Landscape fragmentation and forest fuel accumulation: Effects of fragment size, age, and climate

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Ariel Lugo, Director - IITF, USDA Forest Service

Abstract: Landscape fragmentation creates an increasingly complex environment in which to manage forests in the United States. The effects of fragmentation on productivity, mortality, and decomposition in forests vary with fragment size, forest type, and climate. Fragmentation can affect fuel accumulation, increase the spatial variability of fuel loads, and affect the susceptibility of forests to fire. Developing a landscape-scale picture of spatial variability in fuel loads requires an understanding of fragmentation effects at a variety of scales.

We propose to address the effect of forest fragmentation on fuel loads along gradients of climate, stand age, and fragment size. We will use a combination of remote sensing, field sampling and experimentation, GIS, multivariate analyses, and empirical modeling in order to quantify and compare fuel loads in fragments of different sizes (*e.g.* ha to km^2), ages (*e.g.* remnant, young to old secondary), and in different climates (*e.g.* tropical, temperate, and boreal).

Our goal is to develop methods to better predict and map fuel loads in fragmented forests and aid in management decisions on public forested lands. The research will be coordinated from USDA Forest Service Stations in Puerto Rico and the Pacific Northwest. We will conduct field work at sites in Puerto Rico, Oregon, and Alaska to investigate a climatic gradient defining a wide range of high biomass evergreen forest types found in the United States. Field studies, remote sensing analyses and mapping of fuel loads will focus on state and federal forests, experimental forest sites, and National Science Foundation Long term Ecological Research Sites in all three states.

Introduction

1) Project justification. Our national landscapes can be viewed as a mosaic of forested and unforested fragments that vary from region to region depending on climate, landuse, and fire history. Accelerating rates of fragmentation in a variety of forest types creates increasingly complex forest environments nationwide. Many public lands, including National Parks and Forests, military bases, parks, and riparian buffer zones, contain or are surrounded by forest fragments that widely vary in structure, function, biodiversity, habitat quality, and susceptibility to fires. It is widely acknowledged that forest structure and the spatial morphology and distribution of fragments can significantly affect fuel accumulation and fire frequency but remote sensing of fuel loads is difficult to accomplish in fragmented environments (Cummings 2001, Weir et al. 2000, Holdsworth and Uhl 1997). These complex landscapes require new tools and models to predict fuel loads within individual fragments and the effects of this fragmentation on fuel loading at a landscape level.

We propose to integrate remote sensing, field sampling and experimentation, multivariate analyses, and empirical modeling to characterize forest fragments at multiple scales. We will look at fuel load characteristics and landscape fragmentation along a climatic gradient that spans our national lands from tropical to boreal forests. Our goal is to improve methods for predicting fuel loads in order to guide decisions regarding resource allocation for both wildfires and prescribed fires.

This research will directly address the following tasks of the Joint Fire Science Program: Task 3: Fuel Management and Landscape Level Processes; Task 4: Remote Sensing; and Task 7: Decision Tools. In addition, the research will provide valuable information for Task 1.2: Managing Fuels in Areas with Restricted Access; and Task 6: Climate and Fuel Loads. The research combines efforts of four contributing scientists, four collaborating scientists, two USDA Forest Service Research Stations and a variety of research and experimental forests.

2) Project objectives. The research has two principal objectives; 1) To develop an understanding of the role of forest fragments in fire management by empirically defining relationships between fuel loads and fragment characteristics, and 2) to develop methodology that will allow managers to predict forest fragment-fuel load relationships at three spatial scales: within individual fragments, between fragments within a landscape, and between fragmented landscapes in different climatic regions. These objectives will be met by quantifying and comparing fuel loads in fragments of different sizes (*e.g.* ha to km^2), ages (*e.g.* remnant, young to old secondary), and in different climates (*e.g.* tropic, temperate, and boreal). Research activities to accomplish these objectives will follow these testable hypotheses:

Hypothesis 1: At the scale of individual fragments, fuel loads will be greater along fragment edges than centers (Fig 1). We predict that because of increased windthrow at edges, and microclimatic and environmental gradients from edge to center affecting productivity and decomposition (González and Seastedt 2001), fragment edges will have greater mortality and productivity and lower decomposition rates than fragment centers. This will result in greater fuel loads along fragment edges and increasing fuel load with increasing perimeter/area ratios. Experimental work on decomposition rates in fragment edges and centers will investigate mechanisms responsible for variation in fuel loads *i.e.* increased mortality and productivity *vs.* decreased decomposition rates. We will describe mathematical relationships that predict within-fragment variation in fuel loads by conducting ground-transect surveys in a range of fragments. This information will assist in the efficient allocation of resources when managing particular fragments (*e.g.* decisions regarding prioritization of fuel treatment areas, prescribed fires in areas of restricted access, Task 1.2 and Task 7).

Hypothesis 2: At the landscape scale within a given climatic regime, fuel loads will be greatest in fragments of mid- to late-successional forests and in those with high perimeter/area ratios. Forest age affects forest structure, composition, and fuel accumulation (Weir *et al.* 2000) and fragment size and morphology influence the accumulation of fuel loads by affecting forest composition, mortality, productivity and decomposition (Suanders *et al.* 1991, González *et al.* 2001). We will combine field measures of fuel loads, classification of forest age, and remote sensing of fragment morphology and distribution within a landscape in order to develop relationships to predict differences in fuel loads between fragments and allow the prioritization of fuel management activities at the landscape level (*e.g.* Task 3).

Hypothesis 3: At the regional scale, fuel loads in fragments will be greatest in moist temperate and dry to moist tropic forests, where ratios between temperature and precipitation (T/P) and annual evapotranspiration rates (AET) are at intermediate levels (Fig. 2). Climatic controls on productivity and decomposition regulate the amount of total aboveground biomass and the dead/live biomass ratio. By comparing fragment fuel loads in high biomass evergreen forests across climatic gradients we will identify geographic regions where fragment analysis is most critical to fire management activities (*e.g.* Task 4 remote sensing, Task 6 climate and long-range fire and land management planning).

