

Cerrado Conservation is Essential to Protect the Amazon Rainforest

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INTRODUCTION

Despite widespread deforestation the forests of Amazonia still cover more than 5 million km² and may host up to a quarter of the world's terrestrial species (Dirzo and Raven 2003)—many of which are still undocumented. Conservation of these forests is important, not just for the biodiversity they contain, but also for the vital ecosystem services they provide. Historically, the greatest threat to Amazonia has been conversion to agriculture, initially through small-scale farming and, more recently, also through well-capitalized organizations producing agricultural and forestry products for global markets (Rudel et al. 2009). The attention of scientists and conservationists has recently shifted toward another factor that could radically alter the distribution, ecology, and value of the forest—climate change.

Climatologists predict that changes in atmospheric composition in the twenty-first century will cause Amazonia to experience an increase in temperatures of around 3°C and a reduction in precipitation of about 20% (IPCC 2007). In addition to well-documented changes in atmosphere chemistry, climate change in Amazonia may also be caused by the impacts of deforestation on vegetation–atmosphere interactions. These processes are not mutually exclusive, and both could act together to induce a more rapid shift in the system (Costa and Foley 2000).

Changes in the local climate—either caused by rising greenhouse gases or by local deforestation—may cause some parts of the Amazon rainforest to cross an ecological

tipping point during this century (Cox et al. 2000; Lenton et al. 2008; Nobre and Borma 2009). Here, ‘tipping point’ refers to a critical threshold at which a relatively small perturbation can qualitatively alter the state or development of a system (Lenton et al. 2008). In Amazonia, scientists have suggested that the tipping point is represented by some threshold in the area of the rainforest that, if crossed, would lead to a reduction of the rainfall and to an extension of the dry season, causing further reduction of the rainforest and shifting the system into a new and drier equilibrium. Such radical restructuring and re-sorting of the forest community is supported by evidence from paleoecology and ecophysiology. Mayle et al.'s (2004) review of paleovegetation and paleoclimate datasets revealed that a period of reduced precipitation 8,000–3,600 years ago resulted in widespread, frequent fires in southern Amazonia leading to “the competitive replacement of lowland evergreen rainforest taxa by drought-fire-tolerant semi-deciduous dry forest taxa and Cerrado savannas” (p. 510). Rainforests extended their range again in the late Holocene (Mayle et al. 2004), but it seems likely that another period of low precipitation would result in similar ecosystem transformation.

Predicting the geographic location of tipping points is clearly vital for the future conservation of the Amazon region. Fortunately, rapid progress is being made, thanks to the latest generation of ecophysiological models. Malhi et al. (2009) used global datasets to infer precipitation-based boundaries for rainforest viability and combined this with global climate change models to estimate the critical thresholds for water availability and, by extension, the potential extent of climate change-induced ecosystem transitions in Amazonia. Although they found no sharp boundaries in rainfall regime space—unsurprising, given that biome characteristics are also influenced by soil properties and hydrology—they were

