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Climate Change as a threat to Brazil's Amazon forest

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ABSTRACT

Climate changes predicted for Brazilian Amazonia place much of the forest in danger of dieoff from the combined effect of drought and heat within the current century, and much sooner for some areas. Increases are expected in the frequency and magnitude of droughts from both the El Niño phenomenon and from the Atlantic dipole. These changes imply increased frequency of forest fires. Forest death from drought, fires or both would be followed by a transformation either to a savanna or to some type of low-biomass woody vegetation, in either case with greatly reduced biodiversity. This risk provides justification for Brazil to change its negotiating positions under the Climate Convention to accept a binding target now for national emissions and to support a low atmospheric concentration of carbon dioxide (400 ppmv or less) as the definition of “dangerous” interference with the climate system.

KEYWORDS: Global warming, Carbon, CO_2, Amazon forest, Tropical forest, Rainforest, Savannization, Mitigation, Adaptation, Reserves, Greenhouse effect, Brazil

I.) INTRODUCTION

Amazonian Forest and other ecosystems face serious threats from climate change. Projected changes lead to major increases in extreme events such as droughts and floods, as well as to shifts in mean precipitation and temperature to a dryer and hotter climate in Amazonia. The trends toward longer dry seasons and towards greater variability are more important than the shifts in the annual mean rainfall and temperature. The text that follows will briefly review projected climate changes in Brazilian Amazonia, their impacts, and priorities for mitigation and adaptation. More information is available at http://philip.inpa.gov.br.

II.) PROJECTED CLIMATE CHANGES

Several different changes in the climate system are expected to lead to hotter, dryer and more-variable climate in Amazonia. On a global scale, the result of increased warming from greenhouse gases will be (and already is) increased atmospheric water content and intense rainfall events (Trenberth et al., 2007, pp. 254-265). This is because, as the oceans warm, more water evaporates). However, with the exception of coastal areas, average rainfall in Amazonia is expected to be less, rather than more.

One reason for the expectation of less rain in Amazonia is the frequency of major El Niño events. These events, which are triggered by a warming of surface waters in the tropical Pacific Ocean, invariably lead to droughts in Amazonia, especially in the northern portion of the region. Roraima is the best-known location for forest fires from El Niño events, such as the Great Roraima Fire of 1997-98 (Barbosa & Fearnside, 1999).

El Niño events are already becoming more frequent. Since 1976 the frequency of these events has been greater, a statistically significant change noted by the Intergovernmental Panel on Climate Change (IPCC) since its 1995 report (Nicholls et al., 1996, p. 165). However, the IPCC was unable to reach agreement on whether this trend was caused by global warming until its last report in 2007, when a major advance was made. Examination of 21 global climate models showed that all by three of them predicted more frequent “El Niño-like conditions” with continued global warming (Meehl et al., 2007, p. 779). “El Niño-like conditions” refers to the patch of warm water in the Pacific, as distinct from El Niño itself, which refers to the pattern of droughts and floods in different places around the world. The models still do not agree on the second part – the connection between the Pacific sea-surface temperatures and the pattern of droughts and floods. However, for Amazonia, the significant question is the connection between the warm water in the Pacific and droughts in the Amazon region. The fact that the entire global pattern, with floods in Brazil’s state of Santa Catarina and droughts in Ethiopia, Indonesia and other places, is not reproduced consistently in today’s climate models does not make us any safer in Amazonia. Direct experience indicates a connection between warm water in the Pacific and El Niño droughts in Amazonia, as in the major events in 1982, 1997-98, and 2003. In other words, recognition of this connection for Amazonia does not depend on a climate model, but rather on direct observation.

It is important to recognize that different climate models show a variety of results for Amazonia. However, most of them show significantly dryer climate (Kundzewicz et al., 2007, p. 183). The model with the most catastrophic result for Amazonia is the Hadley Center model from the UK Meteorological Office (Cox et al., 2000). Unfortunately, this is also the model that achieves the best reproduction of the connection between Pacific water temperatures and Amazonian droughts (Cox et al., 2004). Although the Hadley Center model is known to exaggerate the temperature and the dryness of Amazonia’s current climate (Cândido et al., 2007), discounting the exaggeration (which is by about 30% in the case of drought) would still be far from sufficient to keep climatic parameters within the range of tolerance of Amazonian trees. The model’s predictions of massive dieoff would therefore not be altered. A recent revised version of the model indicates less dieoff than its predecessors (Gornall et al., 2011).

