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Election-driven weakening of deforestation control in the Brazilian Amazon

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ABSTRACT

Commodity prices, exchange rate, infrastructural projects and migration patterns are known and important drivers of Amazon deforestation, but cannot solely explain the high rates observed in 1995 and 2003–2004 in six Brazilian Amazon states. Deforestation predictions using those widely applied drivers can underestimate deforestation rates by as much as 50%. We show that years with the highest deforestation rates also correlate with large administrative shifts caused by presidential elections which results in periods of managerial instability associated with episodic inefficiency, leading to weak institutions unable to properly combat illegal deforestation. Although surveillance and regulatory action plans to combat deforestation have held back deforestation in the Brazilian Amazon since 2005, our results suggest that environmental management institutions should be aware such administration shifts set a burden on the policy targets associated with conservation policies. Institutional vulnerability immediately after major elections is an acknowledged fact in Brazil, though it has been mostly disregarded as an indicator of ecological threat.

Introduction

Land use is the largest source of greenhouse gas emissions in Brazil. While deforestation, cattle, soy and biofuel production represent the main sources of carbon emissions, land use policies in Brazil play a key role for facing important sustainability challenges, specially climate change and biodiversity loss. Moreover, human health has also been threatened by biomass burning processes (Tsao et al., 2012). A transition towards a more sustainable development in Brazil thus calls for appropriate land use policies.

Causes of deforestation in the Amazon are manifold, while drivers operate in a complex manner and at different spatial scales. For example, infrastructure projects, land reform and distance to roads have shown to be prime drivers of deforestation at local scales (Nepstad et al., 2002; Fearnside, 2006; Morton et al., 2006; Laurance, 2007), resulting in the famous 'fishbone' structures of deforested areas. On the other hand, volatility of commodity prices like soy can boost deforestation as well (Laurance et al., 2011). The deforestation patterns in at least four Brazilian Amazon states, notably Mato Grosso, Pará and Rondônia and Amazonas (Fig. 1) are remarkable similar; oscillating rates with the years 1995 and 2003–2004 having the highest values. In the other states within the Legal Amazon, however, this pattern is much less pronounced (Fig. 1). Nonetheless, such patterns suggest nation-wide and global drivers are operating in addition to more localised drivers, such as distance-to-road and migration variables.

Since the early 1990s forest depletion in the Amazon averaged 1.86 million hectares per year and is accompanied by an extraordinary growth of soybean production in the central region of Brazil. Considering the state of Mato Grosso only, soy production increased up to 270% from 1990 to 2005, a growth three times higher than in any other soybean-producing region in the country. As a consequence, cattle ranchers are moving towards forests located in the northern and central part of the Legal Amazon and become, together with logging industries, primary protagonists of deforestation. Cattle herd in the Amazon region has increased 200% over the same period, against a 55% growth in the Midwest region and just 7% elsewhere in Brazil (IBGE, 2008). These findings thus suggest (world) market prices for soy, beef and timber boost deforestation.

