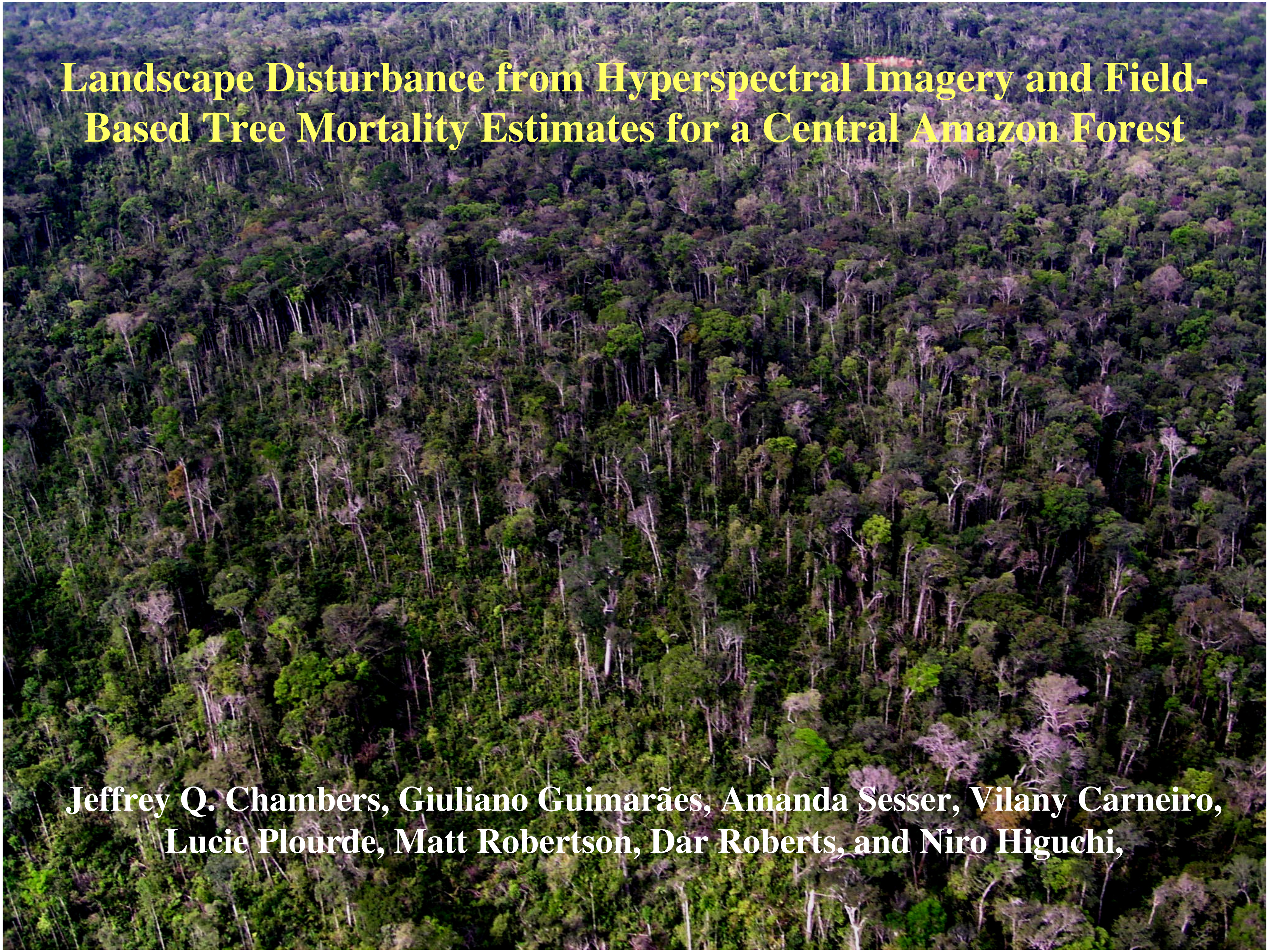

Landscape Disturbance from Hyperspectral Imagery and Field-Based Tree Mortality Estimates for a Central Amazon Forest

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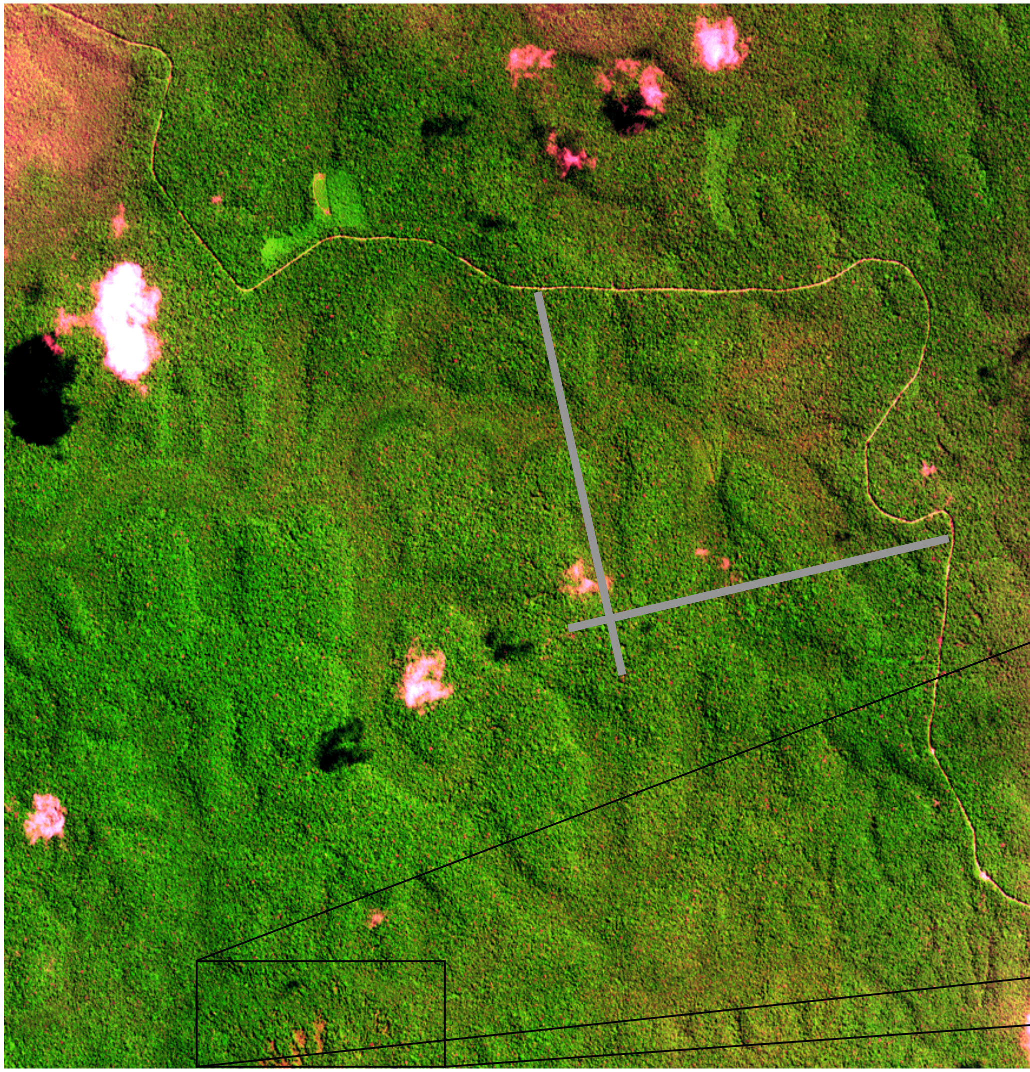
Background