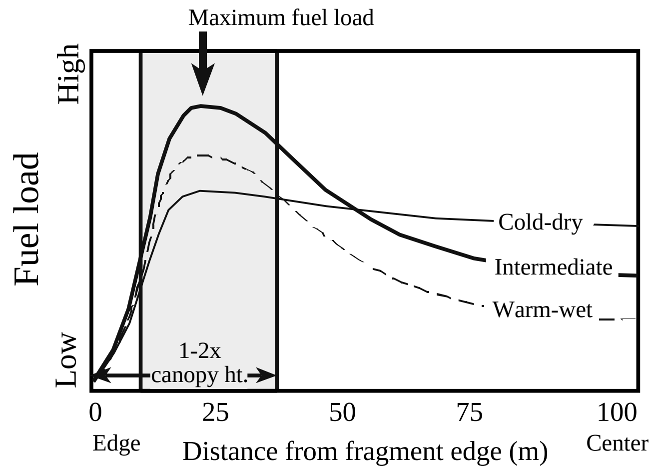


Figure 1. Fuel load will vary both with climate and with location relative to fragment edges. Maximum fuel loads will occur along fragment edges, within a zone one to two times the canopy height. Productivity (light availability) and mortality (windthrow) will be greatest in these regions. Additionally, productivity and decomposition will be highest in warm, wet environments, and lowest in cold dry environments (Gonzalez ands Seastedt 2001). We predict that the interaction of productivity, mortality, and decomposition will lead to peak in fuel loads in intermediate environments (moist temperate and dry to moist tropic forests) as measured by AET and T/P ratios.

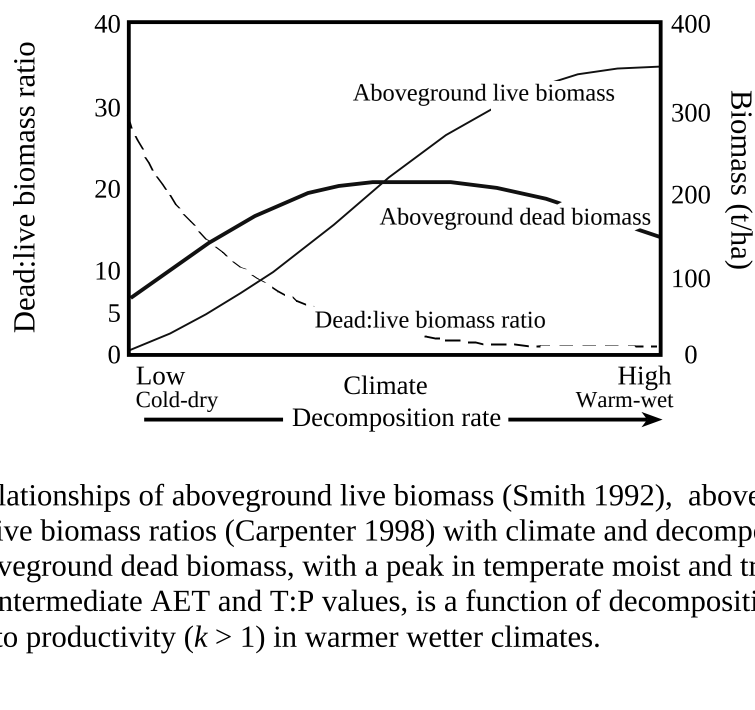


Figure 2. Relationships of aboveground live biomass (Smith 1992), aboveground dead biomass, and dead to live biomass ratios (Carpenter 1998) with climate and decomposition. Pattern of potential aboveground dead biomass, with a peak in temperate moist and tropical dry to moist forests with intermediate AET and T:P values, is a function of decomposition rates (*k*) increasing with respect to productivity ($k > 1$) in warmer wetter climates.

3) Background: The abundance and types of forest fragments is increasing as a result of current land management practices including the establishment of riparian buffer zones and migratory corridors and the abandonment of farmland. The importance of forest fragmentation on ecological processes and the conservation of biodiversity is widely acknowledged (Laurance and Bierregaard 1997, Turner *et al.* 1994). Nevertheless, little is known about how fuel loads vary within and between fragments. Although fire potential can be evaluated using climatic and fuel load variables, estimating fuel loads using readily available remote sensing techniques is difficult at best (Wessman and Asner 1998). Empirical data on the ecology of fragments suggest that forest composition, structure, and fuel loads are strongly related to the morphology of fragments (area, shape, and perimeter) (Didham and Lawton 1999). Remote sensing and field analyses of fragment fuel loads and spatial distributions can lead to better spatial prediction of fuel loads.

Fragments created by clearcuts and subsequent forest regeneration differ from continuous forest in that they increase the percentage of fragment edges relative to total forest cover and alter the proximity and connectivity of fragments (Ranta *et al.* 1998). The amount of forest edges is important in two ways: 1) edge structure differs from center structure due to differing environmental conditions and 2) edge structure affects fragment center structure. Edge structure may differ from fragment centers in terms of susceptibility to fire (Kellman *et al.* 1998) and tree mortality (Bierregaard and Lovejoy 1992), and edge area can exceed core area in fragmented forests (Ranta *et al.* 1998). Edge structure (open *vs.* closed) significantly affects fragment microclimate (Didham and Lawton 1999).

Fragmentation can affect fire frequency, increasing the length of the fire cycle in temperate regions (Weir *et al.*2000) and increasing fire susceptibility in tropical regions (Holdsworth and Uhl 1997, Cochrane and Schulze 1999). This is primarily due to alteration of fuel load patterns. Forest fragmentation creates a matrix of accumulated fuels in forest wildlands in two ways, 1) by increasing the diversity of forest types and ages, and 2) by increasing forest edges, which differ from core areas in composition, adaptivity to fire, fuel loading, and other ecosystem properties (Kellman *et al.* 1998). Quantifying this variation in terms of fuel load within forest types and the degree of difference in fuel load between forest edges and centers will allow spatially explicit mapping of fuel loads and prediction of the effects of forest fragmentation on fuel accumulation.

Fire potentials can be evaluated using existing software packages using that include climatic and fuel loading variables (Andrews 1986, 1989).

Understanding the relative importance of fragmentation on variation in fuel loading within a single climatic regime, and the variation in this relationship along climatic gradients, will improve our ability to manage forest fuel load and predict fire behavior in increasingly fragmented forest landscapes. This study represents a comprehensive approach to gaining this understanding in that it analyzes landscapes from tropical to boreal climates, analyzes patterns within fragments and landscapes, and investigates mechanisms controlling fuel load.

