Land cover dynamics following a deforestation ban in northern Costa Rica

Fagan, M.E.[1], DeFries, R.S. [1], Sesnie, S.E. [2], Arroyo, J.P. [3], Walker, W.[4], Soto, C.[5], Chazdon, R.L. [6], and Sanchun, A. [7]

Columbia University in the City of New York

Ecology, Evolution, & Environmental Biology

Introduction

Forest protection policies potentially reduce deforestation and redirect agricultural expansion to already-cleared areas. In 1996, the Costa Rican government banned deforestation country-wide and concentrated payments for environmental services (PES) within Biological Corridor zones to promote tree plantations and protect forests on private land.[1] **Using satellite imagery, we assessed whether deforestation for pasture and cropland decreased in the lowlands of northern Costa Rica following the ban on forest clearing**, despite a tripling of area under pineapple cultivation in the last decade.

Results and Conclusions

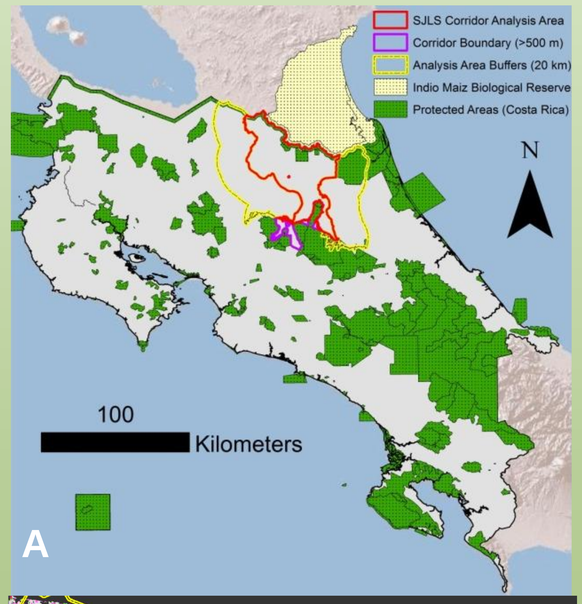
Following the ban:

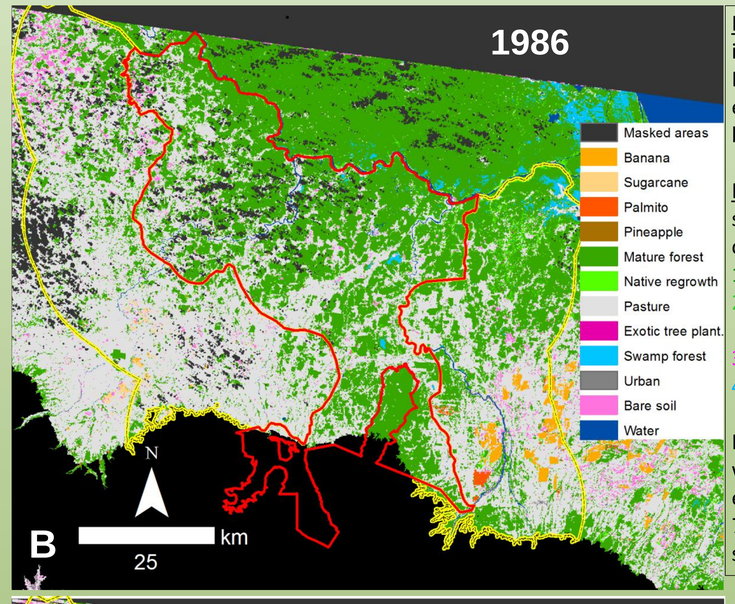
- Mature forest loss decreased from 2.2% to 1.2% per year (Fig. 2).
- The proportion of pineapple and other export-oriented cropland derived from mature forest declined from 16.4% to 1.9% (Fig. 3).
- All agricultural land covers decreased their proportional expansion into mature forest (Fig. 4).

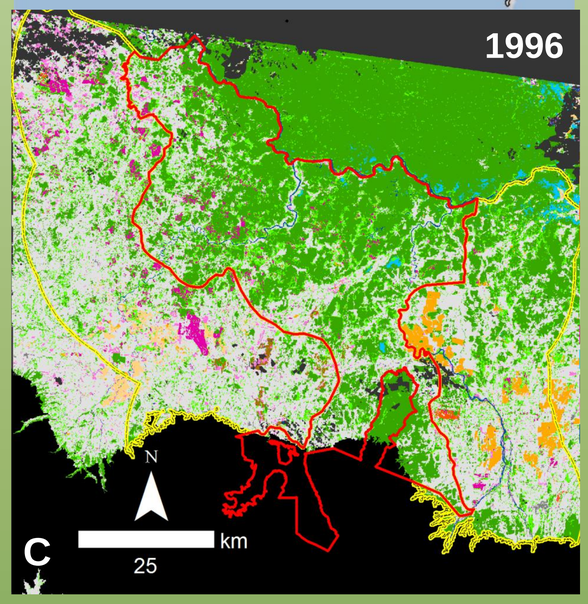
Overall, there was a small net gain in forest cover due to a shifting mosaic of regrowth and clearing in pastures (Figs. 5 and 6).

