Why Economists Shouldn't Care About Deforestation

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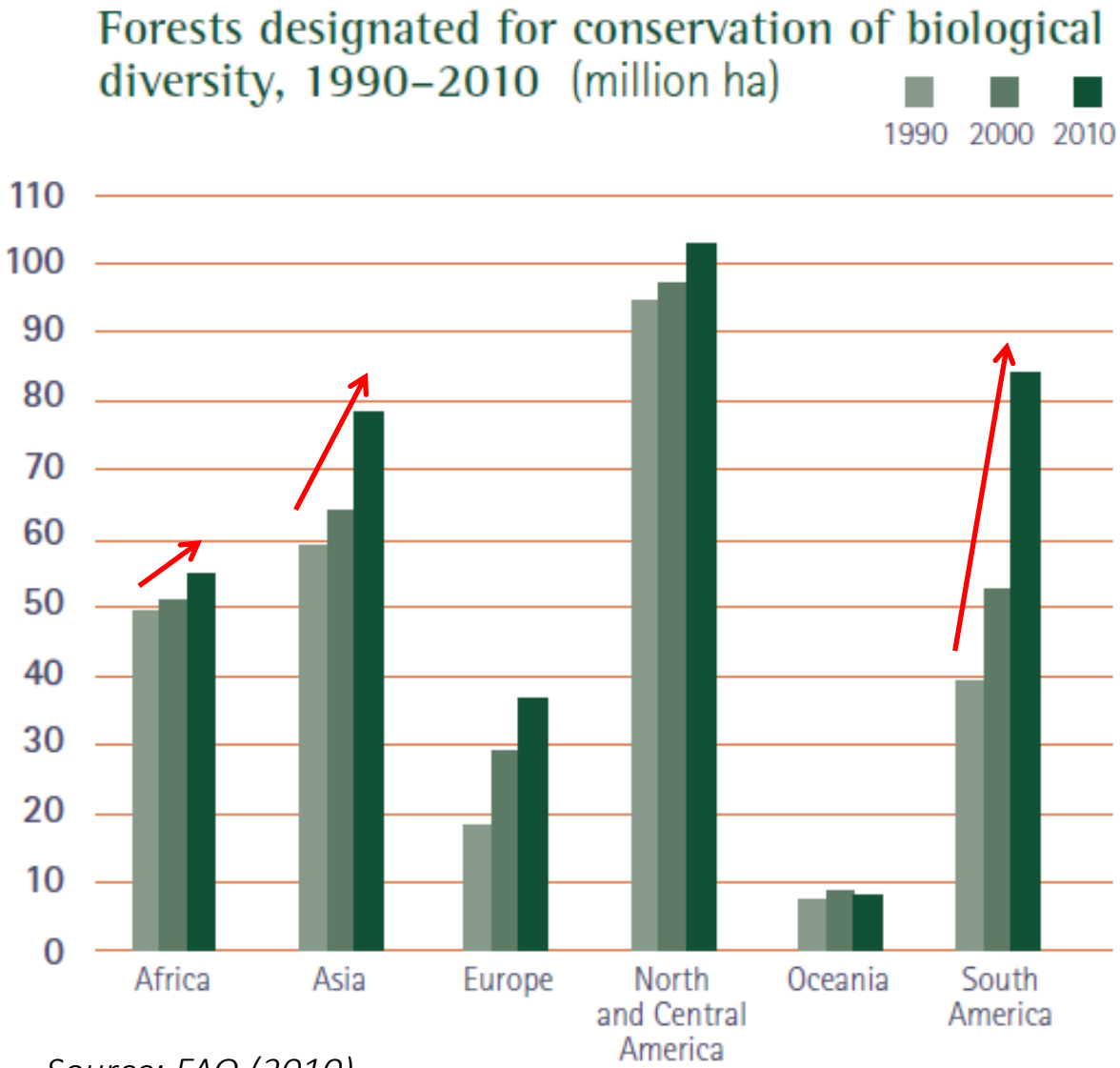
My humble objectives

To get you to think twice about:

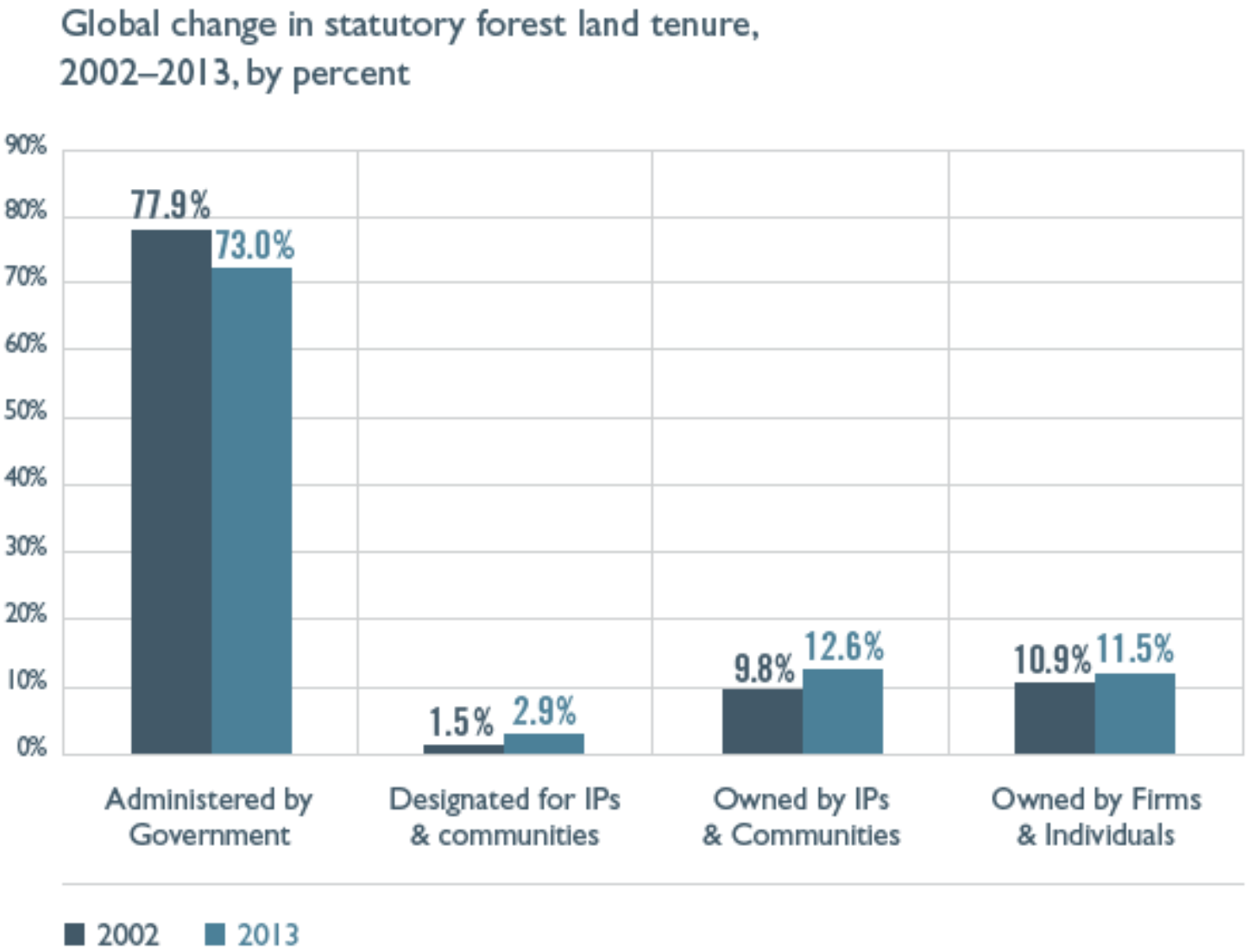
1. Analyzing deforestation rates, instead of the benefits and costs associated with deforestation
2. Analyzing deforestation in general, instead of primary forest loss
3. Using satellite data on forest cover, without carefully checking it against ground-based data

1. Deforestation, benefits, and costs

Best of times, worst of times

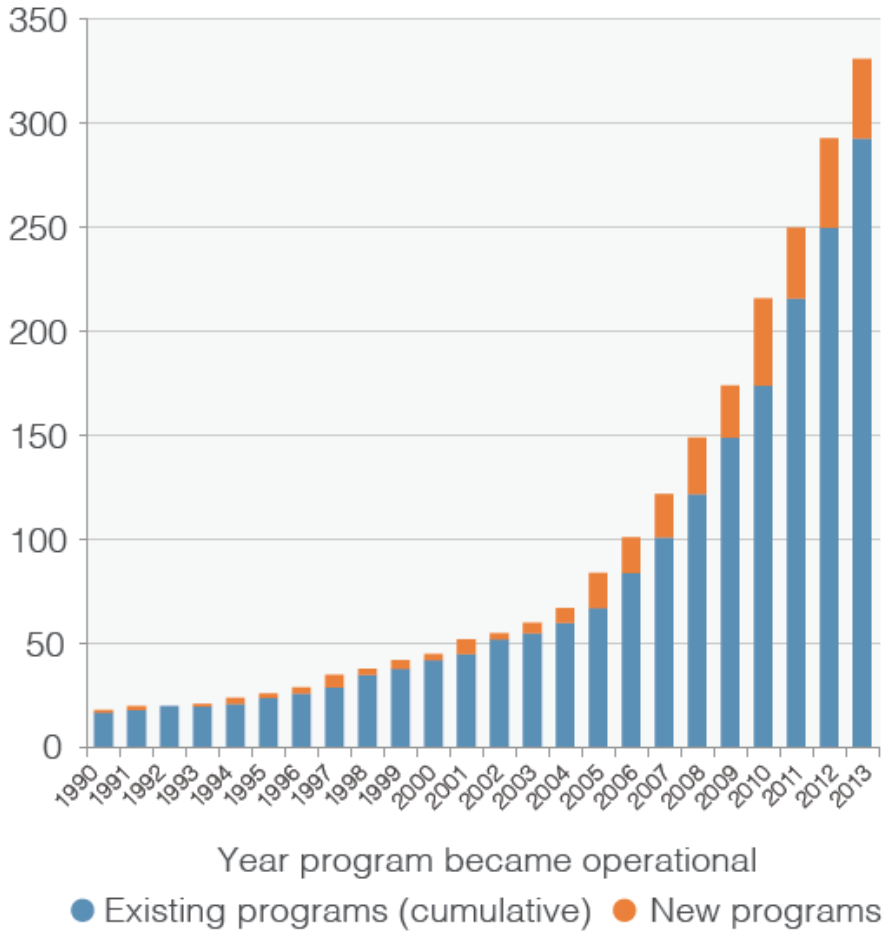


Source: FAO (2010)

