Interactions between the spatial patterns of tropical forest disturbance and biomass:

Results from two studies that use Landsat and forest inventory (FIA) data

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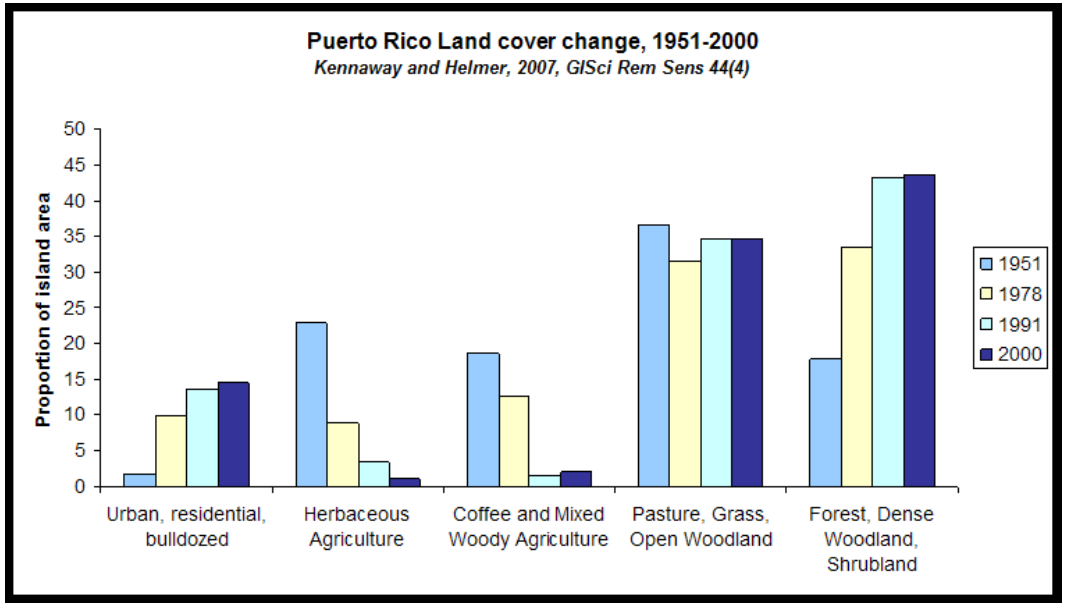
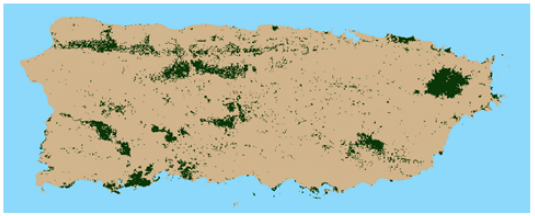
Landsat Science Team Meeting
January 6-8, 2008
Fort Collins, CO, USA

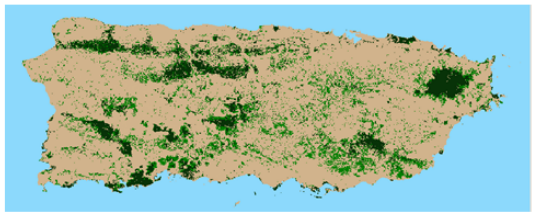


Puerto Rico Forest Cover, 1951 - 2000

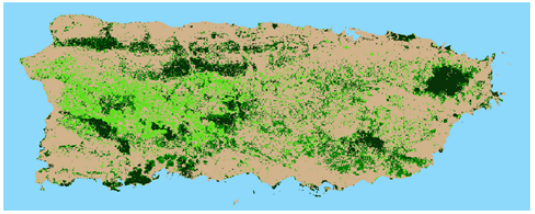
Kennaway and Helmer, 2007, GISci. Rem. Sens. 44(4)



1951 (aerial photos)

