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COMMENTARY

# Global valuation of ecosystem services: application to the Pantanal da Nhecolandia, Brazil

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**Abstract**

In Costanza et al.'s famous *Nature* paper [Costanza, R., d'Arge, R, de Groot, R, Farber, S., Grasso, M., Hannon, B., et al. The value of the world's ecosystem services and natural capital. Nature 15 (387), 253–260.] a value for the world's ecosystem services is posited as a point of departure for further discussion. These calculations were re-estimated and qualitatively assessed in application to the Pantanal sub-region Nhecolandia. The original study was re-estimated to evaluate the sensitivity of the original study to more detailed and accurate data and to better understand the potential for the people of the Pantanal to benefit from environmental stewardship. Refocusing the analysis to the regional watershed level using locally derived data provided an opportunity to explore appropriate local policy alternatives and recognize regional biophysical heterogeneity which is largely impractical at the global, hemispheric or, perhaps, national scale. A value of more than US$15.5 billion, or US$5 million per resident was derived; an annual per hectare value of approximately 1/2 of Costanza et al.'s calculations. More biophysically diverse, but largely drier, regional conditions indicated by our data explain this discrepancy. Water supply and disturbance regulation contribute close to 2/3 of the total calculated value. Waste treatment, cultural value, and water regulation each contribute substantially (6–9%) to the total. Nutrient cycling, recreation, and habitat values play more minor roles (1.5–3%) in the total valuation. The concepts of imperfect substitutes and comparative advantage are applied within the broad category of natural capital in order to evaluate the potential of alternative economic development strategies for the region. 

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## 1. Introduction

In Costanza et al. (1997) (reprinted Costanza et al., 1998) a value for the world's ecosystem services is posited as a point of departure for further discussion of ecological-economic valuation techniques, potentials and pitfalls. The authors calculate average global values of ecosystem services across 17 distinct types of services and 16 biomes. The Brazilian Pantanal is implied by this study to be a global 'hot spot,' or area of distinctly high value ( $\approx$ US$ 10 000 per hectare per year).

Published data from the Center for Agricultural Research in the Pantanal were used to re-estimate and qualitatively assess these calculations in application to the Pantanal sub-region Nhecolandia. Refocusing the analysis to the regional watershed level using locally derived data provides an opportunity to explore appropriate local policy alternatives and recognize regional biophysical heterogeneity which is largely impractical at the global, hemispheric or, perhaps, national scale. A more accurate representation of the region's biological heterogeneity facilitates an understanding of the breadth of economic opportunities and ecosystem values presented by the region.

## 2. Approach and methods

The Brazilian Pantanal is a 138 000 km$^2$ tropical seasonal wetland located in the geographic center of South America (see red spot in map in Costanza et al., 1997). Nhecolandia is the second largest of the eleven Pantanal sub-regions, comprising some 19.5% (26 921 km$^2$) of the region (Silva et al., 1998).

Using Landsat™ satellite data representing 3.09% of the sub-region, Abdon et al. (1998) identified seven distinct land types and one water category based upon prevalent resource management regimes within the region. Field plots were used to catalogue and typify the general biophysical features of these seven land categories. These data and the Landsat™ images were combined to derive a view of the distribution of regional land characteristics and land cover. Data estimation from satellite images has at least two advantages to alternative data collection methods:

1. in a remote region like the Pantanal, data are extremely difficult and expensive to obtain. Representative field sampling combined with satellite images provide the ability to extrapolate results with reasonable expectation of accuracy for relatively little cost;
2. most available data are based upon geopolitically determined units.

No Brazilian municipalities or states lie entirely within the Pantanal region of the Upper Paraguay River Basin. Satellite imagery allows researchers to investigate the geophysical unit (i.e. watershed) rather than the geopolitical unit where appropriate.

As a result of the relative homogeneity within Nhecolandia, using these data it is considered reasonable to extrapolate results to the sub-regional level, but not to the regional level. The seven broad resource inventory categories are, in turn, combined into four of Costanza et al. (1997) world biomes in order to proceed with recalculation (Table 1).

However, the most important ecological feature in the Pantanal region is the water regime. This regime can render up to 70% of the Pantanal largely inaccessible to earth-borne creatures for as much as 6 months of the year because of inundation with flood waters. Abdon et al. (1998) calculations reflect Nhecolandia′s approximately 8-month dry season. Costanza et al. (1997) calculations reflect annual rates, presumably for continuously inundated swamps and floodplains, and a homogeneous landscape. This broad-brush approach is understandable given the global scale of their analysis. However, an opportunity and responsibility for greater accuracy in portraying local conditions arises by focusing efforts at a smaller spatial scale. As a result, Abdon et al. (1998) resource categories were put into Costanza et al. (1997) world biomes according to season. The values of ecosystem services were then weighted to appropriately reflect the amount of time and area spent providing services of a particular type; low-lying, flat grazing-lands were considered grasslands (representing more than half of all lands in Nhecolandia) for two-thirds of the year and wetlands for one-third of the year. Of course, the magnitude and duration of the wet

season varies over time and space. These proportions are considered typical for Nhecolandia, not necessarily other Pantanal sub-regions.