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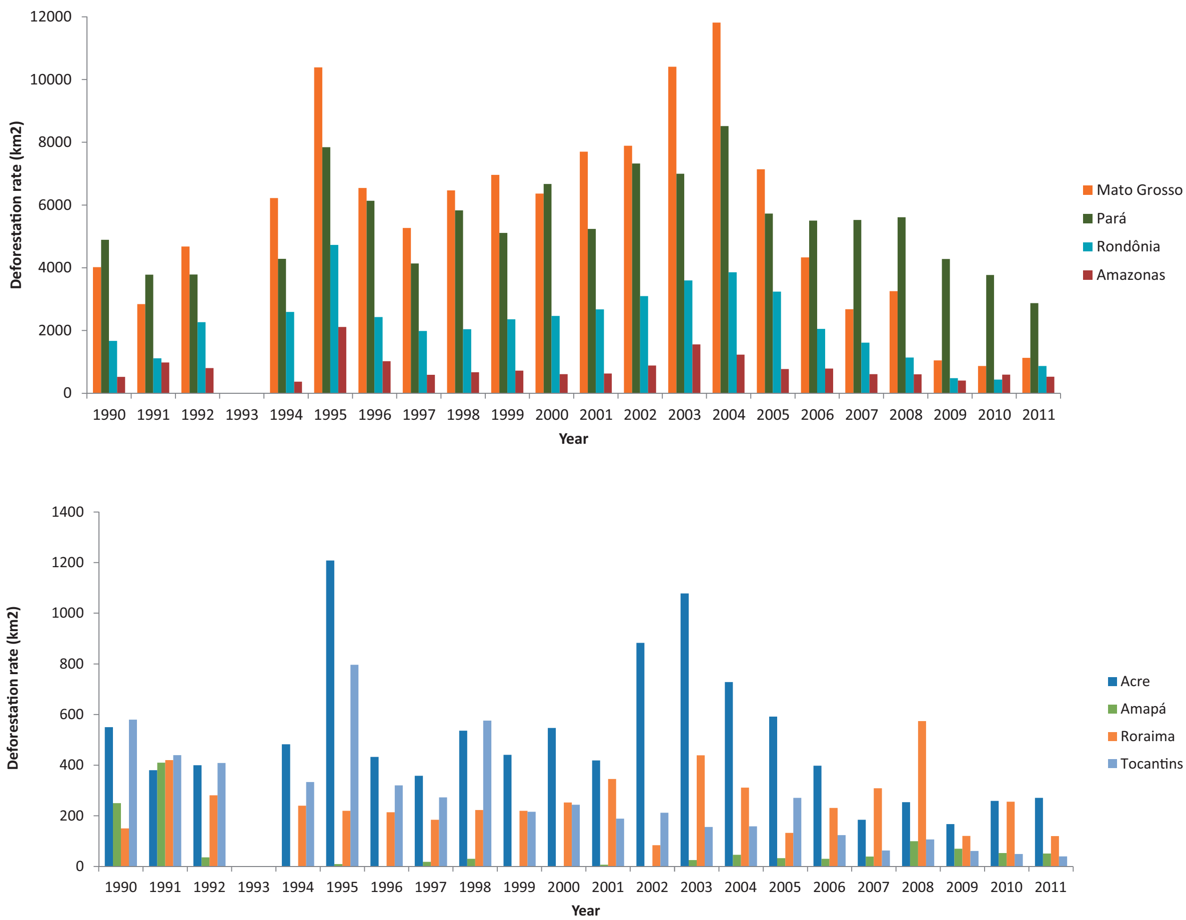

Fig. 1. Deforestation patterns in eight Amazon states in Brazil from 1990 to 2010.

Data: INPE (2012).

In addition, the exchange rate between Brazil Reais and US Dollars influences the profit of commodity production as well. Even in years of low international commodity prices, devaluated local currency can make production interesting. This happened in Brazil during late 1990s. When the floating exchange rate was introduced in Brazil in January 1999, the international soy prices were low compared to the high values of previous years.

According to Brandão and Souza (2006), this maintained domestic grains' prices, despite the unfavourable international context, prevented great losses in the agriculture sector. As such, currency devaluation functioned as a buffer to international commodities market's uncertainties. On the other hand, the higher exchange rates overlap the growth trends of international soy prices from 2002 to 2004, which might have amplified the soy expansion. Brandão and Souza (2006) also pointed out that exchange rate boosted cattle prices substantially from 1999 onwards, influencing the expansion of cattle herds.

Indeed, beef, soy and timber prices and exchange rates go along with observed patterns of deforestation rates in different Amazon states, most notably in 2003–2004 (Fig. 2), but correlation matrices between these drivers and the state level deforestation rates are indistinct, suggesting a strong temporal component. For example, beef prices show significant correlation with deforestation rate but only in the first part of the time series, while for soy price this pattern was only found in the second part of the deforestation time series analysis.

To predict state level deforestation rates with the three commodity prices and exchange rate we applied a time series regression using univariate autoregressive integrated moving average (ARIMA). This time series analysis enables to take into account temporal variations. Moreover, yearly deforestation rates are not temporally independent so that ordinary regression techniques would not suffice.

In addition, in recent years, there has been increasing recognition of the need to take account of the institutional dimension in planning models (Acherson, 2006; Andersson and Ostrom, 2008), including land-use planning models and assessment of governance scenarios. Therefore, the present paper not only analyses nationwide and global drivers of deforestation, but also explores the role of administration shifts after major elections in episodic increases of deforestation rates in the Brazilian Amazon as a likely consequence of exceptionally bad governance conditions.

Data and methods

Data sources and post calculation of data

State level deforestation data were taken from the INPE database (INPE, 2012). Deforestation data between 1978 (the first year of measurement) and 1988, however, is based on the accumulation of yearly data and therefore not reliable. Moreover, deforestation rates in 1993 were estimated as an average value of 1992 and 1994 since that year no reliable data from satellite images were available (Yoshikawa and Sanga-Ngoie, 2011). Hence we took a time series between 1990 and 2011 and omitted 1993 from our data analysis. Drivers of deforestation were considered commodity prices of soy, beef and timber and currency exchange rates between Brazilian Reais and US Dollars. Yearly soy prices and beef prices were taken