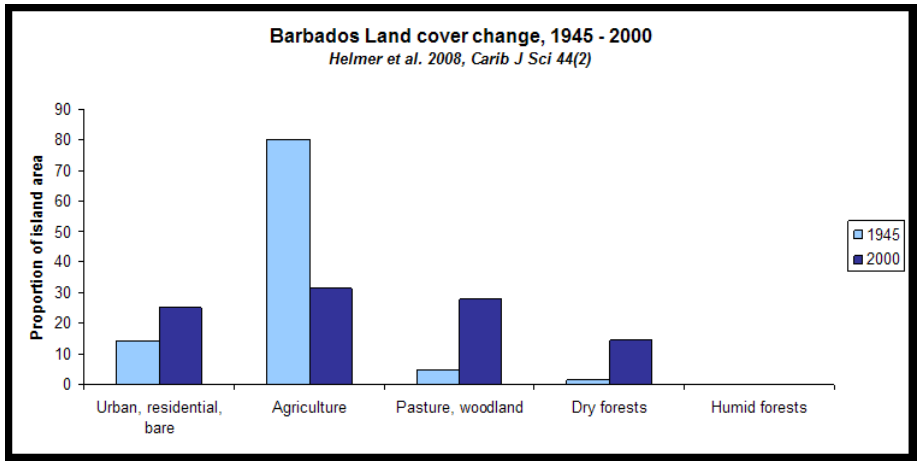


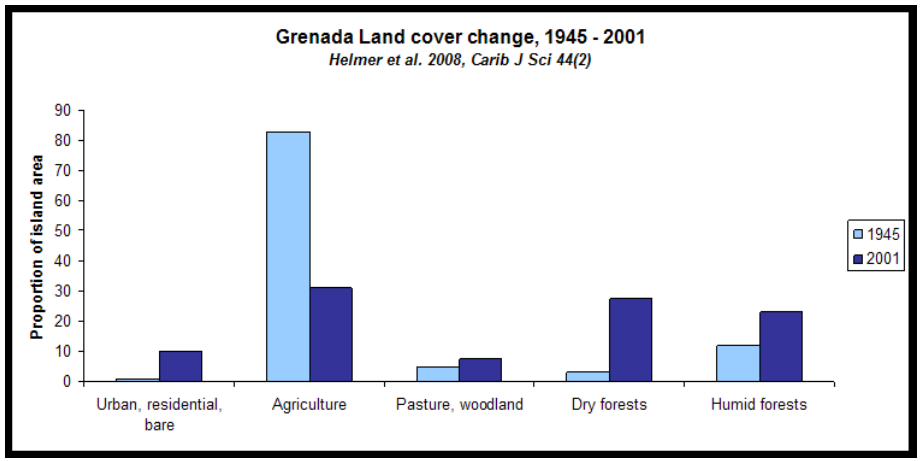
1977 (aerial photos)

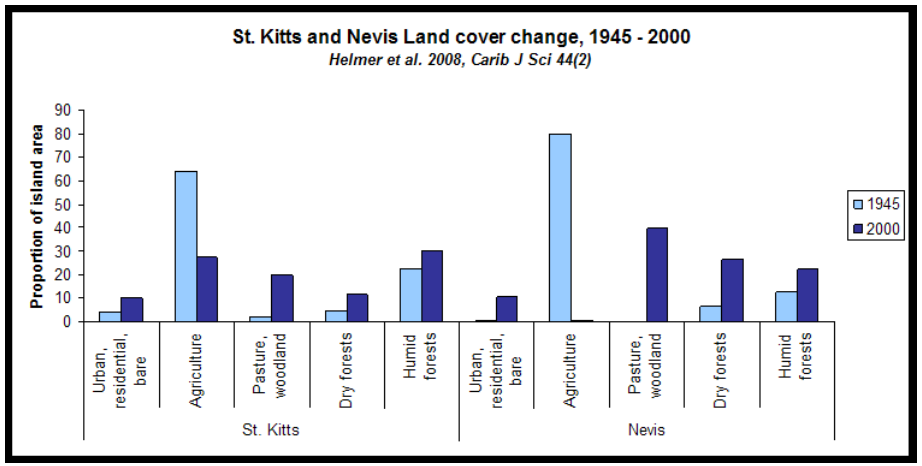


1991 (Landsat mosaic)

2000 (Landsat mosaic)





