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Are capacity deficits in local government leaving the Amazon vulnerable to environmental change?

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ABSTRACT

The last 20 years have seen remarkable progress in monitoring and modelling environmental change in the Amazon region. As a result, scientists and policy makers now have robust and spatially explicit knowledge and forecasts of critical phenomena such as deforestation and bioclimatic uncertainty. However, whether this knowledge is used to support the implementation of policies and initiatives to cope with environmental changes in the Amazon depends on the ability of the political institutions to proactively integrate the scientific evidence into land planning at multiple spatial scales. In Brazil, municipalities are constitutionally responsible for legislating on land planning and therefore have a power to significantly influence the future trajectory of environmental change. Here, we assess the environmental capacity of municipalities in the Brazilian legal Amazon based on data from a self-assessment survey and from the Brazilian Institute of Geography and Statistics database. Municipalities generally have a low level of institutional capacity and there is no evidence that the municipalities most at threat from environmental change are taking proactive measures to reduce their vulnerability. We argue that structural reforms and capacity raising initiatives are urgently needed, especially in smaller, less economically developed municipalities located in areas at high risk of imminent environmental change.

1. Introduction

The Amazon region contains the largest remaining area of continuous rainforest in the world and is considered vital for maintaining regional ecosystem services such as hydrological and biogeochemical cycles (Foley et al., 2007; Malhi et al., 2008). The Amazon rainforest is also one of the regions with the highest levels of terrestrial biodiversity (Antonelli and Sanmartín, 2011; Malhado et al., 2013), and may still contain considerable numbers of undiscovered species (Funk et al., 2012; Scheffers et al., 2012). Notwithstanding its enormous size, the future of many Amazonian forests is uncertain due to the interlinked threats of deforestation, fires and climate change (Davidson et al., 2012; Malhado et al., 2013; Malhi et al., 2008). Indeed, the latest generation of land use models suggest that Amazonian land cover changes due to deforestation may be sufficient to cause ecological ‘tipping points’ in some regions, transforming tropical forests into deciduous forests or even savannahs (Nobre, 2014; Pires and Costa, 2013). These impacts are predicted to be strongest in transitional forests at the margins of Amazonia and within the highly threatened arc of deforestation region in southeast of the region (Costa and Pires, 2010; Pires and Costa, 2013).

Responding to these complex threats requires actions at multiple scales (Ladle and Malhado, 2007; Ladle et al., 2011). Specifically, it will be essential to effectively integrate policy with the results of land use models to pre-emptively respond to the coupled threats of climate change and deforestation (Ferreira et al., 2012; Ladle et al., 2011). Such actions are not only essential for conservation, but also to ensure regional food security which could also be threatened by wide-scale changes in precipitation regimes (Lapola et al., 2011). For example, one recent model indicated that, due to climate feedbacks, increased

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agricultural expansion in the Amazon will lead to lower agricultural productivity in both new and established areas (Oliveira et al., 2013).

Brazil contains the highest proportion of the Amazon (60%), and is relatively well placed to meet many of these complex conservation and development challenges. The country has some of the most robust and comprehensive environmental legislation in the developing world (McAllister, 2008), and has recently developed a suite of forward thinking policy initiatives such as the Low Carbon Agriculture Plan (Amaral et al., 2012) and various Payment for Ecosystem Services (PES) schemes (e.g. Figueiredo et al., 2013; Zanella et al., 2014). However, despite this impressive legislative framework, Brazil has been far less successful at implementing and enforcing its environmental laws with high levels of non-compliance, especially in the agricultural sector (Sparovek et al., 2010). Environmental policy implementation and the capacity to react to environmental threats is especially problematic over large, sparsely populated areas such as Amazonia, where responsible institutions may lack appropriate resources, infrastructure, personnel, etc.

Brazil has a three-tiered (Federal, State and Municipality) structure of government, with state and municipal administrations having a high degree of autonomy with regards to the development of environmental policies and actions. On-the-ground implementation of environmental policies was largely devolved to local (municipal) government in the 1988 constitution and subsequent legislation. Most importantly, municipalities are constitutionally responsible for legislating on land planning (Castro et al., 2009) and therefore have a critical role in regulating agricultural expansion, urban development, transport infrastructure and, by extension, deforestation. This has proved highly problematic due to low institutional capacity, further exacerbated in some Amazonian municipalities by familial or economic connections between politicians and those involved in the illegal extraction of natural resources (McAllister, 2008). Consequently, local land planning decisions are often in conflict with federal laws leading to protracted and often unresolved legal disputes (Castro et al., 2009). The Brazilian Amazon contains 797 municipalities of widely varying area, resources and infrastructure and which vary considerably in their capacity to deal with the complex environmental threats to both natural and agricultural areas (Dias et al., 2015).

