ANALYSIS

Cattle ranching and deforestation in the Brazilian Pantanal

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Abstract

Regional economic indicators and incentives for agricultural landowners in the Brazilian Pantanal were explored in order to understand better the observed increases in deforestation for the implantation of cultivated pastures to assist in the extensive management of beef cattle. About 95% of Pantanal lands are privately owned and about 80% are used as extensively managed cattle ranches. The mean size of agricultural property in the Pantanal is increasing, the cattle density and numbers are decreasing, the proportion of land in cultivated pastures is decreasing, but the area is increasing, land and animal wealth is highly concentrated, and the amount and proportion of land in natural pastures is decreasing. Statistical analyses reveal that land and animal wealth, intensification of agricultural effort, human population, natural pastures and location relative to infrastructure and regional markets influence either the magnitude or the proportion of Pantanal lands deforested for the purpose of implanting cultivated pastures or both. A nonlinear link between wealth measures and deforestation was not established. Improving the profitability of forestland should unambiguously improve the likelihood of its continued management as forest and the maintenance of biological diversity. Potential sustainable uses of forested lands and native biological diversity in the Pantanal include the sustainable extraction of forest species, ranching of wild and feral species, and tourism. © 2001 Elsevier Science B.V. All rights reserved.

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1. The Brazilian Pantanal

At more than 138 000 km², the Brazilian Pantanal is known as the largest freshwater wetland in the world. The Pantanal is home to at least 650 species of birds, 260 species of fish, 80 mammal species, 50 species of reptiles (Wade et al., 1993), and more than 2000 identified floral species (Pott, 1998). Among its most renowned fauna are the jaguar, jaburu stork, blue hyacinth macaw, capybara, anaconda, giant anteater, coati and piranha.
The Pantanal’s principal economic activities include fishing, mining, tourism, and cattle ranching. Extensive cattle ranching has been the dominant economic activity and land use in the region for the past two centuries. About 95% of Pantanal lands are privately owned. About 80% (118 000 km²) of the lands are found on cattle ranches (Silva et al., 2000). The estimated present value of the existing herd of 3 million is about US$1 billion (Seidl et al., 1999).

According to the Brazilian constitution, the Pantanal is considered to be a part of the ‘national patrimony’ and is of high priority for protective management of its natural condition. This designation can run counter to the perceived interests of agriculturists. For example, the largest extensively managed cattle ranch in the southern Pantanal reported more than 1700 calf deaths due to jaguar attacks from 1993 to 1996 or about 1/3 of the calf crop (Marson, 1996). Article 1 of Federal Law 5197 legally protects jaguars and other wild species by stating:

> those animals of any species, in any phase of development, which live naturally out of captivity, are considered wild species, as well as their offspring, and their breeding areas, and are considered property of the state, making their utilization, persecution, hunting or apprehension prohibited (Marson, 1996) (translated from the Portuguese).

Since cattle ranchers are stewards of the great majority of Pantanal lands and since aspects of extensive cattle ranching, namely, deforestation for implanting pastures, may conflict with national (and international) priorities for protection of the region’s unique natural resources, an exploration of the relationships between the ‘pantaneiros’ and their landscape is proposed. A principal objective of this analysis is to provide information toward crafting agricultural and natural resource policy such that individual and regional objectives for natural resource management can be met for the least expense. A regional perspective is adopted recognizing that precise farm/ranch level information is also necessary for policy formation and implementation. Factors affecting agricultural land use in the Pantanal region of Brazil are discussed including economic incentives’ role in understanding land use relationships; regional land use trends and correlates with natural habitat conversion (deforestation); and strategies to meet ‘pantaneiros’ objectives while minimizing the rate and absolute amount of natural habitat conversion in the Pantanal.

2. Land use, cattle and economic incentives

2.1. Land use

The carrying capacity of the Pantanal for terrestrial species is constrained by the magnitude and duration of the annual floods. Aquatic species diversity and health are affected by human actions on the land and the water. As the primary stewards of Pantanal lands, sustainable development and biodiversity conservation of the region are dependent upon the behavior of cattle ranchers. Ranchers are likely to follow the economic incentives they feel they are facing. Since the early 1970s, ranchers have cleared land and planted pastures in order to increase the cattle stocking rates. Clearing land and implanting pastures for cattle is perceived as the economically optimal land use alternative.

Ranchers tend to plant pastures on the highest ground available, which also tends to be forested since it is not subject to regular flooding. Clearing the land in order to plant pastures has resulted in more than 500 000 ha of deforested land (13% of woodlands) over the past quarter of a century (Silva et al., 1998a,b), likely increases in land erosion, sedimentation of rivers, decreases in floral and in faunal biodiversity (Coutinho et al., 1997).