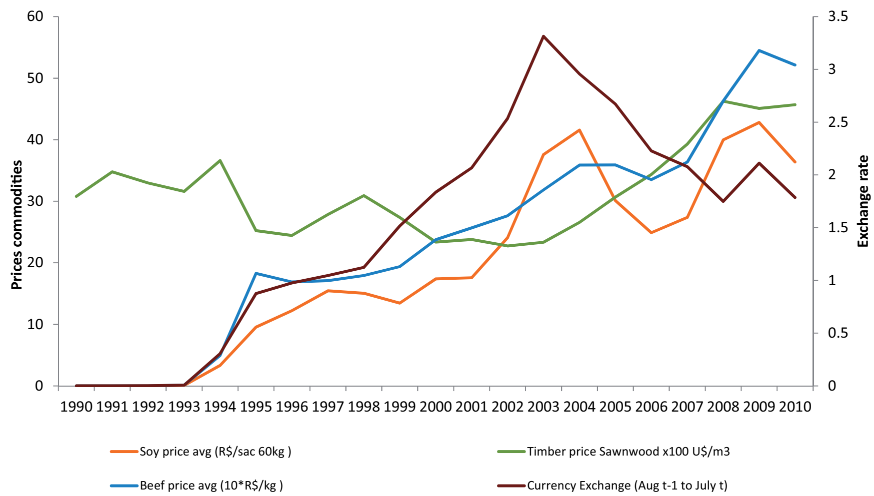

Fig. 2. Changes of commodity prices (soy in RS$/sac 60 kg, beef in 10× RS$/kg, timber in 100× US$/m^3 all displayed in left axis) and the exchange rate of Brazil Reais to US Dollars (displayed on right axis) from 1990 to 2010.
Data: beef, soy, exchange rate, IPEA (2012), timber prices of non-coniferous sawn wood derived from FAO data.

from IPEA (2012). As a proxy for timber prices we used FAO data of non-coniferous sawn wood, because only this wood source has a long time series in the FAO database. We simply divided export value by export quantity to derive a price per m^3. The exchange rate between Brazilian Reais and US Dollars were taken by Yoshikawa and Sanga-Ngoie (2011). State level migration rates were derived from the IBGE database (IBGE, 2006). The full data set led to four drivers that operate for all states equally and one driver, migration rate, that was state specific.

Data analysis

Pearson product-moment correlations were made between deforestation rates and drivers (soy, beef and timber prices, exchange rate and migration rates) for each state separately for the time series 1990–2011. These results showed some significant but inconclusive correlations (Table 1). A breakdown into two time series (1990–1997 and 1998–2011) show a large number of significant correlations between drivers and deforestation, indicating that the drivers have only significant partial effect on deforestation and therefore may not be operational throughout the entire time-series.

Ordinary (multiple) regression models that have time as independent variable cannot be used in our case, since deforestation rates are time dependent. That is, the rate at $t = 1$ is to some extent dependent on the rate at $t = 0$. Therefore we used Box–Jenkins autoregressive integrated moving average (ARIMA, Box and Jenkins, 1976) models for the time series regression predicting deforestation rates. ARIMA models have been used in various regression studies, such as precipitation patterns of pollutants (Nickerson and Madsen, 2005), forecasting energy demands (Ediger and Akar, 2007), analyzing population demography patterns (Lee et al., 2006) and testing stock return and volatility (French et al., 1987). The ARIMA procedure estimates exponential smoothing and produces forecasts. For our analysis we included all dependent variables. First results suggested to use Soy price at a next year (soy at $t + 1$) in the state of Pará to be a better dependent variable than soy price at t. For each state regressions (stationary-R^2 values) were calculated, including Ljung–Box statistics. The analysis of Ljung–Box statistics provides an indication of whether the model is correctly specified. A significance value less than 0.05 implies that there is structure in the observed series which is not accounted for by the model. All statistics were carried out using SPSS version 19 (IBM, 2010).

Results and discussion

We constructed various ARIMA models for the prediction of deforestation rates in eight Brazilian states within the Legal Amazon; Mato Grosso, Para, Rondonia, Amazonas, Acre, Tocantins, Amapa and Roraima. These regressions showed that nationally and globally operating drivers were able to predict patterns, but the addition of the state specific driver population growth improved the different correlation coefficients considerably. The observed and predicted deforestation rates are depicted in Figs. 3 and 4. The ARIMA models showed stationary-R^2 values ranging between 0.78 for Mato Grosso and 0.22 for Roraima (Table 2). Among the four states that constitute the centre of the ‘arch of deforestation’ (Mato Grosso, Pará, Rondônia and Tocantins) these R^2 values were the highest, while the deforestation rates in Acre, Amazonas, Amapa and Roraima were less well predicted, indicating that outside the “arch of deforestation” forest clearing is not only less significant but also controlled by different drivers.

