Acta Scientiarum. Biological Sciences
ISSN: 1679-9283
eduem@uem.br
Universidade Estadual de Maringá
Brasil

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A conservationist approach on environmental diagnosis of ground use in the Iguatemi river basin, Mato Grosso do Sul State, Brazil
Acta Scientiarum. Biological Sciences, vol. 34, núm. 3, julio-septiembre, 2012, pp. 271-277
Universidade Estadual de Maringá
.png, Brasil

Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9283
ISSN on-line: 1807-863X
Doi: 10.4025/actascibiolsci.v34i3.9001

A conservationist approach on environmental diagnosis of ground use in the Iguatemi river basin, Mato Grosso do Sul State, Brazil

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ABSTRACT. Landscape Ecology is a contemporary approach in conservation studies in which, coupled to the development and use of GIS-based tools, provides new methods for the analysis of forest fragments. Based on these new approaches, the environmental assessment of ground use in the Iguatemi river basin Mato Grosso do Sul State, Brazil is provided through conservation-based flora and ecology aspects. A regional map of ground use with field-collected data using Rapid Ecological Assessment methodology and digital satellite images was prepared. AER analysis showed a highly impacted region featuring intense transformation in ground use with a conversion of 87% of native forest into grazing and agriculture land. The general situation is inconsistent with APA guidelines, the conservationist unit which operates in the river basin. PPAs' recovery, erosion control and adjustment to current environmental regulations are mandatory.

Keywords: landscape ecology, conservation, forest fragments.

Enfoque conservacionista no diagnóstico ambiental do uso do solo na bacia do rio Iguatemi, Estado do Mato Grosso do Sul, Brasil

RESUMO. A Ecologia de Paisagem é uma abordagem atual nos estudos conservacionistas que, aliada ao desenvolvimento e uso de ferramentas baseadas em SIG, proporciona novas metodologias de análise de fragmentos florestais. Baseado nessas novas abordagens, o objetivo do estudo foi realizar o diagnóstico ambiental do uso do solo na bacia do rio Iguatemi, Estado do Mato Grosso do Sul, utilizando aspectos florísticos e ecológicos com um foco conservacionista. Pelos dados coletados, em campo utilizando metodologia da Avaliação Ecológica Rápida e imagens de satélite tratadas digitalmente, foi elaborado um mapa de uso do solo da região. A análise da AER indicou uma região intensamente antropizada com a conversão de 87% de floresta nativa em área de uso antrópico, como pastagem e agricultura. A situação geral não condiz com as diretrizes de uma APA, unidade de conservação na qual está inserida toda a bacia. Há necessidade de recuperação de APPs, controle de erosão e adequação quanto à legislação ambiental vigente.

Palavras-chave: ecologia da paisagem, conservação, fragmentos florestais.

Introduction

Landscape Ecology, a new section in Ecology which has recently given rise to relevant approaches and contributions, may be defined as the study of the ecosystem's regularity, arrangement, distribution and contents within a determined geographical area, taking into account human impact and ground use (NAVEH; LIEBERMANN, 1984). It is a highly useful tool for the analysis of native forest remnants.

Geographic Information Systems (GIS)-based tools are on the increase in the fields of Conservation Biology and Landscape Ecology. This is mainly due to the issues highlighted in such research and within the researchers' perception that the species' local diversity (ANDRÉN, 1994; FRANKLIN, 1993; GASCON et al., 1999) and the probability of a species's local extinction (DUNNING JR. et al., 1995; FAHRIG; PALOHEIMO, 1988; VANAPELDOORN et al., 1992) may be affected by the region's space structure.

The vegetation formation of the area comprised by the Iguatemi river basin may be defined as an ecologically tension area (IBGE, 1992, 2004) featuring specific characteristics such a high biodiversity and a singular habitat for many species (AB'SÁBER, 1971). However, the southern and northern regions of the states of Mato Grosso do Sul and Paraná, Brazil, respectively, are extensively devastated. In fact, the native forest covering is approximately a mere 5% of total area (SEMA, 2002). The native ecosystems were replaced by anthropic activities such as agriculture, pastureland

and commercial reforestation with a consequent fragmentation of native vegetation. Forest fragmentation is a great threat to global biodiversity (STEININGER et al., 2001) since forest species are influenced by loss of habitat and may be extinct if the remnant areas are so small that populations become unviable (MMA, 2003).

