Assessment of threats to ecosystems in South America

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Abstract

South America is blessed with both world-leading levels of biodiversity, and world-record breaking levels of habitat conversion in some areas. Under this highly dynamic context, sound conservation planning is needed and one component of effectively prioritizing conservation interventions is through the assessment of threats to natural ecosystems. Here we present a continent-wide and spatially explicit threats assessment to natural ecosystems. A conceptual framework is presented which quantifies threat as a function of both the magnitude of the impacts of specific damaging human activities, and the variable response of different ecosystems to those impacts. The framework is then applied on seven different threat layers (accessibility, conversion to agriculture, fires, grazing pressure, infrastructure, oil and gas, recent conversion) to map out and spatially quantify the level of threat expected over the coming 2-5 year period. An aggregate threat layer is calculated, and the threats to major habitat types is evaluated. Tropical and Subtropical Grasslands, Savannas and Shrublands and Flooded Grasslands and Savannas are found to be under the greatest threat (0.36 and 0.35 aggregate threat respectively), both threatened most by fires (0.96), the former by accessibility (0.72) and the latter by grazing pressure (0.62). Tropical and Subtropical Moist Broadleaf Forests are the least threatened of all ecosystems (0.13), closely followed by Montane Grasslands and Shrublands (0.14). Overall, accessibility is shown to be a major issue across much of the continent, and fires are a significant threat in some identified regions. The results are being used by The Nature Conservancy to target conservation efforts in the region, and also to drive policies for threat abatement. Furthermore, the conceptual framework and methodology is applicable to any region and presents a useful means of prioritizing conservation interventions across broad geographic regions.

Introduction

Sound conservation planning requires conservation professionals to have a firm understanding of the threats affecting biodiversity. In order to make investments of financial resources and staff time, we need to know not just where biodiversity has been lost or degraded in the past, but where new threats to conservation may be emerging in the immediate future (Pressey et al. 2007)

Since the 1980's, conservation organizations including The Nature Conservancy have relied on a rigorous analysis of threats to biodiversity to guide their strategies, actions and investments towards the most critical conservation needs (Weeks 1997; TNC 2000). The Conservancy developed standardized approaches for analyzing conservation threats at the site level (TNC 2007), and generalized guidelines for assessing threats at an ecoregional level (Groves et al. 2000). Similar methodologies have been widely developed and utilized by other conservation organizations. (e.g., Salafsky et al. 1999; CMP 2004; Margoluis et al. 2001).

As large conservation organizations such as the Wildlife Conservation Society, World Wildlife Fund, Conservation International, The Nature Conservancy and others attempt to have an impact at scales larger than individual sites, there is a concomitant need for access to threat data at larger scales to enable these organizations to decide on how and where to invest time and funding for greatest impact (Murdoch et al. 2007).

Although sophisticated methodologies for assessing threats have been in wide use at local and regional scales, little analysis had been done to look at multiple threats affecting biodiversity conservation at a continental scale. Once such analysis that exists for South America (indeed globally) was the Human Footprint project conducted by the Wildlife Conservation Society (Sanderson et al. 2002). As an example of this type of large scale threat mapping, the Wildlife

Conservation Society used four types of data to map the Human Footprint – population density, land transformation, accessibility, and electric power infrastructure (Sanderson et al. 2002).

In 2005, the Conservancy undertook an effort to gauge the status of global conservation (Hoekstra et al. 2005). This approach used three criteria to determine conservation status – biodiversity viability, threat, and conservation management status (defined as a measure of the likelihood a given conservation situations is sufficient to secure biodiversity and allow for its persistence (TNC 2006). Within this analysis, the WCS Human Footprint was used as the data layer representing threats in this analysis.

The global assessment undertaken by Hoekstra et al. (2005) was useful in guiding the Conservancy to develop global priorities for conservation. In order to develop conservation priorities, at a continental rather than a global scale, additional detail was needed, specifically on the interaction of threats to biodiversity and their impacts on individual ecological systems.

Therefore, in order to establish priorities at a scale that would allow The Nature Conservancy to make investment decisions for South America at a broad scale, the authors undertook a continent-wide analysis of threats to biodiversity conservation in South America and the impacts of human activities on specific ecological systems. A threats assessment model is also a key tool to inform if threats are being abated or not and provide critical input to adapt conservation strategies of the Conservation Programs in South America. The methodology and results of this undertaking are described in the remainder of this paper.