Materials and Methods

Our research plan involves three phases: *coordination* to insure unified remote sensing, landscape stratification, and field measures at all sites, *sampling and analyses* to provide the data to model and test relationships between fragmentation and fuel loading, and *implementation* to use our models to spatially predict fuel loads for our study areas, to prepare publications and reports on our findings, and to conduct workshops on new methods for integrating fragment analyses into fuel load estimates.

Coordination

Overview. The research will be conducted in Puerto Rico, Oregon, and Alaska in order to span a broad climatic gradient. These regions are highly suited for this research because they have a variety of public lands, dominated by high biomass evergreen forests, which are either fragmented themselves or are surrounded by fragmented landscapes. Broad study areas within each region have been selected to include a range of local environmental conditions (Table 1). Within each study area, specific landscapes were chosen across a range of forest age and degree of fragmentation. These study sites were selected from *a priori* knowledge of their ecology stemming from on-going cooperative research agreements and the depth of published information available from the various research forests. In turn, a subset of fragments in each landscape will be randomly selected for field surveys and model testing (Figure 3).

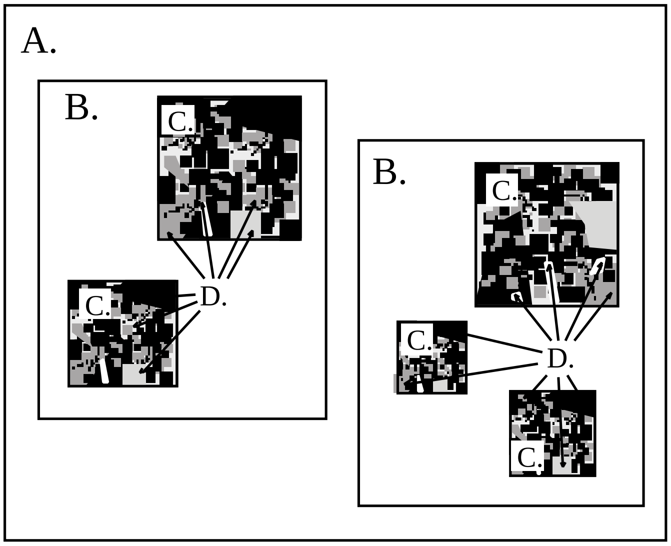
Sampled data will be evaluated using multiple regression analysis to develop models for predicting fuel loads within and between fragments. Modeled fuel loads will be spatially mapped and tested against field measures. Revised models, methods, and mapped results will be presented in publications and workshops conducted with land managers and collaborating and interested scientists (Table 2).

Table 1. Study regions, areas, and study sites with indications of forest types, and dominant physiography.

Study region	Study area	Potential study sites	Forest types	Physiography
Puerto Rico				
Wet tropics	NW PR	Caribbean National Forest (USDA-FS)	Wet-rain	Montane
		Sabana Seca (USN)	Moist	Coastal plain
		Roosevelt Roads (USN)	Moist to dry	Coastal plain
Dry tropics	SE PR	Salinas (US Army)	Moist	Foothills
		Cabo Rojo (USFW)	Dry	Coastal plain
		Guanica (DNR)	Dry	Foothills
Oregon				
Wet temperate	West Cascades	H.J. Andrews LTER	Wet-Moist	Montane
Dry temperate	East Cascades	Metolius Research Natural Area	Dry	Montane
Alaska				
Wet boreal	Coastal	Kenai National Refuge	Wet-moist	Coastal - Montane
Dry boreal	Interior	Bonanza CK LTER	Dry-moist	Interior plain

Table 2. Project timeline.

Activity	Location	Year 1	Year 2	Year 3
Data acquisition (RS and ancillary)	IITF	X		
Landcover classification	IITF, PNR, AK	X		
Field sampling and experimentation	IITF,	X	X	
	PNR, AK		X	
Statistical analyses and modeling	IITF		X	X
Mapping model output and testing	IITF			X
Workshops	IITF, PNR			X



A. Study regions:
PR, OR, AK
B. Study areas:
Northeast PR (wet tropic)
Southeast PR (dry tropic)
West Cascades, OR (wet temperate)
East Cascades, OR (dry temperate)
Interior AK (dry boreal)
Coastal AK (wet boreal)
C. Study sites:
Stratified by forest age, fragment size
State, federal, private forested lands
D. Sampling sites:
Randomly selected within stratified units
Approximately 900 sample sites

Figure 3. Schematic of sampling plan indicating a single study region (A), encompassing two study areas (B), with stratified study sites (C) on forested state and federal lands. These will include a variety of fragment sizes and forest ages. Sample sites (D) will be randomly selected within stratified units.

Landcover classification. Forest types will be identified by a combination of remote sensing analysis and interpretation of existing vegetation maps and ancillary data. Recent acquisitions of Landsat ETM+ imagery will be used and a simple land cover classification done to identify forested *vs.* unforested pixels within six target areas: tropical wet and dry, temperate wet and dry, and boreal wet and dry forests. We will characterize climate by both the annual evapotranspiration (AET) rate and temperature and precipitation ratios (T/P) for each region based on available climatic data. Forested areas will be classified by forest age based on spectral data as well as ancillary information including past land-use records and published vegetation maps.

Landscape Stratification. Within each landscape, candidate fragments will be systematically identified through a preliminary GIS analysis that includes climate, soil, remote sensing (Landsat TM) and management (USFS, BLM, and private) layers. The resulting set of fragments will span the full range of variability across these constraints. We will then classify this set of candidate fragments according to additional constraints: fragment characteristics (area, perimeter, shape, and nearest neighbor characteristics) and historical information (age and land use). Finally, we will stratify the fragments by age, size, morphology and distances to nearest neighboring forest fragments, and randomly select a subset for fieldwork. A second subset of fragments will be randomly selected from the remaining fragments for testing output from regression models. Our stratified sampling design across a range of landscapes in different climates will allow the prediction of fuel loads in fragments, across landscapes, and along climatic gradients.

Sampling and analyses

Field sampling. We will characterize each of the fragment size classes in each landcover type and the differences between fragment centers and edges in terms of the amount and characteristics of dead aboveground biomass and the dead/live aboveground biomass ratio. Within each fragment we will establish line transects that span each fragment and record the following: distance to fragment edge, coarse woody debris, fine woody debris, litter and soil characteristics, standing dead biomass, live biomass, canopy height, canopy coverage, dominant and codominant tree species. Fuel loads will be quantified in transects that dissect the fragments and will follow the methodology established by the USDA Forest Service National Forest Inventory and Analysis program now in progress.