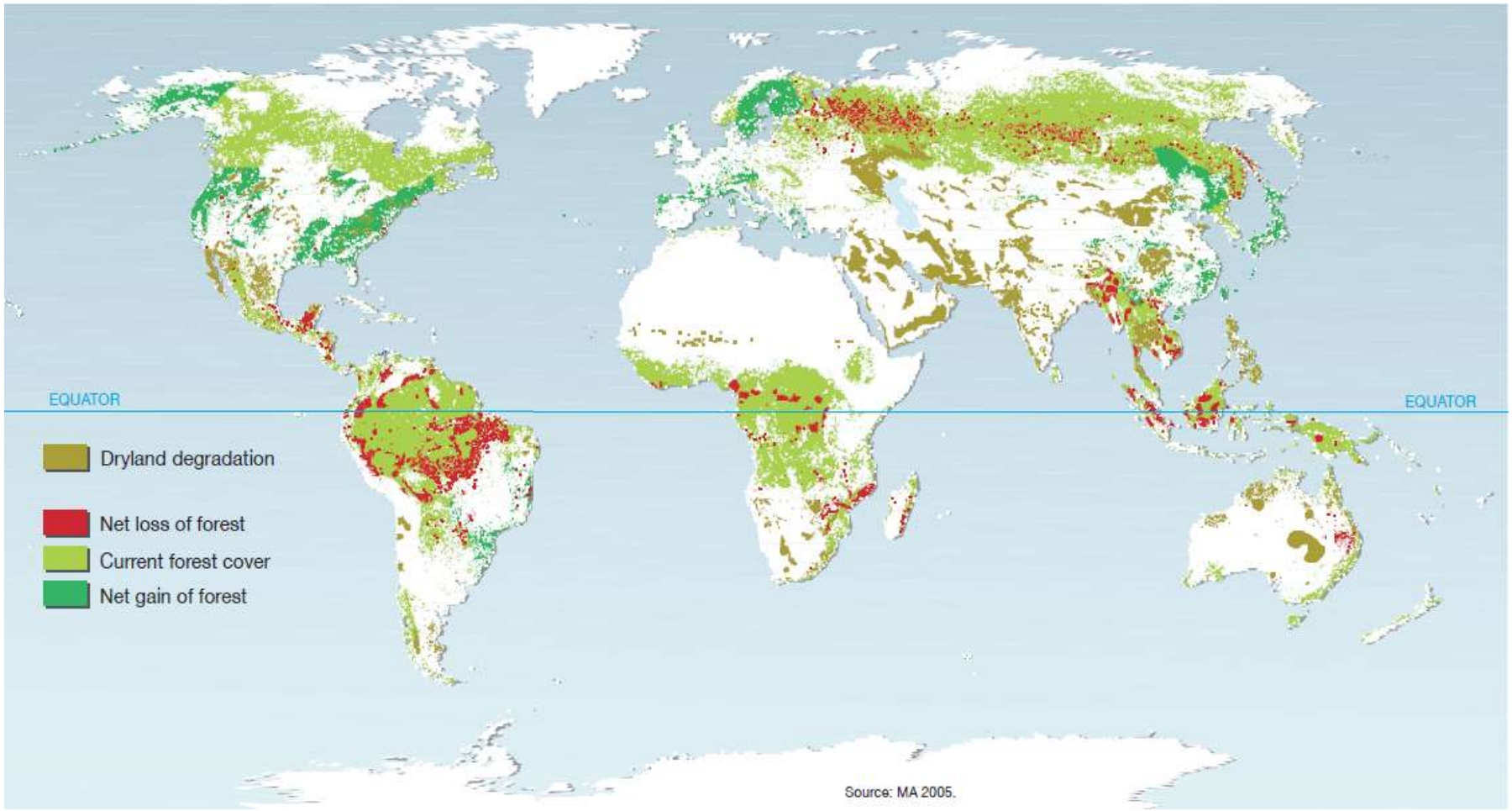


Source: http://www.rightsandresources.org/resources/tenure-data/

Figure 2: Count of Newly Operational Programs, 1990-2013



Source: Bennett & Carroll (2014)



Source: FAO (2012)

Table 1. Extinction rates calculated by cohort analysis and fractions of species that are critically endangered (CR). Data from (*13*, *37*, *50*, *51*). Bird species thought to be "possibly extinct" are counted as extinctions.

When described	Species	Extinctions	Species-years	Extinction rate	CR	% CR
			Birds			
Before 1900	8922	89	1,812,897	49	123	1.4
1900 to present	1230	13	98,334	132	60	4.9
			Amphibians			
Before 1900	1437	14	212,348	66	37	2.6
1900 to present	4972	22	206,187	107	483	9.7
			Mammals			
Before 1900	2983	36	500,252	72	70	2.3
1900 to present	2523	43	176,858	243	126	5.0

Source: Pimm et al. (2014)

What is the impact of conservation programs?

Table 1: Protected area studies using rigorous empirical analysis

Study	Location	Unit of analysis	Sample size (protected/ unprotected)	PA type	Methods	Outcome
Andam *et al.*, 2008	Costa Rica	pixel	2,711/10,371 2,022/4,724	IUCN I–VI[a]	matching	11 per cent reduction in deforestation
Ferraro and Hanauer, 2011	Costa Rica	pixel	same as in Andam *et al.*, 2008	IUCN I–VI[a]	matching	tradeoffs b/w deforestation and poverty reduction
Ferarro *et al.*, 2011	Costa Rica	pixel	same as in Andam *et al.*, 2008	IUCN I–VI[a]	matching, PLM	11 per cent deforestation reduction; tradeoffs b/w deforestation and poverty reduction
Ferraro *et al.*, 2011	Thailand	pixel	same as in Sims, 2010	IUCN I–II[a]	matching	15 per cent deforestation reduction; tradeoffs b/w deforestation and poverty reduction
Joppa and Pfaff, 2010	147 countries[b]	pixel	5 per cent of PA in each country/4x unprotected area	IUCN I–VI	matching	deforestation reduction in over 75 per cent of the countries in the sample
Gaveau *et al.*, 2009	Sumatra and Siberut	pixel	463/423	conservation and hydrological PAs	matching, regressions	24 per cent deforestation reduction
Pfaff *et al.*, 2009	Costa Rica	pixel	4,229	IUCN I–II	matching, regressions	1–2 per cent deforestation reduction
Haruna, 2010	Panama	pixel	9,467/27,559 8,372/27,121	IUCN I–II	matching	12–16 per cent deforestation reduction 12–15 per cent deforestation reduction
Sims, 2010	Thailand	locality	20,565	IUCN I–II	IV	7–19 per cent deforestation reduction
Schwarze and Jurhbandt, 2010	Indonesia	pixel	10,418/13,888	Lore-Lindu National Park	matching	9.4 per cent deforestation reduction
Nelson and Chomitz, 2011	tropical developing countries	pixel	varies	All PAs[c]	matching, LOESS	some reduction in forest fires, impacts vary by intervention, time period, and distance to major city

Source: Miteva, Pattanayak, and Ferraro (2012)

Table 2: Decentralization studies using rigorous empirical analysis

Study	Location	Unit of analysis	Intervention	Sample	Method	Outcome
Burgess *et al.*, 2011	Indonesia	Pixel	Number of political jurisdictions	Large number of pixels	Poisson model	decentralization increased deforestation
Coleman and Fleischmann, 2011	Bolivia	Forest user group	National versus municipal institutions	11 treatment, 42 control groups	Probit, matching	(+) forest investments (+) perceived forest quality (not statistically significant)
Andersson and Gibson, 2007	Bolivia	Municipality	National versus municipal institutions	30 observations, 2 period GIS data	IV	No effect of municipal institutions on total or permitted deforestation; (+) impact on illegal deforestation
Pfaff *et al.*, 2011	Brazil	Pixel	State versus federal management	40,321 pixels	Matching	Federal PAs reduced deforestation, impact varies by type of PA
Edmonds, 2002	Nepal	Household	State versus local	1,200 households	Matching, IV, RD	14 per cent reduction in fuelwood collection
Baland *et al.*, 2010	India	Forest transect	State versus local	83 villages, 399 forest transects	OLS and Clogit w/ village FE,	20–30 per cent reduction lopping no impact on DBH, canopy cover, #saplings or fuelwood collection time
Somanathan *et al.*, 2009	India	Pixel	State versus council managed forests	355 treatment, 582 controls for broad-leaved pixels; 318 treatment, 504 controls for pine trees	Regressions, Matching	Forest degradation (per cent crown cover): (+) impact for pine tree forests, no impact for broad-leaved forests, reduced cost of conservation
Heltberg, 2001	India	Village, household	Local institutions	180 households, 37 villages	IV	no impact on degradation (household firewood dependence, state of the forest)
Bandyopadhya and Shyamsundar, 2004	India	Household	Community management	8,307 households in 524 villages	Matching	Fuelwood consumption increase in villages with community management (some concerns with the model, though)
Coleman and Fleischman, 2011	Kenya	Forest user group	Community management	14 treatment, 57 control groups	Probit, matching	(–) forest investments (–) perceived forest quality (not statistically significant)
Coleman and Fleischman, 2011	Mexico	Forest user group	National versus community management	19 treatment, 21 control groups	Probit, matching	(+) forest investments (+) perceived forest quality
Coleman and Fleischman, 2011	Uganda	Forest user group	National versus community management	42 treatment, 102 control groups	Probit, matching	(+) forest investment[a] (–) perceived forest quality (not statistically significant)

Source: Miteva, Pattanayak, and Ferraro (2012)

Table 3: PES studies using rigorous empirical analysis

Study	Location	Unit of analysis	Sample	Methods	Outcome
Rios and Pagiola, forthcoming	Colombia	farm plots	72 PES contracts, 29 controls	Tobit/OLS	3.6 ecosystem services pts
Alix-Garcia *et al.*, forthcoming	Mexico	farm plots	352 PSAH contracts, 462 controls	Matching and tobit	50 per cent deforestation reduction[b]
Scullion et al., 2011	Mexico	farm plots	38 PES contracts, unspecified # controls	DID	34.8 per cent deforestation reduction (pine-oak forest)18.3 per cent deforestation reduction (cloud forests)
Honey-Roses *et al.*, 2011	Mexico	polygon[a]	425 treatment, 3,778 controls	Matching, DID	3–16 per cent deforestation reduction in high quality habitat 0–2.5 per cent deforestation reduction in lower quality habitat
Sierra and Russman, 2006	Costa Rica	farm plots	30 PES contracts, 30 controls	OLS	0.4 ha fallow –0.25 ha forests
Arriagada *et al.*, 2008	Costa Rica	census tracts	1,050 PSA tracts, 7,138 controls	PSM and regressions	21.2–34.1 ha forest gain
Pfaff *et al.*, 2008	Costa Rica	pixel	40 PSA pixels, 40–240 controls	PSM	<1 per cent deforestation reduction
Arriagada *et al.*, 2012	Costa Rica	farms	50 treated PSA farms, 152 control	Matching and DID regression	gain of 11–17 per cent of the mean contracted forest area
Robalino *et al.*, 2008	Costa Rica	pixel	925 PSA pixels, 925–4,625 controls	PSM	0.4 per cent deforestation reduction

Source: Miteva, Pattanayak, and Ferraro (2012)

Ex post deforestation in area protected – Ex ante deforestation in area protected?

Before 2007

After 2007

Ex post deforestation in area protected – Ex ante deforestation in area protected?

Before 2007

After 2007

"Before" ≠ counterfactual: other factors may differ over time

Ex post deforestation inside area protected – Ex post deforestation outside area protected?

After 2007

After 2007

Ex post deforestation inside area protected – Ex post deforestation outside area protected?