While El Niño droughts are provoked by warming waters in the Pacific, another kind of drought is caused by a patch of warm water forming in the southern part of the North Atlantic. This causes drought in the southern portion of the Brazilian Amazon, as in 2005 and 2010 (Lewis et al., 2011; Marengo et al., 2008, 2011). The increase in rainfall over the oceans is cleaning the air of aerosols, such as the dust from African deserts and the particulates from European pollution that normally form a pall over this part of the Atlantic. These aerosols have provided a sort of shield that prevents part of the solar radiation from reaching the ocean surface. With the cleaner air, this energy reaches the surface and warms the water. The observed rate of increase of the water temperature in this portion of the Atlantic is extremely rapid, having increased by 0.6 ºC over the 20 years from 1985 to 2005 (Evan et al., 2009). When this trend is combined with patterns such as the North Atlantic oscillation, the resulting increase in temperature peaks is much more rapid than the increase in El Niño events. The consequent droughts in southern Amazonia pose a significant threat to the forests in this area on a time scale of only a few decades (Cox et al., 2008).

Uncertainty in climate model predictions is substantial, especially for Amazonia. Predictions of temperature change are subject to much less uncertainty than are those for rainfall. However, the general agreement of models regarding dryer climate in Amazonia is quite robust, despite differences in predictions of how severe the changes would be and how long they would take to occur.

Although the differences among models in their results for Amazonia are a general reflection of the level of uncertainty, it is important to understand that not all models are equal. Some are more highly developed than others, especially for phenomena affecting a specific area such as Amazonia. There are also sources of uncertainty that affect all models equally, like the proverbial rising tide lifting all boats. Most important in this regard is "climate sensitivity", which refers to how much the average temperature of the planet would increase if the pre-industrial atmospheric concentration of 280 ppmv of CO_2 were doubled to 560 ppmv, a benchmark that is expected to be passed between 2050 and 2070 if current emissions trends continue. The most probable value for climate sensitivity is approximately 2.8°C, and values in this neighborhood are used in virtually all climate simulations, including those generating the well-known IPCC projection of 4°C of temperature increase by 2100. However, this parameter is subject to substantial uncertainty, and the probability distribution is not symmetrical: there is much more chance of the true value being much higher than much lower than the "most probable" value (Hegrl et al., 2006). In other words, the climate has a significant chance of warming much more than the "most probable" calculation predicts. It should be remembered that about 70% of our planet is covered with water, meaning that mean global temperature is heavily influenced by what happens over the oceans, where air temperatures would increase less than over the land. Continental areas, like Amazonia, would warm much more than the global average, be it the IPCC's estimate of 4°C by 2100 or be it more if the true value of climate sensitivity proves to be higher than 2.8. Recent reconstruction of temperature and atmospheric composition at the last glacial maximum have greatly reduced the probability of climate sensitivity exceeding 6°C (Schmittner et al., 2011).

The most important aspect of uncertainty is the question of how to interpret it in terms of policy decisions. A frequent reaction is to seize upon the existence of uncertainty as an excuse for delaying any action until after more research is done. George W. Bush, when he was president of the United States, used this as his rationale for not making any commitments to reduce that country's emissions or to make any of the costly changes that would be needed to achieve major reductions. The negative impact of postponing a reduction in emissions is enormous, and affects Amazonian forests (among many other consequences). The response to uncertainty should be precisely the opposite: to take even greater action to avoid possible impacts. This is the precautionary principle. In the case of uncertainty regarding the true value of climate sensitivity, mitigation and adaptation measures should be based on a mean temperature rise greater than 2.8°C, perhaps at the 95% probability limit. If one bases everything on the "most probable" value, with 50% of the probability distribution on each side of 2.8°C, one is accepting a 50% chance of warming by more than this amount, as if flipping a coin. This is an unacceptable risk for a catastrophic event, such as loss of the Amazon forest.