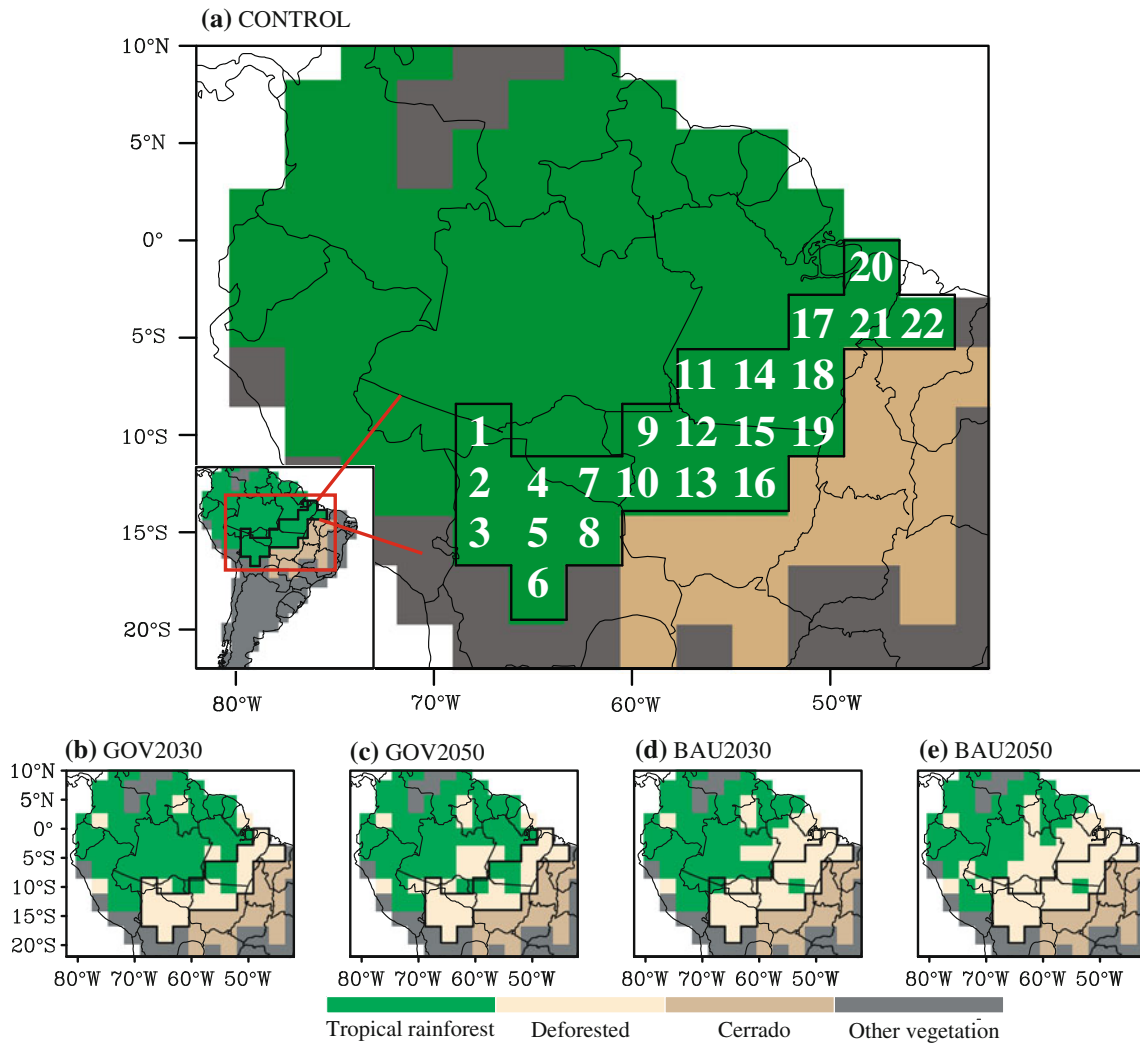


Fig. 1 ‘Arc-of-deforestation’ region in Amazonia (a) and four deforestation scenarios (b, c, d, and e) for 2030 and 2050 illustrating the consequences of continuing trends (the business as usual or BAU

scenario) and of improved forest governance (GOV scenario). *Numbered plots* display pixels described in this study

still able to identify broad climatic thresholds based on measurements of annual rainfall and the most negative value of maximum climatological water deficit (MCWD) and rainfall. These boundaries can be converted into the following crude typology: (i) evergreen ‘rainforest’: $MCWD > -200$ mm; (ii) ‘seasonal forest’: $MCWD < -200$ mm and rainfall $> 1,500$ mm; (iii) ‘savanna’: $MCWD < -300$ mm (midpoint of the broad transition range, -400 mm $< MCWD < -200$ mm) and rainfall $\leq 1,500$ mm.