Table 1
P-values of the predictor parameters in the different ARIMA time series model estimates for the different states.

State	Beef price	Soy price	Timber price	Exchange rate	Population growth	Soy price $t + 1$
Mato Grosso	0.1995	0.1083	0.0056	0.8232	0.4162	
Pará	0.2844		0.1132	0.3871	0.6310	0.2991
Rondônia	0.5923	0.6676	0.0570	0.7857	0.7330	
Acre	0.6592	0.3904	0.0543	0.7478	0.4516	
Amazonas	0.8126	0.3019	0.0281	0.2593	0.1303	
Amapá	0.1828	0.4184	0.2949	0.8541	0.8227	
Roraima	0.1232	0.2172	0.3987	0.9649	0.6800	
Tocantins	0.7977	0.7092	0.0671	0.0758	0.6734	

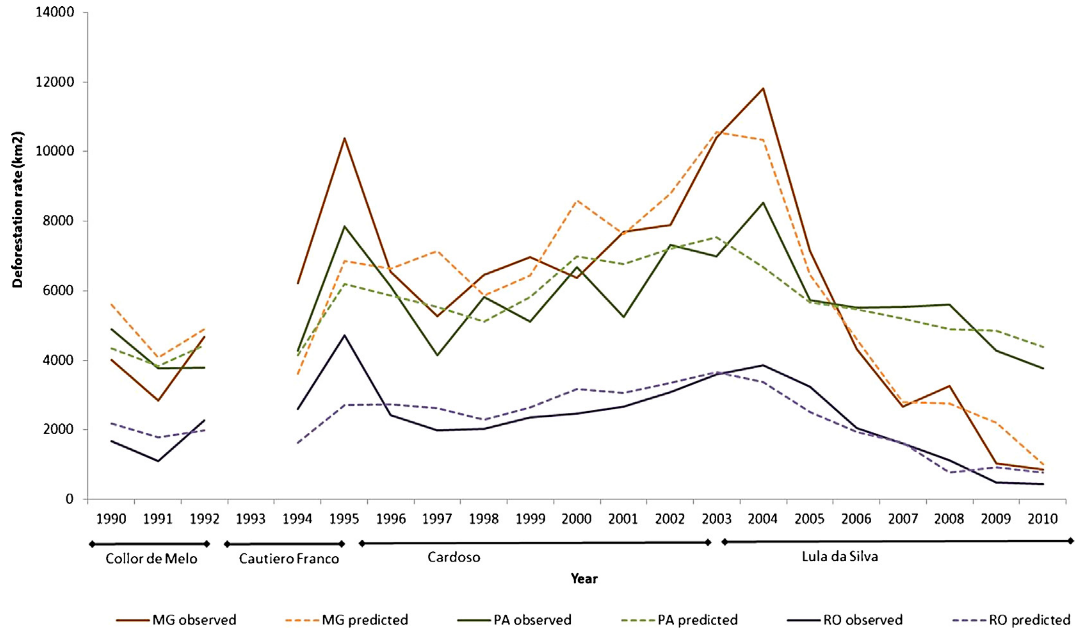

Fig. 3. Observed and predicted deforestation rates using ARIMA on three 'arch of deforestation' states Mato Grosso, Pará and Rondônia.

Agricultural pressures, like soy and pasture expansion are much more pronounced within the 'arch of deforestation' and as a consequence we observe the drivers that are underlying this expansion very well fit the various regression models in those states. Although the explained variation of the various ARIMA models was relatively high, the Ljung–Box statistics also revealed highly significant values (Table 2). These values indicate there is a structure in the observed time series which is not accounted for by the five predictors in the regression models. In most states we observe consistently up to 50% higher deforestation levels in 1995 and 2004 than the ARIMA models predict (Figs. 3 and 4). Since this deviation between observed and predicted rates is rather consistent among the various states, we suggest an additional driver, not currently under study, is likely responsible. The effect of such a driver could be derived from the observed patterns in the residual values of the time series regressions. The plotted residuals of the different time series regressions – the measure of unexplained variation – show some comparable and consistent patterns among the states within the 'arch of deforestation' (Fig. 5), while these patterns are also found in the other states under study, but much less pronounced (Fig. 6). The years 1995, 2003–2005 and to a lesser extent 2008 all have much higher deforestation rates than the time series model predict, while 1997