Assessing and monitoring threats to the biodiversity in South America is a task composed of different components, that can be summarized as follows:

(i) Design and create of an information system capable of spatially representing the geographic distribution of threats.

(ii) Model the severity and scope of these threats to provide information about how biodiversity targets (ecosystems) are altered, deteriorated or lost.

The objectives of this study were to:

1. Develop a model that spatially maps the threats to natural ecosystems over a 2-5 year time frame
2. Apply the model in South America to get a detailed map of likely threats to natural ecosystems
3. Use the results as a basis for making decisions on conservation investments in the region.

Methodology

Conceptual Model

Prior to explaining the conceptual model, it is important to define the terms we use throughout this paper, not to provide new definitions but merely to clarify the meaning of the language we use. The current impact (also could be referred to as the "footprint") represent current sites where a threat has degraded or converted natural ecosystems. We refer to the immediate threat as the likely impacts from a specific activity on ecosystems in the next 2-5 years, and we refer to future threats in a similar vain except that the impact is expected in the 5-20 years time frame. In this paper we are presenting an analysis of immediate threats to natural ecosystems.

The immediate threat of specific site within an ecosystem is considered to be a function of the magnitude of the threat and the sensitivity of the ecosystem to that threat:

Immediate Threat = f (magnitude current impact, distance to current impact, sensitivity of ecosystem to threat)

A simple example illustrates these three factors. If there is a road running through a natural habitat, the space that the road occupies represents a complete loss of habitat. Under this conceptual model, the current impact is therefore a map of roads. The areas immediately around the road may be natural but could be considered to be threatened as the road provides for access to the natural habitat and may permit colonization and/or degradation or destruction of the natural resource. Furthermore, the threat can be considered to diminish with greater distance from the road, as these sites become less and less accessible to humans. Therefore, the actual threat to natural systems is a function of the distance from the road and the decay function of that threat with distance. Once the potential threat is quantified, it is important to take into account that different ecosystems have different sensitivities and responses to different threats. In the case of a road, perhaps a desert ecosystem is less sensitive to the threat of a road when compared with a tropical forest ecosystem. Under this logic, the ecosystem response to a threat can be considered to be a function of the type of response (linear, exponential etc.) and the magnitude of that response (minimal impact vs. significant impact).

We incorporate this concept into a spatially explicit model of threats to natural ecosystems based on spatial datasets of current impacts, expert knowledge on ecosystem sensitivity and a set of algorithms that model how a threat impacts on ecosystems. We map the current impact of human-activities on ecosystems in South America, and use that as a basis to model the threat on surrounding natural ecosystems over a 2-5 year time frame. This approach is novel in particular as it attempts to model how threats act spatially, and takes into account the different types of responses that ecosystems may have to a specific threat.

The threats considered for this study are based on an expert consultation with biodiversity experts, who rated different threats in order of importance to biodiversity conservation. Based on detailed analysis of data sources for South America, the list of threats used in this study are:

1. Accessibility
2. Conversion to agriculture
3. Fires
4. Grazing Pressure
5. Infrastructure
6. Oil and Gas
7. Recent Conversion

The threats that were identified as being important in the next 2-5 year time period but lacked sufficient data to merit their inclusion were forestry activities (whilst data on forest concessions exist, these have different meanings in different countries and are not available for all countries in South America), invasive species (insufficient knowledge of key invasive species and their current distribution), pollution (no continental-wide dataset available on pollution levels) and mining (a USGS dataset exists but includes both active mining sites and mining concessions and was considered to violate the 2-5 year vision of the threat analysis). Other threats that act over longer time periods (e.g. climate change, new infrastructure) are currently being included in a different threats analysis but are not discussed here.

Expert parameterization of model

In order to apply the conceptual model, maps of current impacts of threats are required, alongside knowledge of the way in which those threats act over distance and how the ecosystems respond to each threat. The ecosystems map used in this analysis (see below for description) contains 608 distinct ecosystems, classified based on nine major habitat types. Precise data on how these ecosystems respond t a threat is not available in conventional literature, hence the approach taken was to capture expert knowledge on the threats and ecosystems through a consultation process. Specifically, field practitioners and scientists with experience of the different ecosystems across the continent provided values for the distance over which a threat impacts on ecosystems (in kilometers), the decay function of this threat over distance, the response function that the ecosystems have to each threat and the magnitude of that response. Every single combination of 7 threats and the 608 ecosystems in South America were evaluated by the expert team during a three day workshop, and subsequent interactions.