THE LINK BETWEEN DEFORESTATION AND CLIMATE

The tight coupling between the climate of the Amazon and the characteristics of its land surface means that widespread deforestation is predicted to have significant effects

on local and regional climate dynamics. In general, scientists predict a weakening of precipitation recycling under scenarios of extensive Amazonian deforestation, and reduced totals of annual precipitation (see review in D’Almeida et al. 2007).

Changes in regional climatic conditions in the Amazon rainforest may also be strongly influenced by transformation and land use change of surrounding ecosystems such as the Cerrado. In central Brazil, Costa and Pires (2009) demonstrate that continuing deforestation of the Cerrado (which has already been deforested by more than 50%) could combine with the climate impacts of Amazonian deforestation to produce a significant increase of the duration of the dry season in the ‘arc-of-deforestation’ region in south east Amazonia. Specifically, when the effects of both deforestation scenarios were combined, the dry season was predicted to increase from 5 to 6 months.

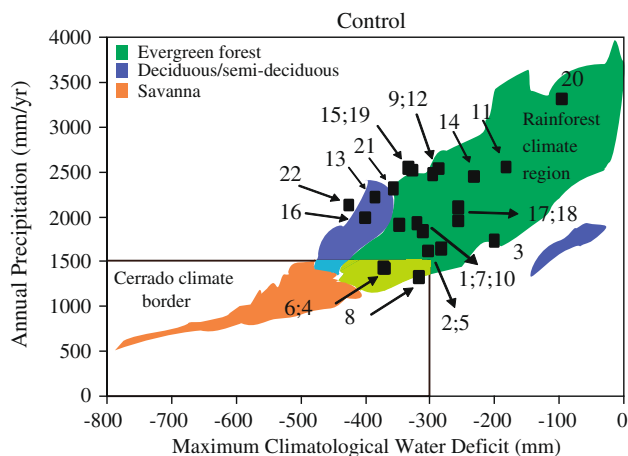


Fig. 2 The simulated climate of the ‘arc-of-deforestation’ pixels for the control simulation showing the relationship between vegetation type and rainfall regime. The suggested Cerrado climate border is maximum climatological water deficit < -300 mm and annual precipitation < 1,500 mm

Put another way, deforestation in the Cerrado and in the ‘arc-of-deforestation’ may combine to push parts of the latter region over the climate thresholds needed for the continued viability of rainforest leading to wide-scale conversion of rainforest to savanna or seasonal forest.

Identifying forests that are approaching or have crossed climatic tipping points will clearly be essential for prioritizing future conservation efforts. In this brief synopsis we combine the modeling results derived by Costa and Pires (2009) for future precipitation regimes in the ‘arc-of-deforestation’ region (Fig. 1) with the climatic thresholds identified by Malhi et al. (2009) in order to identify forests whose long-term viability is threatened.

REGIONAL IMPACTS OF DEFORESTATION

Deforestation Scenarios

The Costa and Pires (2009) study is based on two future scenarios of deforestation for the Amazon in 2030 and 2050 produced by Soares-Filho et al. (2006):

- (1) The ‘business-as-usual’ scenario (BAU) assumes that recent deforestation trends will continue, no new protected areas will be created, and that the currently low levels of compliance with conservation legislation will continue. The BAU scenario assumes that as much as 40% of the forests inside of protected areas will be subject to deforestation, climbing to 85% outside (Fig. 1).
- (2) The ‘governance’ scenario (GOV) assumes that Brazilian environmental legislation is implemented across Amazonia through the extension of current

experiments in frontier governance (Fig. 1). For example, mandatory forest reserves on private properties, agro-ecological zoning, and the expansion of the Amazon Region Protected Areas Program.

The Cerrado region has lost more than 1 million km² of natural vegetation since 1940 due to agricultural expansion (Klink and Machado 2005; Sano et al. 2008). Given these historically high rates and the correspondingly weak conservation governance, scenario C assumes that all of the Cerrado will be deforested by 2030.