2.2. Economic incentives

In order to encourage the conservation of regional biodiversity, improved understanding of Pantanal cattle ranchers’ responses to economic incentives is required (e.g. Angelsen, 1999). Traditionally, regional research and extension efforts have concentrated on improving the productive
efficiency of Pantanal beef cattle operations. It is implicitly assumed that improving per hectare returns to cattle production entices conservation of lands not in native pasture. However, by improving the profitability of land in pasture, the opportunity cost of land not yet in pasture increases, increasing the profitability of land in pasture may increase the incentive to convert ‘unproductive’ land to cultivated pastures.

Since cattle ranching is commonly viewed as the only economically viable activity in the region, land that is not producing beef is perceived as ‘unproductive’. Whether improved profitability of natural pastures results in more or less habitat conversion through deforestation depends upon: (1) the relative scarcity of other productive inputs; and/or (2) how Pantanal cattle ranchers respond to economic incentives. If ranchers respond to increasing profitability of natural pasture land by conserving (not converting) non-pasture lands, other productive inputs (e.g. labor, financial capital) may have become the principal cost factor constraining cattle production; the rancher maximizes profits. Alternatively, ‘unproductive’ land conservation due to increasing land productivity may result from a rancher reaching some acceptable living standard for his family; the rancher maximizes happiness where income is only one factor to be balanced against other conflicting objectives (e.g. recreation, time with family), or to ‘be satisfied’ with respect to income.

Table 1 reviews the implications of different behavioral assumptions in efforts to model tropical deforestation. If ranchers respond to increasing profitability of natural pastureland by converting non-pasture lands, they behave in concert with the theory of the profit-maximizing firm (production and consumption decisions are separable) and small open economy expectations for descriptive variables apply. If they are observed to respond by maintaining lands in forests, either subsistence or consumption tradeoff (Chayanovian), behavioral assumptions may be more appropriate (Kaimowitz and Angelsen, 1998). Only ecologically and economically sustainable alternative practices on forested lands (explored later) should have unambiguously desirable impacts on deforestation pressures.

2.3. Land productivity and profitability

One estimate of the biophysically sustainable stocking rate for extensively managed beef cattle on planted (converted, cultivated) pasture in the Pantanal is 1.25 AU/ha in the summer and 0.77 AU/ha in the winter. Estimates for natural (native) pasture are 0 in the summer (due to inundation) and 0.4 AU/ha in the winter (Marson, 1996). Alternatively, Comastri Filho (1997) puts the carrying capacity of planted pasture at 0.77 AU/ha, does not mention seasonal differences, and fails to consider any productivity on native pastures. Comastri Filho (1997) estimates that planted pasture would need to cover 10% of the Pantanal in order to accommodate traditional cattle densities.

Assuming 6-month seasons and the ability to seasonally adjust herds to reflect annualized stocking constraints, the Marson (1996) estimates can be manipulated to demonstrate that planted

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Table 1
Influence of model specifications on variable expectations a

<table>
<thead>
<tr>
<th>Variable/model</th>
<th>Subsistence</th>
<th>Chayanovian</th>
<th>Open economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher agricultural prices</td>
<td>↓</td>
<td>⇐</td>
<td>↑</td>
</tr>
<tr>
<td>Population growth</td>
<td>↑</td>
<td>↑</td>
<td>⇋</td>
</tr>
<tr>
<td>Lower transport costs</td>
<td>⇋, ↓</td>
<td>↑</td>
<td>⇋</td>
</tr>
<tr>
<td>Higher agricultural productivity</td>
<td>↓</td>
<td>⇐</td>
<td>↑</td>
</tr>
<tr>
<td>Higher wages</td>
<td>NA (↓)</td>
<td>NA (↓)</td>
<td>↓</td>
</tr>
</tbody>
</table>

*a Source: Kaimowitz and Angelsen, 1998; ↑, increase; ↓, reduce; ⇋, no effect; ⇐, indeterminant; NA, not applicable.*
pasture provides the ability to increase stocking rates by 0.81 AU/ha over native pasture and 1.02 AU/ha over forestlands. Comastri Filho (1997) estimates yield an improvement of 0.55 and 0.77 AU/ha over native pasture and forestlands, respectively. These estimates constitute overestimates of the value of planted pasture because not all native pastures are seasonally inundated, and summer grazing is possible on semi-forested lands. Unfortunately, estimates of their productivity are not available.