After 2007

After 2007

Non-park ≠ counterfactual: other factors may differ across space

Impact evaluation

- Methods
  - Randomized controlled trials
  - Matching
  - Difference in differences
  - Instrumental variables
  - Regression discontinuity
- Results
  - "The limited set of rigorous studies suggests that **protected areas** cause **modest reductions** in deforestation": only 10-15%
  - "the evidence base for **payments for ecosystem services**, **decentralization policies** and other interventions is **much weaker**"

Does a low impact on deforestation imply a bad conservation decision?

Not necessarily!

1. Focus on deforestation rate—a physical outcome measure—ignores conservation benefits and costs (Vincent 2015)

2. Deforestation is not the only—or even the most important—reason for establishing protected areas

3. Satellite data likely underestimate deforestation

Impact evaluation: 2 periods, n sites

- Period 0: conservation agency selects sites

  Period 1: outcome observed, and program evaluated

- Notation: i = site

  s_i = treatment dummy (1 = protected, 0 = not)

  d_{0i} = outcome dummy if <u>not</u> protected

  (1 = deforested, 0 = not)

- Average treatment effect on the treated (ATT): $\frac{\sum_{i=1}^{n} s_i d_{0i}}{\sum_{i=1}^{n} s_i}$

  – Fraction of protected sites that *would have been* deforested in the absence of protection

Benefit-cost analysis of the program

- Notation: C = conservation agency's budget

  c_i = cost of protecting site i

  v_i = benefit (value) from protecting site i

  ρ = continuous discount rate

- Budget constraint: $$C < \sum_{i=1}^{n} c_i$$

- Benefit-cost ratio (BCR): $$\frac{\sum_{i=1}^{n} s_i d_{0i} v_i}{\sum_{i=1}^{n} s_i c_i e^{\rho}}$$

ATT: $$\frac{\sum_{i=1}^{n} s_i d_{0i}}{\sum_{i=1}^{n} s_i}$$ *No economic variables!*

Does a higher ATT signal a higher BCR?

- Yes, if benefits and costs are uniform across sites ($v_i = v$, $c_i = c$)

BCR: $$\frac{v}{ce^{\rho}}\left(\frac{\sum_{i=1}^{n} s_i d_{0i}}{\sum_{i=1}^{n} s_i}\right)$$

ATT: $$\frac{\sum_{i=1}^{n} s_i d_{0i}}{\sum_{i=1}^{n} s_i}$$

- Two problems:
  1. ATT doesn't tell us if BCR > 1: evaluation requires valuation
     - And, should be forward-looking
  2. $c_i \neq c$, $v_i \neq v$: heterogeneity rules

Heterogeneity in costs

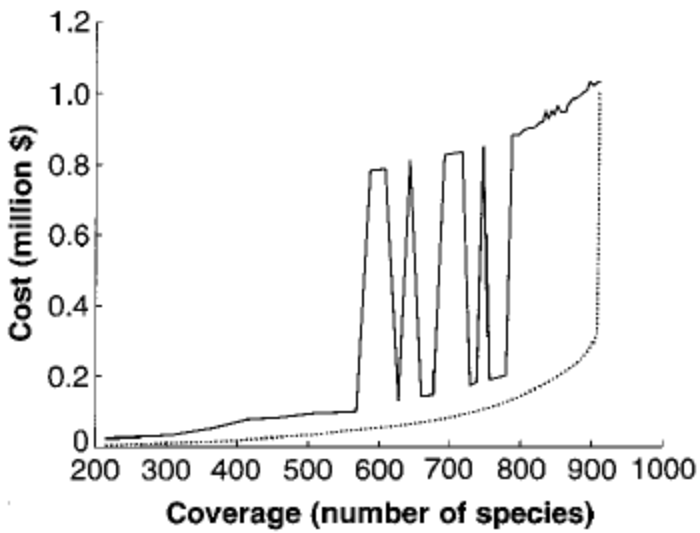


Fig. 1. Cost versus coverage for site-minimizing (solid curve) and cost-minimizing (dotted curve) solutions.

Source: Ando et al. (1998)

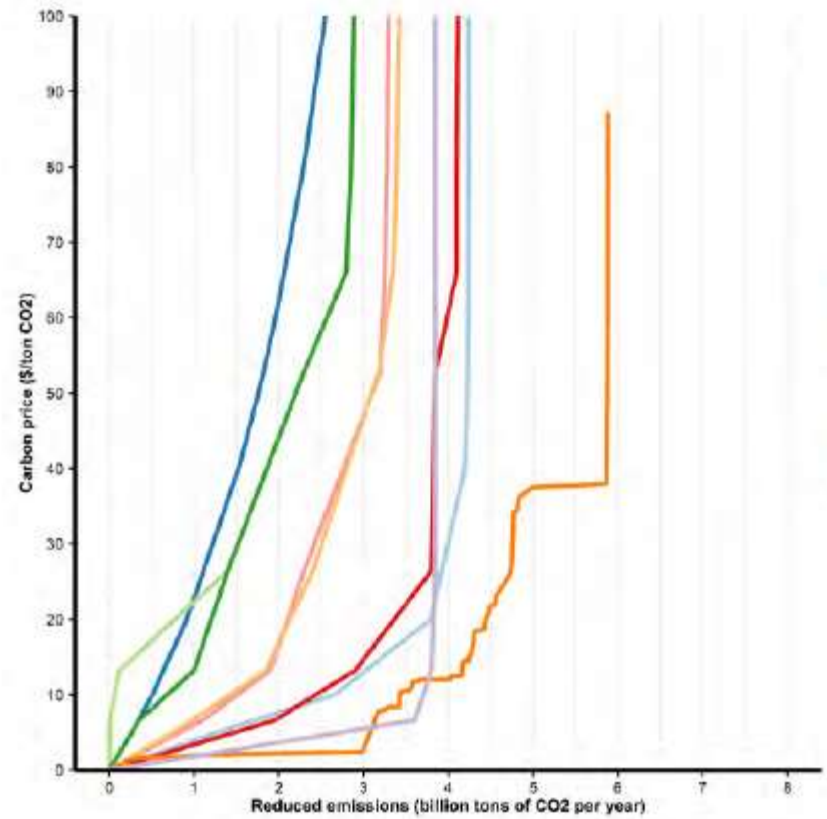
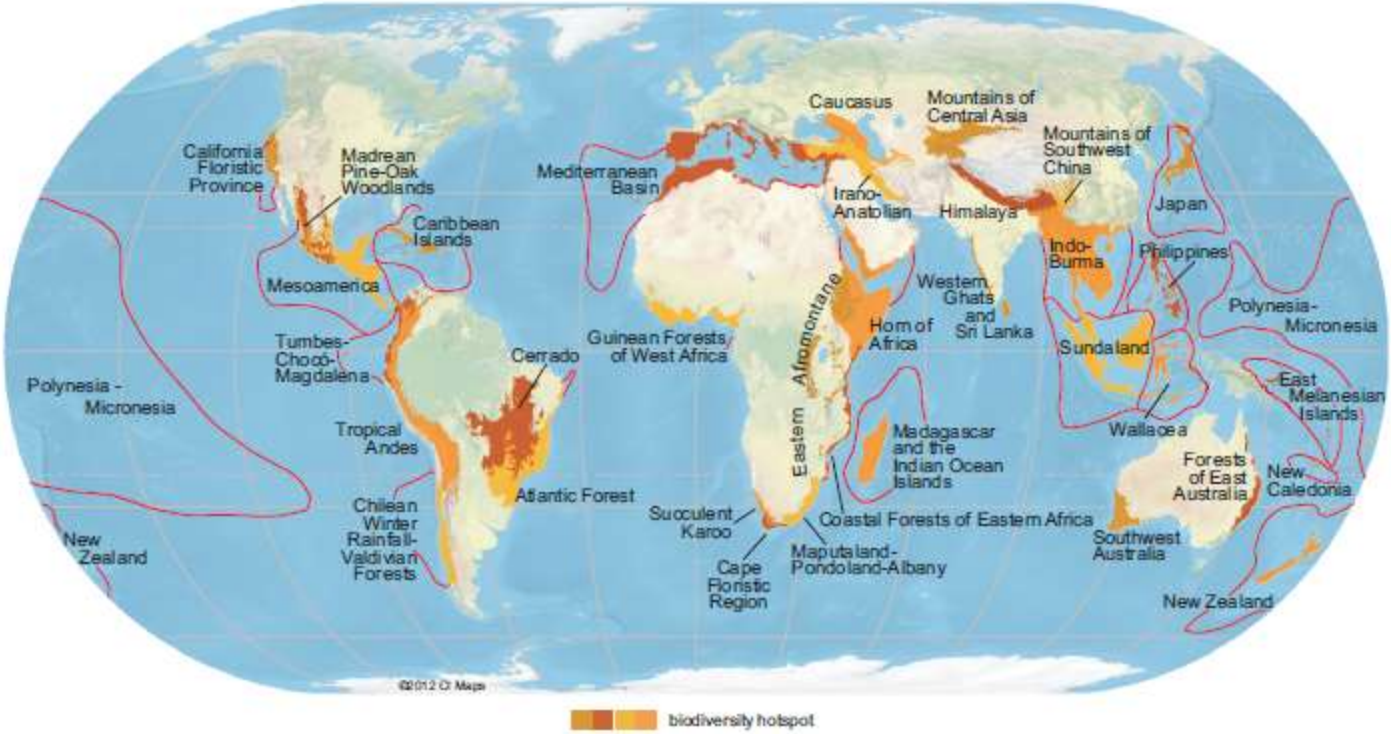


Figure 11a. Marginal abatement cost curve for pan-tropical forest loss, 2020, by study.