Since studies on the region's original vegetation and activities on environmental recovery are lacking and conservation of local ecosystems should be supported by reliable data, current analysis undertakes the environmental diagnosis of ground use in the Iguatemi river basin, Mato Grosso do Sul, Brazil, employing flora and ecology aspects with a conservational approach.

Material and methods

Study area

The Iguatemi river basin lies at the extreme south of the state of Mato Grosso do Sul, with its eastern part bordering on the State of Paraná and its western and southern part bordering on Paraguay. Its total area of approximately 830,000 ha comprises nine municipalities (Amambaí, Coronel Sapucaia, Eldorado, Iguatemi, Japorã, Mundo Novo, Paranhos, Sete Quedas and Tacuru).

The Semi-deciduous Seasonal Forest and the Savannah are the two ecological dominions that affect the Iguatemi river basin. Since they lie in a transition zone, they mix up and compose the regional vegetation physiognomy. In spite of its ecological importance, most of the native vegetation was replaced by anthropic activities causing intense fragmentation of the habitat.

According to IBGE (2002), the region's relief displays slightly rolling hills, a mean altitude of 500 m above sea level, a sub-hot tropical climate typical of Central Brazil with mean temperature of 22°C and yearly rainfall ranging between 1,400 and 1,700 mm.

Data collection and analysis

A field phase between June and July 2008 was reserved for data collection on vegetation formation and local flora survey of the Iguatemi river basin. Twenty-six satellite-defined geo-referential sites with ecological interest and good accessibility were visited.

Characterization of forest fragments was undertaken from pathways and dirt roads opened within and at the borders of the fragments where observations and material collecting of vegetation species were identified. Handbooks confirmed the species collected and their identification on the field (LORENZI, 2000, 2002).

Rapid Ecology Evaluation (REE), which is a diagnosis method to assess conservation of native forests, forest fragments and remnants, was employed for data collection, based on indexes that provide different conservation degrees (SOBREVILLA; BATH, 1992). Main ecological indexes were wood clearings, lianas, exposed soil, undergrowth, burnt vegetation, silting, timber removal and new vegetation growth. REE was employed due to its time-saving and low cost methods for the evaluation of conservation areas under analysis, providing reliable data on the local conditions (SOBREVILLA; BATH, 1992).

Data on the phyto-physiognomy of extant vegetation communities were also provided. Flora, structure and historical aspects of the analyzed communities were also taken into account, when possible, coupled to their importance within the regional context and the area in which the unit is inserted. Issues on extant pressures and threats were also provided when possible.

Besides data collection at the sampling sites, constant reports were also taken during displacement so that the regional landscape could be precisely characterized and possible variations in its structure identified.

Data were analyzed by the quality and quantity interpretation of REE data, whereas the mapping of ground use in the Iguatemi river basin was undertaken by means of remote sensoring and geo-processing techniques. The map was constructed by a mosaic with three scenes obtained from Landsat 5 TM images, 2007 and 2008 transit dates, geo-referred to the cartography projection Universal Transverse Mercator (UTM) coordinate system in ArcGIS - 9.1. Image was interpreted from optimized color band compositions so that the region's natural and artificial features could be visually distinguished by field sites using the maxlike method where knowledge and geo-referenced samples of the landscape under analysis is of paramount importance. Vegetation typology and ground use were determined and surface areas calculated. Terminology from IBGE's Classification System of Brazilian Vegetation was adopted.

Results

The Iguatemi river basin is a mosaic of agriculture and pastureland, clusters of exotic trees and isolated forest remnants in different succession stages of which some are heavily man-manipulated.

Mapping and field research showed main vegetation typology and ground use of the Iguatemi river basin as anthropic formations, river-dependent

pioneer formations, forest fragments at the initial secondary stage of natural regeneration and forest fragments at the intermediate secondary stage of natural regeneration. Whereas Table 1 shows respective rates in the area and in the relative area.

Table 1. Classification of typologies of land use in the Iguatemi river basin MS Brazil with respective total and relative areas.

Vegetation formation	Area (ha)	Relative area (%)
Anthropic formations	721,182.03	86.93
River-dependent pioneer formations	32,333.20	3.90
Forest fragments at initial secondary stage	26,687.18	3.22
Forest fragment at intermediate secondary stage	49,419.43	5.96
Total	829,621.84	100.00

Anthropic formations are or have been continuously human degraded areas and are characterized by great surface uniformity and low species diversity. Pastureland, cash-crop land and commercial reforestation make up the above land typology. In fact, it is the dominant basin landscape comprising 86.93% of total area (Table 1), mainly composed of grass (*Brachiaria* sp.) or cultivated species such as corn, soybean and rice, with isolated individual trees, generally of great height. The most frequent species are *Anadenathera falcata* (angico-do-cerrado), *Copaifera langsdorfii* (copaíba), *Erythrina falcata* (corticeira) and *Syagrus oleracea* (palmeira bocajá). Small strips of land with *Eucalyptus* sp., reforestation are extant.