In this viewpoint we evaluate various aspects of the capacity of municipalities in the Brazilian legal Amazon to respond to current and future environmental threats, with a focus on municipalities in areas that vary in risk of future environmental change. The latter on the basis of coupled biosphere-atmosphere models that predict the probability of ecosystem transition due to deforestation-induced climate change (Ladle et al., 2011; Pires and Costa, 2013).

2. Material and methods

2.1. Municipal capacity metrics

Municipalities of the Brazilian legal Amazon region (composed of the states of Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Rondônia, Roraima and Tocantins) were identified using Brazilian Institute of Geography and Statistics (IBGE) data (http://www.ibge.gov.br/). Information on the conservation capacity for each of these municipalities was derived from two sources: i) a dedicated self-administered survey of municipal institutions with a focus on environmental policy; ii) publicly available data from the 2013 IBGE survey (see below).

The dedicated self-administered survey was implemented in two steps. First, between January and March 2014 all 797 municipalities in the Brazilian Legal Amazon were contacted via email or phone and the individual(s) responsible for environmental policy were identified. These individuals were then invited to take part in the survey over the phone or via email. For municipalities that did not respond to the first approach, several further attempts at communication were made, finally terminating in August 2014.

The self-administered survey questions focused on the capacity of each municipality to deal with the challenges of environmental change (full questionnaire in Supplementary Material A). The questionnaire contained nine questions: questions one to eight concerned infrastructure, policy development, personnel and resources. Question nine asked respondents to complete a self-assessment matrix to ascertain the capacity (on a four-point scale from no activities to high capacity) of the municipality to conduct activities related to conservation, climate change and sustainable agriculture.

Data from the self-administered questionnaires and responses to the 2013 IBGE survey of Brazilian municipalities were tabulated, analyzed and eight capacity metrics were created, three related to policy and five related to the implementation of policy. The policy metrics and their sources were: i) existence of a municipal biodiversity conservation policy (survey); ii) existence of a municipal climate change policy (survey), and; iii) existence of specific legislation to deal with environmental issues (IBGE). The implementation metrics and their sources were: i) self-assessment index (survey − see below); ii) existence of municipal environmental committee (IBGE); iii) existence of municipal environmental fund (IBGE); iv) number of environmental staff (IBGE); and, v) number of permanent environmental staff (IBGE).

The *self-assessment index* was based on how each municipality rated its own capacity to deal with environmental change. Each of ten self-assessment criteria was scored from 0 (no capacity) to 3 (high capacity) with a maximum score of 30 (high capacity for all 10 criteria). The selected criteria consisted of capacity to: i) perform climate change research; ii) evaluate risks and impacts of climate change; iii) combat deforestation; iv) conserve biodiversity; v) restore forests; vi) sustainably manage water resources; vii) develop sustainable agriculture; viii) develop sustainable use of forest resources; ix) deliver environmental education; and, x) prevent and control forest fires.

2.2. Socio-political/geographical characteristics

To better understand the drivers of institutional capacity in Amazonian municipalities we also extracted the following data from the 2013 IBGE survey: i) total area (km^2); ii) population size; iii) population density; iv) Human Development Index (HDI); v) Gross Domestic Product (GDP); and, vi) Gross Domestic Product *per capita* (GDP *per capita*). To these data we added the following metrics; vii) % of area of municipality designated as a conservation unit or indigenous territory (from the ICMBio spatial database of protected areas); viii) accessibility, in terms of minimum time (hours) to travel by an appropriate mode of transport (e.g. boat, car, aeroplane, etc.) from any point in the municipality to a city with > 50,000 inhabitants. This provides a measure of the isolation of the municipality which, in turn, may influence the ability to attract qualified staff and implement environmental policy.