Bioclimatic Scenarios

To assist interpretation and visualization, the study region (the ‘arc-of-deforestation’) is divided into 22 grid squares (P1 to P22—illustrated in Fig. 1). Under current rainfall conditions the vast majority of forests in the region clearly fall well within the required boundaries of annual precipitation and maximum climatological water deficit to sustain lowland tropical rainforest (Fig. 2). Most of the grid squares are clearly within the rainforest climate region boundaries, with the exception of P13, P16, and P22 which are situated within the deciduous/semi-deciduous forest climate space. Three grid squares in the southwest of the arc (P4, P6, and P8) are at the edge of the rainforest–Cerrado climate boundary.

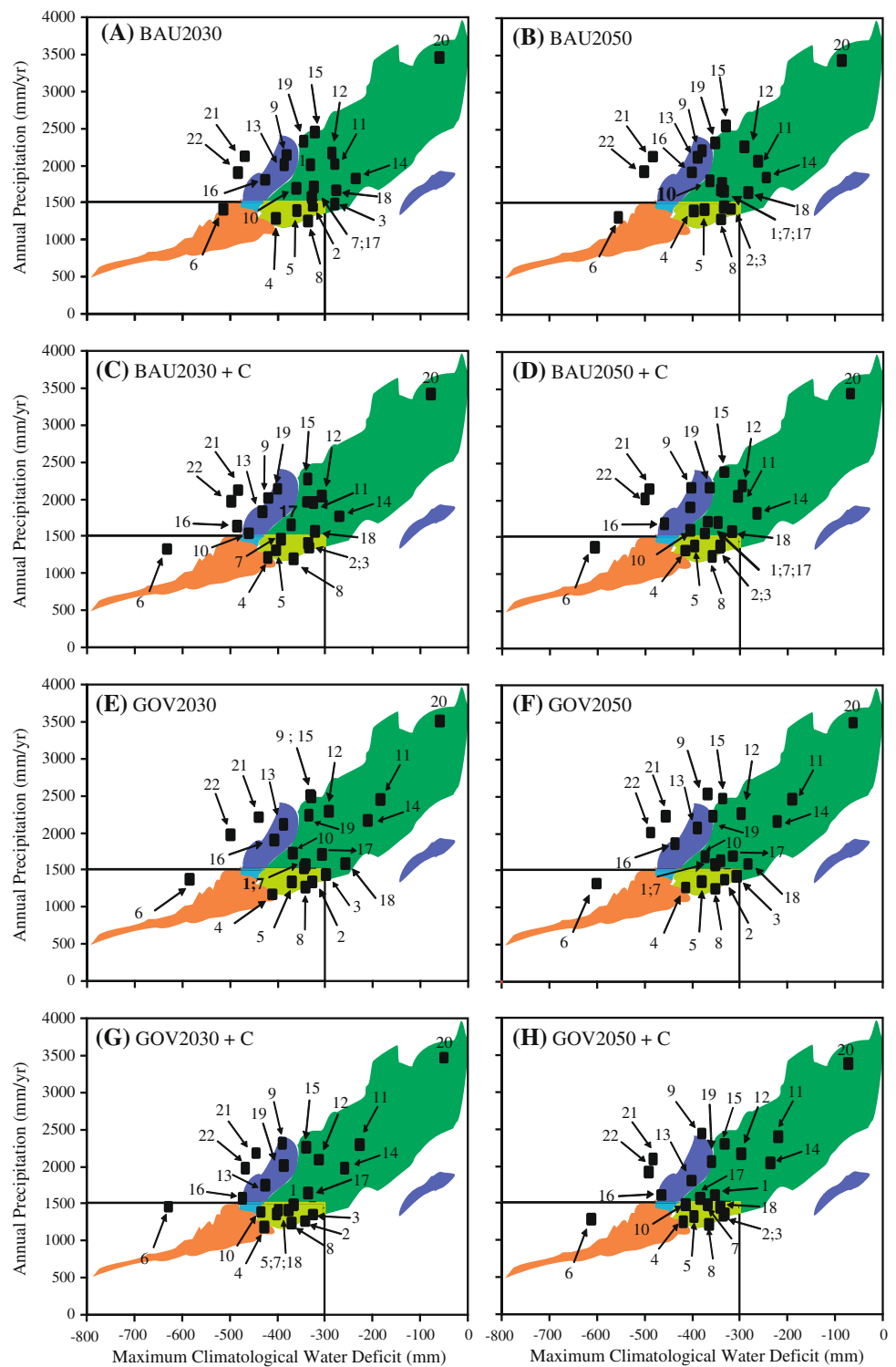
Under the BAU scenario there is a strong tendency for areas that are currently rainforest to move toward the rainforest–Cerrado climate boundary (Fig. 3a–b), a tendency clearly exacerbated by deforestation in the Cerrado (Fig. 3c–d). The southwest of the study area (P4–P8) is predicted to be most at risk of transition to Cerrado, while those on the southern edge (P10, P13, P16, and P19) are pushed into the climate space currently occupied by deciduous/semi-deciduous forest. The northeast region (P21, P22) also suffers from a drier climate, driving some areas beyond the identified climate threshold.