Climate change is expected to affect the mean values of parameters in Amazonia, with a close relation between increased mean temperature and decreased mean rainfall in model results for the region (Huntingford et al., 2004). However, the mean value of each parameter is not the only feature that is expected to change in a way that is damaging to Amazon forest. The length of the dry season is also expected to increase in the region (e.g., Salazar et al., 2007). The zones with different numbers of months of dry season are expected to shift into the interior of the region. Variability in rainfall amount and timing is also expected to increase, including greater frequency and severity of extreme events such as droughts. Increased variability is evident from recent events, such as the El Niños of 1982, 1997-98 and 2003, the Atlantic dipole events of 2005 and 2010, and the record high water level in Manaus in 2009 followed by a record low water in 2010. These changes are expected to have a greater impact on the forest than the changes in the mean values themselves.

III.) IMPACTS

Drought and heat act together to kill Amazonian trees because any plant requires more water at higher temperatures. Because rainfall is decreased (especially in the dry season) at the same time that the forest will be facing unprecedented peaks in temperature, many trees will not resist these periods of stress. The forest is affected in these periods both by trees halting their normal growth and by increased mortality. For example, the 2005 drought has been calculated to have caused massive net emissions of carbon through both biomass loss and retarded growth (Phillips et al., 2009). The potential of dryer, hotter conditions to kill Amazonian trees is dramatically demonstrated by edge effects under study for over 30 years in the Biological Dynamics of Forest Fragments (PDBFF) project north of Manaus. There 65,000 trees have been tagged, mapped and monitored, and 97% of them have been identified to species or morpho-species. The results show much higher tree mortality and tree damage near the forest edge, where the microclimate is dryer and hotter than inside the continuous forest (Laurance et al., 2006; Nascimento & Laurance, 2004). The greatest effect is for large trees, with individuals with at least 60 cm diameter at breast height decreasing dramatically near the edges at the same time that these large trees are increasing in frequency in the forest interior. The same effects have been found in a study near Santarém by the Large-Scale Atmosphere-Biosphere Experiment in Amazonia (LBA), where a hectare of the forest floor was covered with plastic panels to remove 60% of the rainwater from the plot. The same pattern occurred, with the large trees dying first and the forest losing its biomass and structure over the course of a few years (Nepstad et al., 2007).

The ranges of tolerance of many Amazonian trees are exceeded by the projected climate changes in the region. A study of 69 tree species with the most complete distribution data revealed that 43% of them had their current habitats rendered inappropriate for these species by 2095, considering the projections of the Hadley Center model (Miles et al., 2004).

Tree mortality from heat and drought, with the trees essentially dying of thirst, is the only factor included in model projections indicating catastrophic forest loss within the 21st Century (e.g., Cox et al., 2000, 2004). However, the real situation is made worse by the link of dry, hot conditions to the risk of forest fires. Forest fires in Amazonian forest are already a major mortality factor, with events during the El Niño of 1997-98 having provoked widespread fires in Roraima and other parts of the northern portion of Brazilian Amazonia (Alencar et al., 2004, 2006; Barbosa & Fearnside, 1999; Barlow et al., 2003; Nepstad et al., 2004). The 2005 Atlantic dipole event provoked unprecedented fires in Acre and neighboring areas in Bolivia (Brown et al., 2006; Pueyo et al., 2010; Vasconcelos & Brown, 2007). In addition, forest fires have a strong synergism with logging (which leaves dead wood in the forest from slash and from unintended tree mortality) and with human occupation, which increases the number of ignition sources (Cochrane et al., 1999, Cochrane, 2003; Uhl & Bushbacher, 1985; Nepstad et al., 1999, 2001).