In addition to biological productivity measures, the fixed costs of clearing land for implanting pastures and the variable costs of their maintenance must be considered in estimating the relative benefits of cultivated over natural pastures in the Pantanal. Marson (1996) estimates the cost of a cattle operation on a very large industrial ranch (70 000 ha in cultivated pastures and 120 000 ha in planted pastures) with some highland and some Pantanal land as about $35/AU. About 40% of these costs are in land maintenance activities and 27% are labor costs (Marson, 1996). Comastri Filho (1997) estimates the cost of pasture formation as $287/ha for higher ridges and $227/ha for flatter woodlands. Deforesting or clearing land comprises about 20% of these cost estimates. Much of the remaining formation costs are attributed to various types of tractor work. These estimates could not be confirmed as either accurate or representative of the region. For example, field visits to several ranches in the Nhecolandia subregion in 1997 yielded estimates of $120/ha for clearing costs.

Using these rough estimations, the net present value of native pasture or forested land conversion to cultivated pasture can be calculated. The current value of an animal unit is about $250 in the Pantanal (Seidl et al., 1999). Cultivated pasture life is about 15 years (Moraes, 1999) and, lacking information, we assume productivity is maintained over the period of use. The net benefits of converting native pasture to cultivated pasture are 0.81 or 0.55 AU/ha. The net benefits of converting forestland to cultivated pasture are 1.02 or 0.77 AU/ha. The fixed costs of cultivated pasture formation including forest clearing are $227/ha for land with little forest cover and $287/ha for forested land. Finally, we assume the variable costs of cultivated pastureland maintenance are the same as native pastureland on a per head basis, or $35/AU. Higher discount rates discourage the investment in land conversion, but also discourage good long-term land management practices and the converse (Angelsen, 1994, in Kaimowitz and Angelsen, 1998). For illustrative purposes, we explore the implications of discount rates of 8–14% (Table 2).

Table 2 indicates that our best estimate of the net present value of investment in conversion of native pasture to cultivated pasture for increasing beef cattle herd size is between $499 and 1466/ha, or an annualized return of $81–171/ha per year over the 15-year estimated project life. Our best estimate of the net present value of the conversion of forestland to cultivated pasture is between $730 and, $1845/ha, or an annualized return of $119–

<table>
<thead>
<tr>
<th></th>
<th>Native I</th>
<th>Native II</th>
<th>Forest I</th>
<th>Forest II</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV 8%</td>
<td>1466</td>
<td>922</td>
<td>1845</td>
<td>1322</td>
</tr>
<tr>
<td>Annualized return @ 8%</td>
<td>171</td>
<td>108</td>
<td>216</td>
<td>155</td>
</tr>
<tr>
<td>NPV 10%</td>
<td>1098</td>
<td>672</td>
<td>1381</td>
<td>972</td>
</tr>
<tr>
<td>Annualized return @ 10%</td>
<td>144</td>
<td>88</td>
<td>182</td>
<td>128</td>
</tr>
<tr>
<td>NPV 12%</td>
<td>959</td>
<td>578</td>
<td>1207</td>
<td>840</td>
</tr>
<tr>
<td>Annualized return @ 12%</td>
<td>141</td>
<td>85</td>
<td>177</td>
<td>125</td>
</tr>
<tr>
<td>NPV 14%</td>
<td>843</td>
<td>499</td>
<td>1060</td>
<td>730</td>
</tr>
<tr>
<td>Annualized return @ 14%</td>
<td>137</td>
<td>81</td>
<td>173</td>
<td>119</td>
</tr>
</tbody>
</table>

* Notes: native I and forest I calculations are derived from estimates found in Marson (1996). Native II and forest II are calculated from Comastri Filho (1997). NPV, net present value. Project life, 15 years.
216/ha per year over the estimated project life. Estimate variation depends upon the source of information and the imposed discount rate. These calculations imply that if the annualized net benefits from complementary or alternative uses of native pasturelands relative to cultivated pasture exceed $171/ha per year, then land conversion is unjustified from an economic perspective. Analogously, if the sum of the annualized direct and indirect values of forest products, tourism, decreases in river sedimentation, and wildlife habitat from forestlands relative to cultivated pastures exceed $216/ha per year, either the rancher should choose not to deforest his land or he may be enticed to do so through policy incentives worth no more than $216/ha per year on average.

3. Regional analysis of land use change

3.1. Data

Analyses of panel census data may provide some insights into existing incentives and the behavior of ranchers faced with these incentives. Available census data for agricultural properties include, total area; area of various agricultural land uses (not rural residential, however); number of cattle; number of people; number of tractors; municipality; and time period. Urban (commercial, industrial and residential) land uses were excluded from analysis. Unfortunately, neither regional nor representative property level data were available for wage rates, land values, values of other agricultural property, transportation costs, or cattle prices. Weather information is not available for the entire time period and is not in a useful form. Agricultural credit programs are not evident in the region, nor can individual property data be tracked over time.

