on a wet area forms a picture of an exceptional landscape in Brazil with the recognition of its importance on the international scene.

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