We conclude that forest protection efforts in northern Costa Rica likely have slowed mature forest loss and succeeded in re-directing expansion of cropland to areas outside mature forest.

Our results suggest that deforestation bans may protect mature forests better than older forest regrowth and **may restrict clearing for large-scale crops more effectively than clearing for pasture.**







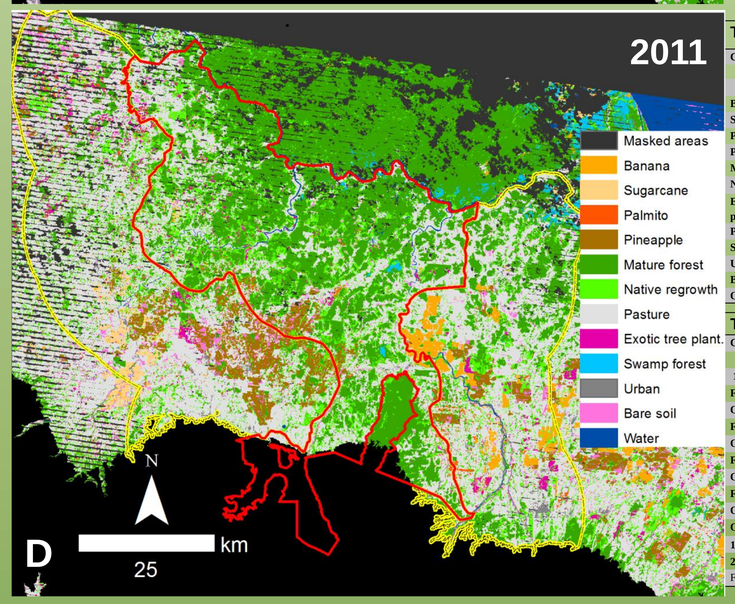


Figure 1A: Landsat image of the area of interest in northern Costa Rica: the San Juan-La Selva Biological Corridor and two 20 km buffers to either side. We analyzed land cover change below 500 m in elevation within this area.

Figures 1B-1D: Classified land-cover maps from selected years in the image series. The forest classes are defined as:

1. Mature lowland forest (>30 years in age)
2. Native reforestation/regrowth (native tree plantations and secondary forests)
3. Exotic tree plantations (teak and gmelina)
4. Mature swamp forest (>30 years)

Native tree plantations and secondary forests were combined in the final map because extensive confusion lowered accuracies below 70%. Most native tree species planted are secondary forest species.

Table 1: Classification accuracy of individual image-dates

Classes	2011		2005		2001		1996		1986	
	Accuracy (%)		Accuracy (%)		Accuracy (%)		Accuracy (%)		Accuracy (%)	
	Prod.	User	Prod.	User	Prod.	User	Prod.	User	Prod.	User
Banana	87	98	98	100	100	98	98	98	70	88
Sugarcane	79	100	92	100	86	100	93	100	"	"
Palmito	71	79	80	94	67	83	"	"	"	"
Pineapple	98	95	96	100	92	100	100	100	"	"
Mature Forest	98	96	98	98	99	97	98	99	98	98
Native Reforestation	85	89	87	91	87	88	82	85	77	80
Exotic tree plantation	81	91	77	89	90	87	82	82	"	"
Pasture	95	83	97	86	93	87	100	91	96	91
Swamp forest	92	100	91	100	92	100	100	100	92	100
Urban	93	93	100	92	93	100	93	100	92	100
Bare soil	60	50	82	93	85	89	100	100	83	80
Overall	**90**		**93**		**93**		**96**		**93**	

Table 2: Forest/Open change accuracy (1986-1996-2011)

Classes	Description	Accuracy (%)	
1986-2001-2011		Producer's	User's
Forest-Forest-Forest	Stable Forest	96	99
Open-Forest-Forest	Early persistent reforestation	92	93
Forest-Open-Forest	Deforestation then reforestation	92	75
Open-Open-Forest	Late reforestation	80	67
Forest-Forest-Open	Late deforestation	100	73
Open-Forest-Open	Reforestation then deforestation	90	95
Forest-Open-Open	Early deforestation	93	93
Open-Open-Open	Stable Nonforest	93	96
Overall		**93**	
1986-2001 deforestation	**F-O-O and F-O-F combined**	94	90
2001-2011 deforestation	**F-F-O and O-F-O combined**	92	88

Forest (F) and nonforest (O) transitions are from 1986 to 2001 to 2011.