Decomposition. A decomposition experiment will be conducted to measure decomposition rates of litter, coarse, and fine woody debris in a subset of fragments along the climatic gradient. Sampling will address the question of variation in decomposition rates in fragment edges and centers, in different forest ages, and along the climatic gradient. Measured quantities of fuel material will be place along transects at the time of initial field sampling and recollected after one and two year intervals. Initial mass and mass remaining will be measured from each sample to determine decomposition rates. Variation in decomposition rates will be analyzed with respect to variation in fuel load within and between fragments, allowing better predictions of environmental control on fuel loads.

Statistical analyses. Multiple regression analyses will be used to determine the correlations between AET, T/P, fragment size, forest type, fragment edge/center ratio, distance to nearest neighbor forested fragment and dependant variables making up components of fuel load: aboveground dead biomass (woody and nonwoody), coarse and fine woody debris, and aboveground live/dead biomass ratio. The degree of difference between edges and centers in terms of fuel load characteristics will be analyzed with respect to forest age and AET. Regression models will be developed to predict fuel load based on the independent variables most strongly correlated with fuel load.

Prediction and testing. Fuel load characteristics will be predicted and mapped for each target area and tested for accuracy using the subset of fragments sampled previously as a test set. We will assess the fuel load predictions in a variety of ways in order to measure both the accuracy of the regression models and the accuracy of mapped fuel loads. We will 1) determine the Pearson correlation between predicted and measured values, 2) determine chi-squared values for expected and observed fuel loads, 3) classify fuel loads into a set of categories (high to low), and use error matrix analyses (Congalton 1991, Muller *et al.* 1998) to assess the proportion of correctly classified fragments and 4) employ fuzzy set analyses (Gopal and Woodcock. 1994, Muller *et al.* 1998) which allow a degree of certainty to be expressed for each variable tested, to determine where predictions are most and least accurate. These analyses will be used to produce final regression models and fuel maps for our study areas.

Implementation

This phase of the research will involve integrating what we learn about the relationships between fragment size and morphology, forest type, decomposition rates, and fuel loads into spatially explicit maps of fuel loads with known degrees of accuracy, and the presentation of our findings in peer reviewed and technical publications and technology transfer workshops.

Products. Final maps of fuel loads will be prepared for the study areas. Peer reviewed publications will be prepared which address 1) fragmentation and fuel accumulation patterns at three scales: fragment, landscape, and regional, 2) the effects of fragmentation on fuel accumulation along climatic gradients, 3) the mechanisms controlling fuel accumulation in tropic, temperate, and boreal forests, and 4) methods for assessing and mapping fuel loads in fragmented forests. Technical reports will be prepared addressing 1) remote sensing data acquisition and analyses for landscape fragment analyses, and 2) methods for spatial prediction of fuel loads based on forest type and the degree of forest fragmentation. Workshops will be conducted in Puerto Rico and the Pacific Northwest Research Station to disseminate to land managers and interested scientists information on methods for measuring and mapping fuel loads in fragmented forest ecosystems.

Linkages

This project involves a variety of federal and academic personnel and research sites. The research will be primarily conducted at the International Institute for Tropical Forestry, USDA Forest Service, San Juan, Puerto Rico (Drs. Gould, González, Scatena). Oregon based field activities and workshops will be coordinated from the USDA Forest Service Pacific Northwest Research Station (Dr. Andrew Hudak) and sites will be investigated that encompass the H.J. Andrews Experimental Forest LTER (Dr. Barbara Bond, collaborator) and Melotius Research Natural Area (Dr. Beverly Law, collaborator). Alaskan field work will be conducted at the Bonanza Creek LTER (Dr. Marilyn Walker, collaborator) and the Anchorage area with in consultation with the Anchorage USFWS (Dr. Steve Talbot., collaborator).

Project Duration

The project duration will be 36 months beginning September 2001 and running through August 2004 (Table 2). The remote sensing analyses of all regions and field surveying of the Puerto Rican and Oregon landscapes will begin in year 1. During the second year, the field work in all regions will be conducted and completed. During the last year of the project, the analysis and synthesis will be conducted along with workshops with land managers and collaborating scientists.

References

Andrews P.L. 1986. *BEHAVE: fire behavior prediction and fire modeling system - BURN subsystem, PART 1.* Forest Service General Technical Report INT - 194, U.S. Department of Agriculture, Ogden, UT.

Andrews P.L. and C.H. Chase. 1989. *BEHAVE: fire behavior prediction and fire modeling system - BURN subsystem, PART 2.* Forest Service General Technical Report INT - 260, U.S. Department of Agriculture, Ogden, UT.

Bierregaard, R.O. and T.E. Lovejoy. 1992. The Biological Dynamics of Tropical Rainforest Fragments. *Bioscience*. 42: 859-866

Carpenter, S.R. 1998. Ecosystem Ecology. *In* Ecology. Dodson *et al.* editors. Oxford University Press. NY.

Cochrane M.A. and M.D. Schultz . 1999. Fire as a recurrent event in tropical forests of the Eastern Amazon: Effects on forest structure, biomass, and species composition.

Congalton, R.G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sensing of the Environment.* 37:37-46.

Cumming S. G. 2001. Forest type and wildfire in the Alberta boreal mixedwood: What do fires burn? *Ecological Applications.* 11:97-110.

Didham R.K., and J.H. Lawton. 1999. Edge structure determines the magnitude of changes in microclimate and vegetation structure in tropical forest fragments. *Biotropica*. 31:17-30.

González, G., R. Ley, S.K. Schmidt, X. Zou, and T.R. Seastedt. 2001. Soil ecological interactions: comparisons between tropical and subalpine forests. Oecologia.

González, G., and T.R. Seastedt. 2001. Soil fauna and plant litter decomposition in tropical and subalpine forests. Ecology. 82:955-962.

Gopal S. and C. Woodcock. 1994. Theory and methods for accuracy assessment of thematic maps using fuzzy sets. Photogrammetric Engineering and Remote Sensing. 60:181-188.

Holdsworth, A.R. and C Uhl. 1997. Fire in Amazonian selectively logged rainforest and the potential fort fire reduction. *Ecological Applications.* 7:713-725.

Kellman, M., R. Tackaberry, L. Rigg. 1998. Structure and function in two tropical gallery forest communities: implications for forest conservation in fragmented systems. *Journal of Applied Ecolog*y. 35:195-206.