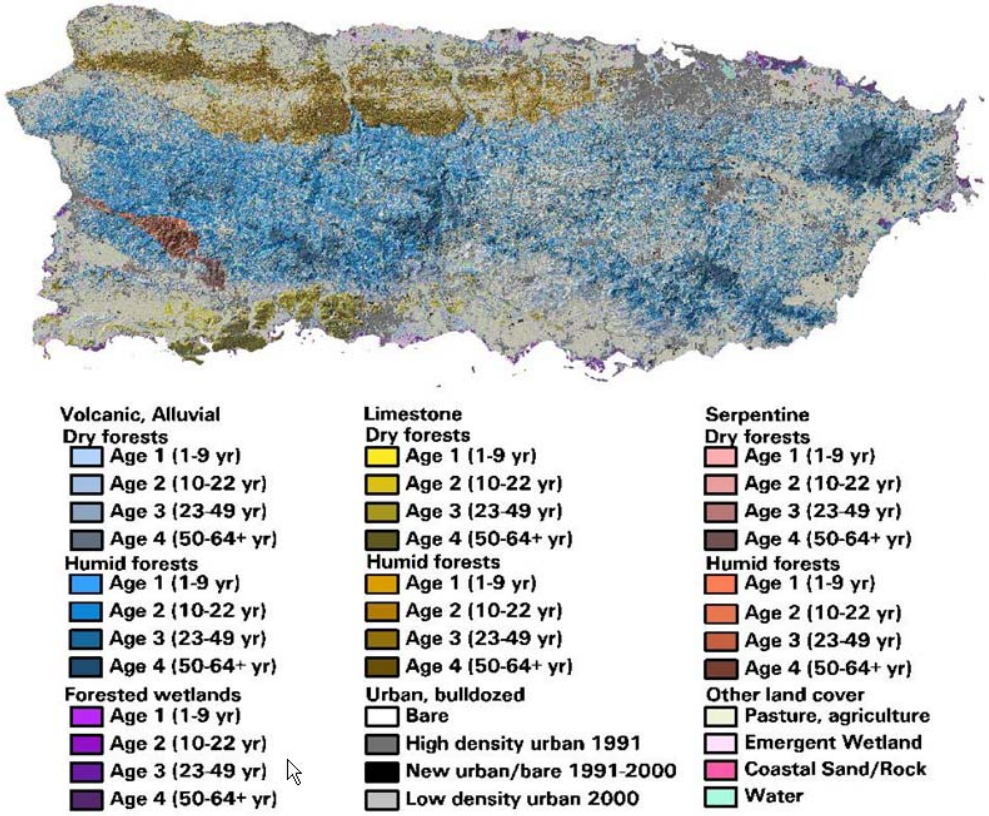


Helmer et al. 2008, Carib. J. Sci. 44(2)

Study 1 – Puerto Rico

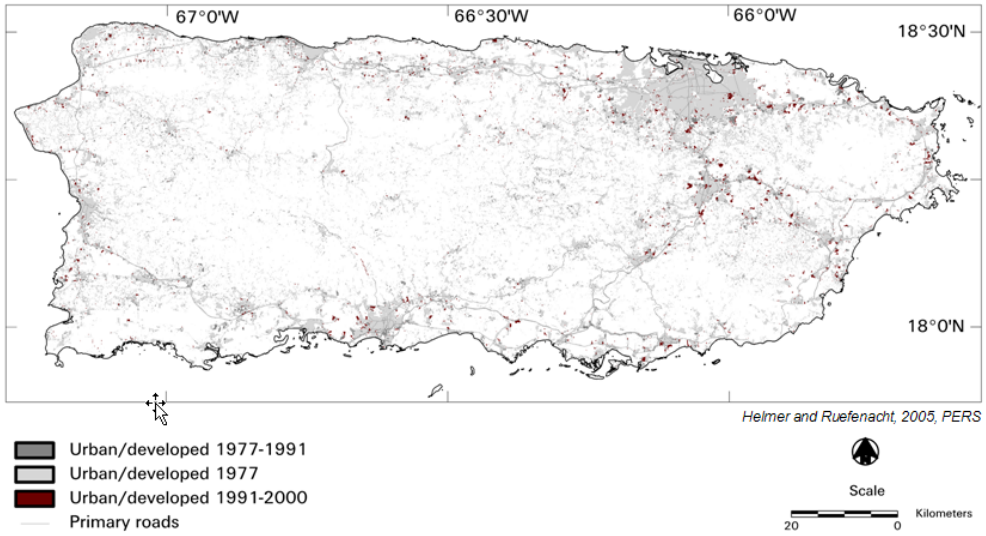
- Helmer, EH, TJ Brandeis, AE Lugo and T Kennaway. 2008. *Factors influencing spatial pattern in tropical forest clearance and stand age: implications for carbon storage and species diversity*. Journal of Geophysical Research: Biogeosciences 113: G02S04