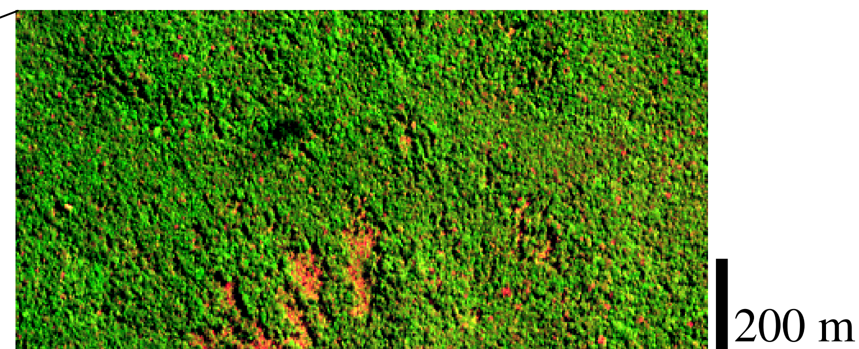
- **Forest inventory plots provide little information on catastrophic (gaps > 0.1 ha) mortality events.**
- **Example: Of 1284 gaps studied by Hubbell et al. (1999), only 9 were larger than 0.04 ha with the largest gap occupying just 0.11 ha (1100 m^2).**
- **Conversely, Nelson et al. (1994) detected large natural gaps > 30 ha in size (*blowdowns* produced by high-velocity downburst winds) using spectral reflectance differences in Landsat TM images across the entire Brazilian Amazon.**
- **In the Nelson et al. (1994) study, only 19 blowdown patches had spectral properties indicative of new clearings, occupying 0.4% of scene area, leading Nelson et al. to predict that if these patches formed over a two-year period, and events did not strike the same area twice, forest turnover by large blowdowns would take about 5000 years [1/(0.0004/2)].**
- **However, in a more detailed analysis of one TM scene, inclusion of smaller blowdowns (5-30 ha) increased the number of disturbed patches by an order of magnitude.**
- **There is a critical gap in studies of blowdowns and other catastrophic mortality events at the 0.1 to 5 ha, and this intermediate scale may be important for many ecological processes including the maintenance of tree species diversity and landscape carbon balance.**

Catastrophic Tree Mortality and Microburst Winds

IKONOS image of a blowdown in the Central Amazon. Each large patch is 2-3 hectares in size, where most trees were instantly razed by intense downdraft winds from a microburst.