Distance and decay function: The distance refers to the distance over which a threat may impact natural ecosystems away from where it is currently impacting, and is expressed in kilometres. The decay function refers to the rate at which the threat decreases with distance. During the workshop, the distance over which each threat is likely to impact over the next 2-5 years was defined for each threat based on group appraisals, and three types of decay function were agreed upon; fast decay, linear decay, and slow decay. The distance and decay functions used for each threat are shown in Table 1.

Ecosystem response: The response of an ecosystem to a threat was parameterised in two ways; the relationship between threat and ecosystem, and the magnitude of the impact (see Figure 1). The expert group described four types of ecosystem response; linear (1), exponential (2 - low levels of threat have minimal impact), logarithmic (3 - any level of threat has potentially large impacts) and polynomial (4-low impact in mid-threat levels). The polynomial response was specifically included in the context of threat from fire, whereby some ecosystems are actually fire dependent hence intermediate levels of the threat are actually beneficial. The magnitude parameter defines the maximum level of impact that the threat has on the ecosystem. During the workshop, experts assigned a response curve and magnitude to each individual ecosystem, for each of the seven threats.

Model implementation

The conceptual model was implemented in an Arc/Info Arc Macro Language (AML) script, which performed the following steps in the threats analysis:

1. The raster map of current impact is indexed to contain values from 0-1 and reprojected to a Lambert Equal Area projection
2. The distance function over which the impact threatens natural ecosystems is applied through a neighbourhood-based calculation (FOCALMEAN) using the distance decay function that applies to the threat under analysis, and the map is reprojected back to a geographic (WGS1984) projection
3. The intermediate threat layer is then indexed once more to have values from 0-1
4. The indexed intermediate threat layer is adjusted based on the response of the ecosystem

This model has also been integrated into an extension for ArcGIS 9.0, which permits the easy repetition of the analysis not only for South America, but also for different geographic areas and using different parameters for distance, decay functions and ecosystem response.

Data sources and threat surfaces

The study area consists of continental South America, and the desired spatial resolution for the threat map was defined as 1km, based on the resolution of most available data sources and the demands for spatial detail from conservation practitioners.

The ecosystems map for South America used in this analysis was based on the Nature Serve classification (Josse et al. 2003), and developed using the ecological land unit modelling methodology (Anderson et al. 1999) which used elevation, landform, geology, bioclimate and land cover as baseline datasets for developing the ecosystem classes (Sayre et al. 2008). The ecosystem map contains 608 distinct ecosystems in all of South America, distributed across nine major habitat types. Those areas identified as converted or degraded in the GLC2000 dataset were omitted from the analysis based on the fact that they do not represent natural ecosystems.

Data was collated on current impacts on natural ecosystems based on the most recent and highest resolution sources available across all South America (Table 2). In some cases national datasets were also used whenever available to improve the level of detail in the data, but effort was made to ensure consistency in the detail of the data across the entire study region.

In all cases the threats model was used on the baseline impact maps to derive a surface of immediate threat for the 2-5 year time frame:

Accessibility: Accessibility is calculated using a combination of analysis of transport networks to quantify the time from any site to the nearest populated place, and an analysis of population density to provide an index that captures the accessible population to a site. The accessibility calculation is made using a cost distance model that uses speed of movement across pixels as a means of calculating time from any site to a target destination. The target destinations were defined as populated places using the 30% threshold in the nightlights dataset (Elvidge et al. 1997), selected to account for bias in the sensor that overestimates urban area (Small 2004) and which roughly represent settlements of more than 1000 people. For transport speeds, we assumed that if you are traveling on water, roads, railways or an urban surface, you will be traveling by boat, motor vehicle or train. We assigned the following velocities to road, rail and waterways:

Primary roads (highways)	60 km hr^{-1}
Secondary road (paved)	35 km hr^{-1}
Tertiary road (unpaved/seasonal)	25 km hr^{-1}
Waterway (navigable rivers)	10 km hr^{-1}
Railway	40 km hr^{-1}

If you are not on the transportation surface, walking velocities were assigned according to land-use and varied between 2 and 5 km hr^{-1}. All pixels on international borders were assigned a value of 1 km per hour to reflect the time that it might take to cross the border, given customs and passport checks. The method also assumes that times are reduced in areas in high elevations and with sloping lands.