Source: Busch & Engelmann (2015)

Heterogeneity in benefits



Source: http://www.conservation.org/publications/Documents/Migrated%20Files/CI_Biodiversity-Hotspots_2011_Map.pdf

Figure 2. *Map of Indonesia (arrow points to Flores Island)*

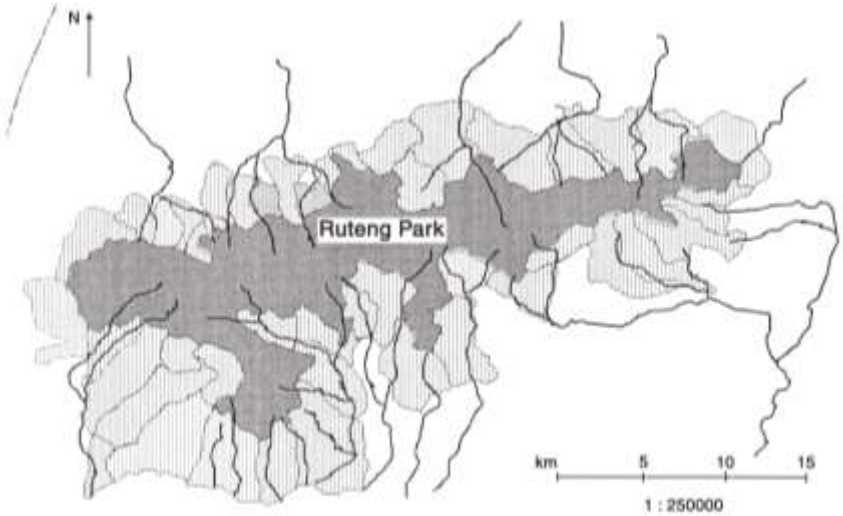
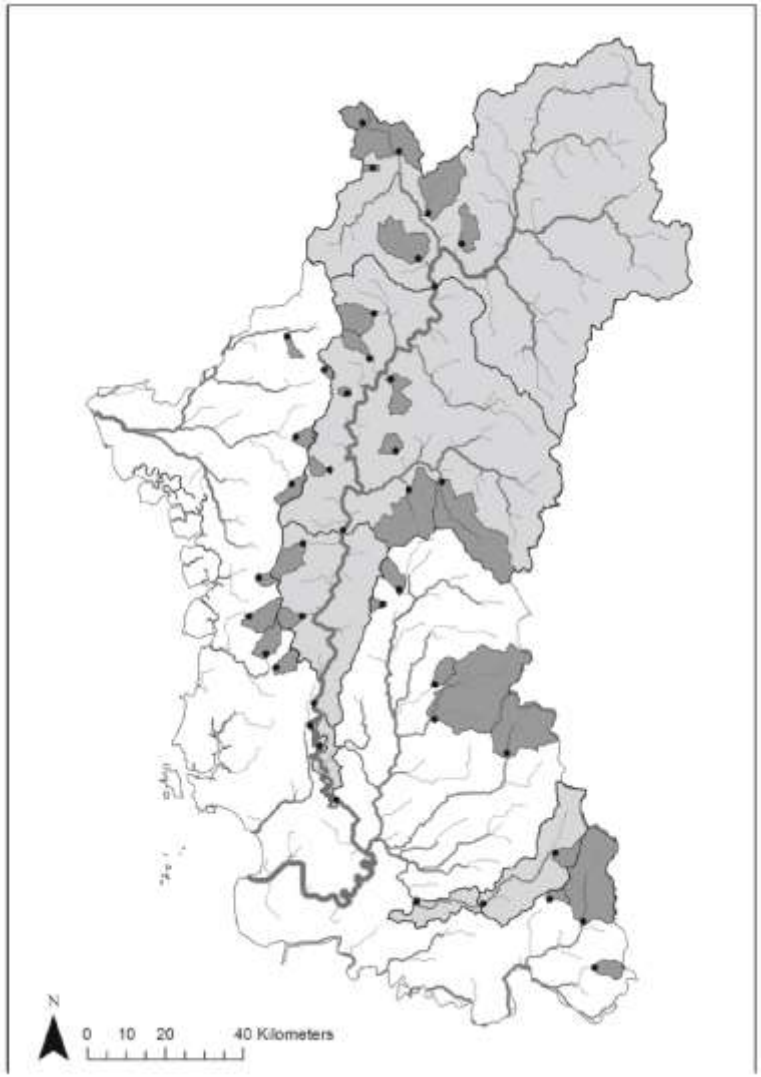


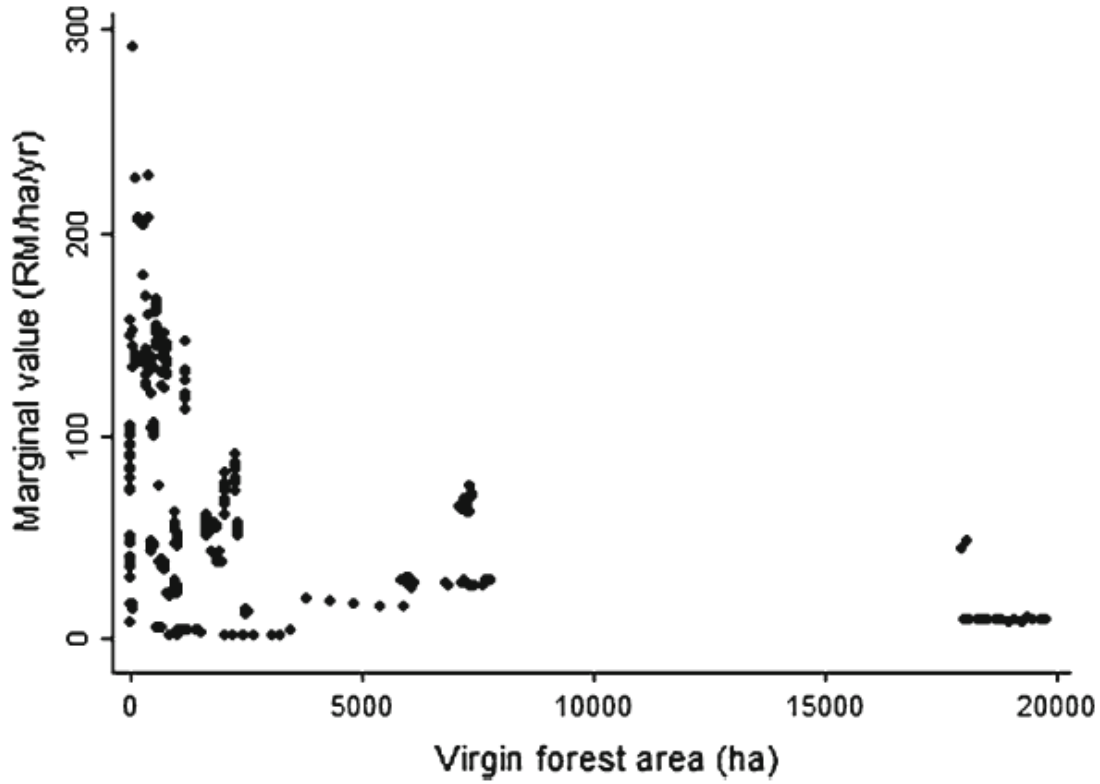
Figure 3. *Rivers of Manggarai (37 watersheds in west-central Flores)*

Table 6. *Drought mitigation benefits of increased forestation (25% and 75%) in Manggarai counties*

Kecamatan *(county)*	*Baseflow increase from 25% increase in forest cover* (mm)*		*Drought mitigation benefits of 25% forest cover increase* ($)***	
6A	*median*	*min/max*	*median*	*min/max*
Borong	15	−25/49	4.27	−10.67/20.45
Elar	−17	−25/14	−6.74	−12.76/4.73
Langke Rembong	−25	−27/12	−9.57	−12.72/3.42
Pembantu Borong	9	−25/48	3.36	−9.74/19.54
Pembantu Elar	36	12/36	10.15	3.31/15.28
Pembantu Lambaleda	−23	−34/−4	−8.06	−14.15/−1.32
Pembantu Ruteng	−12	−12/−12	−4.25	−6.23/−3.38
Ruteng	−5	−25/16	−0.86	−10.46/6.37
Satarmese	9	−26/23	3.35	−11.52/10.12

Source: Pattanayak & Kramer (2000)





Source: Vincent et al. (2015)

Impact evaluation vs. BCA: 2 countries, ∞ periods

- Is the deforestation rate (d_{0i}) positively correlated with conservation benefits (v_i) and negatively correlated with conservation costs (c_i)?
  - If so, ATT is positively correlated with BCR
- Two forested countries: identical, except one is farther along socially optimal deforestation path than other
  - Forest poor: farther along
  - Forest rich: less far along

- Two donor countries: each protects marginal area in one country
  - Do avoided deforestation rates for marginal areas reveal which donor country made the better aid decision in BCR sense?
- No!
  - Avoided deforestation rate: higher in forest-rich country
  - Marginal conservation benefits: lower in forest-rich country

    Marginal conservation costs: higher in forest-rich country

Economic variables, avoided deforestation rate: counterposed

Clinical trials: bad analogy for conservation evaluation

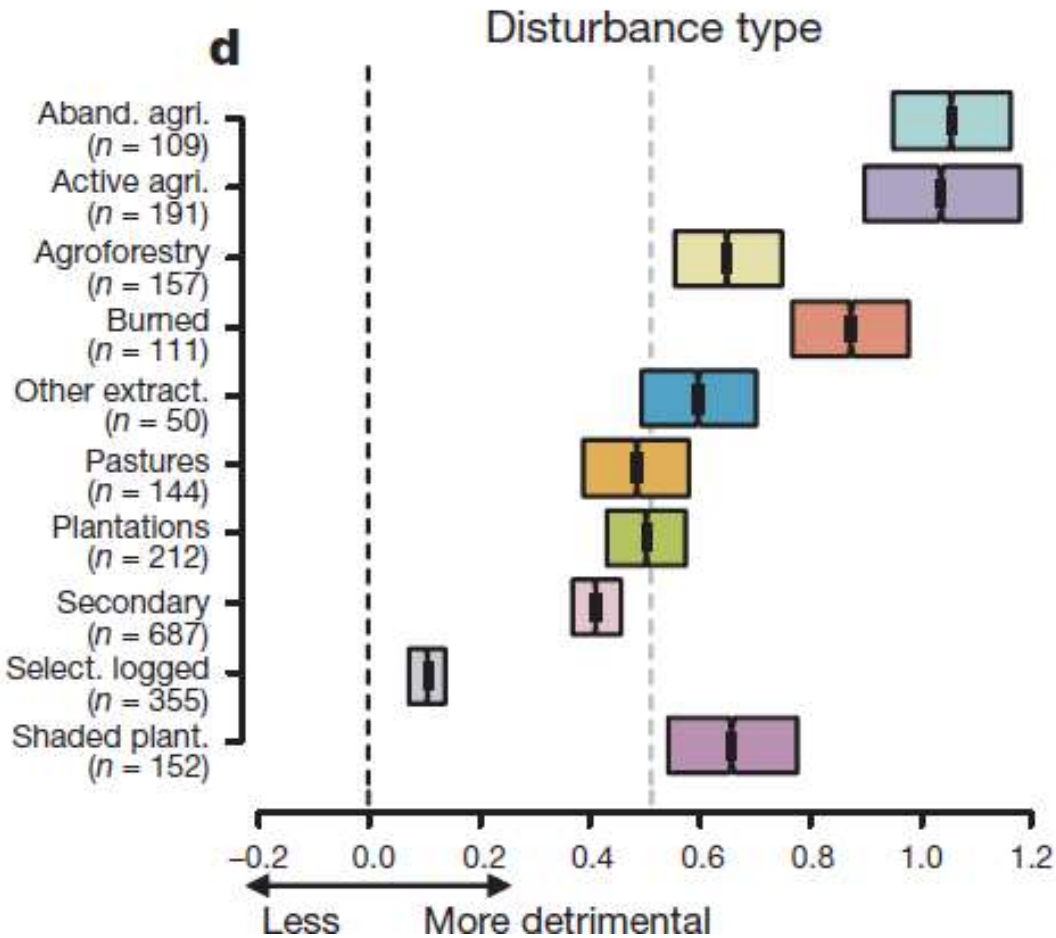
- Cost of treatment doesn’t vary across subjects
- Benefit of treatment not valued differently by subject characteristics (gender, race, etc.)