Figure 2

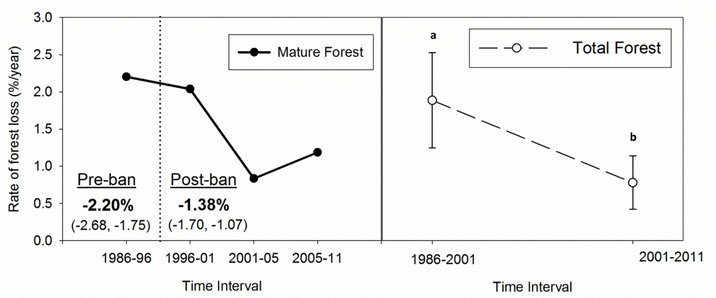


Figure 3

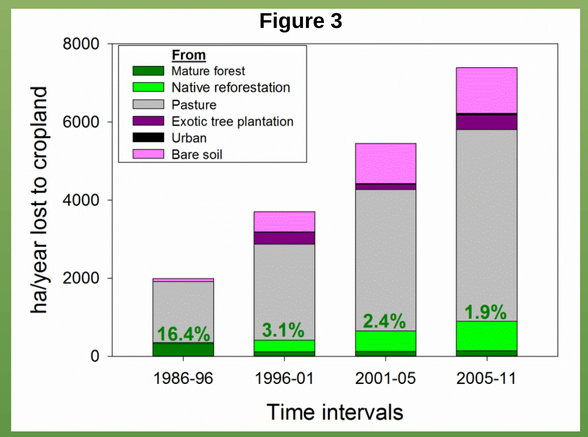
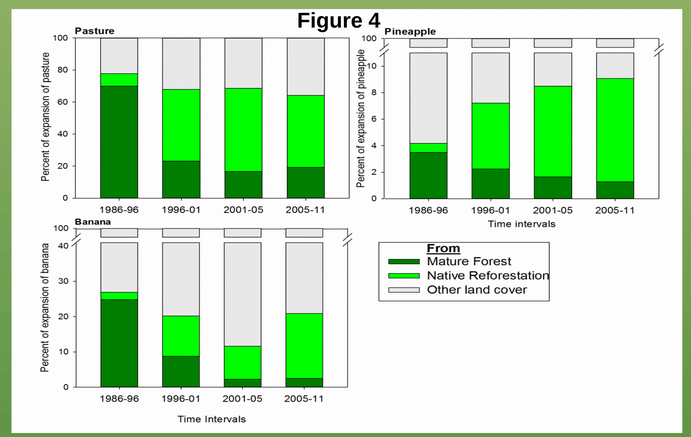