- Accounting for tropical forest age yields a 19% smaller estimate of the forest biomass cleared for land development than if forest age is not accounted for



Helmer, Brandeis, Lugo, Kennaway, 2008, JGR Biogeosciences

Average FIA forest plots to estimate forest biomass per hectare by:
(1) generalized type only
(2) both type and age class



Helmer and Ruefenacht, 2005, PERS

Sum biomass of forest cleared for land development,comparing the two biomass estimates.

Forest class (all Puerto Rico forests are Subtropical)	Non age-weighted biomass cleared (Mg)	Age-weighted biomass cleared (Mg)
Dry forest	11,354	10,879
Moist and wet forest	96,885	78,830
Dry forest, karst	11,762	11,545
Moist forest, karst	8,090	7,364
Dry forest, serpentine	187	277
Cloud forests	53	51
Forested wetlands	1794	701
Total	130,125	109,649

Helmer, Brandeis, Lugo, Kennaway, 2008, JGR Biogeosciences

Three econometric models help explain the result

- Forest age
- Cleared forest age
- Forest cleared *vs.* not cleared (testing if forest age is influential)

Spatially explicit land-use models

$$\text{Ln}\left[(\text{Pr. Land use A}) / (\text{Land use B}) \right] = \beta_1 + \beta_2 X_1 \ldots + \beta_n X_n$$

Dependent variables are proxies for processes that determine land use at a given place

- Human decisions aimed at maximizing land rent
- Land accessibility and quality determine land use

e.g. Forest age class

$$\text{Ln}\left[(\text{Pr. Age class}_k) / (\text{Pr. Age class}_j) \right] = \beta_1 + \beta_2 X_1 \ldots + \beta_n X_n$$

- Land accessibility and quality determine the spatial pattern of agricultural abandonment over time

Model Results

FOREST AGE INCREASES WITH…	*CLEARED FOREST AGE INCREASES WITH…*	*FOREST CLEARING DECREASES WITH…*
Surrounding forest cover (decreasing pasture cover)	Surrounding forest cover (decreasing pasture cover)	Surrounding forest cover (decreasing pasture cover)
Elevation	Elevation	Elevation
Slope	Slope	Slope
Road distance	Road distance	Road distance
Limestone, Serpentine	Limestone	
Protection		Protection
Wetland		Wetland
Proximity to urban[1]		Distance to urban
		Oldest age class[2]

[1]The largest protected areas are close to urban centers

[2]No difference between other ages, implying that the age of cleared forest depends mainly on the spatial pattern of forest age before clearing

Why do the forests cleared for land development have less biomass?

- Accessibility, arability and spatial contagion determine 1) the pattern of agricultural abandonment that permits forest regrowth, and 2) where humans leave old-growth forest remnants.

- The factors patterning forest age and urban development co-vary, with the result that forests are increasingly younger in more accessible and fertile areas where agriculture has lasted longer and land development is most common.

Study 2 – Virgin Islands

- Kennaway, T., E. H. Helmer, M. A. Lefsky, T. A. Brandeis and K. R. Sherrill. 2008. *Mapping land cover and estimating forest structure using satellite imagery and coarse resolution lidar in the Virgin Islands*. Journal of Applied Remote Sensing 2:023551.

- The same forest formations mapped from Landsat imagery can have 18% to 86% more biomass in largely protected landscapes (Kennaway et al. 2008, J. Applied Rem. Sens.)