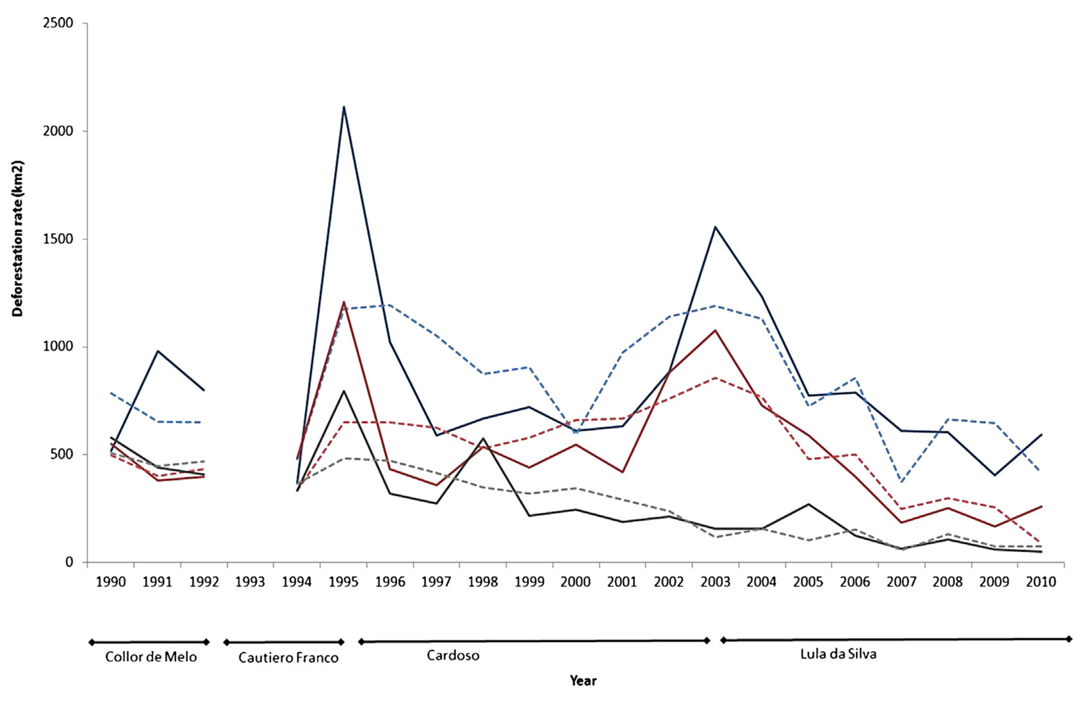

Fig. 4. Residuals of the ARIMA regressions for three 'arch of deforestation' states Mato Grosso, Pará and Rondônia.