Laurance W.F. and R.O. Bierregaard. 1997. Tropical Forest Remnants; ecology, Management and Conservation of Fragmented Communities. University of Chicago Press 616 pages.

Muller, S. V., D. A. Walker, F.E. Nelson, N.A. Auerbach, J.G. Bockheim, S. Guyer, and D. Sherba. 1998. Accuracy assessment of a land-cover map of the Kuparuk River basin, Alaska: considerations for remote regions. *Photogrammetric Engineering & Remote Sensing.* 64: 619-628.

Ranta, P., T. Blom, J. Niemelä, E. Joensuu, and M. Siitonen. 1998. The fragmented Atlantic forest of Brazil: size, shape and distribution of forest fragments. *Biodiversity and Cons.* 7:385-403.

Smith, R.L. 1992. *Elements of Ecology*, 3rd edition. Harper Collins Press. NY.

Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology. 5:18-32.

Turner, M., W. Hargrove, R. Gardner, and W. Romme. 1994. Effects of fire on landscape heterogeneity in Yellowstone National Park, Wyoming

Weir, J.M., E.A. Johnson, and K. Miyanishi. 2000. Fire frequency and the spatial age mosaic of the mixed-wood boreal forest in western Canada. *Ecological Applications.* 10: 1162-1177.

Wessman, C.A. and G.P. Asner. 1998. Ecosystems and the problems of large-scale measurements. *In* P. Groffman and M. Pace, editors. Successes Limitations, and the Frontiers in Ecosystem Ecology. Springer-Verlag, Berlin, Germany.

Deliverables

- Map products: Variation in fuel loads for 6 study areas - wet and dry tropical (PR), wet and dry temperate (OR), and wet and dry boreal (AK) forests: Year 3.
- Publications in peer-reviewed scientific journals on relationships between climate, forest fragmentation, and fuel loads: Years 2 and 3.
- Peer-reviewed Forest Service publication on protocol for evaluating the vulnerability of forest fragments to fire: Year 3.
- Workshop with local and federal resource managers on the evaluation of fuel loads and fire risks of forest fragments: Year 3.

Technology transfer

Two 2-day workshops will be arranged, one in Río Piedras, Puerto Rico at the International Institute of Tropical Forestry, USDA Forest Service, the second in Corvallis, Oregon at the Forestry Sciences Laboratory (FSL). The goal of these workshops will be to present techniques, map products, and regression models useful in spatially predicting fuel loads in fragmented forest ecosystems. Workshops will be organized by Bill Gould at IITF and Andrew Hudak in FSL. Invited participants will include Forest Service scientists, fire fighters, state and private forestry personnel, and collaborating and interested scientists.

List of cooperators

Bill Gould USDA FS - IITF, San Juan PR, project PI
Andrew Hudak USDA FS - PNW, Corvallis OR, co-PI
Fred Scatena USDA FS - IITF, San Juan PR, co-PI
Grizelle Gonzalez USDA FS - IITF, San Juan PR, co-PI
Marilyn Walker, USDA FS - PNW, Fairbanks AK, collaborator

Curriculum Vita

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Expertise and interests

Research and teaching in ecology with a focus on vegetation and plant community ecology, biodiversity patterns and ecosystem consequences, vegetation change, remote sensing analysis, hierarchical GIS spatial analyses, and mapping vegetation and ecosystem properties.

Education

1998 Ph.D. EPO Biology, University of Colorado–Boulder
1992 M.S. Plant Biology, University of Minnesota
1988 B.S. Biology, University of Minnesota

Positions

- National Science Foundation PFSMETE Fellow, University of Minnesota 1999-2001
  Postdoctoral fellowship to design curricula incorporating ecological research, undergraduate education, and indigenous ecological knowledge in arctic and tropic ecosystems.
- Adjunct Scientist, International Institute of Tropical Forestry, 2000-2001
  USDA Forest Service, developing *Tropic Field Ecology* course.
- Research Associate, University of Alaska Fairbanks, Inst. of Arctic Biol. 1999-2001
  Involved as co-PI on the Circumpolar Arctic Vegetation Mapping (CAVM) project with the Northern Ecosystem Analysis and Mapping Lab (NEAML).
- Instructor, University of Minnesota, Dept. of Ecology, Evolution and 1998-2001
  Behavior, Lake Itasca Forestry and Biological Station summer courses.
- Research Associate, University of Colorado, INSTAAR 1998-1999
  Involved as co-PI on the Circumpolar Arctic Vegetation Mapping (CAVM) project in the Tundra Ecosystem Analysis and Mapping Lab (TEAML).
- Graduate Research Assistant, University of Colorado 1996–1998
  Involved in research at Niwot and Toolik Lake LTER sites as well as the CAVM.
- Graduate Teaching Assistant, University of Colorado 1992–1997
- Graduate Teaching Assistant, University of Minnesota 1988–1992

Selected publications

Gould, W.A., D.A. Walker, M. Raynolds, H. Maier, S. Edlund, and S. Zoltai. In press Canadian Arctic Vegetation Mapping. *International Journal of Remote Sensing.*

Gould, W.A. 2000. Remote sensing of vegetation, plant species richness, and regional diversity hotspots. *Ecological Applications.* 10:1861-1870.

Walker, M.D., W.A. Gould, and F.S. Chapin III. 2000. Scenarios of biodiversity changes in arctic and alpine tundra. In: Chapin, F. S. III, O. Svala, and Janetos, *Scenarios of global biodiversity*, Springer-Verlag. In press.

Gould, W.A. and M.D. Walker. 1999. Plant communities and landscape diversity along a Canadian Arctic river. *Journal of Vegetation Science*, 10:537-548.

Gould, W.A. and M.D. Walker. 1997. Landscape scale patterns in plant species richness along an Arctic river. *Canadian Journal of Botany*. 75:1748-1765.

In review

Gould, W.A., D.A. Walker, M. Raynolds, H. Maier. Biophysical patterns along the climatic gradient from treeline to the high Arctic in Canada. In review, special issue for *JGR*. June, 2001.