The resultant map of accessibility is then scaled using the exponential function. The maximum time to a populated place for South America was calculated to be 158 Hours. Unless re-scaled, areas approximately 80 hours from a populated place would be classified as having moderate threat from accessibility when this is clearly not the case. The exponential function was applied three times and the accessibility surface was indexed to have values from 0-1.

The scaled map of accessibility is then adjusted based on population. An occurrence is deemed to be under greatest threat if it is both highly accessible (low travel time to the nearest populated place) and in the vicinity of high population. The CIESIN gridded population of the world dataset was used for population density. The map was highly skewed, and so was normalized using the logarithmic function, and converted to an index between 1-2. The final map of accessibility was then produced by multiplying the indexed map of accessibility with the indexed map of population density. Those areas with high accessibility but no population maintained a value of 1, whilst areas highly populated and accessible were accentuated and had values of 2.

Conversion to agriculture: The map of current impact of agriculture was based on global surfaces of agricultural area and production at 10 km spatial resolution (You & Wood 2006). Agricultural census and survey statistics form the basis of these global surfaces and are combined with global maps of crop suitability. The statistical data was compiled at sub national administrative levels, usually the first or second subdivision of the national boundary of each country. These data are adjusted to the year 2000 using the official national figures that each country reports to FAO. Within administrative districts, the area and production for each 10 km pixel is spatially allocated based on the suitability of each pixel to each individual crop. The dataset contains distribution data for 19 crops, and these were categorised into subsistence and industrial crops in order to capture the different levels of habitat destruction that each crop might cause. For example, many coffee farms have much more negative impacts on natural ecosystems than an industrial soy bean field. The crops classified as industrial were rice, maize, wheat, sorghum, barley, soy bean, sugar cane, sugar beets and cotton. Subsistence crops were millet, potato, sweet potato, cassava, plantain and banana, beans, other pulses, coffee, groundnut and other oil crops. The current impact map consisted of the total density of crop cultivation in a pixel, with industrial crops given a double weighting.

Fires: The map of current impact from fires is constructed based on MODIS data documenting some 2.46 million individual fire events registered from 2000 – 2005. First, the point dataset was converted to a raster layer of fire frequency within each of the 1km pixels used in the mapping. The total number of fires over the 5 year period of the data varied between 0 and 257 for each 1km^2 pixel. Due ot the heavy skewedness in the frequency distribution, it was subjected to normalization by applying the natural logarithm twice.

Grazing pressure: The map of current impact from grazing (grazing pressure) was derived from the FAO Atlas of Livestock (FAO 2004), consisting of surfaces of livestock density for cattle, sheep and goats. Each livestock type was mapped separately and due to heavy skewedness were subjected to one round of normalization using the natural logarithm. The immediate threats model was applied separately to each type of livestock, and integrated into a single immediate threat map with double weighting to cattle.

Infrastructure: Whilst infrastructure includes a broad range of factors, only those not included in other layers were used. This means roads, railways, waterways, and oil and gas drill sites were not included. The infrastructure current impact map therefore is based on points where an airport or dam exists, based on the Digital Chart of the World (DCW).

Oil and gas: The oil and gas drilling layer is constructed using a dataset of points of drill sites across South America from the World Petroleum Assessment 2000.

Recent conversion: Recent conversion is not a threat in itself, but was included because many of the other threat surfaces used in the model represent the status in 2000, and we know that much has changed since then (e.g. soy bean expansion in parts of the Amazon). The recent conversion layer was therefore conceptualized as representing change since 2000, reflected in the loss of green vegetation in the land surface from 2000 to end 2006. This captures both deforestation in forests and degradation of natural ecosystems due to conversion or extraction, but does not differentiate between which threats actually impacted on the land surface.

The input data for this threat layer is derived from NDVI (normalized difference vegetation index) surfaces captured from MODIS satellite images every 16 days, 2000 to end of 2006 with a spatial resolution of 250m. The data measures the greenness of the land surface. For the seven year period, a regression line was fitted to the yearly mean NDVI (excluding dates when there was cloudiness in a pixel), and the gradient of this line calculated on a pixel-by-pixel basis. This in essence captures the change in NDVI value per year. Areas losing greenness can be considered to be undergoing some kind of alteration, with the degree of change representing the magnitude of the alteration. This layer is considered important and useful to the threats analysis as a number of recent impacts are captured, including the expansion of soy bean in many parts of Brazil.