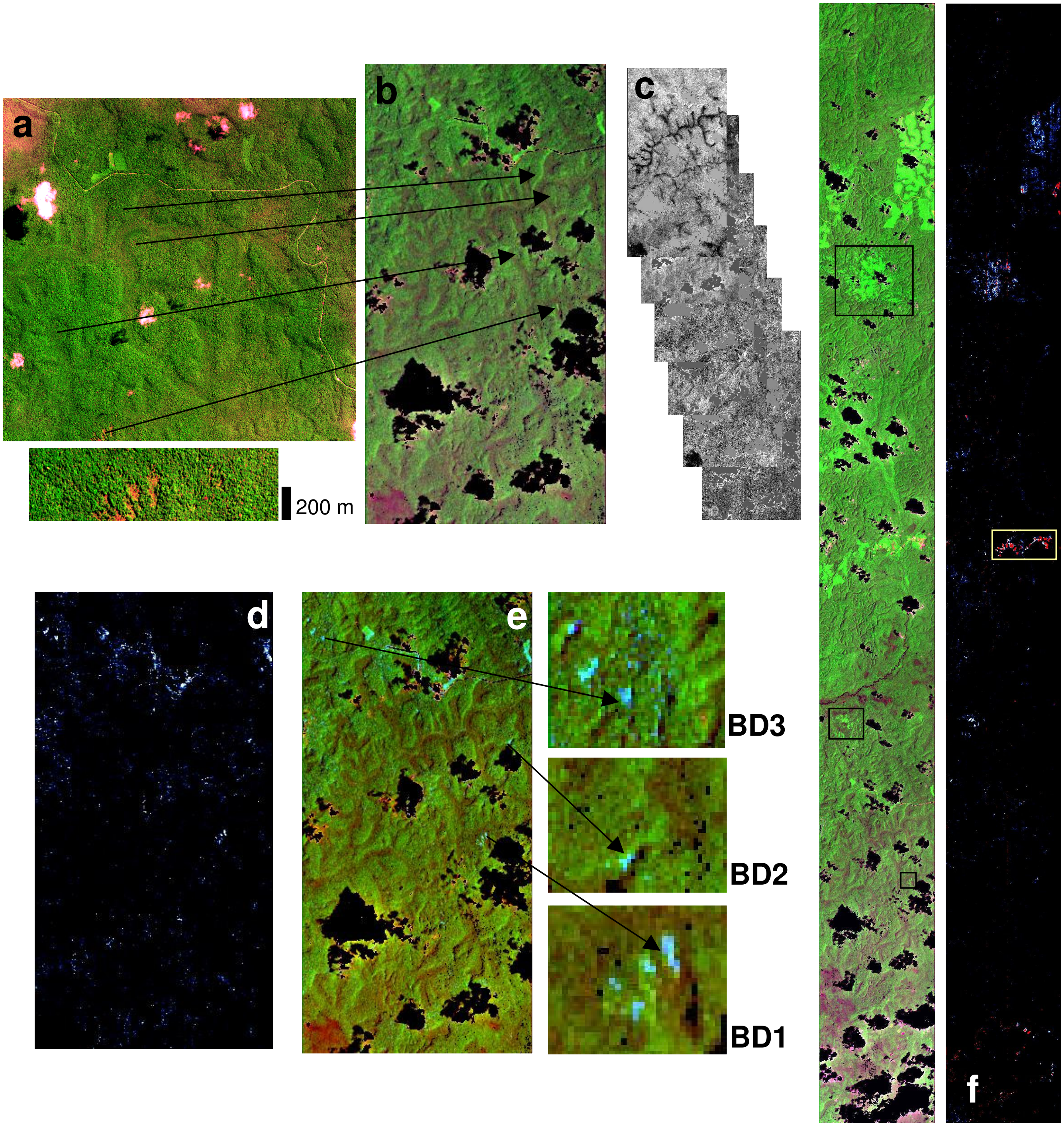
Grey bars indicate permanent forest inventory plots managed by INPA (2.5 km long), and the road is referred to as ZF-2.





IKONOS image

Severe downdraft winds often associated with late dry season storms



Spectral unmixing using image-derived endmembers:

a Ikonos image blowdown detection.

b Mapping blowdown onto Hyperion image captured 3 years after event.

c Reducing spectral data to lowest number of orthogonal data dimensions; transformed bands to generate pixel purity index (PPI).

d Mapping out relative abundance of blowdown vegetation.

e Identifying field sites for forest inventories

f Mapping out blowdown vegetation at the across the landscape

Species List for Hyperion-Identified Blowdown

No	DBH	Family	Species
1	6.8	Melastomataceae	*Bellucia dichotoma* Cogn.
2	5.7	Rubiaceae	*Capirona dicorticans* Spruce
3	8.5a/7.6b	Flacourtiaceae	*Casearia pitumba* Sleumer
4	16.6	Cecropiaceae	*Cecropia sciadophylla* Mart.
5	13.5	Cecropiaceae	*Cecropia sciadophylla* Mart.
6	7.5	Cecropiaceae	*Cecropia sciadophylla* Mart.
7	7.5	Cecropiaceae	*Cecropia sciadophylla* Mart.
8	7.2	Cecropiaceae	*Cecropia sciadophylla* Mart.
9	5.3	Cecropiaceae	*Cecropia sciadophylla* Mart.
10	6.7	Cecropiaceae	*Cecropia sciadophylla* Mart.
11	10.7	Euphorbiaceae	*Conceveiba* cf. *guianensis* Aubl.
12	8.8	Euphorbiaceae	*Croton draconoides* Müll. Arg.
13	9.4	Euphorbiaceae	*Croton lanjouwensis* Jabl.
14	5.9	Euphorbiaceae	*Croton lanjouwensis* Jabl.
15	5	Euphorbiaceae	*Croton lanjouwensis* Jabl.
16	5.2	Lecythidaceae	*Eschweilera coriacea* (DC.) Mart. ex Berg.
17	7	Lecythidaceae	*Eschweilera grandiflora* (Aulb.) Sandwith
18	18.3	Lecythidaceae	*Eschweilera rhododendrifolia* (Kunth) A.C.Sm.
19	11.4	Lecythidaceae	*Eschweilera tessmannii* Kunth
20	5.2	Myrtaceae	*Eugenia* sp.
21	10.4	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.
22	9.2	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.
23	7.2	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.
24	7.1	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.
25	5.5	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.
26	13.5	Annonaceae	*Guatteria* sp. 3
27	13.6	Moraceae	*Helicostylis tomentosa* (Planch. & Endl.) Rusby
28	5.7	Leg. Mimosoideae	*Inga paraensis* Ducke
29	6.5a/5.8b	Leg.Mimosoideae	*Inga pezizifera* Benth.
30	8.4	Leg. Mimosoideae	*Inga* sp
31	5.4a/4.6b	Leg. Mimosoideae	*Inga thibaldiana* DC. ssp. *thibaldiana*
32	8.7	Violaceae	*Leonia glycycarpa* Ruiz & Pav.
33	5.1	Melastomataceae	*Loureya spruceana* Benth. ex Triana
34	18.6	Euphorbiaceae	*Mabea speciosa* Müll. Arg.
35	14.6	Euphorbiaceae	*Mabea speciosa* Müll. Arg.
36	7.6	Leg. Caesalpinioideae	*Macrolobium* sp. 2
37	14.6	Sapotaceae	*Micropholis venulosa* (Mart. & Eichler) Pierre
38	6.8	Olacaceae	*Minquartia guianensis* Aubl.
39	9.2	Myrtaceae	*Myrcia* cf. *fallax* (Rich.) DC.
40	11.5	Nyctaginaceae	*Neea floribunda* Poepp. & Endl.
41	9.6	Cecropiaceae	*Pourouma ferruginea* Standl.
42	29.2	Cecropiaceae	*Pourouma ovata* Trécul
43	9.7	Sapotaceae	*Pouteria venosa* (Mart.) Baehni ssp. *amazonica* T.D.Penn
44	8	Sapotaceae	*Pouteria venosa* (Mart.) Baehni ssp. *amazonica* T.D.Penn
45	6.6	Burseraceae	*Protium apiculatum* Swart
46	6.8	Burseraceae	*Protium* cf. *rubrum* Cuatrec.
47	8.2	Burseraceae	*Protium spruceanum* (Benth) Engl.
48	7.6	Burseraceae	*Protium spruceanum* (Benth) Engl.
49	9.1	Annonaceae	*Rollinia insignis* R.E.Fr.
50	9.1	Annonaceae	*Rollinia insignis* R.E.Fr.
51	12.4	Leg. Caesalpinioideae	*Sclerolobium* sp. 6
52	6.3	Siparunaceae	*Siparuna glycycarpa* (Ducke) S.S.Renner
53	6	Siparunaceae	*Siparuna poeppigii* (Tul.) A.DC.
54	6.2	Siparunaceae	*Siparuna sarmentosa* Perkins
55	7	Leg. Papilionoideae	*Swartzia reticulata* Ducke
56	6.4	Sapindaceae	*Talisia* cf. *praealta* Radlk
57	6.3	Clusiaceae	*Vismia guianensis* (Aubl.) Choisy
58	6.1	Clusiaceae	*Vismia guianensis* (Aubl.) Choisy
59	5.5	Clusiaceae	*Vismia guianensis* (Aubl.) Choisy
60	5.5	Leg. Mimosoideae	*Zygia racemosa (*Ducke) Barneby & J.W.Grimes