2: Deforestation in general, vs. loss of primary forests

Primary forests

- "forests of native species in which there are no clearly visible signs of past or present human activity" (FAO, 2010)
  - Virgin
  - Old-growth

Source: FAO (2010)



Source: Gibson et al. (2011)

Table 2 Robustness of estimated effects of forest cover on water treatment cost

Variables[a]	Aggregated forest: no controls	Disaggregated forest: no controls	Add rainfall	Add FEs[b] for WTPs	Add FEs for time
	(1)	(2)	(3)	(4)	(5)
ln (1 + Forest share)	−1.13				
	(0.134)				
ln (1 + Virgin forest)		−1.02	−1.01*	−1.35***	−1.63**
		(0.101)	(0.097)	(0.001)	(0.013)
ln (1 + Logged forest)		−0.173	−0.247	−0.974**	−1.17**
		(0.807)	(0.720)	(0.011)	(0.027)
ln (Water volume)	0.648***	0.653***	0.656***	0.146**	0.154**
	(0.000)	(0.000)	(0.000)	(0.030)	(0.028)
ln (Rainfall)			0.290	−0.259**	−0.256**
			(0.281)	(0.037)	(0.014)
ln (Rainfall), squared			−0.0449	0.0255**	0.0239**
			(0.133)	(0.032)	(0.016)
FEs: TPs	No	No	No	Yes	Yes
FEs: TP upgrading	No	No	No	Yes	Yes
FEs: Years	No	No	No	No	Yes
FE: Months	No	No	No	No	Yes
Observations	3894	3894	3894	3894	3894
R^2	0.674	0.691	0.696	0.954	0.956

Source: Vincent et al. (2015)

Deforestation has slowed down since 1990 …

TABLE 2.4
Annual change in forest area by region and subregion, 1990–2010

Region/subregion	1990–2000		2000–2010	
	1 000 ha/yr	%	1 000 ha/yr	%
Eastern and Southern Africa	-1 841	-0.62	-1 839	-0.66
Northern Africa	-590	-0.72	-41	-0.05
Western and Central Africa	-1 637	-0.46	-1 535	-0.46
Total Africa	**-4 067**	**-0.56**	**-3 414**	**-0.49**
East Asia	1 762	0.81	2 781	1.16
South and Southeast Asia	-2 428	-0.77	-677	-0.23
Western and Central Asia	72	0.17	1 31	0.31
Total Asia	**-595**	**-0.10**	**2 235**	**0.39**
Russian Federation	32	n.s.	-18	n.s.
Europe excl. Russian Federation	845	0.46	694	0.36
Total Europe	**877**	**0.09**	**676**	**0.07**
Caribbean	53	0.87	50	0.75
Central America	-374	-1.56	-248	-1.19
North America	32	n.s.	188	0.03
North and Central America	**-289**	**-0.04**	**-10**	**-0.00**
Total Oceania	**-41**	**-0.02**	**-700**	**-0.36**
Total South America	**-4 213**	**-0.45**	**-3 997**	**-0.45**
World	**-8 327**	**-0.20**	**-5 211**	**-0.13**

Source: FAO (2010)

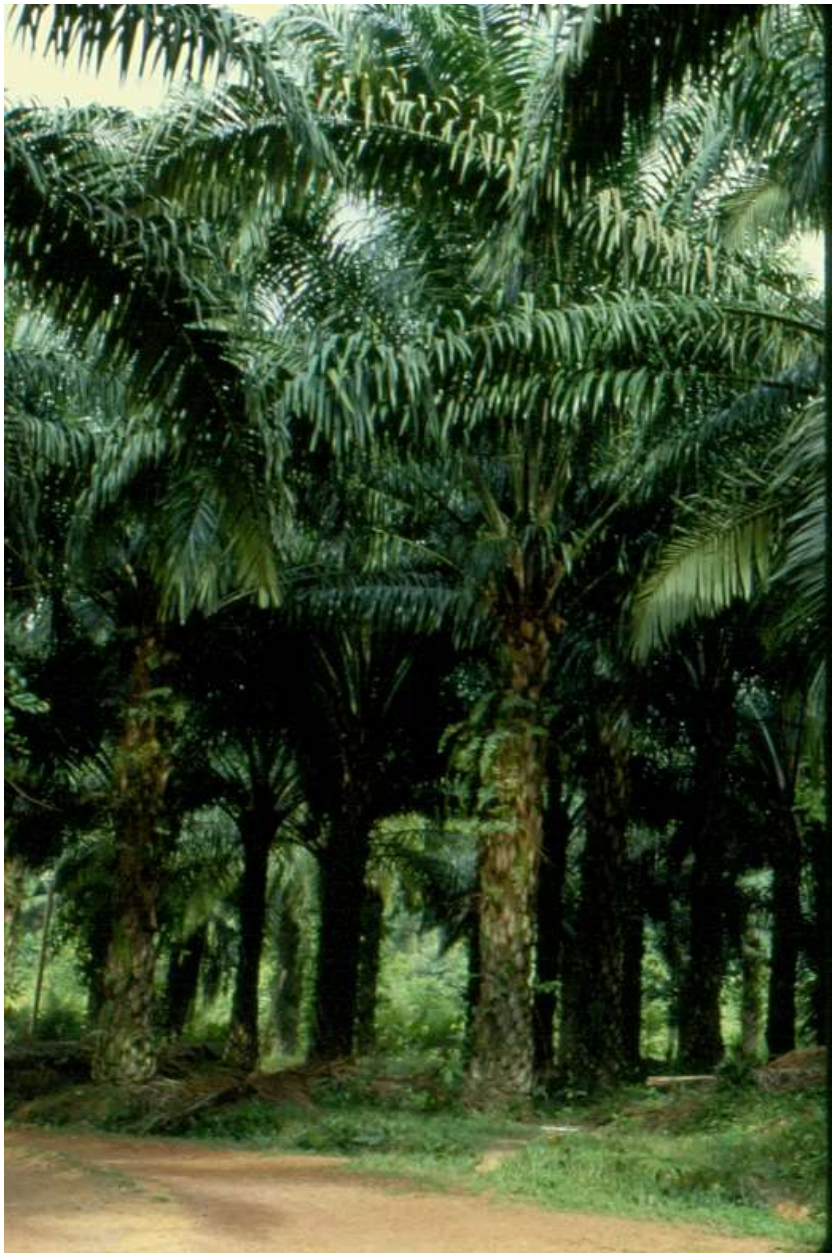
… but loss of primary forests hasn't

TABLE 3.3
Trends in area of primary forest by region and subregion, 1990–2010

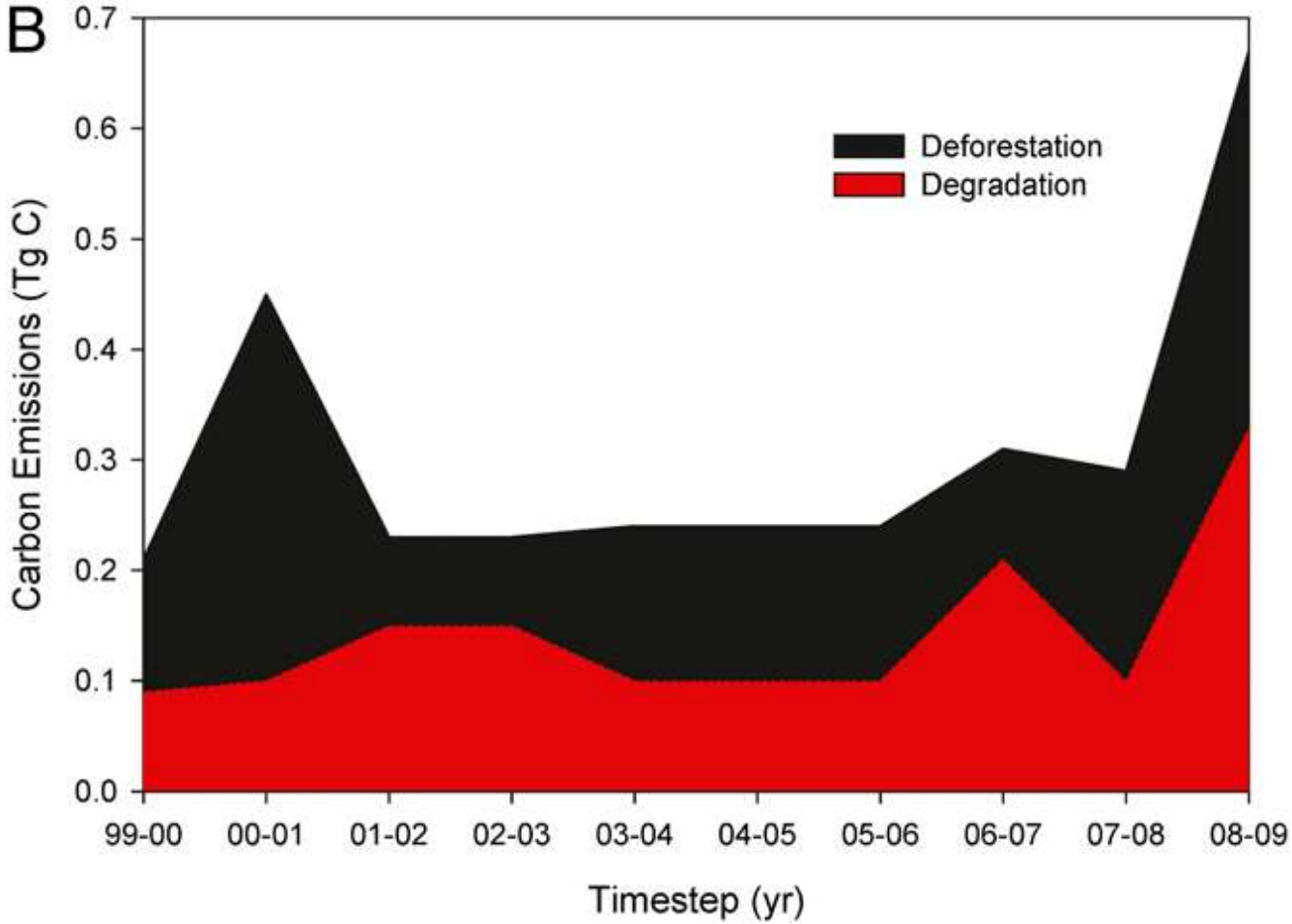
Region/subregion	Information availability		Area of primary forest (1 000 ha)			Annual change (1 000 ha)		Annual change rate (%)	
	Number of countries	% of total forest area	1990	2000	2010	1990–2000	2000–2010	1990–2000	2000–2010
Eastern and Southern Africa	23	100.0	7 594	7 024	6 430	-57	-59	-0.78	-0.88
Northern Africa	8	100.0	15 276	14 098	13 990	-118	-11	-0.80	-0.08
Western and Central Africa	23	46.9	37 737	32 540	27 527	-520	-501	-1.47	-1.66
Total Africa	**54**	**74.2**	**60 607**	**53 662**	**47 947**	**-695**	**-572**	**-1.21**	**-1.12**
East Asia	5	100.0	28 179	26 456	25 268	-172	-119	-0.63	-0.46
South and Southeast Asia	17	100.0	87 062	83 587	81 235	-348	-235	-0.41	-0.29
Western and Central Asia	23	96.9	2 924	3 083	3 201	16	12	0.53	0.38
Total Asia	**45**	**99.8**	**118 166**	**113 127**	**109 705**	**-504**	**-342**	**-0.43**	**-0.31**
Total Europe	**42**	**19.1**	**5 183**	**5 360**	**5 438**	**18**	**8**	**0.34**	**0.14**
Caribbean	16	70.4	207	206	205	n.s.	n.s.	-0.07	-0.02
Central America	7	100.0	5 766	5 226	4 482	-54	-74	-0.98	-1.52
North America	5	100.0	274 920	273 795	275 035	-113	124	-0.04	0.05
Total North and Central America	**28**	**99.7**	**280 893**	**279 227**	**279 722**	**-167**	**50**	**-0.06**	**0.02**
Total Oceania	**16**	**99.7**	**41 416**	**39 191**	**35 493**	**-222**	**-370**	**-0.55**	**-0.99**
Total South America	**13**	**94.6**	**684 654**	**653 691**	**624 077**	**-3 096**	**-2 961**	**-0.46**	**-0.46**
World	**198**	**74.3**	**1 190 919**	**1 144 258**	**1 102 382**	**-4 666**	**-4 188**	**-0.40**	**-0.37**