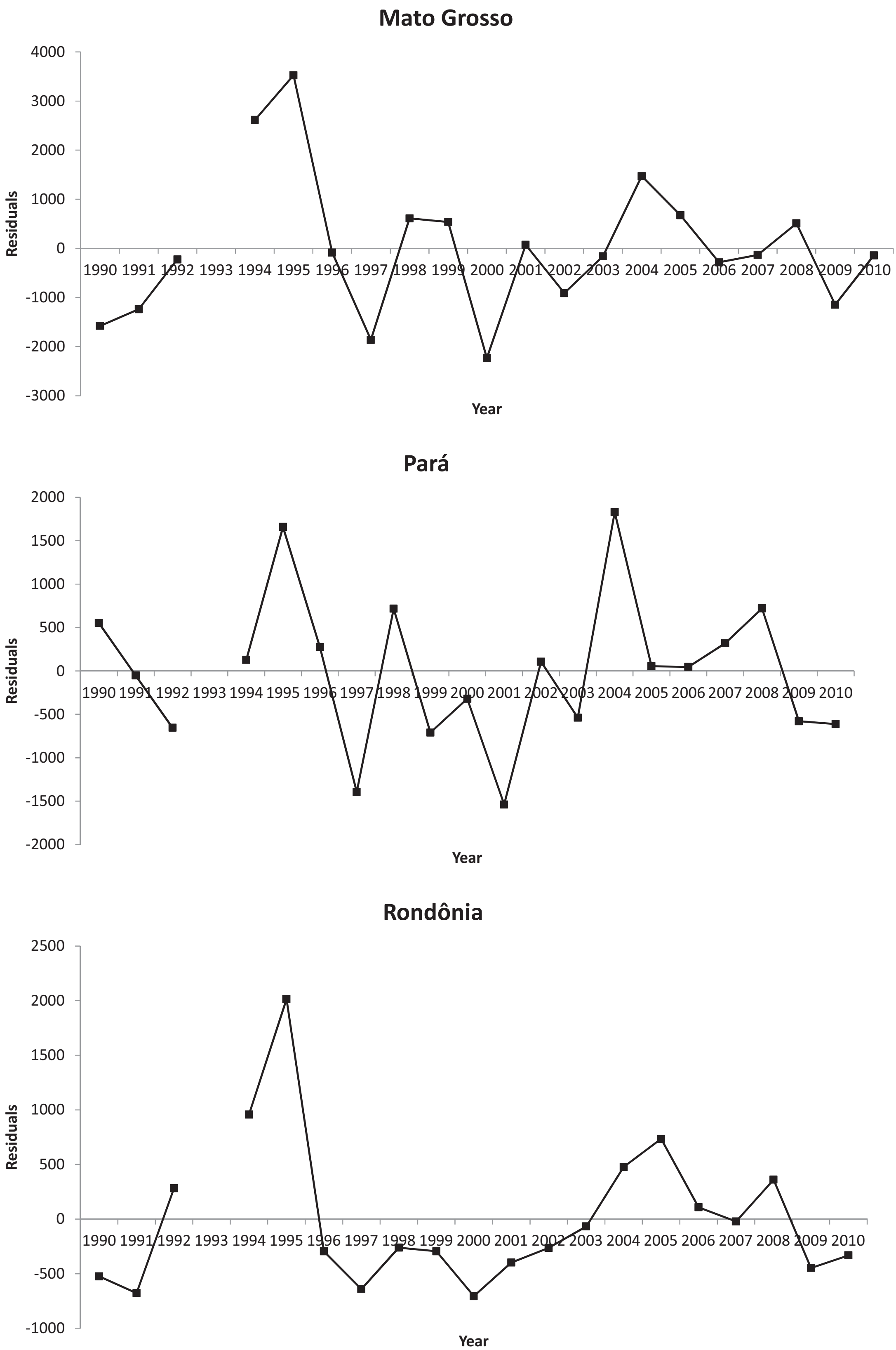

Fig. 5. Residuals of the ARIMA regressions for Mato Grosso, Pará and Rondônia.

and 2001 have much lower deforestation rates. Moreover, some states outside the 'arch of deforestation' have not only very different deforestation patterns, these patterns seem to be less affected by the additional driver, specially in the states of Amapa, with a minimum of residuals, and Roraima with a random distribution of residuals.

The 'peaks' and 'valleys' of observed deforestation rates through time relative to the predicted rates suggest the additional driver(s)