Classic pioneer species in genera *Cecropia* and *Vismia* represented 20% of stems > 5 cm DBH in this initial 400 m² plot, whereas in a nearby 9 ha plot these genera were only 1.3% – other blowdown sites has similar species composition.

Comparing Blowdown and Primary Forest Tree Species Composition and Structure

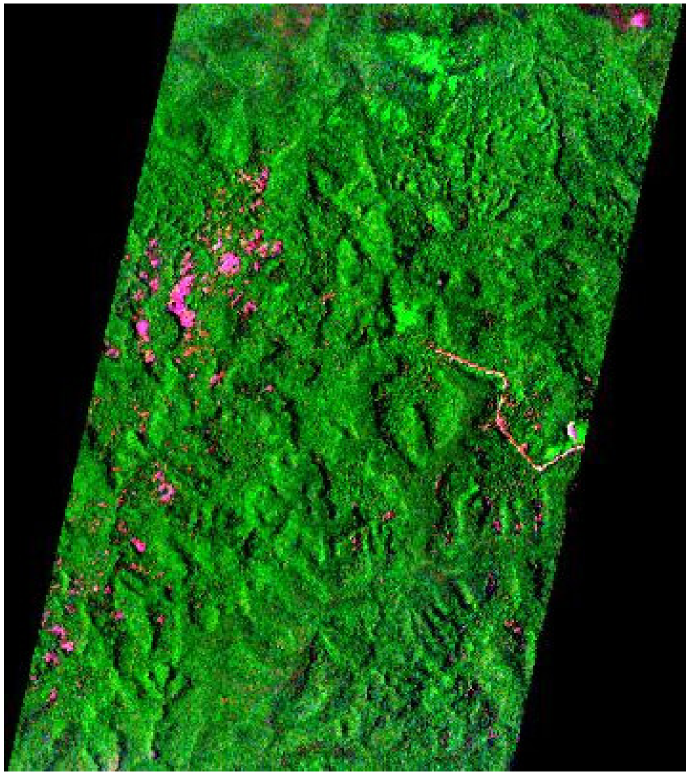
Variables	Blowdown plots		Primary plots
Shannon's *H'*	4.71		4.16
Wood density	0.55	*	0.71
Basal area	1541.37	*	2991.82
Stem density	1525		1217

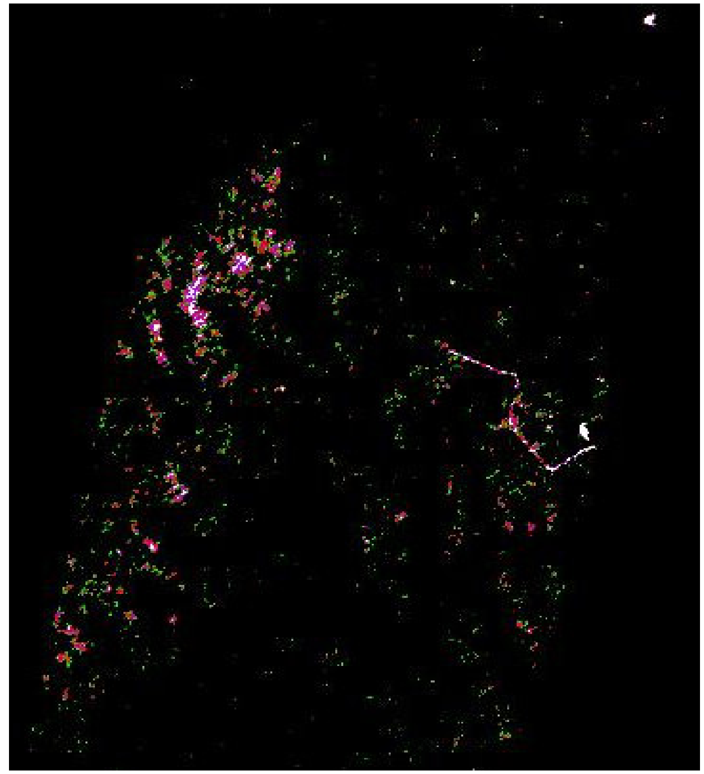
Table 2. Mean similarities of forest type comparisons using Sorenson's coefficient of similarity[a]

Comparisons between plot combinations:	Mean Sorenson's similarity and range
Blowdown x primary	0.059 (0.025 - 0.113)
Blowdown x blowdown	0.119 (0.086 - 0.160)
Primary x primary	0.115 (0.100 - 0.122)

[a] Means are compared using t-tests. All plot comparisons show significantly different mean values ($P < 0.05$) with the exception of blowdown x blowdown compared to primary x primary means.