Figure 4



Methods

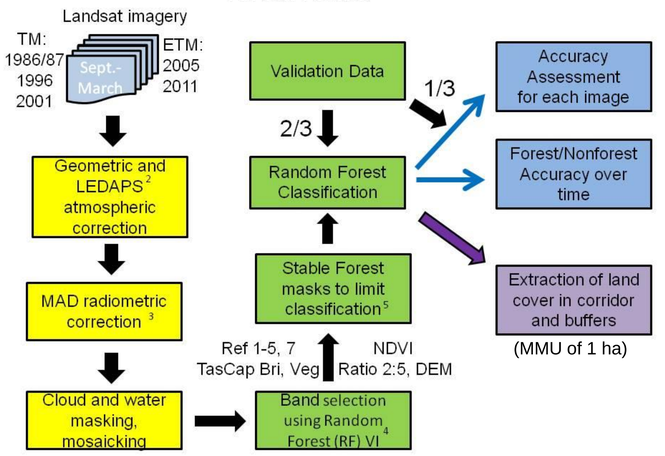


Figure 5

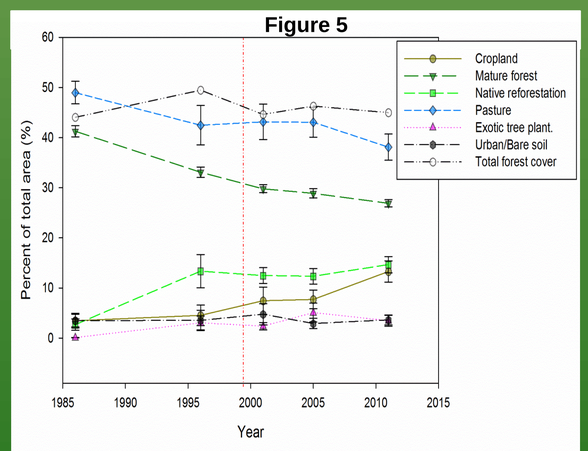


Figure 6

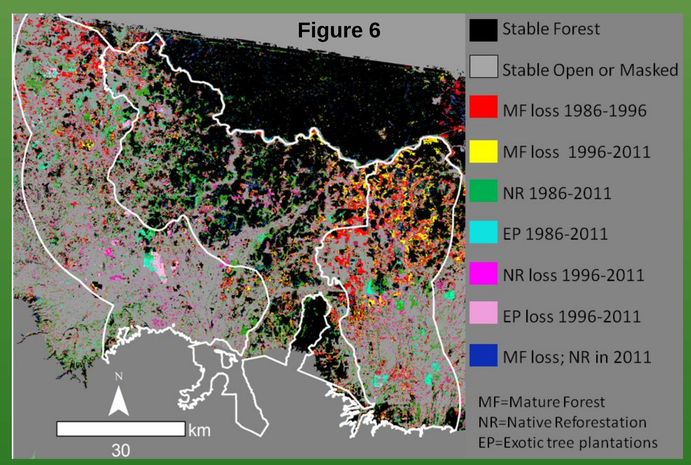


Figure 2: A) Mature forest loss rates over time from single date classifications; B) Total forest (mature forest, native reforestation (natural regeneration and native tree plantations), and exotic tree plantations) loss rates over time. All errors are 95% confidence intervals derived from Tables 1 or 2, respectively.

Figure 3: Conversions of other land-uses to cropland. The percentage of total land converted to cropland from mature forest is labeled in dark green.

Figure 4: The expansion of banana, pineapple, and pasture into other land covers over time; note the different axis scales. From 1986-1996, pasture expanded into mature forest proportionally more often than it was represented in the landscape (see Figure 5).

Figure 5: Percent change in each land cover category over time within the study area. Error bars are 95% confidence intervals.

Figure 6: Map of land cover changes over time in the region, in two time intervals: 1986-1996 and 1996-2011. Native reforestation and exotic tree plantations regrew from 1986 to 1996, and may have persisted to 2011 or have been cleared between 1996 and 2011 (loss).

Affiliations: [1] Department of Ecology, Evolution, and Environmental Biology, Columbia University, USA. [2] U.S. Fish and Wildlife Service, USA. [3] Department of Geography, McGill University, Canada. [4] Woods Hole Research Center, USA. [5] La Selva Biological Station, Costa Rica. [6] Department of Ecology and Evolutionary Biology, University of Connecticut, USA. [7] FUNDECOR, Costa Rica.

Acknowledgements: We would like to thank CENAT-PRIAS (San Jose, Costa Rica) and the NASA LCLUC program for sharing high-resolution imagery. This work was funded by NASA NESSF Fellowship NNX10AP49H.

Literature Cited: **1)** Morse, W. C., J. L. Schedlbauer, et al. (2009). "Consequences of Environmental Service Payments for Forest Retention and Recruitment in a Costa Rican Biological Corridor." Ecology and Society **14(1). 2)** Masek, Jeffrey G., Eric F. Vermote, Nazmi E. Saleous, Robert Wolfe, Forrest G. Hall, Karl F. Huemmrich, Feng Gao, Jonathan Kutler, and Teng-Kui Lim. "A Landsat surface reflectance dataset for North America, 1990-2000."*Geoscience and Remote Sensing Letters, IEEE* 3, no. 1 (2006): 68-72. **3)** Canty, M.J., A.A. Nielsen, M. Schmidt. 2004. "Automatic radiometric normalization of multitemporal satellite imagery." Remote Sensing of Environment **91(3-4):** 441-451.. **4)** Breiman, Leo (2001). "Random Forests". Machine Learning **45 (1):** 5–32. **5)** Helmer, E. H., M. A. Lefsky, and D. A. Roberts. 2009. Biomass accumulation rates of Amazonian secondary forest and biomass of old-growth forests from Landsat time series and the Geoscience Laser Altimeter System. Journal of Applied Remote Sensing **3.**