Annual Progress Report to the LCLUC Program

Anthropogenic Landscape Changes and the Dynamics of Amazon Forest Biomass

Grant number: NCC5-290

Principal Investigators
Principal Investigator: William F. Laurance, Ph.D.
Biological Dynamics of Forest Fragments Project, National Institute for Amazonian Research (INPA), C.P. 478, Manaus, AM 69011-970, Brazil
Smithsonian Tropical Research Institute, Apartado 2072, Balboa, Republic of Panamá
Email: wfl@inpa.gov.br

Brazilian co-investigator: Rita Mequita, Ph.D.
Biological Dynamics of Forest Fragments Project, National Institute for Amazonian Research (INPA), C.P. 478, Manaus, AM 69011-970, Brazil
Email: rita@inpa.gov.br

Other Team Members
Heraldo Vasconcelos, Ph.D., Eduardo Ventincinque, Ph.D., Ana Albernaz, Ph.D., Susan Laurance, Henrique Nascimento, Carlos Rittl, Sammya D'Angelo, Ana Andrade, Marcelo Moreira, Tito Fernandes
Biological Dynamics of Forest Fragments Project, National Institute for Amazonian Research (INPA), C.P. 478, Manaus, AM 69011-970, Brazil

Bruce Williamson, Ph.D.
Department of Botany, Louisiana State University, Baton Rouge, LA 70803, USA

Scott Bergen
Department of Forest Science, Oregon State University, Corvallis, OR 97331, USA

Collaborators
Philip M. Fearnside, Ph.D.
Ecology Department, National Institute for Amazonian Research (INPA), C.P. 478, Manaus, AM 69011-970, Brazil

Mark A. Cochrane, Ph.D., Chris Barber
Basic Science and Remote Sensing Initiative, Michigan State University, East Lansing, MI 48823, USA

Dana Slaymaker, Ph.D., Chris Hayward
Department of Computer Science, University of Massachusetts, Amherst, MA 01224, USA

Abstract

This project is focused on assessing the effects of intensive land uses, such as habitat fragmentation, forest regeneration, selective logging, and fire, on biomass and carbon storage in Amazonian forests. Ancillary goals include developing GIS models to help predict the future condition of Amazonian forests, and assessing the effects of anthropogenic climate change and ENSO droughts on intact and fragmented forests. Ground-based studies using networks of permanent plots are being linked with remote-sensing data, including Landsat TM and AVHRR at regional scales, and high-resolution videography at local and micro-scales.

This project's specific objectives are quite eclectic and include: (1) determining the effects of habitat fragmentation on forest dynamics, floristic composition, and the various components of aboveground biomass; (2) assessing historical and physical factors that affect trajectories of forest regeneration and carbon sequestration; (3) evaluating the influence of soils and topography on aboveground biomass in intact forests; (4) assessing the short-term impacts of selective logging on aboveground biomass; (5) examining interactions between forest fragmentation and fire; (6) assessing litter dynamics in fragmented and continuous forests; (7) testing the hypothesis that intact Amazonian forests are functioning as a major carbon sink, using long-term (>20 year) data on forest structure and biomass; and (8) developing GIS models that integrate current spatial data on forest cover, deforestation, logging, mining, highways and roads, navigable rivers, vulnerability to wildfires, protected areas, and existing and planned infrastructure projects, in an effort to predict the future condition of Brazilian Amazonian forests over the next 20-25 years.

Keywords

Research fields: Carbon Cycle, Habitat Fragmentation, Policy

Geographic Area/ Biome: Amazonia

Remote Sensing: Aerial Photography, AVHRR, Landsat

Methods/Scales: GIS, Local Scale, Regional Scale

Questions, Goals, and Approaches

1) Which scientific questions will be addressed: This project is addressing all three of the possible LCLUC questions, although it is especially focused on determining the causes and consequences of land-use and land-cover change.