The projected changes in climate regimes, especially the distribution of dry-season lengths, is expected to change significant areas that are currently occupied by Amazonian forests into areas appropriate for savannas, based on the relation between current climate and the current distribution of savanna and forest ecosystems (e.g., Oyama & Nobre, 2003). This process, known as “savannization”, would affect a substantial part of Amazonia, with at least the half of the region (*i.e*., Manaus to the east) becoming appropriate for savannas according to most of the climate models analyzed by Salazar et al. (2007). The climatic regime in these areas is close to a tipping point, with only a little change needed to provoke the transformation to a new equilibrium as a savanna or other non-forest ecosystem (Huytra et al., 2005; Malhi et al., 2008, 2009; Nepstad et al., 2008; Nobre & Borma, 2009). The result may be a low-stature woody vegetation instead of a savanna dominated by grasses with scattered trees. However, whether or not the result is a "savanna" in biological terms has little importance for policy decisions, as either case would be a great loss in many ways, including both carbon stock and biodiversity. However, at the diplomatic level, Brazil has attempted to deny a connection between global warming and risk of savannization, with the Brazilian delegation at the meeting that approved the summary for policy makers of the most-recent IPCC report having opposed inclusion of a mention of this link (FSP, 2007). Some biologists who were advising Brazilian delegation at that IPCC plenary meeting supported questioning the term "savannization" based on the possibility that the replacement vegetation might not fit the biological definition of a savanna. This would appear to be an ill-advised insistence on academic purism, at the expense of the practical impact of denying the existence of a major impact of climate change. The position of denial of a link between global warming and savannization is similar to the notorious denial of George W. Bush of the very existence of global warming while he was president of the USA. So long as the existence of the problem is denied, no serious action is needed to solve it. The first step is to admit that a problem exists, after which the appropriate measures will follow.

Drought and heat are not the only climatic disturbances of Amazonian forest. Flooding and the raising of water table during years with abnormally heavy rainfall also have negative effects on upland trees (e.g., Mori & Becker, 1991). The record flood of 2009 probably had these impacts on upland trees in areas that had not previously been flooded, or in areas that were flooded to unprecedented depths and for longer periods of time than had been the case under the prevailing climatic conditions. The importance of flooding is illustrated by results from CO_2 uptake measured at two towers monitored by the LBA program north of Manaus. Located only 11 km apart, researchers were surprised to see significantly different rates of carbon uptake between the two towers. The explanation found was that the tower with less carbon uptake is surrounded by land with a substantially larger proportion of low areas (*baixadas*) that are subject of flooding and elevated water tables (Araújo et al., 2002). The advent of radar remote sensing that is capable of seeing through clouds and forest vegetation has revealed that the area of Amazonian forest that is subject to temporary flooding is much larger than had been previously thought (Melack et al., 2004). These areas are likely to be subject to effects from climatic extremes with greater rainfall, for example in stronger La Niña years.

Terrestrial ecosystems are not the only ones that can suffer from climatic changes in Amazonia. Aquatic ecosystems suffer impacts from changes in the timing and heights of flooding in Amazonian rivers. In addition, hydroelectric dams are being promoted as a form of climate mitigation based on substituting electricity that would otherwise be generated by burning fossil fuels. Unfortunately, the view of these dams as "green" energy based on lack of greenhouse gas emissions is fallacious, as these dams are significant sources of gases, especially methane (e.g., Fearnside, 2005, 2008, 2011). These emissions give Amazonian dams a negative effect on global warming during many years. For example, in the case of Belo Monte and the first of the dams that have been planned for upstream water storage (the Babaquara Dam, renamed the "Altamira" Dam), would take 41 years to break even in terms of global warming impact, paying off the emission "debt" from the large amounts of methane and CO_2 emitted during the first few years (Fearnside, 2009a). Because of the threat from climate changes projected in Amazonia, we do not have 41 years to begin to mitigate global warming, and dams like this cannot be considered to be “green” energy. Dams have severe impacts on human populations (including indigenous peoples) in the affected areas. They also have impacts on aquatic biodiversity, as well as on the terrestrial ecosystems that are impacted by creating the reservoir.