Dry to Dry-Moist Forests - Drought Deciduous/Semi-deciduous

- Open Woodland
- Dense Woodland
- Mixed Forest or Shrubland, with or without Succulents
- Alluvium and Volcanic Substrates
- Karst/Carbonate Substrate (incl. Semi-evergr. Forest)
- Serpentine Substrate (incl. Seas. Evergr Gallery Forest)

Forested Wetlands

- Mangrove
- Seasonally Flooded Savannas and Woodlands
- Pterocarpus Swamp

Moist to Moist-Wet Forests - Seasonal Evergreen/Evergreen

- Karst Substrate (Semi-deciduous and Seas. Evergr. mosaic)
- Alluvium and Volcanic Substrates
- Abandoned Coconut Palm on Alluvium
- Karst Substrate (Seas. Evergr. and Evergr. mosaic)
- Serpentine Substrate

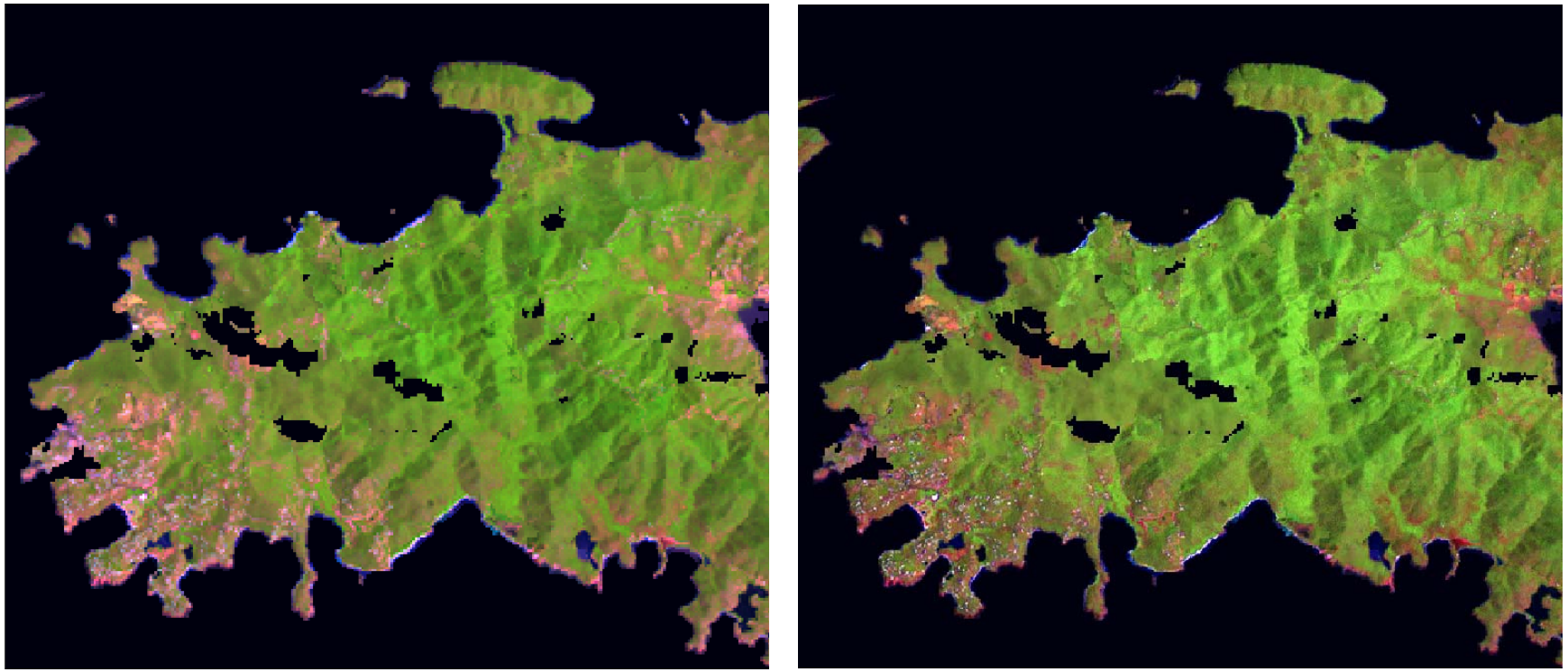
Wet to Rain Cloud Forests - Evergreen

- Sierra Palm, Transitional and Tall
- Elfin and Sierra Palm

Pan-sharpened cloud-free image mosaics from regression tree normalization can be used to map tropical forest types and land cover