Gould, W.A., D.A. Walker, D. Biesboer. Combining research and education: Bioclimatic zonation along a Canadian Arctic transect. In review, *Arctic.*

Walker, M.D., W.A. Gould, and D.A. Walker. Increased canopy cover and density in Alaskan Arctic vegetation. In review, *Proc. Nat. Acad. Sci.*

In preparation

Gould, W.A., G. Gonzalez, S Eyegetok, and L. Kamoayok. New land, old ways: teaching field ecology in Nunavut. In prep. for *Arctic.*

Gonzalez. G. and W.A. Gould. Soil fauna and vegetation along topographic and climatic gradients in the Canadian Arctic. In prep.

Gould, W.A., F. Daniëls, S. Edlund, A. Elvebakk, N. Matveyeva, D.A. Walker, and B. Yurtsev. Plant community composition along climatic, substrate and moisture gradients in the Canadian Arctic.

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Education

Ph.D., 1999, University of Colorado, Environmental, Population, and Organismic Biology
B.S., 1990, University of Minnesota, Ecology, Evolution, and Behavior
A.A., 1987, Itasca Community College (Grand Rapids, MN), Liberal Arts

Professional Experience

Research Associate, Department of Forest Science, College of Forestry, Oregon State University, Corvallis, OR, 06/00-present
Research Ecologist, Pacific Northwest Research Station, USDA Forest Service, Corvallis, OR, 04/99-present
Graduate Research Fellow, University of Colorado, Boulder, CO, 09/95-04/99
Graduate Teaching Assistant, Department of Environmental, Population and Organismic Biology, University of Colorado, Boulder, CO, 09/94-05/95
W.M. Keck Foundation Fellow, University of Colorado, Boulder, CO, 08/93-07/94
Secondary School Science Teacher, U.S. Peace Corps, Malawi, Africa, 07/90-07/92
Undergraduate Biology Laboratory Teaching Assistant, General College, University of Minnesota, Minneapolis, MN, 09/89-06/90

Publications

Hudak, A., Gregory, M., Ohmann, J., Mouer, M., Lefsky, M. and Cohen, W. Imputing species-level structural attributes from canonical relationships between environmental and forest inventory plot data. *Journal of Vegetation Science*, in prep.
Hudak, A.T., Lefsky, M.A. and Cohen, W.B. Geostatistical integration of lidar data with Landsat ETM+ imagery. *Remote Sensing of Environment*, in prep.
Hudak, A.T. and Brockett, B.H. Fire history of a South African savanna landscape, 1972-2000. *Conservation Ecology*, in prep.
Hudak, A.T., T.R. Seastedt and C.A. Wessman. Effects of bush encroachment on C and N pools in South African savanna. *Journal of Applied Ecology*, in review.
Byers, B., R. Cunliffe and A. Hudak. Linking the conservation of culture and nature: a case study of sacred forests in Zimbabwe. *Human Ecology*, in press.
Hudak, A.T. and C.A. Wessman. Textural analysis of high resolution imagery to quantify bush encroachment in Madikwe Game Reserve, South Africa, 1955-1996. *International Journal of Remote Sensing*, in press.
Hudak, A.T. and C.A. Wessman. (2000) Deforestation in Mwanza District, Malawi, Africa from 1981 to 1992 as determined from Landsat MSS imagery. *Applied Geography* 20(2): 155-175.
Hudak, A.T. (1999) Rangeland mismanagement in South Africa: failure to apply ecological knowledge. *Human Ecology* 27(1): 55-78.
Hudak, A.T. and C.A. Wessman. (1998) Textural analysis of historical aerial photography to characterize woody plant encroachment in South African savanna. *Remote Sensing of Environment* 66(3): 317-330.
Braswell, B.H., D.S. Schimel, J.L. Privette, B. Moore III, W.J. Emery, E.W. Sulzman and A.T. Hudak. (1996) Extracting ecological and biophysical information from AVHRR optical data: an integrated algorithm based on inverse modeling. *Journal of Geophysical Research* 101 (D18): 23,335-23,348.

Proceedings

Hudak, A.T. (2000) Quantifying bush encroachment in Madikwe Game Reserve, South Africa. Proceedings of the International Symposium on Remote Sensing of Environment, Cape Town, South Africa, CD-ROM.
Hudak, A.T., B.H. Brockett and C.A. Wessman. (1998) Fire scar mapping in a southern African savanna. Proceedings of the International Geoscience and Remote Sensing Symposium, Seattle, WA, CD-ROM.

Hudak, A.T. and C.A. Wessman. (1997) Textural analysis of aerial photography to characterize large scale land cover change. Proceedings of the ESRI Users Conference, San Diego, CA. http://www.esri.com/library/userconf/proc97/PROC97/TO650/PAP643/P643.HTM

Invited Talks

Hudak, A.T. Beyond the pretty pictures: some practical applications of remote sensing for characterizing land cover and land cover change. Department of Geography and Center for Institutional, Population, and Environmental Change, Indiana University, Bloomington, IN, 18 Jan 2001.

Hudak, A.T. and M.A. Lefsky. LIDAR, ADAR and other 'DARs'. Long Term Ecological Research Lecture Series, Forestry Sciences Laboratory, Corvallis, OR, 5 May 2000.

Hudak, A.T. Fire scar mapping in Madikwe Game Reserve. Presented at workshop entitled, "Land cover and land use change projects in Pilanesberg National Park and Madikwe Game Reserve." Pilanesberg National Park, South Africa, 5 Apr 2000.

Hudak, A.T. Using image texture to characterize bush density and quantify bush encroachment. Presented at workshop entitled, "Land cover and land use change projects in Pilanesberg National Park and Madikwe Game Reserve." Pilanesberg National Park, South Africa, 5 Apr 2000.

Hudak, A.T. Ecological causes and effects of bush encroachment in South African savanna. Presented at workshop entitled, "Using remote sensing technologies to monitor management impacts on vegetation structure in Madikwe Game Reserve." Madikwe Game Reserve, South Africa, 4 Apr 2000.

Hudak, A.T. Using spectral mixture analysis to estimate vegetation fraction. Presented at workshop entitled, "Vegetation structural characterization: tree cover, height and biomass." International Symposium on Remote Sensing of Environment, Cape Town, South Africa, 26 Mar 2000.

Hudak, A.T. Effects of overgrazing and fire suppression on woody overstory structure and species diversity in South African savanna. Long Term Ecological Research (LTER) Lecture Series, Forestry Sciences Laboratory, Oregon State University, Corvallis, OR, 7 Nov 1998.