Trends in land use in the Pantanal region from 1975, 1980 and 1985 censuses were reviewed. An agricultural census was not conducted in 1990. The 1995 census is not yet available by geophysical unit. Regional land use trends indicate that agricultural property size is increasing, the cattle density and herd size are decreasing, the proportion of land in cultivated pastures is increasing, land and animal wealth is highly concentrated, the amount and proportion of unproductive land is increasing, and the amount and proportion of land in natural pastures is decreasing (Silva et al., 2000).

3.2. Variable definition

Following approaches in the literature (reviewed in Lambin, 1994; Pearce and Brown, 1994; Reis and Margulis, 1994; Kaimowitz and Angelsen, 1998), existing regional information was used to understand better deforestation decisions. The Pantanal is divided among 16 municipalities and two states of Brazil (Fig. 1). None of the municipalities lies entirely within the Pantanal wetland. Portions of each municipality lie in the surrounding highlands, or Planalto. Planalto residents influence municipal and state level policy formation having implications for Pantanal lands and waterways. However, both geopolitical and geophysical land use designations can be useful in designing policy and predicting its influence. By combining census data with GIS images, the Center for Research in the Pantanal (CPAP-EMBRAPA) has created 11 geophysical sub-regions based upon drainage, topographical features and traditional use patterns. Municipal and subregional information was included as a series of dummy variables.

First, wealth has been hypothesized to influence the rate and magnitude of deforestation. However, the expected direction of influence depends upon the behavioral assumptions assigned to decision-makers (Fearnside, 1993; Reis and Margulis, 1994; Faminow, 1998; Kaimowitz and Angelsen, 1998; Angelsen, 1999). Land is wealth and cattle are primary sources of both income and wealth to the Pantanal cattle rancher. Macroeconomic instability, particularly due to political transitions and inflation, make more traditional income measurements potentially less reliable than these proxies.

Secondly, size and density of human population are commonly considered potential explanatory variables in deforestation models (e.g. Reis and Margulis, 1991, 1994; Billsborrow and Geores, 1994; Kummer and Sham, 1994; Palo, 1994;
Rudel, 1994; Faminow, 1998). Regional and municipal rural population and net migration information is available and used in the analysis.

Thirdly, land use intensification and 'investment' potentially influence the rate and magnitude of deforestation (Fearnside, 1993; Mahar and Schneider, 1994; Southgate, 1994; Faminow, 1998). Tractors and 'controlled' fires are the principal land clearing tools available to Pantanal cattle ranchers. Tractors constitute a large financial investment and are probably a good indicator of the intensification of agricultural land use.

Fourthly, infrastructure and transportation costs may influence deforestation rates (Reis and Margulis, 1991, 1994; Fearnside, 1993; Mahar and Schneider, 1994; Southgate, 1994; Faminow, 1998). The transportation of cattle from ranches in the interior of the Pantanal to regional trade centers along its perimeter is normally executed on foot, but may involve small barges or trucks, depending on ranch location. The only paved road in the region connects the three main trade centers and runs along the Southern, Eastern and Northern perimeter of the Pantanal. A combination of municipality information and a variable designating the property as either in the Pantanal or the Planalto may provide some (imperfect) insight into transportation costs.

Since practically all of the land is privately owned, natural pasture (as opposed to cultivated
pasture) can only be created or lost through fluctuations in the flood cycle. Extended periods of flooding will reduce the amount of natural pasture available and result in either greater pressure to convert forested lands to cultivated pasture or a reduction in herd size. Since regional herd numbers are fairly consistent at about 3 million head over the period, changes in the amount of cultivated pasture correlated with changes in the amount of natural pasture can be viewed as the influence of weather on the rate and magnitude of regional deforestation. Cultivated pasture is a direct result of the conversion of land from its natural state. Due to physical and economic issues and the perception that the land is only useful as pasture, most land will be converted from forested or semi-forested lands rather than natural pasture. Long-term conversion of forested and semi-forested lands to some other use is deforestation, by definition (Faminow, 1998; Kaimowitz and Angelsen, 1998).

3.3. Model formation

Using these variables and data, we intend to better understand land use decisions of Pantanal ranchers regarding, (1) the absolute amount; and (2) the rate of deforestation by tracing the principal correlates with changes in cultivated pasture. The dependent variables chosen for the two models are, (1) area of cultivated pasture; and (2) proportion of cultivated pasture per hectare. The independent variables chosen are operation size, area of natural pasture, number of cattle, people, and tractors, cattle density, human population density, tractor density, or number of tractors per hectare, proportion of land in native pasture, and a dummy variable for location in the Pantanal or the Planalto sub-region, for each of the 16 municipalities and for each of the three censuses.