Sampling the Disturbance Gradient Employing RS Metrics





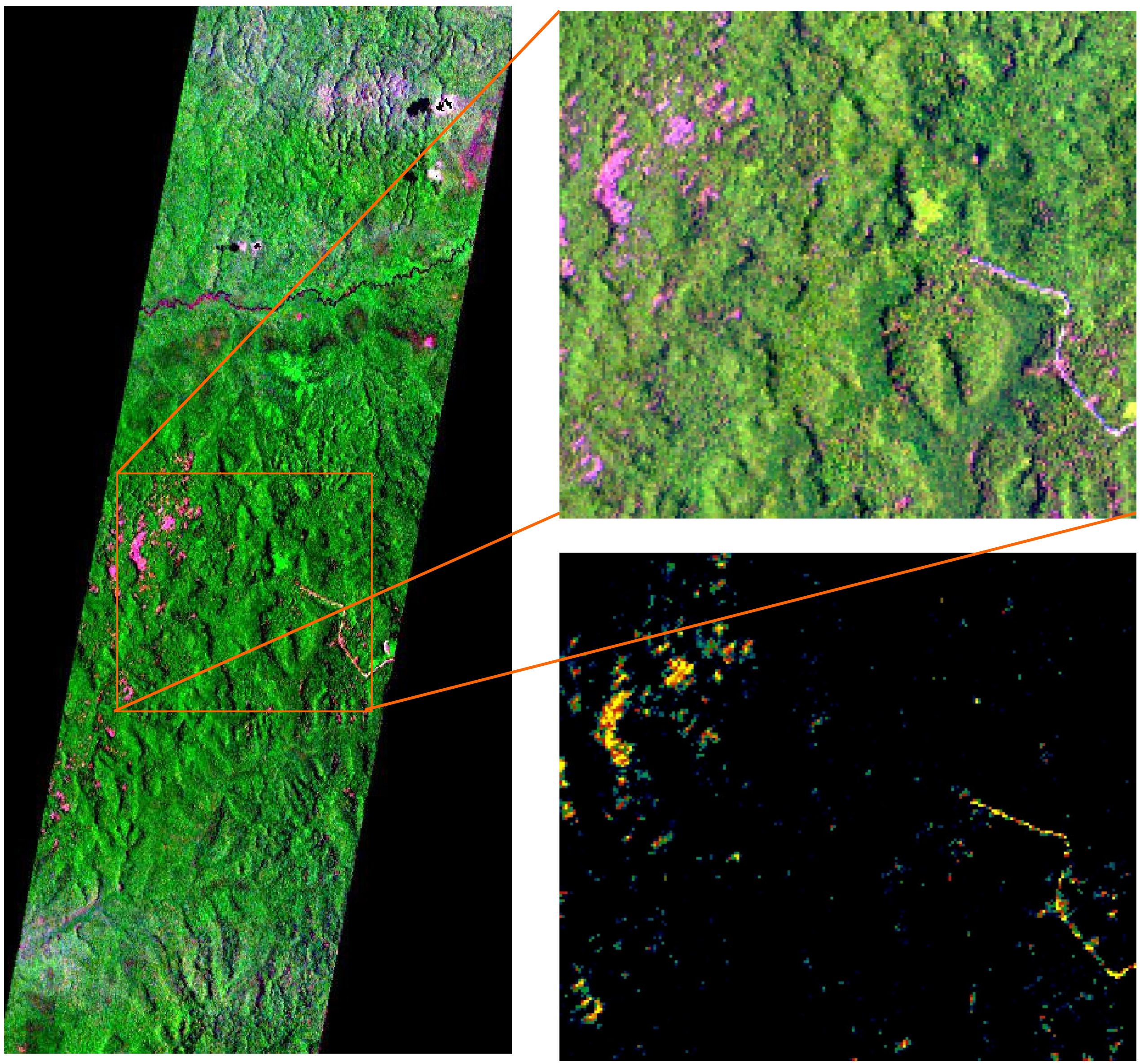
SITE 1

disturbance class	MTFM range	Lat	Long	pixel value	mortality rate
1	> 0.80	2° 35' 10.56"	60° 13' 33.15"	0.81	0.67
2	0.61 - 0.80	2° 35' 8.60"	60° 13' 37.03"	0.64	0.50
3	0.41 - 0.60	2° 35' 9.57"	60° 13' 37.03"	0.56	0.59
4	0.21 - 0.40	2° 35' 10.54"	60° 13' 39.94"	0.28	0.36
5	0.11 - 0.20	2° 35' 13.47"	60° 13' 40.92"	0.09	0.11
6	< 0.10	2° 35' 13.41"	60° 13' 41.88"	0.06	0.47

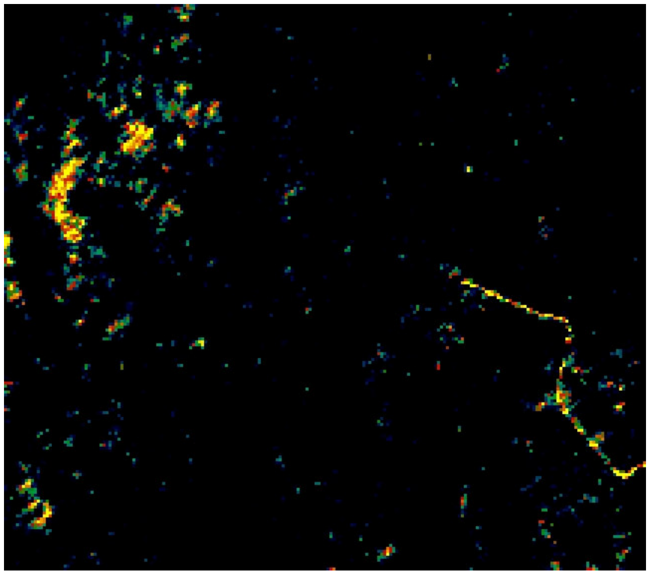
Developing relationships between remote sensing metrics and field-based mortality/damage rates