Conference Presentations

<u>Oral</u>

Hudak, A.T., M.A. Lefsky, M. Berterretche and W.B. Cohen. Geostatistical integration of lidar and Landsat ETM+ data. USDA Forest Service Geospatial 2001 Conference, Salt Lake City, UT, 16-19 Apr 2001.

Hudak, A.T. and C.A. Wessman. Effects of woody plant encroachment on soil carbon sequestration in South African savanna. Ecological Society of America Conference, Spokane, WA, 8-12 Aug 1999.

Hudak, A.T. and C.A. Wessman. A textural index for characterizing heterogeneous savanna canopy structure from high resolution imagery. Ecological Society of America Conference, Baltimore, MD, 2-6 Aug 1998.

<u>Poster</u>

Hudak, A., M. Gregory, J. Ohmann, M. Moeur, M. Lefsky and W. Cohen. Comparison of two models for mapping tree structural and species diversity variables in western Oregon. U.S. Symposium of the International Association of Landscape Ecology, Tempe, AZ, 25-29 Apr 2001.

Hudak, A., M. Gregory, J. Ohmann, M. Moeur, M. Lefsky and W. Cohen. Predictive mapping of tree species basal areas from forest inventory and environmental data: a comparison of two models. Ecological Society of America Conference, Snowbird, UT, 6-10 Aug 2000.

Hudak, A.T. and B.H. Brockett. Fire scar mapping in Madikwe Game Reserve. Grassland Society of Southern Africa Conference, Cedara, KwaZulu-Natal, South Africa, 25-29 Jan 1998.

Hudak, A.T. and C.A. Wessman. Historical quantification of bush encroachment due to chronic overgrazing in South Africa savannas. GIS in the Rockies Conference, Denver, CO, 15-17 Sep 1997.

Hudak, A.T. and C.A. Wessman. Landscape variations in canopy FIPAR-VI relationships due to fire and phenology in a semi-arid South African savanna. Ecological Society of America Conference, Albuquerque, NM, 10-14 Aug 1997.

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Education:
1996-99 : Department of EPO Biology, University of Colorado Ph.D. - Soil Ecology
1994-96 : Department of Biology, University of Puerto Rico (UPR) MS - Biology (Ecology)
1989-93 : Department of Biology, UPR BS - Biology, Honors: Cum Laude

Professional Interests:
Soil Ecology and Biogeochemistry
Ecosystem Ecology
Ecology and Biology of Soil Fauna (earthworms and microarthropods)

Recent Grants and Fellowships:
Mary Pope Alles Botany Endowment Fellowship (1999)
Ph.D. Dissertation Grant, University of Colorado (1999)
Dean's Small Grant, University of Colorado (1998)
Richard C. and Marion B. Waugh Fellowship, University of Colorado (1998)
John W. Marr Fellowship, University of Colorado (1998)
EPO Biology Departmental Grant - University of Colorado (1997-98; 1998-99)
Biosphere and Atmosphere Research Training Program Fellowship, U. of Colo. (1996-1998)
Minority Research Centers of Excellence Fellowship, University of Puerto Rico (1993-1996)

Publications:
Theses:
González, G. 1999. Soil fauna, microbes and plant litter decomposition in tropical and subalpine forests. Ph.D. dissertation. University of Colorado at Boulder, CO.
González, G. 1996. Earthworm abundance and distribution pattern in two plant communities within a subtropical wet forest of Puerto Rico. M.Sc. thesis. University of Puerto Rico, Rio Piedras, PR.

Peer-reviewed articles:
González, G., R. Ley, S.K. Schmidt, X. Zou, and T.R. Seastedt. 2001. Soil ecological interactions: comparisons between tropical and subalpine forests. Oecologia.

González, G., and T.R. Seastedt. 2001. Soil fauna and plant litter decomposition in tropical and subalpine forests. Ecology. 82:955-962.

González, G., and T.R. Seastedt. 2000. Comparison of the abundance and composition of litter fauna in tropical and subalpine forests. Pedobiologia 44:545-555.

González, G. and X. Zou. 1999. Litter control on earthworm abundance in two communities within a subtropical wet forest in Puerto Rico. Biotropica 31(3):486-493.

González, G., and X. Zou. 1999. Earthworm influence on N availability and the growth of *Cecropia schreberiana* in tropical pasture and forest soils. Pedobiologia 43 (6):824-829.

González, G., X. Zou, A. Sabat and N. Fetcher. 1999. Earthworm abundance and distribution pattern in relation to plant communities within a subtropical wet forest of Puerto Rico. Carib. J. of Sci. 35(1-2):93-100.

Zou, X. and G. González. 1997. Changes in earthworm density and community structure during secondary succession in abandoned tropical pastures. Soil Biology and Biochemistry 29(3/4):627-629.

González, G., X. Zou and S. Borges. 1996. Earthworm abundance and species composition in abandoned tropical croplands: comparisons of tree plantations and secondary forests. Pedobiologia 40:385-391.

Zou, X., G. González, and D. Schaeffer. In review. Earthworm density as a measure of plant litter decomposition in terrestrial ecosystems. Environmental Review.

González, G., and W. A. Gould. In preparation. Soil fauna and plant communities along a Canadian arctic river.

Book chapters:

Zou, X., and G. González. In press. Chapter 11- Earthworms in tropical tree plantations: effects of management and relations with soil carbon and nutrient use efficiency. In: Management of Tropical Plantation Forests and their Soil Litter System. M. V. Reddy (ed.). Oxford University Press. New Delhi, India.

McDowell, W.H., R.B. Waide, N.V. Brokaw, G.R. Camilo, A.P. Covich, G. González, D.J. Lodge, C.M. Pringle, B.A. Richardson, M.J. Richardson, F.N. Scatena, D.A. Schaefer, W.L. Silver, J. Thompson, D. Vogt, K. Vogt, M. Willig, J. Zimmerman. In preparation. Chapter 3 - Geographic, Ecological, and Evolutionary Setting. In: Biocomplexity and disturbance: synthesis of long-term ecological research in the Luquillo Experimental Forest, Puerto Rico.

González G. In preparation. Soil organisms and litter decomposition. In: Modern Trends in Applied Terrestrial Ecology. R. S. Ambasht and N.K. Ambasht (eds.). Oxford University Press. New Delhi, India.

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Education

Doctor of Philosophy, 1987. Dept. of Geography and Environmental Engineering, Johns Hopkins University, Baltimore Maryland. Dissertation: "Sediment Budgets and Delivery in Suburban Watersheds".