Integration and visualization of threat layers

The aggregate immediate threat was calculated by taking the average of the 7 component threat layers. Whilst a rule-based system for calculating aggregate threat was considered (whereby combinations of threats might interact to have an impact greater than the sum of their parts), it was thought to be beneficial to maintain simplicity in the calculation. When used in practice, the component threat layers can be considered in detail for specific sites and conclusions reached as to the true aggregate threat based on site-specific criteria. For the purposes of this paper, we summarized threat levels according to 10 major habitat types derived from the WWF map of ecoregions in order to identify the ecosystems most under threat in the 2-5 year time period.

The input datasets, resultant threat layers, and aggregate threat layer were integrated into a Google Earth interface for easy visualization of patterns for non GIS professionals. Members of the Nature Conservancy team were invited to revise the results and provide feedback during a workshop of regional experts. This feedback was incorporated into the analysis through tweaking of parameters found to be producing inaccurate results. Whilst no formal validation is available (one cannot formally validate a prediction of conditions 2-5 years into the future), the revision by experts and subsequent adoption of the results into everyday conservation planning is considered a form of verification of the quality of the results.

Sensitivity Analysis

A sensitivity analysis was performed on each of the seven threat layers to examine their relative contribution to the aggregate threat. This analysis helps evaluate the relation and magnitude parameters, and indicates possible areas where revisions might be needed. In order to quantify the role a single threat surface has on the aggregate threat layer, the threat is omitted from the aggregate threat calculation, and the difference between the outcome of this analysis and the aggregate threat with all threat surfaces is then calculated. The result is a sensitivity map for each threat layer, showing on a pixel by pixel basis the contribution to the aggregate threat, ranging from strong positive values (strongly contributes to increasing the aggregate threat) to strong negative values (strongly contributes to decreasing the aggregate threat).

Results and Discussion

General patterns of threat

By modeling the 7 threats at continental scale general patterns of distribution, severity in certain geographies and a pervasiveness of these threats can be established. These patterns can be summarized as follows, and for selected threats shown in figures:

Conversion to agriculture *(*Figure 2*a)*: The areas with the greatest threat level due to conversion to agriculture are: Southern Amazon basin in Brazil (particularly areas surrounding the deforestation arc), Peruvian northern dry forests and coastal areas, Bolivian Chiquitanía, Paraguayan Chaco, Southern Atlantic Forests in Brazil and the Chilean Valdivian forest region.

Fires *(*Figure 2*b)*: The areas with the highest threat are the Llanos in Colombia and Venezuela, Roraima in Brazil, Tocantins in the Amazon, Central Andes in Peru, Mato Grosso in Brazil, the Chaco in Paraguay and Northern Argentina and Northern Patagonia. Although some of these ecosystems are fire dependent (e.g. some Chaco ecosystems), the frequency of fires in most of these regions was found to be excessive (>1/year).

Grazing Pressure *(*Figure 2*c):* Three areas come up as critical areas under threat from grazing: the Llanos in Colombia and Venezuela, the Northeastern Cerrado in Brazil and the Chaco in Northern Argentina, Paraguay and Bolivia. The response curve for many of these were type 2 (exponential), meaning that those regions identified as having high threat have very high densities of grazing (>1 heads/Ha).

Infrastructure*:* Infrastructure as defined here (dams, airports) does not represent a significant threat across the continent. Some high severity areas exist in peri-urban areas or where dams are established, but these are very localized.

Oil and Gas: The Venezuelan delta and Orinoco region have the highest threat at continental level. Of moderate threat are some smaller portions of Guajira in Colombia, the Amazon region in Ecuador and northern Peru and smaller areas in the Bolivian Chiquitania and northern Argentina. Again, the threats for oil and gas were found to be highly localized, as the experts considered the direct impacts of oil and gas exploration as acting over small distances around the wells (indirect impacts derived from facilitated access are captured in other layers).

Recent Conversion *(*Figure 2*d)*: Recent conversion was found to be highest in areas such as the Chocó in Colombia, the Central Andes in Colombia and Ecuador, Central Peruvian Andes, the Southern Amazon belt in Brazil, Roraima in northern Brazil, dry forests in northern Perú, Northern Argentina and Valdivian forests in Chile. The high impacts in the Choco and Valdivia are partly artifacts of a tendency for increased cloud cover from 2000 – 2006 which has skewed the trend analysis of NDVI data, and partly due to a very high sensitivity (type 3 - logarithmic) and magnitude for these ecosystems attributed by the expert consultations. When viewed in Google Earth, a number of sites identified as having high threat levels from recent conversion have indeed been lost to agriculture based on post-2000 high resolution images (especially in Mato Grosso).