River-dependent pioneer formation areas, occupying 3.9% of the whole Iguatemi river basin, are communities developed on alluvial tablelands and/or in periodically flooded depressions. Vegetation is characterized by uniform physiognomy with a relatively limited diversity of vegetation of the Cyperaceae and Asteraceae families, tall grasses such as *Panicum aristella* and *Paspalum erianthoides*. *Brachiaria* sp., is frequent. Certain tree species such as *Cecropia pachystachya* (embaúba) and *Alchornea triplinervia* (tapiás), height ranging between 3 to 5 m, have been reported in small numbers, either in isolation or in small clusters. Flooded lowlands are in various conservation stages, some of which with satisfactory conditions, although cattle-caused impacts have been reported at other sites.

Remnant native forest fragments form mosaic formations in different succession stages and conservation within an anthropic environment (pastureland). In fact, only a few well-preserved fragments of some extension have been registered in the region, albeit not with primary vegetation.

Initial secondary stage, with 3.22% of the total area, is characterized by low height physiognomy (between 4 and 6 m), non-compacted canopy, breast-high perimeter (BHP) (between 10 and 15 cm) individual trees, lack of epiphytes, absence of forest vertical stratification and low tree diversity.

Species of Melastomataceae, Myrtaceae and Myrsinaceae families were predominant, especially *Myrsine* sp., (capororocas). *Inga uruguensis* (ingá), *Sebastiania commersoniana* (branquilho), (*Sebastiania brasiliensis* (leiteiro), *Sebastiania schottiana* (sarandi) and *Luehea divaricata* (açoita-cavalo) have been reported in humid sites. A size vegetation increase, approximately between 8 and 10 m in height and between 15 and 20 cm in BHP, has been registered, without the existence of a sub-wood, in some initial secondary forest areas. The species *Cecropia pachystachya* (embaúba), *Campomanesia xanthocarpa* (guabirobeira), *Alchornea triplinervia* (tapiá), *Myrsine* sp., (capororoca) and *Zanthoxylum* sp. (mamica-de-cadela) have been reported at this site.

Although several sites with high light incidence due to canopy opening are extant, no densely pioneer heliophyte-occupied sites have been registered. Herbaceous creepers such as *Pithecoctenium* sp., *Serjania* sp. (timbó), *Pyrostegia venusta* (cipó-são-joão) and the cactus *Cereus peruvianus* are extant. Such areas generally show low conservation conditions with high impact index, especially cattle transit.

Intermediary secondary stage forest fragments with natural regeneration occupy 5.96% of total area are characterized predominantly by tree and shrub species, vertical stratification, compact canopy with the eventual occurrence of emerging individual trees, individual trees with large BHP, great quantity of undergrowth and high biological diversity. They may be classified as environments featuring high conservation conditions. Tree canopy, between 15 and 20 m high, comprises *Parapiptadenia rígida* (angico), *Anadenanthera falcate* (angico-do-cerrado), *Cedrela fissilis* (cedro), *Patagonula Americana* (guajuvira), *Bastardiopsis densiflora* (louro-branco), *Ocotea* sp., *Endlicheria paniculata*, *Nectandra megapotamica* and *Nectandra lanceolata* (canelas), *Diatenopteryx sorbifollia* (maria-preta), *Peltophorum dubium* (canafístula), *Albizia hasslerii* (farinha-seca), *Balfourodendron riedelianum* (pau-marfim), *Cordia trichotoma* (louro-pardo), *Syagrus oleracea* (bocajá). Individual trees have BHP ranging between 40 and 60 cm.