2) Proportion of social science in study: Approximately 10%

3) Proportions of themes in study: Carbon: 75%; GOFC: 25%

4) Goals for this performance period:

A) Integrate high-resolution videography of our study area with ground-based data on forest structure and biomass, within intact, fragmented, and secondary forests.
B) Produce a high-quality chronosequence of secondary vegetation types in the central Amazonian region based on Landsat TM imagery from 1983 to the present.
C) Complete a comparison of the impacts of regulated vs. unregulated commercial logging operations on aboveground biomass and forest architecture in the central Amazon.
D) Quantify all components of aboveground biomass in fragmented and continuous forests in our central Amazonian study area.
E) Complete studies on the incremental growth and biomass accumulation of marked trees in secondary forests.
F) Begin to assess the impacts of floristic changes (particularly a general shift from densely wooded old-growth species to light-wooded pioneers) on aboveground biomass in Amazonian forest fragments.
G) Complete an ongoing study of litterfall rates and factors influencing litter decomposition in fragmented and continuous Amazonian forests.
H) Complete a detailed, GIS-based investigation of major development trends, deforestation, and spatial patterns of forest fragmentation in the Brazilian Amazon.
I) Conduct long-term analyses of the biomass dynamics of tree and liana communities in fragmented vs. continuous Amazonian forests.
J) Continue a long-term study of aboveground biomass dynamics in intact Amazonian forests in order to test the hypothesis that these forests are functioning as a carbon sink.
K) Assess the interaction of fire and forest fragmentation in eastern Amazonian forests using multitemporal analyses of Landsat TM imagery.

5) Timeline and accomplishments

The timeline for the various objectives vary. Several will be completed in the next 2 years, although goals E, F, G, H, I, and J above will continue for longer periods (ranging from 3 to many years). Progress toward these objectives has generally been excellent.

6) Gaps and Issues: The only critical issue is the need for continued funding over the next 3-4 years in order to complete our longer-term studies.

7) Methods and approach: This study is based on integrating long-term, local-scale studies of fragmented, logged, regenerating, and intact forests, using permanent forest-mensuration plots, with larger-scale processes and patterns collected using remote-sensing imagery.

Progress to Date

Progress on this project has generally been excellent. During the past four years, team members have published **over 40 refereed articles** from LCLUC-related studies in leading scientific journals (e.g. *Science, Nature, Ecology, Forest Ecology and Management, Conservation Biology, Ecological Applications, Trends in Ecology and Evolution*). These papers have provided **many insights into carbon storage and dynamics in fragmented and continuous Amazonian forests**. Our publications have also helped to stimulate an important domestic and international **debate about the efficacy of current development schemes for the Brazilian Amazon**.

New Findings (a brief sampling)

1) Rainforest fragmentation leads to a substantial loss of live tree biomass, which is not replaced by increased recruitment of small trees and lianas (woody vines).
2) Carbon emissions from fragmented tropical forests worldwide could be as much as 150 million Mg per year.
3) Forest dynamics and carbon cycling are dramatically accelerated in fragmented forests.
4) Lianas increase sharply in abundance near forest edges, and may help explain the dramatically elevated rates of tree mortality in fragmented forests.
5) Large (>60 cm diameter) trees are especially vulnerable to forest fragmentation.
6) Forest fragmentation leads to a dramatic increase in fire vulnerability, especially in more seasonal areas of the Amazon basin. Surface fires can penetrate up to 2-3 km into fragment interiors.
7) Land-use history, age, and distance to primary forest are the main factors determining the trajectories of secondary forest succession and the kinetics of carbon sequestration.
8) The various components of live and dead aboveground biomass are fundamentally altered in fragmented forests.
9) Reduced-impact logging operations can result in substantially reduced forest damage and biomass losses.
10) Permanent monitoring plots suggest that intact Amazonian forests may be operating as a globally significant carbon sink.
11) Current plans for major highways and infrastructure projects in the Brazilian Amazon could sharply accelerate rates of forest loss and degradation and lead to large-scale fragmentation.