Accessibility (*Figure 2*e): Most of South America is accessible in some way, with exception of western-Amazonian forests (especially in the state of Amazonas, Brazil and in south-eastern Colombia and eastern Peru) and northern Amazonas (especially in French Guiana, Guiana and Surinam). The Bolivian Chaco also has low levels of accessibility. The northern Andes and coastal Brazil have the highest threat levels, and despite low population levels, much of Patagonia has high accessibility levels due to a dense network of access roads.

***Aggregate threats** (*Figure 2*f):* The aggregate threat shows the extent to which remaining ecosystems are being threatened in the 2-5 year time horizon. All areas on the edges of converted or degraded ecosystems are under higher threat, as expected. However, some regions in South America deserve close attention: the Orinoco ecoregions, the Pacific Chocó, Roraima, southern Amazon in Brazil (states of Rondônia and Mato Grosso), Peruvian Central Andes, Northern Argentina (Chaco), Pantanal, Cerrado and Northern Patagonia.

Threats by major habitat types

When the average threat levels affecting the major habitat types are considered (Table 3), Tropical and Subtropical Grasslands, Savannas and Shrublands and Flooded Grasslands and Savannas are found to be under the greatest threat (0.36 and 0.35 aggregate threat respectively), both threatened most by fires (0.96), the former by accessibility (0.72) and the latter by grazing pressure (0.62). Dry forests are also found to be significantly threatened (0.29 aggregate threat), principally by accessibility (0.66) and grazing pressure (0.62). Recent conversion has affected most temperate broadleaf mixed forest ecosystems, whilst accessibility also significantly threatens Temperate Grasslands, Savannas and Shrublands (1.05), Deserts and Xeric Shrublands (0.91) and mangroves (0.88). Tropical and Subtropical Moist Broadleaf Forests are the least threatened of all ecosystems (0.13), closely followed by Montane Grasslands and Shrublands (0.14).

Sensitivity of model

The sensitivity analysis provides an indication of the relative contribution of each threat surface to the aggregate threat (Table 4).

The aggregate threat is most influenced by accessibility (average contribution of +0.049 to aggregate threat), whilst infrastructure and oil and gas provide the smallest contribution (on average reducing aggregate threat by 0.033). This is expected as accessibility is a threat that influences a large proportion of the surface area of South America, whilst threats from oil and gas and infrastructure are largely point based and very local. The sensitivity analysis also indicates that fire and grazing pressure are influential in defining aggregate threat.

Spatial maps of the contribution to the aggregate threat were produced for each individual threat layer, and during the expert revision of the results were used to identify possible problems arising from quality issues of the input data. Specifically, two errors were identified in the recent conversion threat layer, where in Valdivia and in the Choco region there was a very high contribution to aggregate threat as a result of a significant loss of greenness. Upon further investigation, this was attributed to problems of excess cloud cover in the MODIS NDVI data, and was subsequently through use of more robust quality filters on input NDVI data.

Implication for conservation

An often used cliché is that generals always prepare to fight the last war. France's reliance on outdated trench warfare at the Maginot Line at outset of World War II, and the rapid manner in which Germany's use of new tank and airplane warfare was able to overcome France's defenses, illustrates that "preparing for the last war" is not a strategy that ensures victory.

Conservation organizations must keep looking over the horizon to identify the next challenges and the next opportunities for conservation, rather than relying on assessments that show which natural areas have already been converted. A tropical forest converted to a soybean field represents an impact that has already taken place, not a threat to conservation. The possibility of that same soybean field expanding to as-yet unconverted tropical grasslands is a threat. The conservation profession must be cognizant of where the most significant new threats will be developing in the coming years, so we can "prepare for the next war" rather than dwelling on the past.

A growing body of literature is focusing on the need for conservation groups to show that they are maximizing their return on investment; that donated dollars are providing the maximum gain for conservation (many citations from Underwood, Wilson, Polasky, etc). An identification of threats to biodiversity conservation provides information upon which organizations can base their decisions about where and how to invest their resources. A dynamic analysis of threats to conservation can serve as a roadmap for making these types of decisions. Without a clear vision of what *will* become threatened in the next several years, conservationists end up chasing the past; in effect preparing to fight the last war. Developing threat models as described in this paper that allow conservation organizations to look beyond the present and quantify what will become threatened and why it will become threatened, allows us to make investment decisions now to maximize our impact five or ten years hence. Different organizations may come to different conclusions about what kinds and magnitudes of threats most need to be addressed (e.g.; high threat versus low threat), but their decisions will be transparent and based on the best available threat-related data.