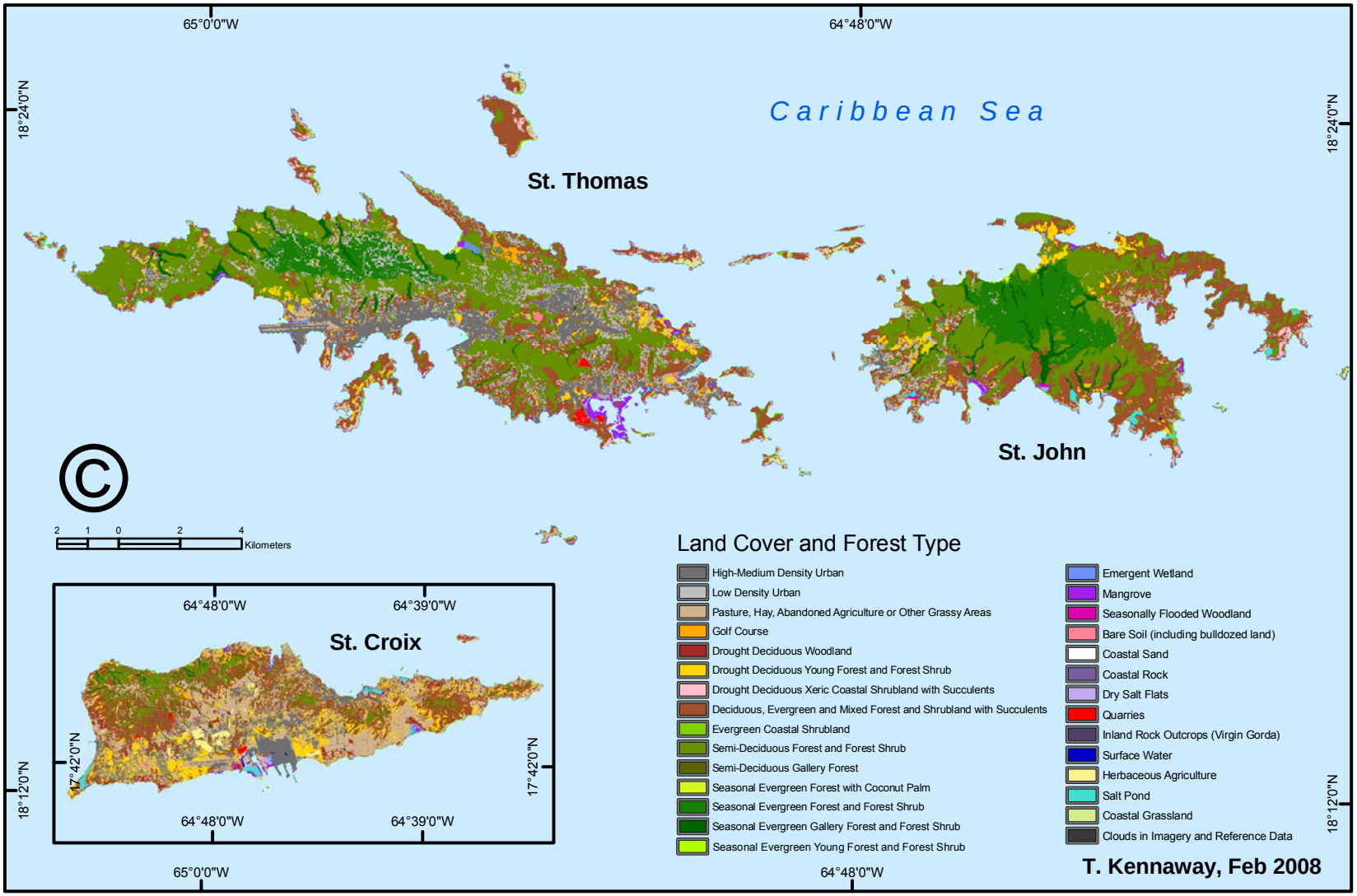
Mosaic from regression tree normalization of 30-m optical bands

The 30-m mosaic pan-sharpened with a regression-tree normalized mosaic of the 15-m panchromatic band