In the first model, the data were modeled using a multivariate first order ordinary least squares regression technique. In the second model, the dependent variable is continuous, but truncated to values ranging from zero to one, necessitating the use of a double-bounded Tobit procedure for the derivation of unbiased estimators.

3.4. Results

3.4.1. Model 1

Through three estimation iterations, the deletion of insignificant variables and subsequent testing for model improvement in the reduced form (Chow test), model 1 was reduced to the form shown in Table 3. The process of model reduction to statistically significant variables indicates that location, proxy for transportation costs to regional hubs, is not a strong predictor of the amount of land converted in the Pantanal. Nor does there appear to be a significant time trend in deforestation for implanting cultivated pastures.

Many of the implications of the estimated model are straightforward and as expected. For each 100 ha increase in operation size, the model predicts an increase of deforestation for cultivated pastures of 7 ha. Each 100 head increase in herd size implies an increase in cultivated pasture of 2

<table>
<thead>
<tr>
<th>Area in cultivated pasture (ha)</th>
<th>Coefficient</th>
<th>S.E.</th>
<th>T-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>−9.73</td>
<td>1.24</td>
<td>−7.87</td>
</tr>
<tr>
<td>Operation size (ha)</td>
<td>0.07</td>
<td>0.002</td>
<td>33.53</td>
</tr>
<tr>
<td>Number of cattle ( # )</td>
<td>0.02</td>
<td>0.001</td>
<td>27.68</td>
</tr>
<tr>
<td>Number of people ( # )</td>
<td>2.71</td>
<td>0.13</td>
<td>21.57</td>
</tr>
<tr>
<td>Number of tractors ( # )</td>
<td>27.47</td>
<td>1.22</td>
<td>22.44</td>
</tr>
<tr>
<td>Amount of native pasture (ha)</td>
<td>−0.15</td>
<td>0.003</td>
<td>−44.63</td>
</tr>
<tr>
<td>Tractor density ( # /ha)</td>
<td>−186.47</td>
<td>43.51</td>
<td>−4.29</td>
</tr>
<tr>
<td>Proportion of land in native pasture (%)</td>
<td>−11.12</td>
<td>2.45</td>
<td>−4.55</td>
</tr>
</tbody>
</table>

* N = 12 972; F (8, 12 963) = 1424; P < 0.0001; R² = 0.468.
The model predicts that one additional person (laborer) on a property implies an increase of 2.7 ha in cultivated pasture. An increase in 27.5 ha of cultivated pasture is predicted with each additional tractor, indicating increased intensity and capitalization of production. A decrease in native pasture of 100 ha, hypothesized to have been caused by an increase in flooding, results in an increase in deforestation for cultivated pasture of 15 ha. Using the same logic, the model predicts that the greater the proportion of land currently in native pasture, the lower the tendency for deforesting the remaining land for implanting cultivated pasture. The predicted relationship indicates that a 10% decrease in the proportion of land in native pasture is associated with an increase of 1.1 ha in cultivated pasture.

The only significant variable that defies expectation is the strongly negative relationship between tractor density and the predicted amount of cultivated pasture. One potential explanation is that the tractor density or intensity of use measure was skewed toward smaller properties since each property received equal weight in these calculations. The presence of tractors on small properties makes large-scale land conversion impossible and sharing or leasing tractors among small producers is read as ‘0 tractors per ha’ in the calculations. As a result, where tractors are present there is little conversion and where there is conversion, but no tractors, land use change is attributed to other variables.

In the modeled relationship, the influence of the wealth indicative variables (i.e. land, cattle, tractors) was assumed to have a linear relationship with the amount of deforestation for implanting pasture. It is no great surprise that larger operations with more cattle and more tractors have a tendency to convert more land. However, increases in wealth may accelerate or decelerate the amount of land converted and may do so in a non-linear fashion. We re-estimated the reduced form model transforming these three variables to indicate acceleration (\(X_i^2\)) and deceleration in the amount of land conversion (\(\log_{10} X_i\)) in order to test this hypothesis. The re-estimated models were inferior to the original model. The only substantive difference among the models is that tractor density became statistically insignificant in each of the re-estimated models. These findings lead to the tentative conclusion that the wealth distribution in the Pantanal does not appear to differentially influence the amount of deforestation for implanting cultivated pastures; regional deforestation is proportional to land and animal wealth measures.

### 3.5. Model 2

In model 2, a double bounded Tobit estimation approach is used to understand the relationship between the degree of deforestation for implanting cultivated pasture in the Pantanal and the independent variables proposed earlier. The reduced form of model 2 is quite distinct from model 1. Most notably, many of the location variables and time are significant in model 2. Due to the significance of a number of dummy variables and the characteristics of maximum likelihood estimators, interpretation of the estimated model parameters is less straightforward than in model 1. Marginal parameter effects were calculated from the mean variable values to facilitate the interpretation of model 2 (Table 4).