New Potential and Products

Our GIS models that have been designed to predict the future condition of Brazilian Amazonian forests are being continually refined and updated. These integrate much biophysical and land-use planning data for the region. These models have been largely responsible for a major national and international controversy in Brazil and have initiated an ongoing public debate about the future of Amazonian forests.

Conclusions

This LCLUC-funded project has made excellent progress but requires continued funding for at least 3-4 years to complete many projects in progress. It has been one of the most productive of all LBA- and LCLUC-related projects in terms of the quality and quantity of scientific output.

Peer-reviewed Publications

Laurance, W. F., S. G. Laurance, L. V. Ferreira, J. Rankin-de Merona, C. Gascon, and T. E. Lovejoy. 1997. Biomass collapse in Amazonian forest fragments. *Science* **278**:1117-1118.

Laurance, W. F., and C. Gascon. 1997. How to creatively fragment a landscape. *Conservation Biology* **11**:577-579.

Ferreira, L. V., and W. F. Laurance. 1997. Effects of forest fragmentation on mortality and damage of selected trees in central Amazonia. *Conservation Biology* **11**:797-801.

Laurance, W. F. 1998. Forest fragmentation: another perspective. *Trends in Ecology and Evolution* **11**:75.

Laurance, W. F., L. V. Ferreira, J. M. Rankin-de Merona, S. G. Laurance, R. Hutchings, and T. E. Lovejoy. 1998. Effects of forest fragmentation on recruitment patterns in Amazonian tree communities. *Conservation Biology* **12**:460-464.

Laurance, W. F. 1998. A crisis in the making: responses of Amazonian forests to land use and climate change. *Trends in Ecology and Evolution* **13**:411-415.

Laurance, W. F., L. V. Ferreira, J. M. Rankin-de Merona, and S. G. Laurance. 1998. Rain forest fragmentation and the dynamics of Amazonian tree communities. *Ecology* **79**:2032-2040.

Mesquita, R. C. G., S. Workman, and C. Neely. 1998. Slow litter decomposition in a *Cecropia*-dominated secondary forest of central Amazonia. *Soil Biology and Biochemistry* **30**:167-175.

Phillips, O. P., Y. Malhi, N. Higuchi, W. F. Laurance, et al. 1998. Changes in the carbon balance of tropical forests: evidence from long-term plots. *Science* **282**:439-442.

Laurance, W. F., S. G. Laurance, and P. Delamonica. 1998. Tropical forest fragmentation and greenhouse gas emissions. *Forest Ecology and Management* **110**:173-180.

Laurance, W. F., L. V. Ferreira, C. Gascon, and T. E. Lovejoy. 1998. Biomass decline in Amazonian forest fragments. *Science* **282**:1611a.

Laurance, W. F. 1998. Fragments of the forest. *Natural History Magazine,* July/August, 107(6), pp. 34-38.

Laurance, W. F., and P. Delamonica. 1998. Ilhas da sobrevivência na Amazônia. *Ciencia Hoje* (Brazil), September, 24(142), pp. 26-31.

Laurance, W. F. 1999. Gaia's lungs: Are rainforests inhaling earth's excess carbon dioxide? *Natural History Magazine* March/April, 108 (2), p. 96.

Laurance, W. F., P. M. Fearnside, S. G. Laurance, P. Delamonica, T. E. Lovejoy, J. M. Rankin-de Merona, J. Q. Chambers, and C. Gascon. 1999. Relationship between soils and Amazon forest biomass: a landscape-scale study. *Forest Ecology and Management* **118**:127-138.

Laurance, W. F., C. Gascon, and J. M. Rankin-de Merona. 1999. Predicting effects of habitat destruction on plant communities: a test of a model using Amazonian trees. *Ecological Application*s **9**:548-554.

Nelson, B. W., R. Mesquita, J. Pereira, S. Souza, G. Batista, and L. Couto. 1999. Allometric regressions for improved estimates of secondary forest biomass in the central Amazon. Forest Ecology and Management **117**:149-167.