Second forest stratum comprises younger individuals from the canopy species besides *Chrysophyllum gonocarpum* (guatambu), *Matayba elaeagnoides* (miguel-pintado), *Casearia* sp., (guaçatunga), *Cabralea canjerana* (canjerana), *Eugenia uniflora* (pitangueira), *Myrcia hatschbachii* (caingá) and

Xylopia sp. (pindaíba), with height between 6 and 12 m and BHP between 20 and 30 cm. Small trees and shrubs of *Sorocea bonplandii* (cincho), *Piper gaudichaudianum* (pau-de-junta), *Actinostemon concolor* (roxinho) and *Trichilia* sp. (catiguá) may be found in the sub-wood. Further, small trees measuring 4 to 5 m of pioneer species have been reported at the margins of the forest fragments, among which may be listed *Guazuma ulmifolia* (mutambo), *Croton floribundus* (capixingui), *Trema micrantha* (crindiúva), *Cecropia pachystachya* (embaúba), *Mimosa bimucronata* (maricá) and (*Alchornea triplinervia* (tapiá). Emerging trees are scanty and are generally represented by *Cariniana estrellensis* (jequitibá), *Hymenaea courbaril* (jatobá), *Aspidosperma polyneuron* (peroba), *Enterolobium contortisiliquum* (timbaúva) and *Copaifera langsdorfii* (copaíba) with BHP between 60 and 100 cm and height ranging from 18 to 22 m.

Discussion

Observations and analyses show that the drastic and severe landscape and land changes in the Iguatemi river basin with the consequent replacement of the original vegetation covering by human impacted areas are mainly due to the region's economic conditions based on activities directly linked to and dependent on the environment and on an unsustainable ecological model with numberless environmental imbalances and impacts (FERNÁNDEZ; GARCIA, 2001).

Different conservation conditions have been reported in river-dependent formations or floodplains although most were according to adequate conservation status. Floodplains are important ecosystems since they form a typology related to highly fragile natural environments liable to floods and water-soaked soil (KOZERA et al., 2009). According to Brazilian law (BRASIL, 1965, 2002), they are permanent preservation areas (PPA). In some cases, their good conservation state may be due either to low physiognomy complexity (KLEIN; HATSCHBACH, 1962) which quickly absorbs impacts, or to low local interest for agricultural and cattle-raising activities. However, cattle-caused impact traces have been reported which may change, even for a short period, the formation structure.

It should be emphasized that changes caused by human activities, mainly the destruction of riparian vegetation, produce 'anthropic floodplains' caused by erosion and silting of rivulets and water bodies. In fact, some ruderal, herbaceous and shrub species adapted to this type of soaked land may already be found in the area.

Although classified as Permanent Preservation Area (PPA) by the Brazilian Forest Code (BRASIL, 1965) and its total or partial destruction is prohibited by law, the conservation state of its riparian vegetation is entirely inadequate. PPAs are actually fragmented and drastically altered by the invasion of exotic herbaceous species, cattle transit and fishing camp sites. Sometimes riparian vegetation is totally removed revealing large erosion areas and silting of water bodies. Riparian vegetation with its differential flora composition featuring species adapted to soil conditions and to floodplain regimes (RODRIGUES; GANDOLFI, 2004), is extremely vital for the maintenance of river, rivulets, water sources and lake quality (LIMA; ZAKIA, 2001). Besides, they are important ecological paths for fauna and flora species (METZGER, 1999). Most riparian vegetation of the Iguatemi river basin fail to comply to mandatory legal sizes and are actually narrow vegetation strips that border the river's and rivulet's water courses. In fact, they are highly susceptible to river margin effects (HILL; CURRAN, 2003), whereas the few remaining riparian vegetation with proper ecological quality lie in highly inaccessible sites or with inappropriate contours for pasture or agriculture.

With regard to compliance with environmental legislation set in the Brazilian Forest Code on river protection, extensive contempt of the law has been verified, with great danger for regional water resources and in spite of the need for preserving natural vegetation.

Quality maintenance of the basin's water bodies may be achieved by PPAs' recovery, or rather, soil correction and the control of invading vegetation are required in places where riparian vegetation is totally absent (RODRIGUES; LEITÃO FILHO, 2004). In the case of small size or modified PPAs, corrective measures, which include planting of native species, enrichment and prohibition of cattle transit, are required. Due to the extensive area in need of recuperation, financial, logistic and technical subsidies and the participation of local and state governments are important for the recovery process. Recuperation of riparian vegetation will also contribute towards the displacement of flora and fauna species (METZGER, 1999) as an ecological path that connects the extant forest fragments and favors the genetic flow among populations with their subsequent maintenance (RODRIGUES; LEITÃO FILHO, 2004). Forest remnants are highly fragmented due to intense modifications in land use within a matrix of agricultural land and pastureland. They are also greatly modified because of selective extraction of timber with drastic degradation throughout the area (DURIGAN et al., 2000). Owing to intense fragmentation, margin effects

decrease the conservation degree of remnant forest through changes in the structure, composition and/or relative abundance of the species within the borders and in the inner core of the forest fragment (LAURANCE et al., 2001), caused by changes in physical characteristics such as luminosity, temperature and humidity (HILL; CURRAN, 2003).