Though far from perfect, this analysis can help to inform decisions about investing in conservation. It is important to keep in mind what this analysis is, and what it is not. The scale of the analysis is continental and as such, it is of use in making conservation investment decisions at that scale. For example, we can make determinations about which of the tropical grasslands are under the greatest degree of threat, and guide our actions accordingly. In looking at the most threatened tropical grasslands, we can derive a broad idea of types of threats that need to be managed. This broad-scale view must be coupled with more localized knowledge when it comes time to take specific actions. In other words, a continental-scale analysis such as this does not preempt the need for more localized analysis to be incorporated into decision-making about conservation.

Conclusions

One of the significant features of the project presented in this paper is not just the analysis of threats at a continental scale in South America, but also the methodology developed to spatially portray the expected impact of immediate threats on specific ecosystems. The conceptual model upon which the South America analysis is based is readily transferable to other places and can be used to analyze threats at broad (continental) as has been done for South America, and, with the addition of more detailed data sets, can also be applied at finer more localized scales. The framework can be applied anywhere by introducing base data from the area of interest and fine-tuning parameters (relationship function, distance and decay function). Also, the methodology is repeatable, so the analysis could be undertaken again in the future for the same area to compare the status of threats, whether they have been abated, or whether new and more significant threats have emerged.

Perhaps most significantly of all, information generated in analyses such as this need to be accessible and understandable to those who make decisions about how and where to focus human and financial resources on biodiversity conservation. Having a visual and spatially-explicit representation of threats and their expected impacts on biodiversity should be an invaluable tool for decision-makers in private conversation organizations as well as government agencies. Making information easily accessible and understandable assists in the process of directing conservation to the places where it is most urgent to take action and where those actions can have their greatest impact on the future of conservation. For example, in a separate analysis the authors have evaluated threats to national parks across South America. Examining which national parks are most threatened and why they are threatened can help government agencies to prioritize funding for threat abatement activities across a national park system. This analysis will be described in a separate publication.

Finally, this analysis has addressed immediate threats – the likely impacts on ecosystems from specific activities in the next 2-5 years. The field is open for new methodologies and models to be developed that will be able to assess future threats in the 5-20 years time frame, and further help to direct conservation efforts to those places likely to become highly threatened in the future.

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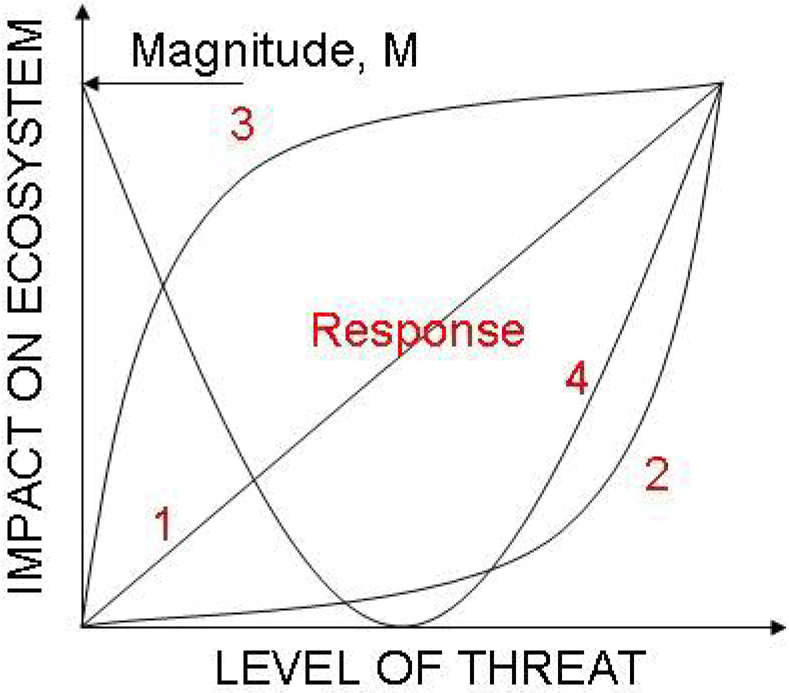
List of Figures