Laurance, W. F., and P. M. Fearnside. 1999. Amazon burning. *Trends in Ecology and Evolution* **14**:457. (Reprinted as an editorial in *H.M.S. Beagle: Biomedical Web Net*, no. 67, 26 November 1999)

Laurance, W. F., and C. Gascon (editors). 1999. Ecology and Management of Fragmented Tropical Landscapes. Special issue of *Biological Conservation* **91(2-3)**:101-247.

Laurance, W. F. 1999. Introduction and synthesis. *Biological Conservation* **91**:101-107.

Laurance, W. F. 1999. Reflections on the tropical deforestation crisis. *Biological Conservation* **91**:109-117.

Mesquita, R. C. G. 1999. O impacto da remoção do dossel de uma mata secundária no crescimento de duas espécies de interesse econômico da Amazônia. In: Gascon, C. e Moutinho, P. (eds.) *Floresta Amazônica: Dinâmica, Regeneração e Manejo.* Cap. 17, pp. 261-276, INPA, MCT, Manaus, Brazil.

Williamson, G. B. , R. C. G. Mesquita, G. Ganade, e K. Ickes. 1999. Estratégias de árvores pioneiras nos neotrópicos. In: Gascon, C. e Moutinho, P. (eds.) *Floresta Amazônica: Dinâmica, Regeneração e Manejo.* Cap. 8, pp. 131-144, INPA, MCT, Manaus, Brazil.

Mesquita, R., P. Delamonica, and W. F. Laurance. 1999. Effects of surrounding vegetation on edge-related tree mortality in Amazonian forest fragments. *Biological Conservation* **91**:129-134.

Williamson, G. B., T. van Eldik, P. Delamonica, and W. F. Laurance. 1999. How many millenarians in Amazonia: sizing up the ages of large trees. *Trends in Plant Science* **10**:387.

Laurance, W. F. 2000. Do edge effects occur over large spatial scales? *Trends in Ecology and Evolution* **15**:134-135.

Laurance, W. F., P. Delamonica, S. G. Laurance, H. L. Vasconcelos, and T. E. Lovejoy. 2000. Rainforest fragmentation kills big trees. *Nature* **404**:836.

Laurance, W. F. 2000. Mega-development trends in the Amazon: implications for global change. *Environmental Monitoring and Assessment* **61**:113-122.

Laurance, W. F. 2000. Edge effects and ecological processes--are they on the same scale? *Trends in Ecology and Evolution* **15**:373.

Laurance, W. F. 2000. Cut and run: the dramatic rise of transnational logging in the tropics. *Trends in Ecology and Evolution* **15**:433-434.

Laurance, W. F., and H. L. Vasconcelos. 2000. A década da decisão para a Amazônia. *Ciencia Hoje* (Brazil), May, 27(160), pp. 59-62.

Williamson, G. B., W. F. Laurance, A. Oliveira, P. Delamonica, C. Gascon, T. E. Lovejoy, and L. Pohl. 2000. Amazonian wet forest resistance to the 1997-98 El Niño drought. *Conservation Biology* **14**:1538-1542.

Laurance, W. F. 2001. Tropical logging and human invasions. *Conservation Biology* **15**:1-2.

Laurance, W. F., D. Perez-Salicrup, P. Delamonica, P. M. Fearnside, S. D'Angelo, A. Jerozolinski, L. Pohl, and T. E. Lovejoy. 2001. Rain forest fragmentation and the structure of Amazonian liana communities. *Ecology* **82**:105-116.

Laurance, W. F., M. A. Cochrane, S. Bergen, P. M. Fearnside, P. Delamonica, C. Barber, S. D'Angelo, and T. Fernandes. 2001. The future of the Brazilian Amazon. *Science* **291**:438-439.

Laurance, W. F., G. B. Williamson, P. Delamonica, A. Olivera, C. Gascon, T. E. Lovejoy, and L. Pohl. In press. Effects of a strong drought on Amazonian forest fragments and edges. *Journal of Tropical Ecology*.