Source: FAO (2010)

Deforestation: mainly conversion to agriculture



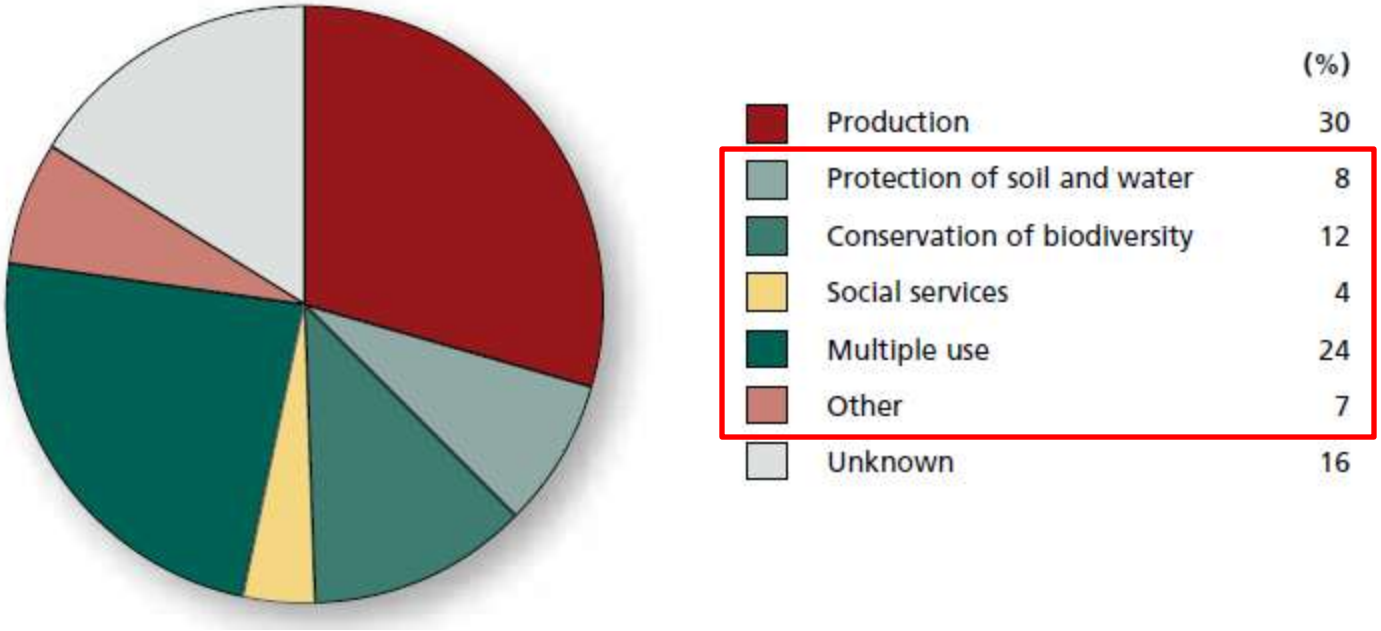
Loss of primary forests: degradation (harvesting), not only deforestation



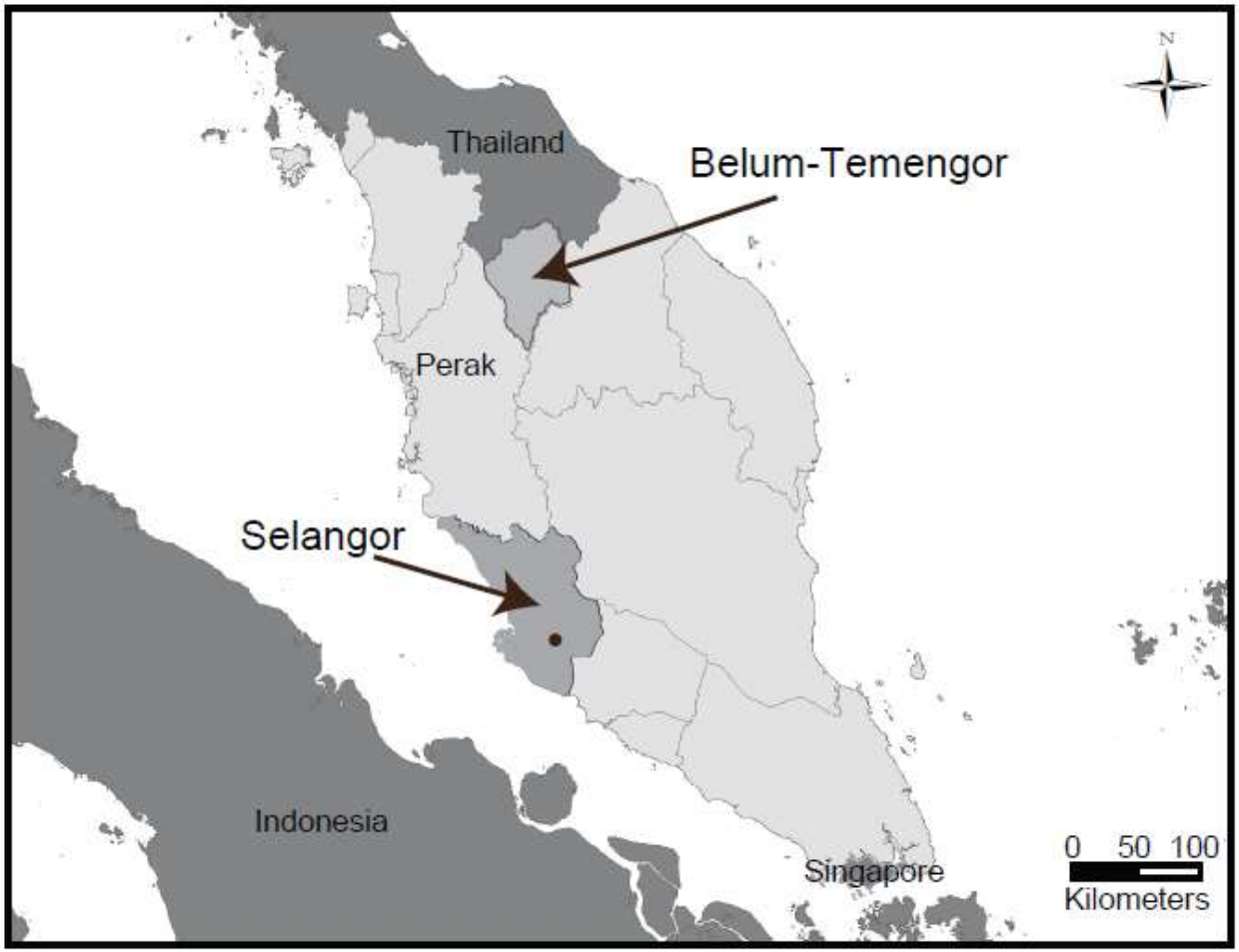
Source: Asner (2010)

Forest protection: not only against deforestation

FIGURE 19
Designated functions of forests, 2010



Source: FAO (2010)



Source: Vincent et al. (2014); see also Schwabe et al. (2015)

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	Policy A	Policy B	No protection
Logging	150,000 ha	0 ha	300,000 ha
	Half these species go extinct	None of these species go extinct	All these species go extinct
Poaching	0 ha	150,000 ha	300,000 ha
	None of these species go extinct	Half these species go extinct	All these species go extinct
Floods in Perak	3 per year	1 per year	5 per year
Jobs created in Perak	5,000	7,500	7,500
Cost to you	RM6 per month	RM6 per month	No cost

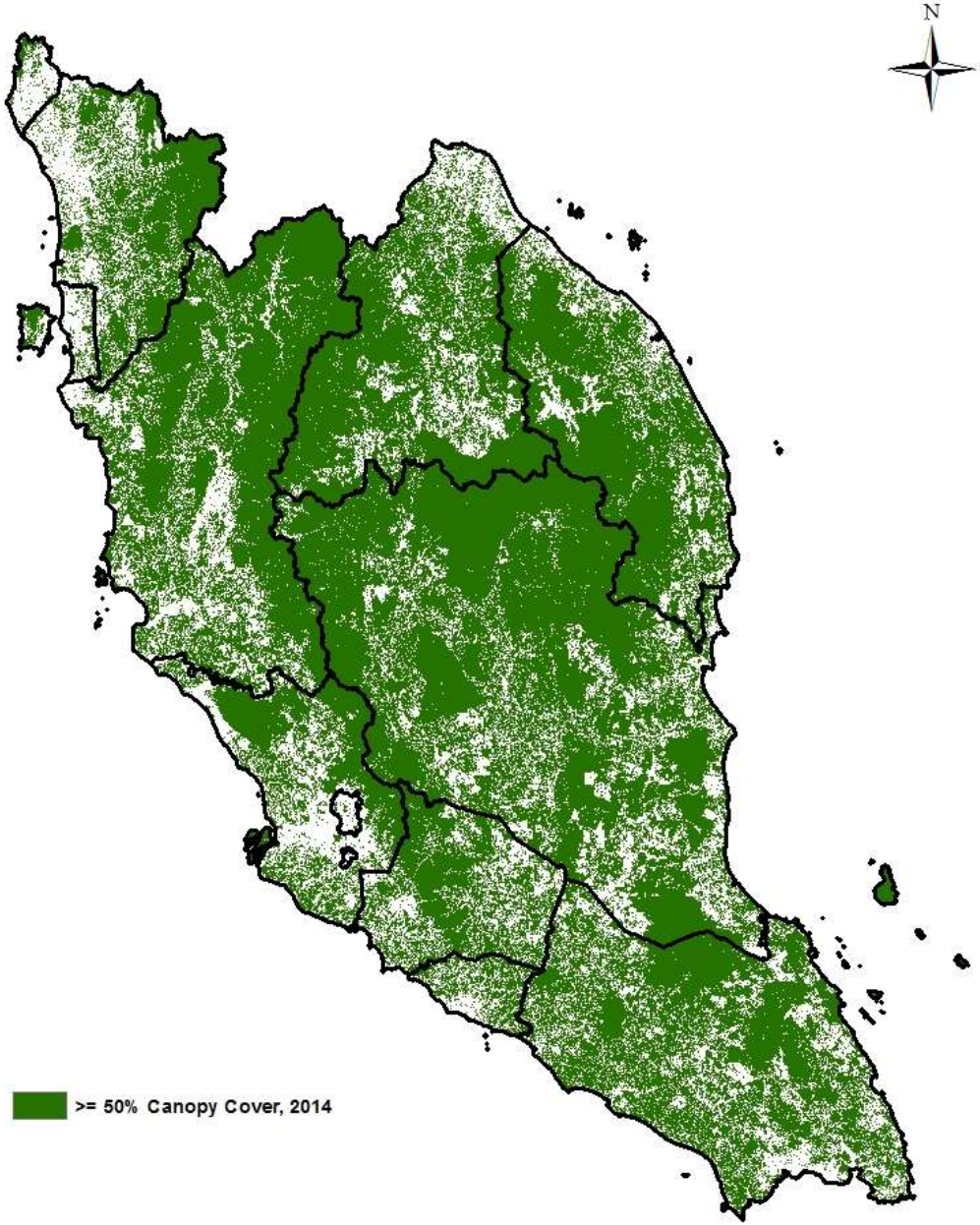
Source: Vincent et al. (2014)