Landsat bands 5, 4, 3 (R, G, B) for part of St. John, USVI

Lidar height and biomass summarized by land-cover classification

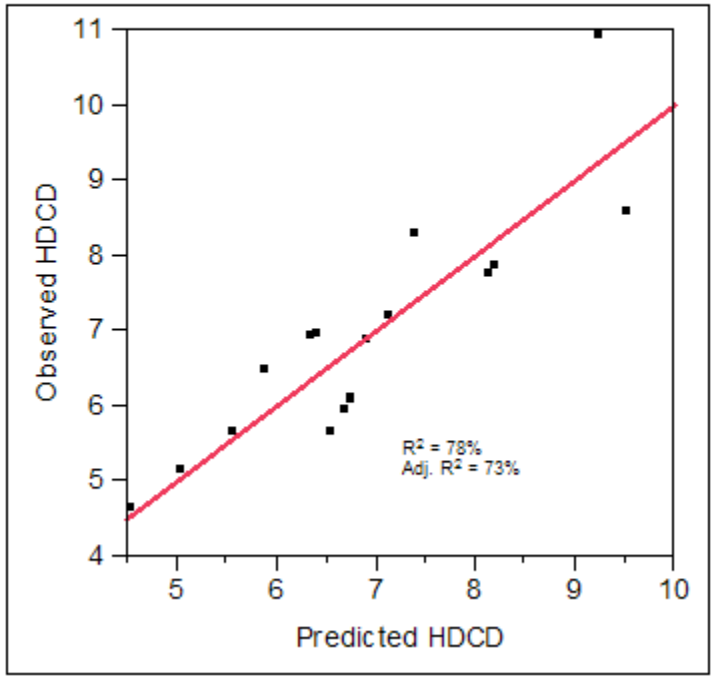


T Kennaway, EH Helmer, MA Lefsky, KR Sherrill, TJ Brandeis. 2008. J. Applied Rem. Sens.

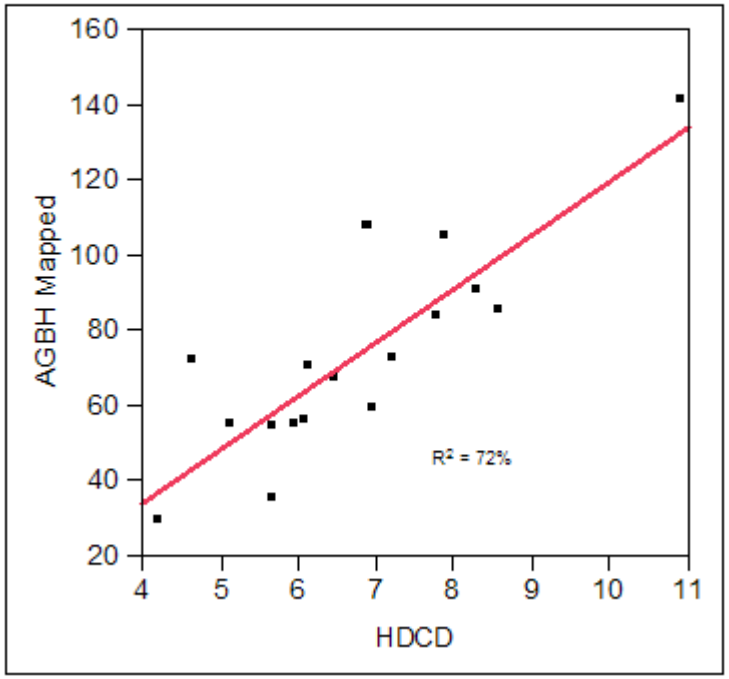
Lidar to map forest height/biomass

- Leica ALS 40 sensor with multiple return data
- Vertical Root Mean Square Error of 9.26 cm
- Point cloud data with 2.76 m shot spacing

Average Height of Dominants Co-dominants (HDCD) (m)