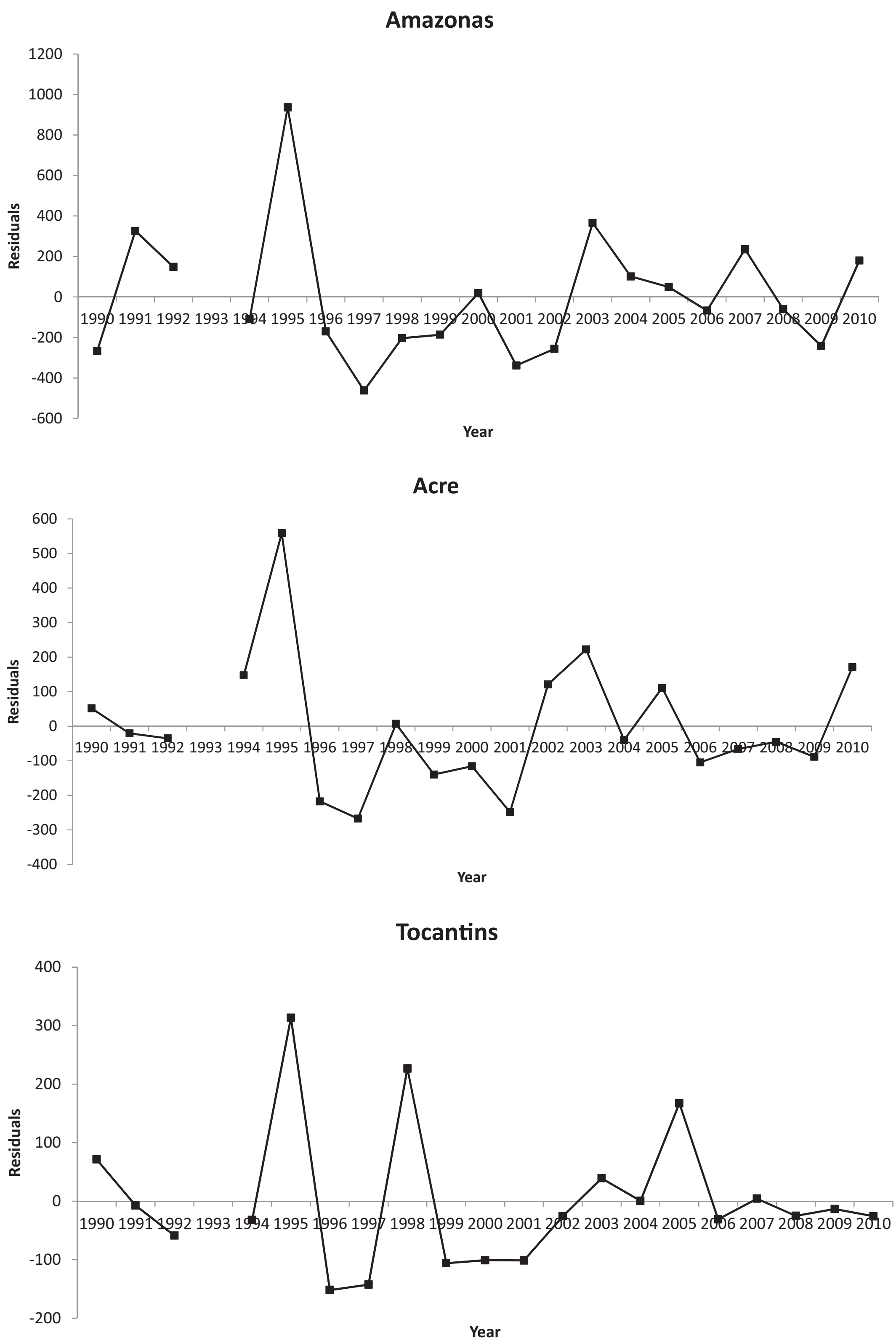

Fig. 6. Residuals of the ARIMA regressions for Amazonas, Acre, Amapá, Roraima and Tocantins.

to operate at a high spatial scale, since the patterns of deviation are consistent in different states. With respect to the 1995 and 2004 periods, they occurred during the first years of the first terms of the two Brazilian presidents in office since 1995. The elections in 1994 and 2002 each led to a change of presidents and therefore a change in administration. By contrast, no significant change in deforestation was observed when elections led to no administrative shifts (presidents Fernando Henrique Cardoso and Luís Inácio *Lula* da Silva were re-elected for second terms in 1998 and 2006, respectively).

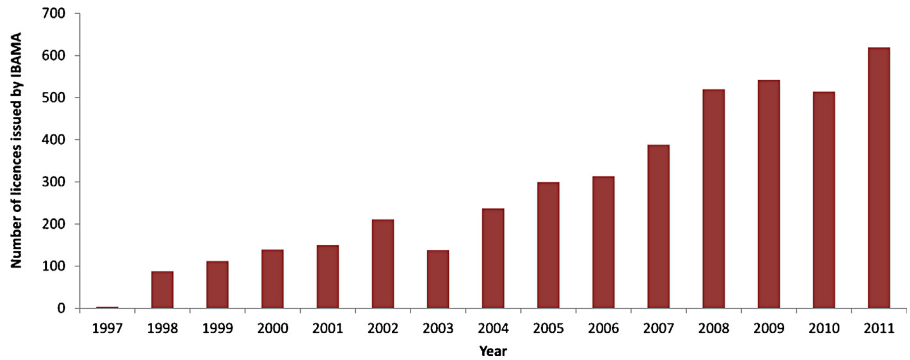

Fig. 7. Number of environmental licences issued by IBAMA from 1997 to 2011.

Table 2
Statistics of the time series regression (ARIMA) and Ljung–Box statistics carried out for different Brazilian Amazon states. Nr. Pred. = number of predictor variables, Stat. R^2 = stationary R^2, RMSE = root mean square error.

State	Nr. Pred.	Model fit		Ljung–Box Q		
		Stat. R^2	RMSE	Statistics	df	Sig.
Mato Grosso	5	0.778	1639.27	78.43	18	0.001
Pará	5	0.615	999.94	93.42	18	0.001
Rondônia	5	0.627	774.23	140.87	18	0.001
Acre	5	0.526	221.04	73.58	18	0.001
Amazonas	5	0.416	367.32	115.09	18	0.001
Amapá	5	0.374	92.259	44.85	18	0.001
Roraima	5	0.224	120.33	401.52	18	0.001
Tocantins	5	0.640	138.16	21.22	18	0.269

These observations support our hypothesis that the unknown driver of deforestation might be of an institutional kind, and therefore reflects institutional weakness that enhances deforestation. In contrast, surveillance and regulatory action plans to combat deforestation have held back deforestation in the Brazilian Amazon since 2005, a process that started only 2 years after the election of President Lula da Silva in 2002 (IBAMA, 2008). This 2-years inefficiency to combat deforestation is arguably due to a vulnerability caused by staff turnover. A similar decrease in deforestation rates started 1 year after election of President Cardoso in 1994.