2.3. Risk of environmental change

Finally, we included (ix) a metric of risk of environmental change in order to compare preparedness of municipalities with high and low risk of bioclimatically induced ecosystem transition. This was quantified in terms of the probability of transition from humid forest to savannization or transitional forest. Recent studies indicate that deforestation in Amazonia and central Brazil could change the Amazon's regional climate driving parts of the forest into bioclimatic envelopes that are more typical of savannas (Malhi et al., 2009; Pires and Costa, 2013). We used data from Pires and Costa (2013) to identify those municipalities that, based on current deforestation scenarios, are predicted to develop climates that can no longer support tropical humid forest by 2050. Using spatial overlap between shape files of bioclimatic risk (provided by G. Pires) and shape files of municipalities (from the IBGE database) we classified municipalities as 'at risk' if more than 50% of their territory was predicted to have a high risk of ecosystem transition.

2.4. Statistical analysis

For the dichotomous response variables (existence of a municipal biodiversity conservation policy, existence of a municipal climate change policy, existence of specific legislation to deal with environmental issues, existence of municipal environmental committee, existence of municipal environmental fund), we used generalized linear models (GLMs) with a binomial distribution to analyze the statistical significance and level of association between the explanatory variables and the response variables. In order to account for the high prevalence of zeros in the continuous response variables (self-assessment index, number of environmental staff, number of permanent environmental staff), we used GLMs with a negative binomial distribution to identify statistically significant associations with the explanatory variables. All possible model combinations (without interactions) were calculated using a multi-model inference approach (Burnham and Anderson, 2004) implemented with the MuMIn package for R Software. We then selected the best performing models according to Akaike's Information Criterion corrected for sample size (AICc) and Akaike's weights (ωAICc). Because no single model clearly outperformed the others (ωAICc < 0.9 for all models evaluated), we used a model averaging approach to obtain averaged parameter estimates and the relative importance of each explanatory variable. For this process, we considered only models with ΔAICc < 4 (Burnham et al., 2011). All the analyzes were implemented in R Software v3.3.0 (R Core Team, 2016).

3. Results & discussion

3.1. Municipal capacity

Our dedicated survey of municipal capacity to deal with environmental change resulted in 175 responses − 3 of which did not answer all questions. This represents 22% of the 797 municipalities in the Brazilian Legal Amazon. Municipalities that responded to our questionnaire were geographically widespread and were indistinguishable from those that did not provide responses in terms of geographic area ($t = 0.635$, $df = 795$, $P = 0.526$) and GDP ($t = 0.885$, $df = 795$, $P = 0.376$). However, responding communities had significantly larger populations ($t = 2.12$, $df = 795$, $P = 0.034$) and higher development (HDI) indices ($t = 4.701$, $df = 795$, $P < 0.001$). The IBGE 2012 data covered all 797 municipalities in the legal Amazon.

The level of capacity for the three policy metrics and the five implementation metrics were low. Specifically, 28.5% (n = 172) had a municipal biodiversity policy, 24.4% (n = 172) had a municipal climate change policy, and 12.2% had both a biodiversity and climate change policy. As would be anticipated, a higher proportion (65.4%, n = 797) had no sort of legislation to deal with environmental issues (e.g. green or brown issues). The performance for implementation capacity metrics was similarly weak: the average self-evaluation index score was 11.4 ± 7.6 (mean ± SD) out of a maximum score of 30, with 16.9% (n = 172) of municipalities declaring no capacity for any of the components of the index. Furthermore, even though 60.4% (n = 797) of municipalities had an environmental council/decision making body, only 44.7% (n = 797) possessed an environmental fund, and only 41.3% (n = 797) had both an environmental council and a dedicated fund. The total number of environmental staff (and the number of permanent environmental staff) was highly skewed, with a few of the larger municipalities employing hundreds and 89.0% of municipalities employing 20 or less environmental staff.

Interpreting these results requires a basic understanding of the roles and responsibilities of municipalities within the Brazilian federal system. Brazilian municipalities have a large degree of autonomy to formulate policies and participation in federally mandated programs is voluntary (Neves, 2012). Such an arrangement naturally leads to immense variability in the degree to which federal policies are implemented among municipalities, depending on the degree of

Table 1
Model averaging conditional parameter estimates (± S.E.) and relative variable importance of explanatory variables in relation to each of the municipal response variables. Only models with ΔAICc ≤ 4 were considered from the full set of possible models. Figures in bold are statistically significant ($P < 0.05$). The full set of models considered for modelling average purposes is available in Appendix A.