The model estimate for the relationship between the number of cattle and the proportion of the land in cultivated pasture indicates that an increase from the mean of 732 head of cattle to 733 head on an average 269-ha property implies an increase from 7.36% of the land in cultivated pasture to 7.36002%. If the marginal effect holds for larger changes, an increase of 100 head implies an increase in deforestation for cultivated pasture of 0.2 m²/ha, or about 54 m² increase in cultivated pasture on the average property. A 1% increase in cattle density implies a 0.0004% increase in the proportion of cultivated pasture per hectare in the Pantanal.

In turn, an increase of one person from the mean of 6.3 has about 120 times the implied impact of a marginal increase in the number of cattle. However, counter to expectations, a 1% increase in the human population density implies a 0.005% decrease in the proportion of lands in cultivated pasture. This result also may be an artifact of the data’s biases toward smaller prop-
properties described above. Smaller properties may have a lower cultivated pasture density due to the potential economies of scale in the fixed costs of land conversion. Since a single family can easily reach the mean number of people per agricultural property, small properties are likely to have a high population density relative to larger holdings.

Each additional tractor from the mean of 0.25 implies a 0.75% increase in the proportion of land deforested for cultivated pasture, or an increase in deforested area of about 12% for each tractor increase. A one-tractor increase from the mean on an average property implies an increase in the proportion of cultivated pasture to 8.11% of 269 ha, or an increase of about 2 ha deforested per additional tractor.

As in model 1, model 2 indicates that cultivated pasture is a substitute for native pasture. Each hectare of native pasture lost implies an increase in proportion of land in cultivated pasture of 0.0012% on the average property, or 32 m². A 1% decrease in the proportion of native pasture implies a 0.64% increase in the proportion of cultivated pastures, potentially reflecting the productivity differences between the two pasture types discussed previously.

Location of an operation within the Pantanal implies 2.6% lower density of cultivated pasture relative to location in the Planalto, or highland region surrounding the Pantanal. Although probably mitigated by the effect of inundation within the Pantanal, this result is expected since cropland and more intensive management of livestock are the dominant land uses in the highland region. Location in municipalities 1, 2, 4, 5, 6, 7, 10, 11, 12, 13, and 14 implies a lower proportion of land in cultivated pasture than location in municipalities 3, 8, 9, 15 or 16. Municipalities 1, 7 and 14 demonstrate the least proportion of land in cultivated pastures while 2, 5 and 10 are closer to the mean responses (Fig. 1).

Potentially, these results may be explained as a combination of physical characteristics and location relative to regional markets that may reflect transportation costs. Those municipalities demon-

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**Table 4**

Model of proportion of land deforested for implanting pastures in the Brazilian Pantanal