Even with the imposition of effective forest governance (GOV + C) there are predicted to be shifts of forests toward or into the Cerrado bioclimatic envelope (Fig. 3e–h), with forests in the south and southwest of the region being driven closer to the Cerrado-rainforest transition zone.

IMPLICATIONS FOR CONSERVATION OF AMAZONIA AND CERRADO

The above analysis indicates that, whatever the future governance situation in Amazonia, large segments of the ‘arc-of-deforestation’ region run a high risk of crossing ecological tipping points in the next 20–40 years. The forests most at risk are those in the far southwest of the

Fig. 3 Climate simulations for the ‘arc-of-deforestation’ pixels for the ‘business-as-usual’ scenario (BAU), governance scenario (GOV), BAU + deforestation of Cerrado (BAU + C), and GOV + deforestation of Cerrado (GOV + C) showing the relationship between vegetation type and rainfall regime. The suggested Cerrado climate border is maximum climatological water deficit -300 mm and annual precipitation <math>< 1,500\text{ mm}</math>



‘arc-of-deforestation’ within the borders of Bolivia, and in the northeast. This indicates a real need for regionally integrated planning for Amazonia and adjoining biomes in South America. Crucially, the analysis indicates that climate change in the Amazon will be significantly influenced by land use changes in surrounding ecosystems and

that, as a consequence, policy makers and conservationists must urgently develop integrated long-term plans that address issues of deforestation and land use transformation in both ecosystems.

These findings also challenge the results of Walker et al. (2009) who argue that desiccation-driven savannization is

not an immediate threat to the Amazon Basin. Their analyses failed to consider the potential importance of the deforestation of Cerrado in driving an increased water deficit. Thus, while we agree that the expansion of protected areas in the ‘arc-of-deforestation’ and other parts of the Amazon is absolutely vital, we also consider it essential that the Amazon forest biome should not be considered in isolation—the long-term ecological sustainability of extensive lowland rainforests on the southern and south-western borders of the Amazon basin also requires conservation of the adjoining Cerrado.

The synthesis of research on ecophysiological thresholds and meteorological modeling offers a powerful new way to identify the forest areas that are most at risk. This, in turn, allows decision-makers to develop pre-emptive plans to safeguard biodiversity and ecosystem services in these areas. For example, conservation planners may need to ensure measures to allow species range shifts and community re-assortments that will inevitably follow ecosystem transformation. Moreover, rare or endangered species that are unlikely to be able to adapt to the changing climate or biome characteristics can be identified (e.g., Lees and Peres 2006) and specific measures put in place to ensure their continued survival. More generally, an urgent political solution to continuing deforestation in the Amazon and the Cerrado should be sought. Some progress is being made in Amazonia through international climate agreements and the modification of supply chains (Nepstad et al. 2009). However, there is a danger that without conserving the Cerrado these interventions will not prevent wide-scale ecological transitions impacting vast tracts of rainforest.

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