## 3. Results

Extrapolating from locally collected and analyzed satellite data, the total estimated annual value of ecosystem goods and services to the Nhecolandia region of the Brazilian Pantanal is more than US$ 15.5 billion, or US$ 5 million per resident; an annual per hectare value of approximately half of Costanza et al. (1997) calculations. More biophysically diverse, but largely drier, regional conditions indicated by our data explain the discrepancy between the sum total of these calculations and those of Costanza et al. (1997) published values. Since Pantanal translates to 'swamp' in English, this is an understandable happenstance.

Alternatively, the Nhecolandia sub-region may be drier than the Pantanal at large. Were a full one-half of the area of the Pantanal considered a wetland for calculation purposes and the other half divided between forestland and grassland, similar values to the Costanza calculations would have been derived. An analogous temporal scenario would also generate this result. Data are not available to evaluate these hypotheses at this time. Calculated values for ecosystem goods and services are five times greater assuming wet season conditions year-round rather than dry season conditions. Defining low-lying flat rangeland (more than half of the total surface area) as wetland in the rainy season generates this difference (Table 2).

While the magnitude of the two total value calculations is interesting, it is perhaps more useful to consider the relative contribution of the different factors to the total value estimate(s) from a local policy perspective. Together, water supply and disturbance regulation contribute close to two-thirds of the total calculated value. Water supply services contribute almost US$ 2 thousand and disturbance regulation almost US$ 1750 to the per hectare value estimates totaling US$ 5840 per year. Waste treatment, cultural value, and water regulation each contribute substantially (6–9%) to the total. Nutrient cycling, recreation, and habitat values play more minor roles (1.5–3%) in the total valuation. The other nine ecosystem service categories provide about 6% of the total estimated annual value (Table 3).

Table 1
Vegetation of Pantanal da Nhecolandia, MS, Brazil[a]

| Resource category | Biome type | | Physical Area | | |
|---|---|---|---|---|---|
| | Dry season (8 month) | Wet season (4 month) | Survey area ($km^2$) | Survey area (% of subregion) | Nhecolandia subregion ($km^2$) |
| Densely forested savanna (DF) | TF | TF | 149 | 17.91 | 4822 |
| Sparely forested savanna (SF) | TF | TF | 18 | 2.16 | 581 |
| SF+Grassy savanna (GS) | G | G | 74 | 8.89 | 2393 |
| GS+SF | G | G | 41 | 4.93 | 1327 |
| GS 1 (low lying flat grazing land) | G | S | 440 | 52.88 | 14 236 |
| GS 2 (aquatic vegetation) | S | S | 26 | 3.13 | 843 |
| GS+DF (wetlands with patchy forest cover) | S | S | 28 | 3.37 | 907 |
| Total land uses | | | 776 | 93.27 | 2511 |
| Permanent water bodies | R | R | 56 | 6.73 | 1812 |
| Total | | | 832 | 100.00 | 26 921 |

[a] Sources for Nhecolandia data: Abdon et al., 1998, Silva et al., 1998. Note: TF, tropical forest; G, grass and rangelands; S, swamps and floodplains; and R, lakes and rivers.

Table 2
Estimated value of ecosystem services: Pantanal da Nhecolandia, Brazil, by resource category and season[a]

| Resource category | Estimated annual values (US$ (1994) × $10^6$) | | |
|---|---|---|---|
| | Dry season (8 month) | Rainy season (4 month) | Weighted average |
| Tropical Forest | 1084.51 | 1084.51 | 1084.51 |
| Grassland/Rangeland | 416.63 | 86.33 | 306.53 |
| Swamp/Floodplain | 3421.17 | 31 297.35 | 12 713.23 |
| Lakes/Rivers | 1539.83 | 1539.83 | 1539.83 |
| Total estimated value | 6462.13 | 34 008.01 | 15 644.09 |
| Total annual value (US$(1994) per hectare) | 2400.41 | 12 632.52 | 5811.11 |

[a] Calculated from Costanza et al., 1997 and Costanza et al., 1998, Abdon et al., 1998 and Silva et al., 1998. Note: for definition and annualized values per hectare of ecosystem service categories see Costanza et al., 1997 or Costanza et al., 1998. Reported total annual per hectare values differ due to rounding in calculations for Table 3.