List of tables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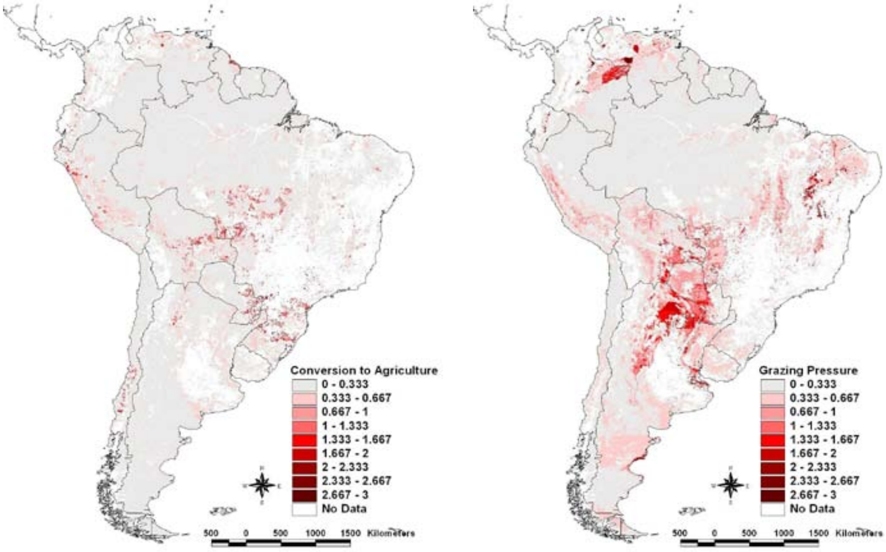
Response
4
2
1
LEVEL OF THREAT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2.667 - 3
No Data
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0.667 - 1
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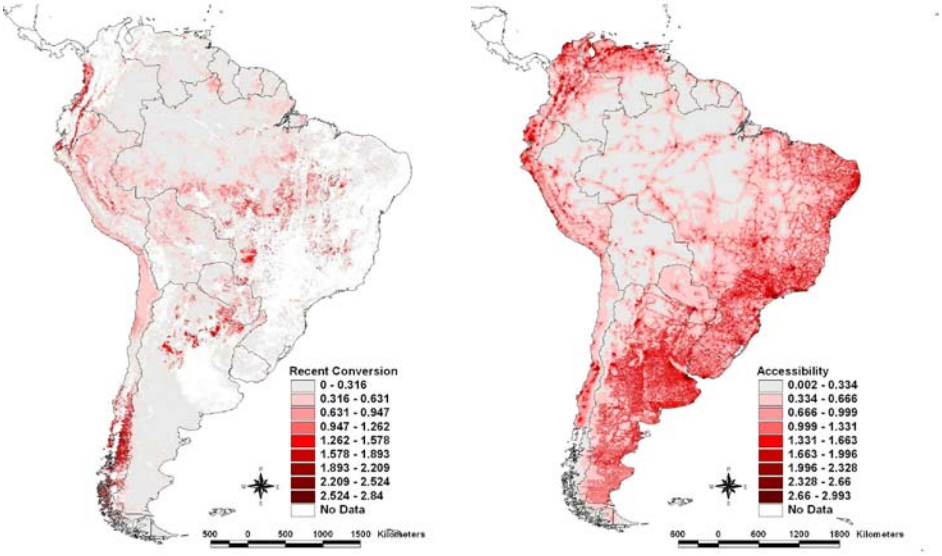
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2.209 - 2.524
2.524 - 2.84
No Data
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Accessibility
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0.334 - 0.666
0.666 - 0.999
0.999 - 1.331
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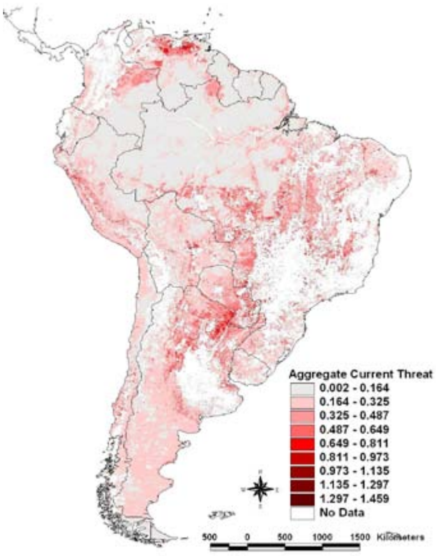
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0.973 - 1.135
1.135 - 1.297
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No Data
500 0 500 1000 1500 Kilometers

3