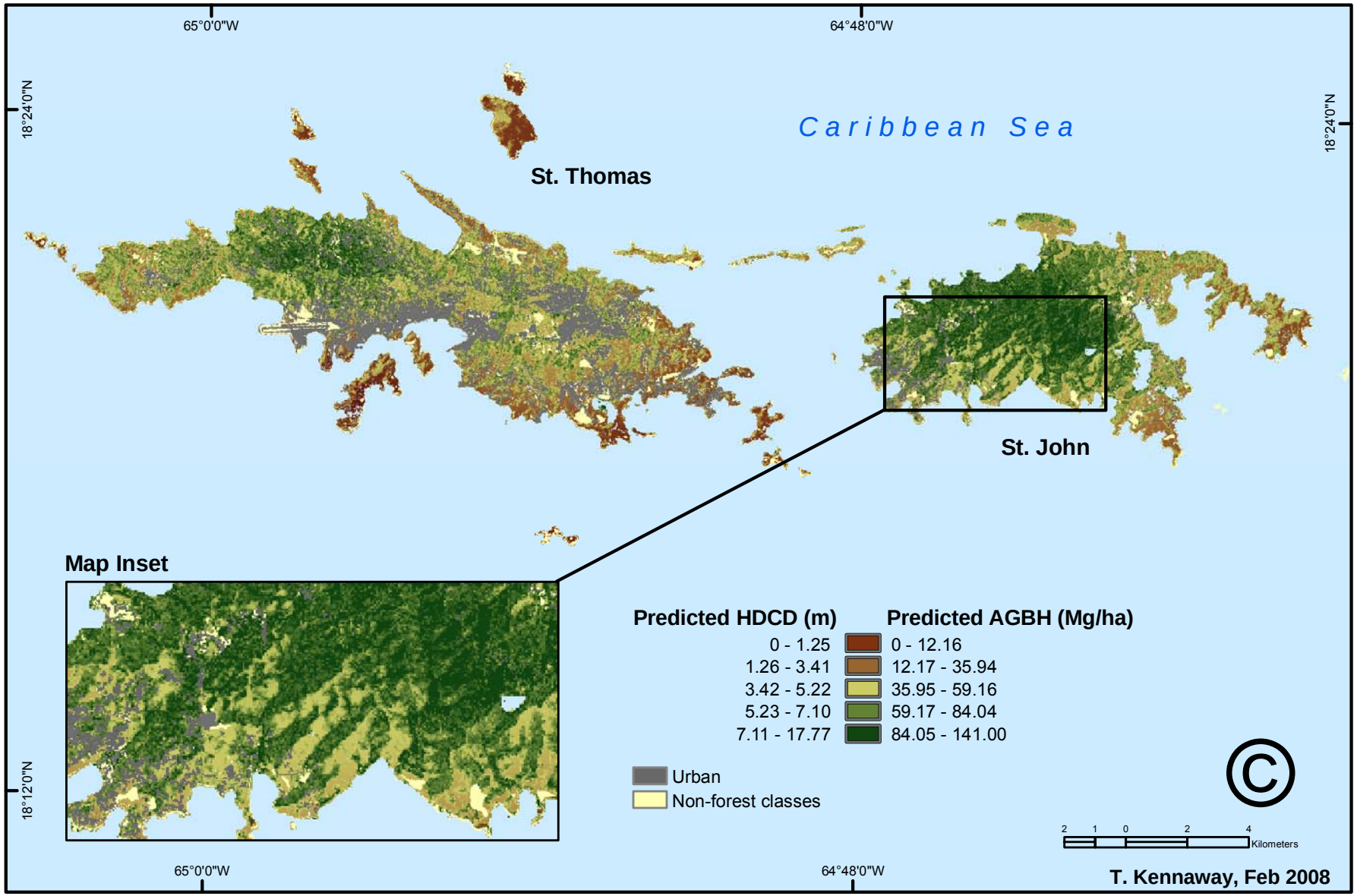


Above Ground Biomass (Mg/ha) relationship with HDCD



T Kennaway, EH Helmer, MA Lefsky, TJ Brandeis, KR Sherrill. 2008. J. Applied Rem. Sens.

Predicted Map (Height/Biomass)



T Kennaway, EH Helmer, MA Lefsky, KR Sherrill, TJ Brandeis. 2008. J. Applied Rem. Sens.

The biomass of major forest types on largely protected St. John is 18% to 86% larger than the same types on largely unprotected St. Thomas

Forest type	Biomass on largely protected St. John (Mg/ha)	Biomass on largely unprotected St. Thomas (Mg/ha)
Drought deciduous with succulents	39 ± 1.1	21 ± 0.8
Semi-deciduous	65 ± 0.9	46 ± 0.7
Seasonal Evergreen	84 ± 1.1	71 ± 1.6

T Kennaway, EH Helmer, MA Lefsky, TJ Brandeis, KR Sherrill. 2008. J. Applied Rem. Sens.