## 4. Discussion

Discussion of these calculated values among researchers at the CPAP generally elicited the response predicted by Daly (1998) in his discussion of the Lauderdale paradox (Lauderdale, 1819). Almost $ 6000 per hectare was an order of magnitude greater than anyone could imagine capturing from Pantanal lands. In the Pantanal, exchange values for rangeland run from US$ 100–300 per hectare (generally, the drier, the more dear), minimum wage is less than US$ 100 per month, and the present value of cattle ranching has been estimated at about US$ 200 per

Table 3
Estimated annual value of annual ecosystem services: Pantanal da Nhecolandia, Brazil[a]

| Ecosystem service categories | Total estimated value | | | |
|---|---|---|---|---|
| | US$ (1994) × $10^6$ | Rank | % | US$ (1994) per hectare per year |
| Gas regulation | 181.31 | 10 | 1.16 | 67.35 |
| Climate regulation | 120.50 | 13 | 0.77 | 44.76 |
| Disturbance regulation | 4703.61 | 2 | 30.07 | 1747.19 |
| Water regulation | 1019.82 | 5 | 6.52 | 378.81 |
| Water supply | 5322.58 | 1 | 34.02 | 1977.11 |
| Erosion control | 170.70 | 11 | 1.09 | 63.41 |
| Soil formation | 60.22 | 14 | 0.38 | 22.37 |
| Nutrient cycling | 498.21 | 6 | 3.18 | 185.06 |
| Waste treatment | 1359.64 | 3 | 8.69 | 505.05 |
| Pollination | 33.03 | 15 | 0.21 | 12.27 |
| Biological control | 30.39 | 16 | 0.19 | 11.29 |
| Habitat/refugia | 285.04 | 8 | 1.82 | 105.88 |
| Food production | 143.76 | 12 | 0.92 | 53.40 |
| Raw materials | 202.03 | 9 | 1.29 | 75.05 |
| Genetic resources | 22.15 | 17 | 0.14 | 8.23 |
| Recreation | 423.64 | 7 | 2.71 | 157.37 |
| Cultural | 1144.49 | 4 | 7.32 | 425.13 |
| Total annual regional value | 15 644.09 | | 100.49 | 5839.72 |

[a] Calculated from Costanza et al., 1997 and Costanza et al., 1998, Abdon et al., 1998 and Silva et al., 1998. Note: Percentages do not sum to 100.00 because of rounding in the category estimates. For definition of ecosystem service categories see Costanza et al., 1997 or Costanza et al., 1998.

hectare (Seidl et al., 1998). The obvious question immediately arose; how can landowners and local indirect stakeholders capture a greater share of the bounty provided to the globe by Pantanal lands and waters?

Useful observations surfaced regarding resource endowments, comparative advantage, environmental policy, and scale effects. Daly (1998) argued that it is likely that natural capital and other productive inputs are imperfect substitutes at best. As a result of growth and the rapid rate of technological change, natural capital is fast becoming (or, perhaps, has already become) the primary constraining factor of production. As such, its stock and flows should be nurtured as common property rather than exploited as open access resources. Arguably, not unlike H.T. Odum's emergy analytics, these ecosystem service calculations could serve as non-market (able) values in the dual of the output maximization problem; minimize expenditure of natural capital for a given level of output.

The concepts of imperfect substitutes and comparative advantage could also be applied within the broad category of natural capital in order to evaluate the potential of alternative economic development strategies. For example, Pantanal habitat for wild terrestrial and aquatic species is considered among the region's greatest assets and potentials for economic development through tourism. Moraes and Seidl (1998) estimated the direct annual expenditures on recreational fishing to the Southern Pantanal at greater than US$ 36 million. Investment in tourism development may come at some cost to other productive (broadly speaking) inputs. Recreation values (rank 4) and cultural values (rank 7) combined comprise about 10% of the total value of ecosystem services estimated here. This low ranking relative to the values ascribed other (less marketable) ecosystem services reveals heretofore unexplored areas of global comparative advantage.

Since many of the ecosystem services provided to the world by the Pantanal and its people are currently non-market and not physically exchangeable, temptation arises to attempt to extract as many rents for their preservation and cultivation from the 'global community' as is possible. This is a matter of local, regional, national and international environmental policy. Through an estimation of the net benefits of the provision of ecosystem services to each relevant scale of decision-maker, a compensation program for environmental stewardship in the Pantanal might be envisaged. An appraisal of the most efficacious (in terms of costs and intended distribution of benefits) tools available to encourage local participation in regional, national or global priorities where they do not coincide might then be explored further.

## 5. Conclusions

Researchers at the Center for Agricultural Research in the Pantanal (CPAP-EMBRAPA) were intrigued by Costanza et al. (1997) estimates indicating that the Brazilian Pantanal is a uniquely valuable watershed to the global value of ecosystem services, while the people of the Pantanal are mostly quite poor. The original study was re-estimated using locally derived data and examined with first-hand knowledge of the region for two principal reasons: to evaluate the sensitivity of the original study to more detailed and accurate data; and to better understand the potential for the people of the Pantanal to benefit from environmental stewardship. This focusing and re-estimation exercise was undertaken recognizing the substantial criticism the original study has withstood (e.g. Masood and Garwin, 1998). We were intrigued by this first approximation and were motivated by it to assess its usefulness in the Pantanal. Based upon the broad assumptions of the original study, re-estimation revealed that the Pantanal is quite likely a unique contributor to global ecosystem services. While local data diminished the magnitude of its total contribution by approximately one-half, they better revealed the rich diversity of opportunity in the region and identified potential areas of global comparative advantage. Now, the task is to craft strategies for *Pantaneiros* to capture greater economic benefits from the lands and waters that provide such enormous ecosystem service values to the world.

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