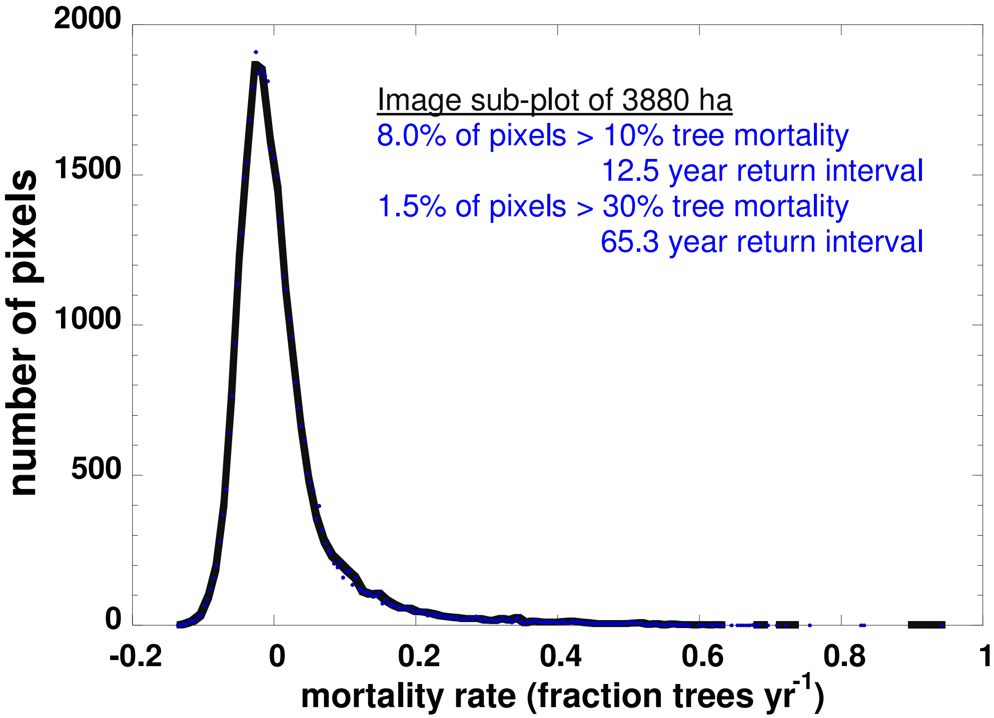
Team Bravo-Delta (BlowDown)

Spatial Distribution of Tree Mortality Intensity

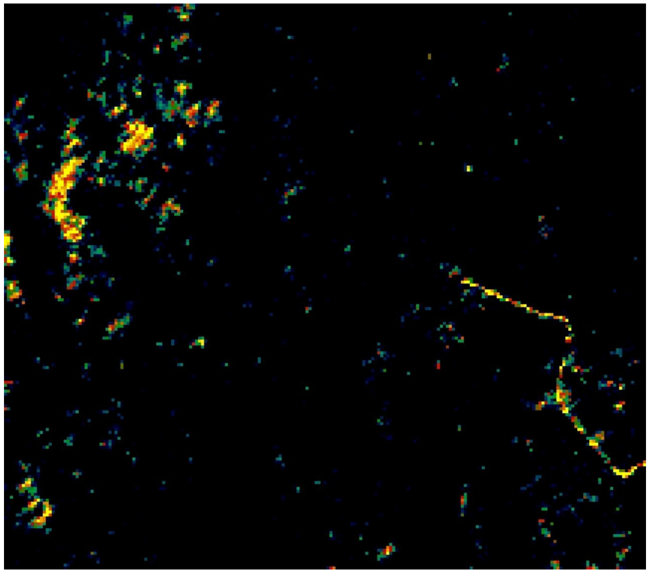


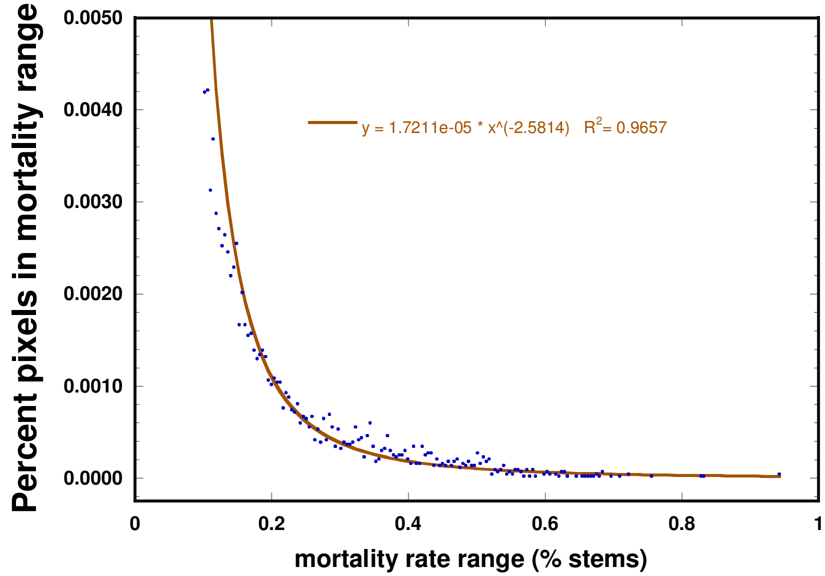
Frequency plot of Tree Mortality Rate Distribution at Landscape (> 1000 ha) Scale