Bierregaard, R., C. Gascon, W. F. Laurance, and J. R. Rankin-de Merona. In press. Deforestation and forest fragmentation in the Amazon. In *Lessons from Amazonia: Ecology and Conservation of a Fragmented Forest* (R. O. Bierregaard, C. Gascon, T. E. Lovejoy, and R. Mesquita, eds.), Yale University Press, New Haven, Connecticut, USA.

Bierregaard, R. O., W. F. Laurance, C. Gascon, et al. In press. Principles of forest fragmentation and conservation in the Amazon. In *Lessons from Amazonia: Ecology and Conservation of a Fragmented Forest*.

Laurance, W. F. In press. Fragmentation and plant communities: synthesis and implications for landscape management. In *Lessons from Amazonia: Ecology and Conservation of a Fragmented Forest* (R. O. Bierregaard, C. Gascon, T. E. Lovejoy, and R. Mesquita, eds.), Yale University Press, New Haven, Connecticut, USA.

Laurance, W. F., M. Cochrane, S. Bergen, P. M. Fearnside, P. Delamonica, S. D'Angelo, C. Barber, and T. Fernandes. In press. The future of the Amazon. In *Tropical Rainforests: Past, Present, and Future* (E. Bermingham, C. Dick, and C. Moritz, eds.), University of Chicago Press, Chicago, Illinois, USA.

Monaco, L., Mesquita, R.C.G. and Williamson, G.B. In press. O banco de sementes de uma floresta secundaria dominada por *Vismia*. *Acta Amazonica.*

Williamson, G. B., and Mesquita, R.C.G. In press. Effects of fire on rain forest regeneration in the Amazon. In: Bierregaard et. al (eds.) *Lessons from Amazonia: Ecology and Conservation of a Fragmented Forest*, Yale University Press.

Laurance, W. F., T. E. Lovejoy, H. L. Vasconcelos, E. M. Bruna, R. K. Didham, P. C. Stouffer, C. Gascon, R. O. Bierregaard, S. G. Laurance, and E. Sampiao. In press. Ecosystem decay of Amazonian forest fragments: synthesis of a 22-year investigation. *Conservation Biology*.

Submitted Manuscripts

Laurance, W. F., and M. A. Cochrane. Submitted. Synergistic effects in fragmented landscapes. *Conservation Biology.*

Laurance, W. F., and G. B. Williamson. Submitted. Positive feedbacks among forest fragmentation, drought, and climate change in the Amazon. *Conservation Biology.*

Cochrane, M. A., and W. F. Laurance. Submitted. Fire as a large-scale edge effect in Amazonian forests. *Journal of Tropical Ecology.*

Malhi, Y., O.L. Phillips, T. Baker, S. Almeida, T. Frederiksen, J. Grace, N. Higuchi, T. Killeen, W. F. Laurance, et al. Submitted. An international network to understand the biomass and dynamics of Amazonian forests (RAIF). *Journal of Vegetation Science*.

Nascimento, H., and W. F. Laurance. Submitted. Total aboveground biomass in central Amazonian rainforests: a landscape-scale survey. *Forest Ecology and Management.*

O. L. Phillips, Y. Malhi, B. Vinceti, T. Baker, S. Lewis, N. Higuchi, W. F. Laurance, P. Núñez Vargas, R. Vásquez Martinez, S. Laurance, L.V. Ferreira, M. Stern, S. Brown, and J. Grace. Submitted. Changes in the biomass of tropical forests: evaluating potential biases. *Ecological Applications*.

Mesquita, R.C.G., Ickes, K., Ganade, G. and Williamson, G. B. Submitted. Alternative successional pathways in the Amazon Basin. *Journal of Ecology*.

Ganade, G., R. C. G. Mesquita, and K. Ickes. Submitted. Natural regeneration in secondary forests of central Amazonia: distance from the forest edge. *Journal of Tropical Ecology*.