Model Parameters	Binomial GLMs										Negative Binomial GLMs					
	Climate Change Policy		Biodiversity Policy		Environmental Policy		Environmental Committee		Environmental Fund		Self-assessment Index		Environmental Staff – Total		Environmental Staff – Permanent	
	Estimate	Rel. Imp.	Estimate	Rel. Imp.	Estimate	Rel. Imp.	Estimate	Rel. Imp.	Estimate	Rel. Imp.	Estimate	Rel. Imp.	Estimate	Rel. Imp.	Estimate	Rel. Imp.
Intercept	−0.89 ± 1.04	–	−1.04 ± 1.04	–	−2.09 ± 1.15	–	**−4.26 ± 1.10**	–	**−3.56 ± 1.06**	–	**9.26 ± 3.64**	–	**2.98 ± 0.64**	–	−0.78 ± 0.90	–
Climate Risk	0.20 ± 0.66	0.14	−0.55 ± 0.63	0.23	−0.75 ± 0.38	0.82	−0.55 ± 0.33	0.63	−0.31 ± 0.32	0.27	−2.18 ± 2.19	0.29	**−0.24 ± 0.12**	**0.71**	−0.14 ± 0.23	0.22
Population density	−5.19 ± 4.79	0.47	−1.40 ± 2.92	0.13	0.43 ± 0.76	0.21	−0.05 ± 0.34	0.15	−0.08 ± 0.30	0.17	−3.21 ± 8.77	0.14	**−0.24 ± 0.07**	**1.00**	**−0.19 ± 0.09**	**0.67**
HDI	−0.56 ± 2.44	0.15	0.63 ± 2.65	0.11	**3.16 ± 1.09**	**1.00**	**4.94 ± 1.08**	**1.00**	**3.41 ± 1.06**	**1.00**	3.90 ± 7.30	0.15	**−1.19 ± 0.53**	**0.84**	**2.55 ± 0.94**	**1.00**
Municipal area	−0.09 ± 0.20	0.19	−0.11 ± 0.20	0.18	0.27 ± 0.16	0.78	**0.33 ± 0.14**	**1.00**	**0.58 ± 0.15**	**1.00**	−0.45 ± 0.68	0.23	0.03 ± 0.04	0.27	0.07 ± 0.07	0.29
% Area PAs	−0.05 ± 0.29	0.13	−0.09 ± 0.28	0.12	0.06 ± 0.13	0.20	−0.01 ± 0.12	0.15	−0.11 ± 0.12	0.30	0.23 ± 0.94	0.12	0.07 ± 0.05	0.46	**−0.19 ± 0.10**	**0.84**
GDP per capita	0.14 ± 0.20	0.24	−0.47 ± 0.39	0.41	−0.03 ± 0.16	0.18	0.07 ± 0.18	0.21	−0.08 ± 0.15	0.21	0.35 ± 0.67	0.13	**−0.17 ± 0.08**	**0.87**	**−0.47 ± 0.15**	**1.00**
Total GDP	−0.27 ± 0.91	0.16	1.69 ± 1.63	0.32	−0.58 ± 0.31	0.97	−0.51 ± 0.32	0.89	−0.59 ± 0.38	0.86	1.73 ± 3.65	0.11	**0.70 ± 0.22**	**1.00**	−0.29 ± 0.25	0.25
Population size	−0.11 ± 0.89	0.16	2.18 ± 1.16	0.78	**1.64 ± 0.59**	**1.00**	**0.89 ± 0.44**	**1.00**	**1.11 ± 0.44**	**1.00**	**10.86 ± 4.11**	**1.00**	**0.99 ± 0.17**	**1.00**	**0.62 ± 0.19**	**1.00**
Accessibility	0.13 ± 0.16	0.26	−0.15 ± 0.19	0.22	0.07 ± 0.12	0.22	−0.01 ± 0.10	0.15	**−0.22 ± 0.11**	**0.90**	−0.17 ± 0.55	0.10	0.06 ± 0.04	0.54	−0.09 ± 0.08	0.39

intergovernmental cooperation (cf. Mertens et al., 2011), the presence of federal bodies (e.g. IBAMA – the federal government's environmental agency) within the municipality, and the capacity and willingness of municipalities to adopt federally mandated policies. In this sense, it is also important to distinguish between capacity to act and willingness to act. Corruption, vested interests, lack of local representation and logistical issues may make it difficult even for municipalities with high capacity to successfully implement programs (Olival et al., 2007).