Part 3: Satellite Estimates of Forest Cover

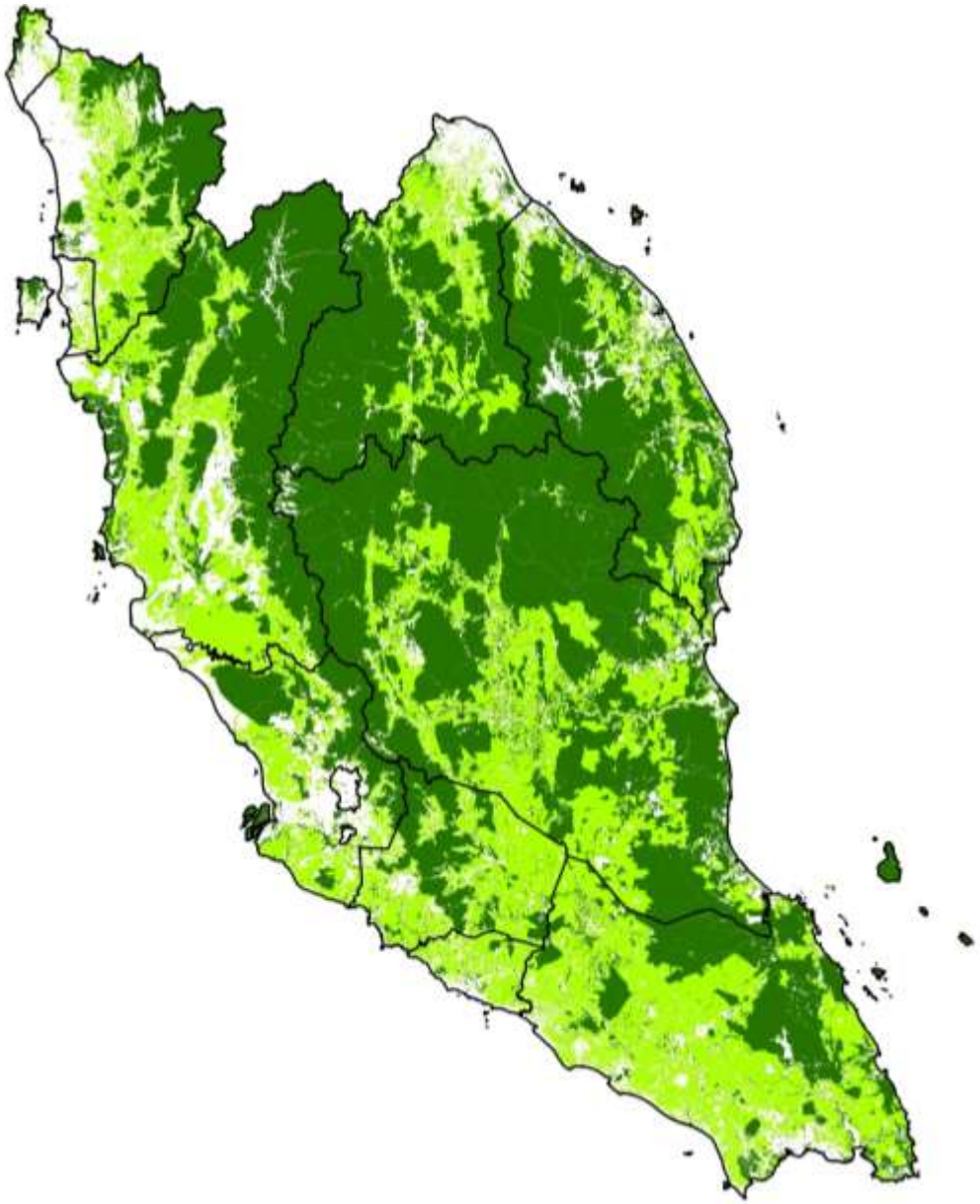
Tree cover
≠ Forest cover

- 2004 forest cover in Peninsular Malaysia: land-use survey (Department of Agriculture, Malaysia)

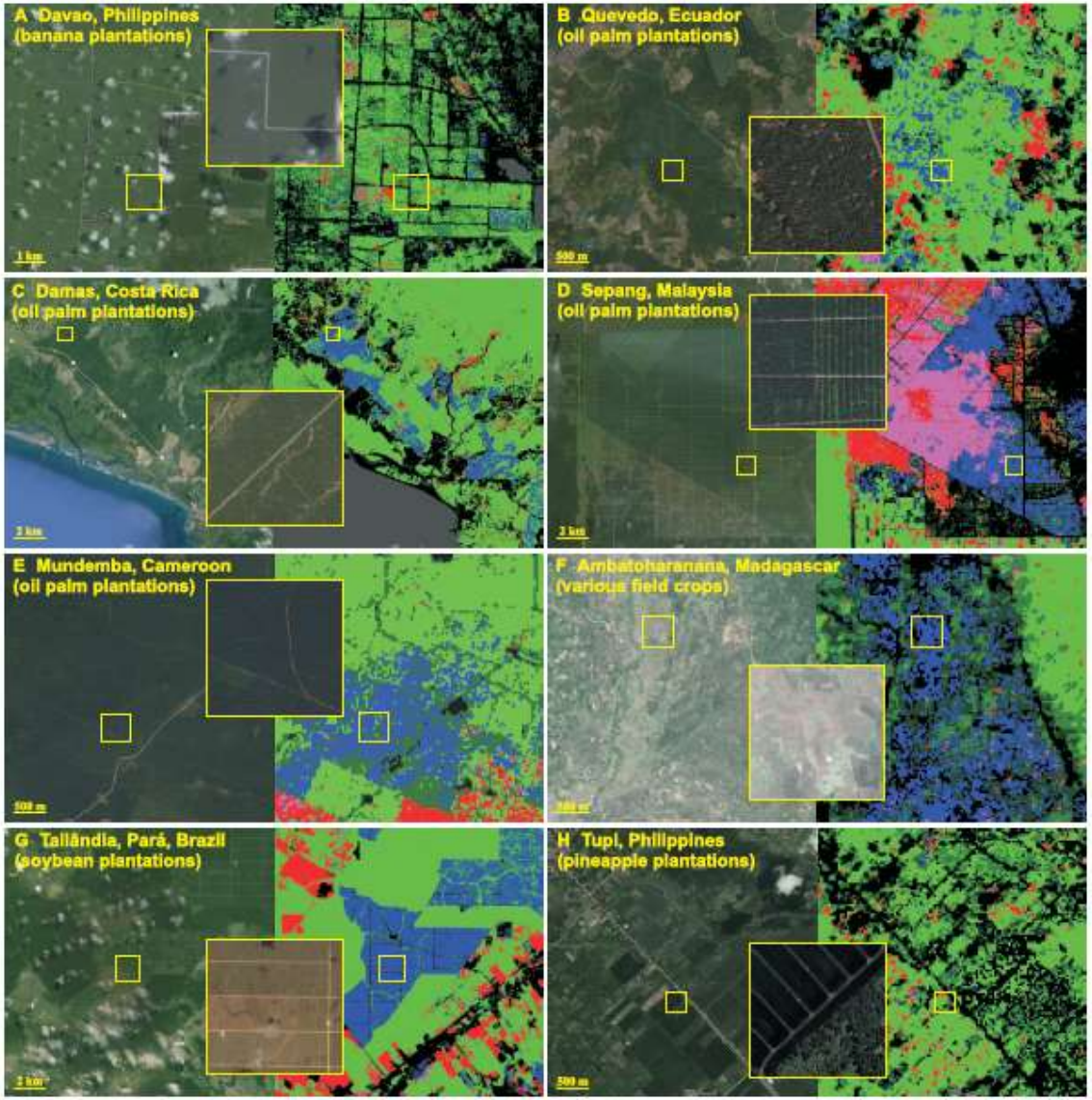
- 2014 tree cover in Peninsular Malaysia, satellite-based (Hansen et al. 2013)



- 2004 oil palm and rubber area in Peninsular Malaysia: land-use survey (Department of Agriculture, Malaysia)



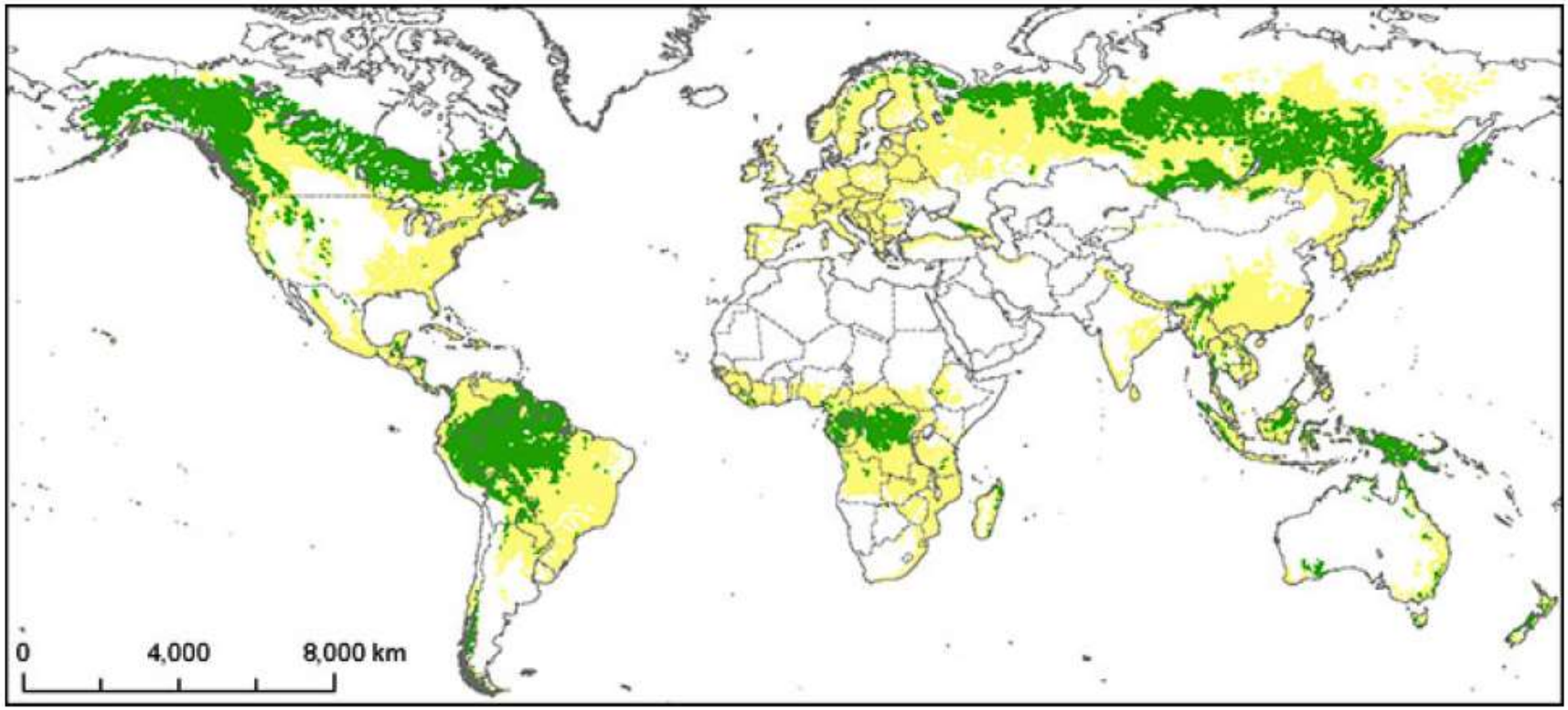
Misclassification: not unique to Malaysia