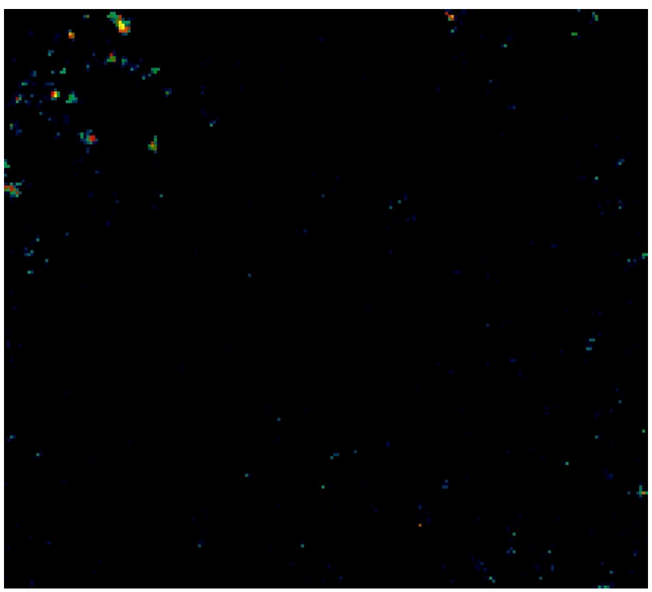


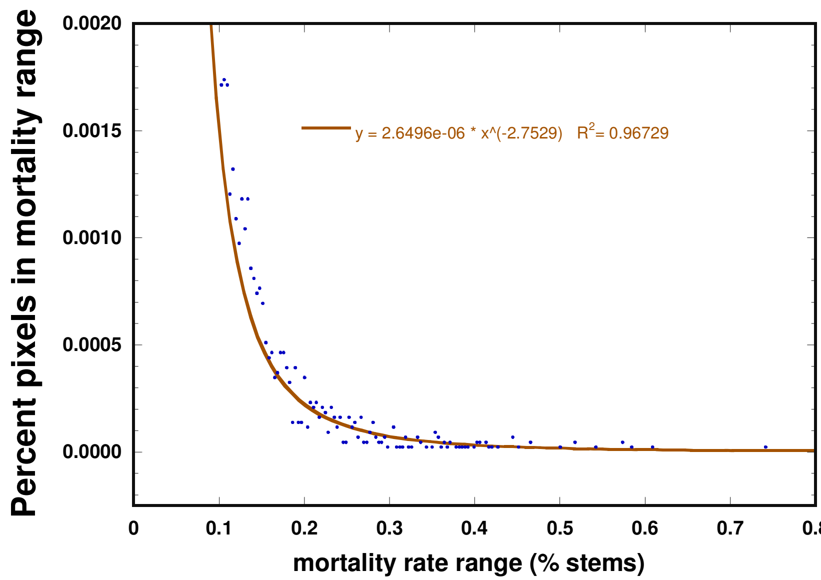


Frequency plot of Tree Mortality Rate Distribution at Landscape (> 1000 ha) Scale