The generally low capacity of municipalities in the Brazilian Legal Amazon to deal with the challenges of environmental change is perhaps unsurprising, given that the majority of Brazilian municipalities suffer from reduced financial and human resource capacity (Moretto, 2014). The underlying reasons behind the observed capacity deficit are probably complex and interlinked. Indeed, the enormous variation in infrastructure and resources at municipal level makes both comparisons and generalizations highly problematic. Nevertheless, our analysis offers some insights into socio-economic and geographical factors that may play a role. Specifically, the GLMs revealed a consistent pattern of association between response and explanatory variables (Table 1). Most generally, Human Development Index (HDI) was frequently associated with capacity. The level of development/capacity for any given municipality is the product of several inter-related factors, being influenced by political culture (past and present), available resources, demographics, and isolation (distance from major cities). These multiple causes are clearly demonstrated in a recent panel data model of the relationship between municipal income and deforestation (Oliveira et al., 2011): although the authors found a significant correlation, the curve was best approximated by an inverted N shape reflecting changes in deforestation during different phases of economic development. Moreover, recent municipal level studies in the Amazon indicate that policy variables, especially environmental fines and the presence of an environmental surveillance agency, play a key role in determining deforestation rates (Arraes et al., 2012; Hargrave and Kis-Katos, 2013). Nevertheless, direct evidence for a the link between good environmental governance at the municipal level (as measured by official statistics) and deforestation rates is elusive (Dias et al., 2015). For this reason, even municipalities in our study with apparently high institutional capacity may struggle to translate this into effective conservation actions.

Population size was also significantly positively associated with capacity. Area of municipality was significantly and positively associated with capacity for existence of an environmental committee and an environmental fund. Namely, more developed, larger, more populous municipalities tend to have higher capacity. Such development and size related associations with municipal capacity are not surprising given that there are well known efficiencies of scale at the municipal level for the provision of basic services (Kuwahara et al., 2010). Moreover, smaller municipalities may have more difficulty accessing technical assistance when it is available (da Costa Gomes, 1994). While unsurprising, our findings demonstrate the importance of targeting smaller, poorer municipalities for technical and administrative support. It also suggests that, at least for effective environmental management, smaller municipalities may benefit considerably from closer integration. This is supported by a recent study of social networks and environmental governance in the Amazonian Gateway Territory that demonstrated that inter-municipal dialogue is essential for reducing conflicts and promoting sustainable use of natural resources (Mertens et al., 2011).

Accessibility was only significantly (negatively) associated with the existence of an environmental fund (Table 1), implying that less isolated municipalities might be slightly more likely to possess dedicated resources. Nevertheless, the negative relationships between population density and the number of environmental staff (total and permanent) suggests that more rural municipalities have invested more heavily in human resources in this sector. This interpretation is further supported by the negative relationship between these two response variables and municipal GDP per capita, given that rural municipalities will contain a higher proportion of subsistence farmers.

3.2. Environmental change

A total of 57.8% (n = 797) of Amazonian municipalities had a high risk of climate-induced ecosystem transition following the analysis of Pires and Costa (2013). Surprisingly, such high risk was significantly negatively associated with the total number of environmental staff (Table 1). It was also negatively associated, though not statistically significant, with existence of an environmental policy or the existence of a municipal environmental committee. It would be unwise to read too much into these results given the low level of statistical association. Nevertheless, they clearly illustrate that municipalities are not proactively responding to the imminent threat of climate change. Such an interpretation is supported by the observations of Inoue (2012), who found little evidence of Amazonian municipalities were actively engaging in climate change governance. In some respects, this lack of action is unsurprising given the contrasting scales of environmental change and governance. In this context, the capacity of an individual municipality to proactively react may depend, to a large extent, on effective coordination with upper decision-making levels as well as the existence of a broader scale vision/policy. Unfortunately, due to local pressures municipal land planning decisions are often in conflict with federal environmental legislation leading to "interminable judicial battles" (Castro et al., 2009).

4. Conclusions

We demonstrate that municipalities in the Brazilian Legal Amazon are generally poorly prepared to deal with the challenges of biodiversity conservation and environmental change. Based on our results we have four main recommendations: i) further efforts need to be made by federal and state government, environmental NGOs and private organizations to more effectively engage Amazonian municipalities in conservation and climate change governance; ii) more research is needed to develop and validate measures of capacity, especially ones that quantify the ability and willingness of municipalities to implement policies, enforce regulations and monitor effectiveness; iii) all possible efforts should be made by the modelling community to more precisely identify areas (and associated municipalities) that will undergo extensive environmental change, and; iv) finally, there needs to be better integration between the academic modelling community and the diverse actors involved in environmental governance of the Amazon so that resources, technical support and capacity raising can be focused on those municipalities with the greatest needs.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landusepol.2017.07.035.

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