Climate change has additional indirect impacts from migration of human populations, such as the migrations to Amazonia that have been provoked by droughts in Northeast Brazil ever since the drought of 1870. The construction of the Transamazon Highway, which was officially justified by the El Niño drought of 1970 with famine in Northeastern Brazil, began the “modern” period of deforestation in the Amazon region (Fearnside, 1984). Northeastern Brazil continues to be a major source area for migration to Amazonia, a factor that has led to massive deforestation in the central portion of the state of Pará (Fearnside, 2001a). Projected climate changes are expected to provoke further exodus of population from Northeastern Brazil as this region becomes generally drier (e.g., Kundzewicz et al., 2007) and as flooding from torrential rain events becomes more frequent, large uncertainties in the climate projections not withstanding (Christensen et al., 2007).

IV.) MITIGATION

The first priority must be the fight against global warming by reducing emissions so that additional warming will be avoided. This author has long argued for the importance of Brazil assuming a leadership role in combating global warming (Fearnside, 1995, 1999, 2001b). The danger to the Amazon forest posed by global warming provides justification for this, as do the impacts of a substantially more arid climate in northeastern Brazil, increased storm damage in coastal areas of southern Brazil, damage to agriculture in the regions that are currently most productive, among many other impacts. Brazil also has some of the world’s most cost-effective options for mitigation due to the majority of the country’s emission being caused by deforestation, most of which is destined for low-productivity cattle pasture that contributes little to the country’s economy and even less as a source of employment to support its population.

Unfortunately, Brazil has not yet assumed such a leadership role, despite a discourse claiming such leadership on the part of diplomatic and executive authorities. For example, Brazil only endorsed the definition of 2°C of temperature increase over pre-industrial levels as a definition of ‘dangerous’ climate change after over 100 countries had endorsed this definition. This is a critical definition because avoiding this benchmark is to be the basis of all mitigation commitments, as specified in Article 2 of the United Nations Framework Convention on Climate Change (UN-FCCC), better known as the “Climate Convention”. Although the 2°C limit was approved in Copenhagen in 2009 and confirmed in Cancun in 2010, the translation of this limit into a concentration of greenhouse gases has not yet been decided. The abrupt increase in the probability of Atlantic dipole droughts (such as that of 2005) if atmospheric CO_2 concentration exceeds 400 ppmv (Cox et al., 2008) should provide motivation for Brazilian diplomats to support a definition of 400 ppmv or less as “dangerous”. However, Brazil has yet to define its position on this key question that is currently under negotiation under the Climate Convention. The most frequently mentioned concentration is 450 ppmv, which corresponds to only a 50% probability of maintaining average global temperature below the 2°C limit (Meinshausen et al., 2009). Accepting a 50% probability of remaining below this temperature limit, which is roughly the limit for maintaining Amazon forest, is equivalent to flipping a coin to decide the fate of Brazil's most important resource.

Another area where Brazil needs to change its position is in its long-standing refusal to take on a target under the UN-FCCC. A target under the Convention means entering Annex I of the UN-FCCC and Annex B of the Kyoto Protocol, or of an equivalent agreement for the period from 2013 onwards. A target under the Convention implies consequences if the target is not met, in this case buying carbon credit from somewhere else to fulfill the commitment. A target under the Convention also is passed from one presidential administration in Brazil to the next: it cannot be reversed by a presidential decree or by a vote of the national congress. These are important differences from the "voluntary objective" that Brazil took to the Copenhagen conference, which would be a domestic objective without consequences for violation and, furthermore, the decision could be reversed at any moment (Fearnside, 2009b). Brazil's taking on a binding target under the Climate Convention would be a key advance in the struggle against global warming in helping convince other countries to do the same. Unfortunately, the most that Brazil was willing to do at COP-17 in Durban in 2011 was to express willingness to take on a target after 2020, but only if all of the rest of the world agreed to do the same.