<table>
<thead>
<tr>
<th>Cultivated pasture/ha</th>
<th>Coefficient</th>
<th>S.E.</th>
<th>T-statistics</th>
<th>Marginal effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle ( # )</td>
<td>0.0000007</td>
<td>0.000002</td>
<td>3.51</td>
<td>0.000002</td>
</tr>
<tr>
<td>People ( # )</td>
<td>0.0007</td>
<td>0.0004</td>
<td>1.75</td>
<td>0.00024</td>
</tr>
<tr>
<td>Tractors ( # )</td>
<td>0.0225</td>
<td>0.0039</td>
<td>5.84</td>
<td>0.0075</td>
</tr>
<tr>
<td>Area of native pasture (ha)</td>
<td>-0.000035</td>
<td>0.000008</td>
<td>-4.54</td>
<td>-0.000012</td>
</tr>
<tr>
<td>Population density ( # /ha)</td>
<td>0.0011</td>
<td>0.0001</td>
<td>12.54</td>
<td>0.00037</td>
</tr>
<tr>
<td>Proportion of native pasture (ha/total ha)</td>
<td>-0.0146</td>
<td>0.0005</td>
<td>-29.01</td>
<td>-0.0049</td>
</tr>
<tr>
<td>Located in Pantanal (1, 0)</td>
<td>-0.1937</td>
<td>0.0109</td>
<td>-17.74</td>
<td>-0.064</td>
</tr>
<tr>
<td>Municipality 1 (1, 0)</td>
<td>-0.2478</td>
<td>0.0090</td>
<td>-27.55</td>
<td>-0.082</td>
</tr>
<tr>
<td>Municipality 2 (1, 0)</td>
<td>-0.1032</td>
<td>0.0088</td>
<td>-11.68</td>
<td>-0.034</td>
</tr>
<tr>
<td>Municipality 4 (1, 0)</td>
<td>-0.2024</td>
<td>0.0092</td>
<td>-22.10</td>
<td>-0.067</td>
</tr>
<tr>
<td>Municipality 5 (1, 0)</td>
<td>-0.0838</td>
<td>0.0125</td>
<td>-6.71</td>
<td>-0.028</td>
</tr>
<tr>
<td>Municipality 6 (1, 0)</td>
<td>-0.1755</td>
<td>0.0363</td>
<td>-4.84</td>
<td>-0.058</td>
</tr>
<tr>
<td>Municipality 7 (1, 0)</td>
<td>-0.2733</td>
<td>0.0201</td>
<td>-13.60</td>
<td>-0.091</td>
</tr>
<tr>
<td>Municipality 10 (1, 0)</td>
<td>-0.1062</td>
<td>0.0213</td>
<td>-4.99</td>
<td>-0.035</td>
</tr>
<tr>
<td>Municipality 12 (1, 0)</td>
<td>-0.1443</td>
<td>0.0472</td>
<td>-3.06</td>
<td>-0.048</td>
</tr>
<tr>
<td>Municipality 13 (1, 0)</td>
<td>-0.2154</td>
<td>0.0513</td>
<td>-4.20</td>
<td>-0.071</td>
</tr>
<tr>
<td>Municipality 14 (1, 0)</td>
<td>-0.2710</td>
<td>0.1015</td>
<td>-2.67</td>
<td>-0.09</td>
</tr>
<tr>
<td>1975 (1, 0)</td>
<td>0.1888</td>
<td>0.0130</td>
<td>14.56</td>
<td>0.063</td>
</tr>
<tr>
<td>1980 (1, 0)</td>
<td>0.2083</td>
<td>0.0102</td>
<td>20.48</td>
<td>0.069</td>
</tr>
<tr>
<td>1985 (1, 0)</td>
<td>0.2600</td>
<td>0.0101</td>
<td>25.77</td>
<td>0.086</td>
</tr>
</tbody>
</table>

* N = 12 972; F (20, 12 951) = 101.45; P<0.00001; log-likelihood = -4127.45.
strating the lowest proportion of cultivated pasture (i.e. Barao do Melgaco (1), Santo Antonio do Leverger (7), and Sonora (14)) are all located in the state of Mato Grosso and are among the farthest from regional markets and the most difficult to navigate. With the exception of Itiquira (3), those municipalities with the greatest proportion of cultivated pasture (i.e. Aquidauana (8), Bodoquena (9), Porto Murtinho (15), and Rio Verde (16)) are located on the eastern edge of the Pantanal in the state of Mato Grosso do Sul. They have easiest access to regional markets and trade routes through the state capitol, Campo Grande. Those falling into the intermediate range have either proximity to regional markets (i.e. Caceres (2), Ladario (12), Coxim (11), Ladario (12), Miranda (13), Corumba (10)) or physical conditions conducive to land conversion (e.g. Lambari d’Oeste (4), Nossa Senhora de Livramento (5)), but generally not both.

The time trend variables demonstrate the relative irreversibility of the decision to clear (sub)tropical forests indicating an increase in the proportion of land in cultivated pasture over time. In the period between 1980 and 1985, the proportion of converted land not attributed to other factors increased almost three times from 1975 to 1980; The estimated difference between 1975 and 1980 is an 0.6% increase in the proportion of cultivated pasture per hectare, whereas the estimated difference between 1980 and 1985 is 1.7%.

4. Discussion: alternatives and approaches

Although it is not clear what impact increasing cattle profitability might have on natural habitat conversion, an increase in the profitability of land not in cultivated pasture would have an unambiguous impact on conversion pressures. Avenues for future research include an exploration of the extractive and non-extractive income-generating alternatives available to Pantanal landowners on their forested land, in view of our opportunity cost estimates of forestland conversion to cultivated pasture.

Several estimates of the economic potential of extractive tropical forest products have been undertaken, although none so far in the Pantanal (e.g. Peters et al., 1989; Wilson, 1992; Mendelsohn and Balick, 1995). Pantanal research has concentrated upon identifying potential products and understanding their biological growth conditions. A variety of extractive Pantanal forest products have been identified that have some local and sometimes broader market potential. Coutinho et al. (1997) list more than 50 spices, 20 fruits and vegetables, 5 medicinal herbs, 5 wood species, and about one dozen artisanal uses of Pantanal forestlands and native pastures with local and national markets. Both Goncalves (1996) and Souza and Guarim (1996) cite more than 100 plants used for medicinal purposes in the northern Pantanal.