Vegetation formation in secondary stages is caused by past and/or present human disturbances (BRASIL, 1993), with special reference to impacts on land use for pasture and agriculture in the case of initial secondary stages and selective cuttings for intermediate secondary stages. Besides such extremely drastic factors (GUARIGUATA; OSTERTAG, 2001), some areas are highly disturbed by such complicating factors as cattle and invading exotic vegetation species in the fragment's inner core. When cattle displace themselves within the forest fragments, they crush small plants, compact the soil and individual sub-wood vegetation, with the consequent discontinuity of the fragments' natural regeneration (STERN et al., 2002; TOBLER et al., 2003). These factors impede individual plants to reach more advanced phases in forest succession and greatly disrupt the forest structure (TOBLER et al., 2003). In the case of exotic species, such as grass and cultivatable species, local biodiversity is greatly decreased (FEARNSIDE, 2001) and the development of new cultures, such as sugar-cane and eucalyptus, are being encouraged in the region. The above are plantation-based monocultures threatening the few remaining forest fragments in the region, its soil and its water resources (UHL, 1987). Special attention should be meted to the expansion of commercial reforestation of exotic tree species. Beside the need for new planting areas, which is already a direct pressure on forest fragments, the dispersion of propagules constitutes another aspect to be taken into account. The monitoring of a possible natural regeneration of these species with control of their dispersion and recruitment is also required.

No area with primary vegetation or vegetation with the region's pristine natural characteristics has been detected either from field work or by the interpretation of aerial photos (BRASIL, 1993). In fact, there are few relevant extensive fragments that would represent even closely the ecological characteristics of native vegetation. The best conserved forest remnants are in the intermediate secondary stage of natural regeneration. They are areas which did not undergo greater anthropic changes owing to the type of soil and ground relief and to the difficulties in reaching them.

Consequently, it is mandatory that the hedging of remnant forest fragments should be undertaken to prohibit cattle access and to favor the transit of native fauna so that the latter's regeneration and maintenance may be conserved and proper conditions posited. The Brazilian Forest Code (BRASIL, 1965) establishes the free access of people and animals in PPAs for water with the condition that the regeneration and maintenance of native vegetation would not be jeopardized. Legal Forest Reserves on farms, amply supported by Brazilian law (BRASIL, 1965) and aiming at the representative preservation of local and regional biodiversity, are another important tool for local forest conservation and a source of genetic variability. If the farm still does not comply with the rules on Legal Forest Reserves, the re-construction of vegetation should be undertaken and the proper documents should be submitted at the notary office. Extant forest fragments should be maintained since they still conserve the ecological characteristics and local species.

It should be enhanced that since 2003 the Iguatemi river basin is a PPA and according to data produced in current study the region's characteristics fail to comply with the aims of Conservation Units (BRASIL, 2000). According to the Brazilian System for Conservation Units, the PPA should fit within the conservation sustainable units which aim at the conservation of nature, the sustainable use of part of the available natural resources, human occupation, the protection of biological diversity and the control of the occupation process. Data description and analysis show that basic aims have not been met with even though the investigated area still receive state financial aid, such as ecological taxes, for the conservation of the environment and for social and ecological progress.

Anthropic activities with their peak in the transformation of the environment through the replacement of native vegetation by pastureland and monoculture cash-crops imply the continuous and irreversible loss of biodiversity either directly by species extinction or by loss of the species' genetic variability. It is important that forms of production and predatory concepts and paradigms should be altered so that less impacting forms and more sustainable methods of agricultural and cattle-raising production could be introduced. The application and adaptation of current environmental legislation will be a significant asset towards the region's environmental conservation.

Conclusion

The Iguatemi river basin is an environmental protection area for nearly a decade, however, environmental characteristics are not in accordance with the recommendations for this conservation unit. Sustainable use of natural resources, with emphasis on plant resources, compliance with environmental regulations and, as a practical character, the recovery and preservation of riparian forests are indicated as urgent measures to actual results in environmental protection be felt.

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Received on December 8, 2009
Accepted on June 18, 2010.