Master of Arts, 1982. Dept. of Earth & Environmental Science, Wesleyan University, Middletown Connecticut. Thesis: "Patterns of Bedload Transport in the Connecticut River Estuary".

Bachelors of Arts, 1977. Dept. of Geology, San Francisco State University, San Francisco California. Senior Thesis: "A Fortran Computer Program for Calculating the CIPW Normative Mineral Suite".

Professional Experience

International Institute of Tropical Forestry, USDA Forest Service, Rio Piedras, Puerto Rico.
Research Hydrologist and Principal Scientist of Bisley Experimental Watersheds, 1987-present.
Acting Assistant Director, 1993. Ecosystem Group Leader GS-14, 1995-2000. Research Project Leader GS-15, 2000-present. Responsibilities include managing: 8 scientists plus 45 full-time employees; a US$ 3.6 million research budget; field and laboratory facilities; internal and cooperative research agreements, strategic planning and personnel issues.

Luquillo Long-Term Ecological Research Project, 1988-present. Principal Co-Investigator of NSF funded project 1988-2000. Investigator 2000-present. Responsibilities include: providing scientific leadership for the 30+ investigator program; coordinating research in aquatic ecology, geomorphology, and environmental history.

Adjunct Professor. Department of Biology, University of Puerto Rico. 1991-present.

Consulting Hydrologist and Geomorphologist (1978 to 1987).

- Century Engineering Inc., Towson, Maryland, 1985-1987; Urban and storm water hydrology.
- Foster Parents Plan Inc. 1983. Developed water and sanitation program for rural communities on the Pacific coast of Colombia near Ecuador.
- U.S. Peace Corps, Malawi, Central Africa, 1982. Developed watershed management and community water supply programs.
- Church World Services Dominican Republic, 1978-1979. Community water development.

U.S. Peace Corps Volunteer, 1977-1979. Hydrologist, National Institute of Potable Water and Sewage, Dominican Republic, Municipal water resource development.

Selected Publications

Scatena F.N. 1990. Selection of Riparian Buffer Zones in Humid Tropical Steeplands. In R.R. Ziemer, C.L. O'Loughlin, L.S. Hamilton, eds. Research Needs and Applications to Reduce Erosion and Sedimentation in Tropical Steeplands: IAHS-AISH Pub. No. 192: 328-337.

Scatena F.N., Larsen, M.C. 1991. Physical Aspects of Hurricane Hugo in Puerto Rico. Biotropica 23, 4a:317-323.

Scatena F.N., Silver W.L., Siccama T. G., Johnson A.G., Sanchez M.J., 1992. Biomass and Chemical content of the Bisley Watersheds, Luquillo Experimental Forest, Puerto Rico. Biotropica 25:15-27.

Scatena F.N., Doherty S.J., Odum H.T., 1994 The value of water in a Puerto Rican forest. Page 35-36. Proceedings of the International Society for Ecological Economics, Costa Rica.
Scatena F.N., Lugo A.E. 1995. Geomorphology, disturbance, and the soil and vegetation of two subtropical wet steepland watersheds of Puerto Rico. Geomorphology, 13:199-213.
Scatena F.N., 1995. Relative scales of time and effectiveness of watershed processes in a tropical Montane Rain Forest of Puerto Rico. In J.E. Costa, A.J. Miller, K.W. Potter, P, Wilcock (eds.). Natural and Anthropogenic Influences in Fluvial Geomorphology. American Geophysical Union Geophysical Monograph 89:103-111.
Scatena F.N., Walker R.T., Homma A.K.O., 1996. Farm-level landuse dynamics in the piedmont landscape of the Brazilian Amazon: A case study from Santarem, Para, Brazil. Ecological Economics V 18: 29-40.
Scatena F.N., Moya S., Estrada C., Chinea J.D., 1996. The First Five Years in the Reorganization of Aboveground Biomass and Nutrient Use Following Hurricane Hugo in the Bisley Experimental Watersheds, Luquillo Experimental Forest, Puerto Rico. Biotropica V 28, #4a: 424-440.
Scatena F.N., 1997. Integrated Watershed Management in Northeastern Puerto Rico. Pages 252-256 in Proceedings of the Seminar on Integrated Water Resources Management: Institutional and Policy Reform. The Caribbean Council for Science Technology of the United Nations Economic Commission for Latin America and the Caribbean.
Scatena F.N. 1998. Climate change and the Luquillo Experimental Forest of Puerto Rico: Assessing the impacts of various climate change scenarios. American Water Resources Assoc. Proceedings, Third International Symposium on Tropical Hydrology. P. 193-198.
Scatena F.N., Johnson S., 2000. Instream Flow Analysis for the Luquillo Experimental Forest, Puerto Rico. USDA Forest Service General Technical Report. In press.
Scatena F.N., Doherty S., Odum H.T., Karecha P. 2000. Emergy Evaluation of Puerto Rico and the Luquillo Experimental Forest. USDA Forest Service General Technical Report. In press.

Book Chapters

Scatena F.N., 1995. The management of Luquillo Cloud Forest ecosystems: irreversible in a non-substitutable ecosystem. Chapter 21 In L.S. Hamilton, J. Juvik, F.N. Scatena, editors. Tropical Montane Cloud Forests. Ecological Studies 110. Springer-Verlag, pp 296-309.
Scatena F.N., 1998. A comparative ecology of the Bisley Biodiversity Plot and Experimental Watersheds, Luquillo Experimental Forest, Puerto Rico. Chapter 11 pages 213-230 in, Forest Biodiversity in North, Central and South America and the Caribbean: Research and Monitoring. F. Dallmeier, J.A. Comisky editors. Parthenon Press pages 213-230.
Scatena F.N., 2000. Future Trends and Research Needs in Managing Forests and Grasslands as Drinking Water Sources. Chapter 21 p. 197-201. In Drinking Water from Forest and Grasslands–A Synthesis of the Scientific Literature, G. E. Dissmeyer. Editor. USDA Forest Service General Technical Report SRS-39, 248 pp.
Scatena F.N., 2001. Geomorphic hierarchies and the vegetation of humid tropical forests in Latin America. Chapter for Neotropical Human Tropical Forests, M.R. Guariguata *ed.* In press.
Scatena F.N., Planos E., Schellekens J., In final review. Impacts of natural disturbances on the hydrology of tropical forests. International Hydrological Programme Volume on Hydrology of Humid Tropical Forests.