Several wildlife or feral species may have potential to provide additional sources of income to the Pantanal rancher. Caiman (Caiman crocodilus yacare), capybara (Hydrochaeris hydrochaeris), wild pig (Sus scrofa), and rhea (Rhea americana) each has local meat and products markets. Except for perhaps capybara, all have national and international markets. However, regulatory barriers persist and a history of poaching damages public opinion and the efficacy of these alternatives (Goudy, 1997). The pitfalls of suggesting such market and product development are well known; low volume local markets subject to excess supply conditions, high transportation costs, high costs and skill requirements of developing national or international markets, economic rents accruing outside of the producing region, and unintended cultural and environmental impacts of facilitating extractive activities, for example.

In addition to sustainable extractive industries, potentially profit-generating non-extractive uses of natural land show potential. Rural, archeological (Peixoto and Boeira, 1996) or ecological tourism (Geist, 1994; Bordest et al., 1996; Coutinho et al., 1997; Goudy, 1997) may provide economic incentives to conserve forested habitat and biological diversity in the region. A recent study of recreational anglers found that the primary reason for people to fish in the Pantanal was experiencing the unique natural environment, including wildlife-viewing activities. Approximately 46 000 visitors spent an estimated $36 million in 1995 in the Southern Pantanal engaged in this
pursuit (Moraes and Seidl, 1998). Bordest et al. (1996) point to the potentials and the limiting factors regarding tourism development in the Pantanal including poor communication infrastructure; a lack of tourism planning, zoning, and local training/understanding; insufficient fresh water, and water treatment, provisions for human waste management. The combination of information on traditional regional economic practices with research-based information on these potential alternative income generating and habitat preserving activities are among the highest priorities of CPAP.

5. Concluding remarks

Regional economic indicators and incentives for agricultural landowners in the Brazilian Pantanal were explored in order to better understand observed increases in deforestation for the implantation of cultivated pastures to assist in the extensive management of beef cattle. Regional indicators and trends can help researchers and policy makers to begin to understand the incentives for deforestation and biodiversity preservation in the Pantanal.

About 95% of Pantanal lands are privately owned and about 80% are used as extensively managed cattle ranches. The mean size of agricultural property in the Pantanal is increasing, the cattle density and numbers are decreasing, the proportion of land in cultivated pastures is decreasing, but the area is increasing, land and animal wealth is highly concentrated, but becoming somewhat less so, the amount and proportion of unproductive land is increasing, and the amount and proportion of land in natural pastures is decreasing. Whether improving the profitability of cattle production per hectare in the Pantanal results in more deforestation depends upon how landowners react to economic incentives and what the primary constraining factors to cattle production are. Improving the profitability of forestland should unambiguously improve the likelihood of its continued management as forest and the maintenance of biological diversity.

In sum, our attempts at regional census data manipulation to better understand the relationships between Pantanal land owners and their land use decisions have supported conventional wisdom in some situations, provided additional precision to these assertions in other cases, and have refuted these suppositions in still other instances. By and large, land and animal wealth, intensification of agricultural effort, human population, natural pastures and location relative to infrastructure and regional markets influence either the magnitude or the proportion of Pantanal lands deforested for the purpose of implanting cultivated pastures or both. Through these estimations we were not able to establish a nonlinear link between wealth measures and deforestation. Poorer or smaller landowners were equally likely to deforest lands in the same relative proportions as richer or larger landowners. From a policy perspective, it may be more efficient to focus on larger landowners since the magnitude of their deforestation activities is so much greater and, therefore, more land area can be affected with changes in the behavior of fewer people.

Taking these issues into account, several possibilities to improve the likelihood that forested lands and native biological diversity in the Pantanal would be preserved through incentives were suggested including the sustainable extraction of forest species, the potential for generating additional income through ranching of wild and feral species, and the potential to develop various types of tourism in the region. Applied research initiated to improve the profitability of Pantanal lands in order to conserve the unique flora and fauna of the region needs to be cognizant of the additional incentives or disincentives that ranchers face as a result of research design and recommendations. Broader ecosystem-based information requires a broader conception of land productivity than is traditionally assumed within disciplinary bounds.

These results and assertions are not yet ‘ground-truthed’ through completed analyses of on-farm studies. Research continues in building a sufficient store of case study information to analyze the costs of Pantanal calf production at the farm level under a variety of management regimes and land use scenarios. Forage and animal nutrition, livestock breeding and management, live
stock diseases, transportation modes and routes are receiving applied research attention at CPAP. Specific research on nontraditional forest and rangeland products, tourism, impacts of ranch management decisions on river water quality and quantity and fish stocks also continue. The results of these research efforts need to be integrated in order to provide a more complete picture of optimal land use alternatives available to Pantanal ranchers.

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**References**