The administration turnover after presidential elections may take from several months up to 1 year. During the transition process key governmental institutions have their role weakened. This includes institutions related to land use management, such as IBAMA (Instituto Brasileiro de Meio Ambiente e Recursos Renováveis – Brazilian Institute for Environment and Renewable Natural Resources), which is responsible for the environmental surveillance and federal environmental licensing. Fig. 7 shows that just after the election of President Lula in 2002 the number of federal environmental licenses' issued by IBAMA sharply decreased, even though the period as a whole featured a clear trend of increase. This strong decrease seems to give further support to our hypothesis of institutional weakening just after major elections (IBAMA, 2012).

Simultaneously, other institutional factors could explain the residual deforestation. For example, disagreements regarding licensing process seem to have resulted in shifts of high-rank staff in IBAMA in late 2009, during Lula's second term as president. Similarly, in 2008, the Environmental Minister (Marina Silva) resigned. It is alleged that among the main reasons for her resign were disagreements regarding license of huge infrastructure projects in the Amazon. This might have affected the Brazilian environmental license governance. How such political tensions affect the deforestation rates are hard to track and even more difficult to quantify. However, it is possible that part of the residual deforestation observed in 2008 may be explained by such institutional instability in environmental institutions.

Deepening the understanding of the negative residual deforestation in 1997 and 2001 may be found in changes of the Brazilian Forest Code in 1996 and in 2001. Although this Code dated back from 1965, it was only during the 1990s that surveillance polices were enforced as well as the key environmental institutions were consolidated. In 1996 and 2001, president Cardoso edited two *Medidas Provisórias*[3] changing the area of Legal Reserves. The amount of forest in the Forest Code that should be protected in the Amazon increased from 20% to 50% in 1996 (*Medida Provisória* n° 1511-3/1996) and from 50% to 80% in 2001 (*Medida Provisória* n° 2.166-67/2001). The perspective of a tougher law may have affected the decision making process by farmers around these years, who were afraid of legal penalties. Recently (2011), the Forest Code emerged again on the political agenda. In May 2011, the Brazilian Deputies Chamber approved a modified text of the Forest Code to make it more flexible.

So far the literature has demonstrated great attention to socio-economic and infrastructural drivers of deforestation. Commodity prices, road construction and migration are well known factors that determine deforestation trends (Barona et al., 2010; Rodrigues et al., 2009; Soares-Filho et al., 2004). More recently, the role of environmental policies is also receiving attention (Soares-Filho et al., 2006). According to Nepstad et al. (2014) Brazil's remarkable decline in deforestation since 2004 provides valuable lessons on the importance of public policies, monitoring systems, and supply chain interventions in slowing the advance of the agricultural frontier.

However, the underlying institutional framework and political process have been mostly neglected so far. The present study shows that there are positive and negative residual deforestation that cannot be explained solely by the traditional drivers. In this context, we argue that political and institutional aspects are among the explanatory factors. These factors are hard to measure, once they are qualitative and interact in different ways in each institutional/political landscape. Further research is needed in understanding how these factors affect the decision making across scales. At the farm level, how do changes in the legal framework and law enforcement interfere in land use management? At governmental level, how does power turnover affect institutional capacity and resilience? The institutional 'limbo' during 1994 and 2002s presidential shifts, for instance, may explain part of the residual deforestation. Other political events, such as high-rank

[3] *Medidas Provisórias* are constitutional tools allowing the president to edit interim laws irrespective the legislative. However, the law power of *Medidas Provisórias* has a short lifetime if do not approved by the Congress within 120 days.

replacements in governmental institutions and law changes may also have had large consequences in deforestation trends.

In order to reduce institutional vulnerability to combat deforestation a strengthening of governmental institutions is required, by means of reducing staff turnover and applying meritocratic criteria, instead of the historically practiced clientelistic ones for designation of incumbents in more than 20,000 administrative positions at the federal level open to political appointments (Loureiro and Abrucio, 1999; Rodrigues-Filho, 2005).

Conclusion

We present a novel interpretation to explain the exceptionally high deforestation rates of 1995 and 2004 in the Brazilian Amazon by 'filtering' the effect of well-known drivers of deforestation. Although institutional vulnerability immediately after major elections in Brazil is an acknowledged fact, even by Brazilian authorities, it has been disregarded as a possible driver of deforestation dynamics in the scientific community. In many ministries, between 40 and 50% of the staff is renewed in administration shifts, especially in less consolidated ones such as the Ministry of the Environment. This characteristic of the Brazilian state is arguably an important driver of illegal activities and of exceptionally high deforestation rates in the Amazon. Illegal actors may well be aware of this seasonal administrative vulnerability that jeopardises law enforcement in the region, so that illegal surges of deforestation happen preferably during the first year of newly installed political groups in the Brazilian government. Accordingly, a new deforestation surge has been detected as a result of the 2014 presidential election.

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