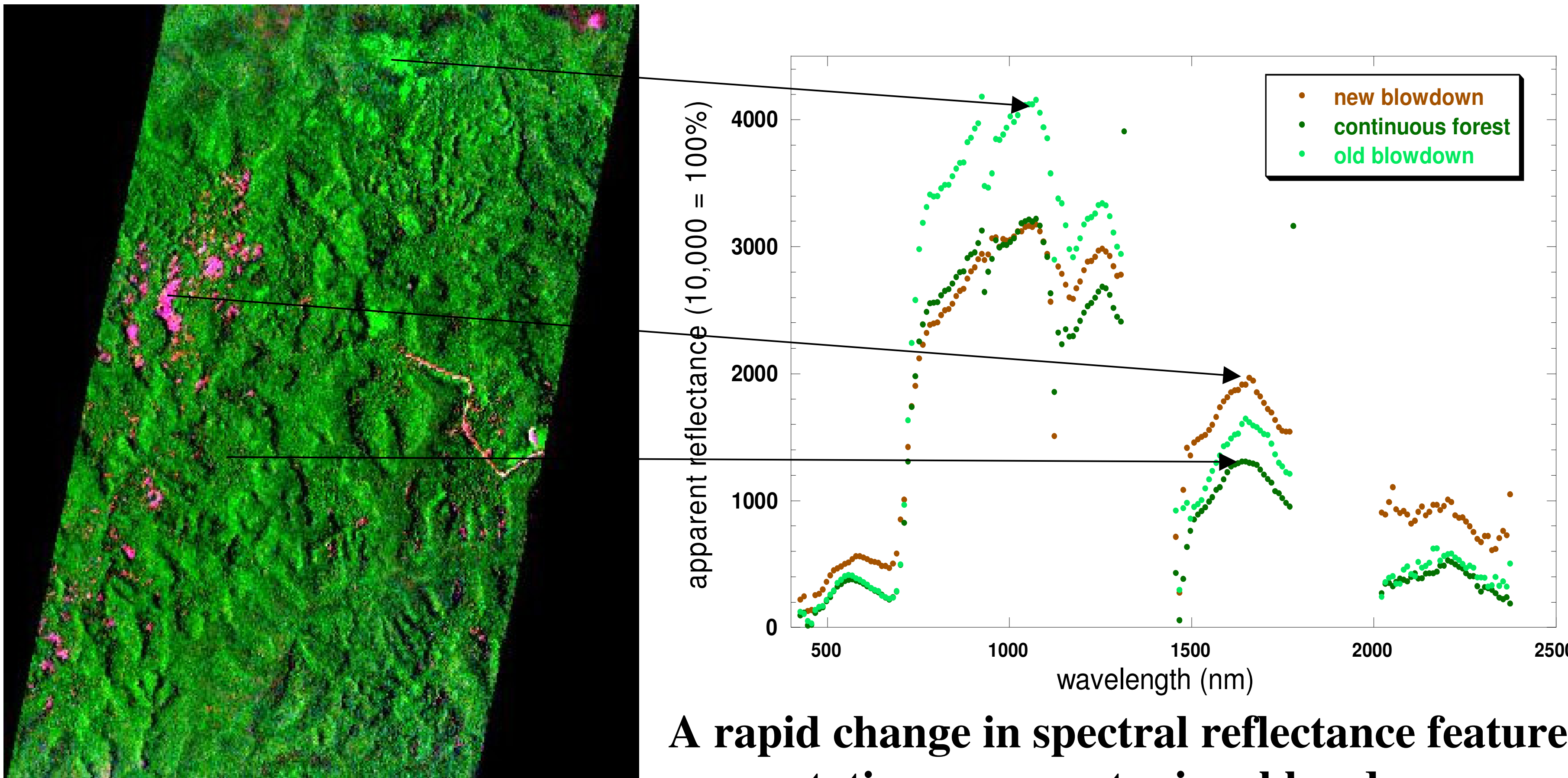






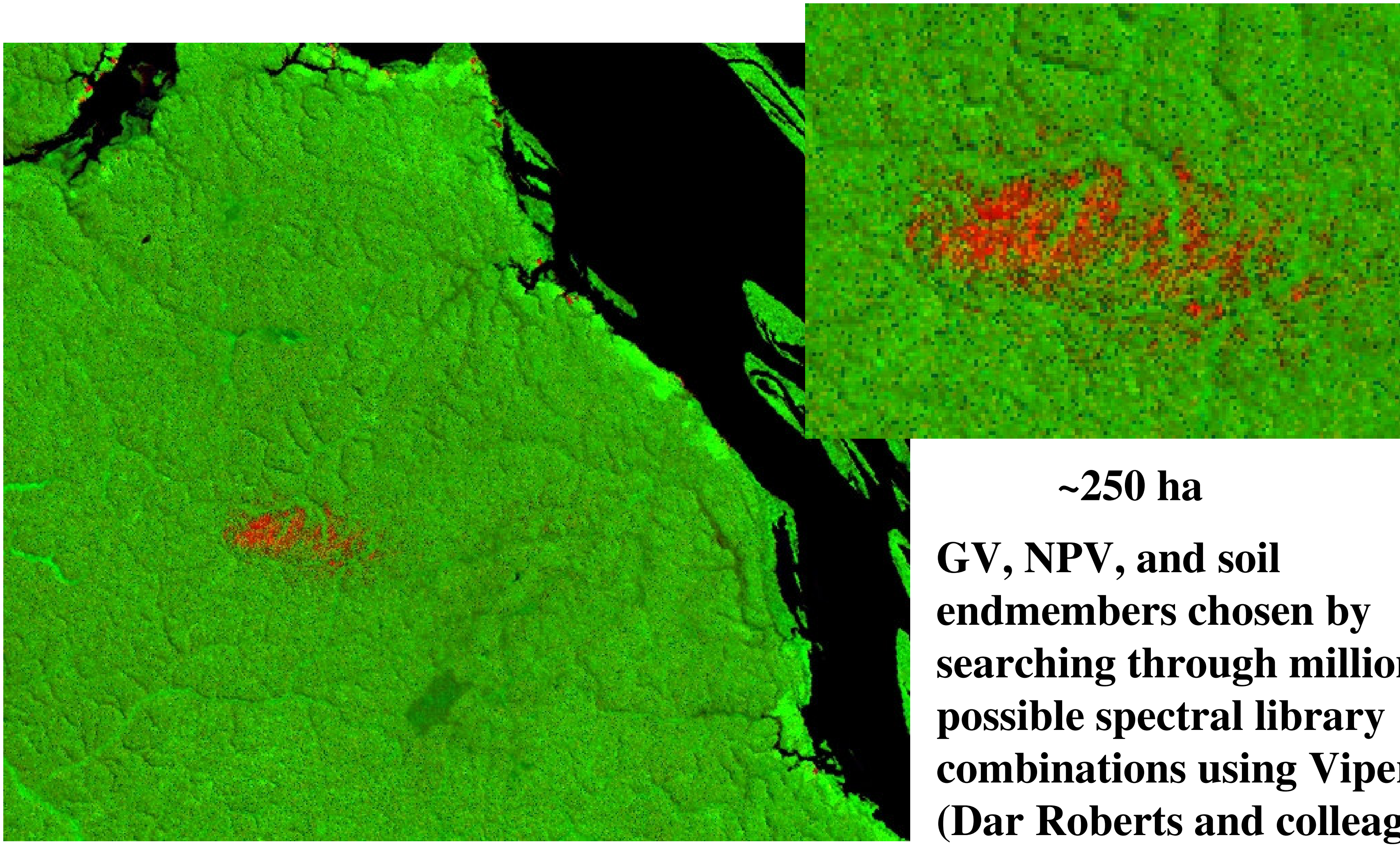


Characteristic forest spectral reflectance: New blowdown, recovering blowdown, primary forest



A rapid change in spectral reflectance features as vegetation regenerates in a blowdown – each point average of 8 pixels.

The Temporal Dimension: Blowdown chronosequence for the Manaus Landsat (p231 r062) years 1984 – 2006



~250 ha

GV, NPV, and soil endmembers chosen by searching through millions of possible spectral library combinations using ViperTools (Dar Roberts and colleagues)

Sub from 1991 image – west bank Rio Negro

Summary

- **Most canopy gaps occurring within forest inventory plots (e.g. RAINFOR, STRI, etc.) are not of sufficient size to initiate classic secondary successional processes and significant changes in tree species composition.**

- **There is a critical gap in our understanding of how catastrophic mortality events (varying from about 0.1 to 5 ha in size) affect ecological and ecosystem processes.**

- **Hyperspectral remote sensing methods appear useful for detecting relatively small vegetation features associated with recovery processes in large canopy gaps, and the distribution of disturbance and recovery processes at the appropriate landscape scale.**

- **Catastrophic disturbances are important for determining landscape carbon balance and also understanding ecological processes for the maintenance and origin of tree species diversity.**

- **The spatial distribution of mortality rate intensity (10% to 100%) follows a power-law function – exponent of 2.5 to 2.8?**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