Finally, the Brazilian government's plans for reducing emissions (Brazil, CIMC, 2008) are conspicuously lack mention of the most obvious change needed to bring about a reduction in deforestation, which is to refrain from building highways that would open up vast areas of forest that has heretofore been inaccessible to deforesters (Fearnside, 2009b). Most critical is the Manaus-Porto Velho (BR-319) Highway, which would link central Amazonia to the notorious arc of deforestation (Fearnside, 2006; Fearnside & Graça, 2006). These plans imply substantial carbon emissions (Barni et al., 2009; Fearnside et al., 2009). Highway construction plans need to be reduced in order to eliminate the inconsistency between the federal government's climate discourse and its Program for the Acceleration of Growth (PAC).

V.) ADAPTATION

Although mitigation, or measures to prevent global warming from occurring, cannot be curtailed in favor of adaptation, meaning measures to allow living with global warming and attempting to reduce its impacts, for example by building sea walls in the case of sea-level rise. However, there is warming that is expected to occur in the next 20-30 years that has already been committed by emissions that are now in the atmosphere but have not yet resulted in global climate stabilizing in a new equilibrium (Hare & Meinshausen, 2006). The delay is mainly caused by the long time lags involved in ocean warming. The warming that is already committed implies that provision for adaptation must also be made, especially for poor highly vulnerable countries such as many of those in Africa and on small islands. It will also affect Amazonia. Adaptation for human populations often involves moving out of the most heavily impacted areas, such as those affected by sea level rise (including portions of the lower Amazon). In interior areas, forest resources would be lost, while agriculture can adapt (within limits) by changes in crops and other adjustments. In high-rainfall areas in western Amazonia a reduction in precipitation would improve suitability for pasture and soybeans, implying other threats to the forest.

For adaptation with the purpose of maintaining Amazonian biodiversity, the question of reserve design is clearly important. Climate changes generally would require shifting of species ranges either towards the poles (i.e., to the south in the southern hemisphere) or upwards along altitudinal gradients. Such movements are limited in Amazonia because it is a vast area that lacks mountains in most parts of the region. Corridors of interlinked reserves would have to be laid out in a north-south orientation. However, the Central Amazon Corridor, which is the only one that was actually created of the five biological corridors originally planned by the Ministry of the Environment is in an east-west orientation. Biological corridors do not have a high probability of successfully saving Amazonian tree species due to the relatively flat topography and long distances that would have to be traversed in a short time, given the very rapid change in climate projected, for example, due to the Atlantic dipole. Corridors would have somewhat greater success for animal species that can migrate faster. Even in the absence of successful countering of range shifts, biological corridors are essential for maintaining the biological viability of populations in forest fragments spread throughout a largely deforested landscape. Most important are the "areas of permanent protection" (APPs), which Brazil's 1965 Forest Code has required along water courses (as well as on steep hillsides and hilltops). A "reform" of the Forest Code that is nearing approval by Brazil's National Congress in 2012 would greatly reduce these areas. One of the key alterations is to change in the water level from which the distances that must be protected are measured (from the high-water to the "regular" water mark), thereby completely eliminating many of these strips of forest. In addition to their hydrological functions, these riparian forests are the main form of biological corridor connecting forest patches. The loss of legal protection would be a major setback for maintaining biodiversity.

Reserves, including reserves that include traditional local populations, are the main tool for maintaining forest in the face of rapid habitat loss through deforestation. Having more and better-distributed reserves is also a high priority for minimizing the losses in the face of climate change. Because reserve creation becomes much more expensive and politically difficult once roads are built and migration to new areas in Amazonia is underway, the network reserves needs to be expanded rapidly before the opportunity is lost (Fearnside, 2011). Given the current state of deforestation in Amazonia, the priority at this stage in history needs to be placed firmly on reserve creation, as opposed to using conservation resources for the recuperation of degraded areas. There is no escape from the conclusion that massive investments must be made quickly in reducing the emissions themselves.

V.) CONCLUSION

The environmental services of Brazil's Amazon forest face serious threats from climate change, some of which appear already to be in evidence. While uncertainties in projections are considerable, the changes expected would result in extreme events far outside of the range of tolerance of many Amazonian species. The risk to forest and other ecosystems in Amazonia should provide ample justification for Brazil to take a much more active role in combating global warming, including taking on a binding commitment under the Climate Convention to reduce its own emissions.

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