Source: Tropek et al. (2014)

Opposite problem for primary forests: remotely-sensed estimates are underestimates

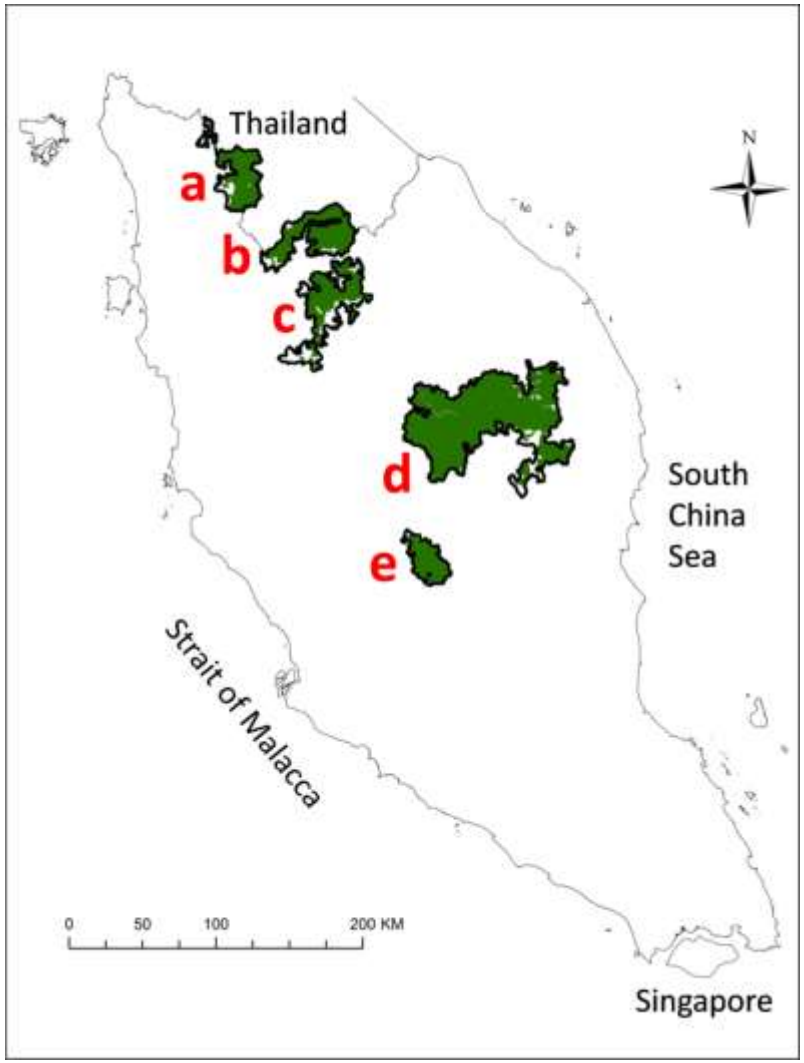
Fig. 2. The world's intact forest landscapes (IFLs): IFL (green), Forest zone outside IFL (yellow).



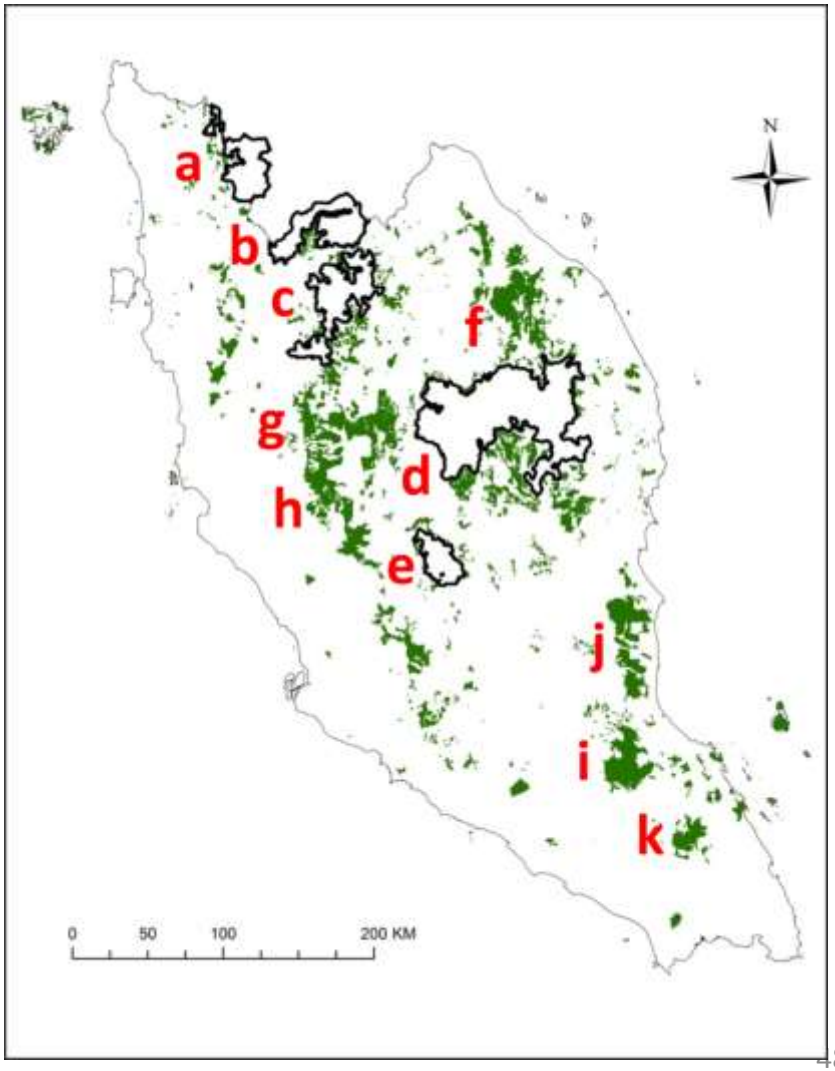
Source: Potapov et al. (2008)

Comparison of 2000 IFL estimates to 2004 National Forest Inventory estimates reveals:

Low false positive rate

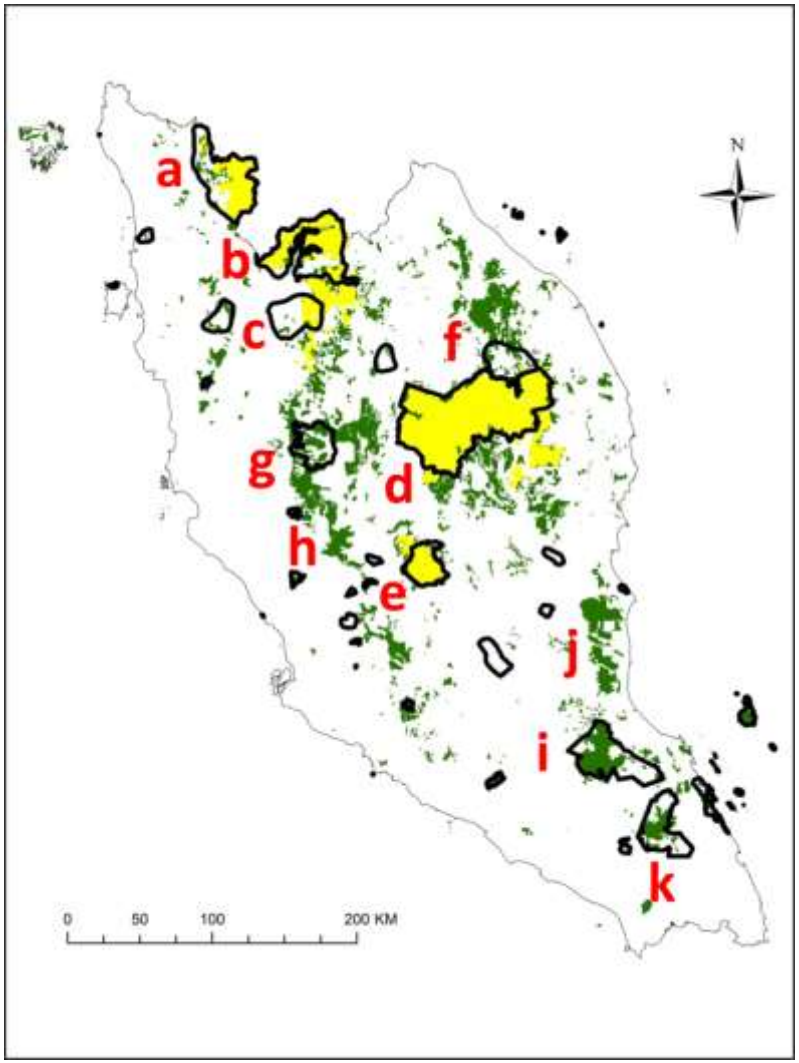


High false negative rate



Source: Adnan et al. (in review)

IFL (yellow) + WDPA (black polygons) $\Rightarrow$ nothing left to protect!



WDPA: woefully incomplete

- Omits nearly entire Permanent Forest Estate in Peninsular Malaysia: 85% of forest area as of 2013
  - Production Forest (IUCN Category VI, “Protected area with sustainable use of natural resources”)
  - Protection Forest (IUCN Category Ia, “Strict Nature Reserve”)
  - Amenity Forest (IUCN Category III, “Natural Monument or Feature”)
- Includes 694 terrestrial protected areas for Malaysia, but reports the IUCN category for only 215

My humble objectives

To get you to think twice about:

1. Analyzing deforestation rates, instead of the benefits and costs associated with deforestation
2. Analyzing deforestation in general, instead of primary forest loss
3. Using satellite data on forest cover, without carefully checking it against ground-based data

Literature cited

N. Adnan et al., “Remotely sensed estimates of Intact Forest Landscapes exclude large areas of primary forest” (*PLoS ONE*, in review)

A. Ando et al., “Species distributions, land values, and efficient conservation” (*Science* 279:2126–2128, 1998)

G.P. Asner et al., “High-resolution forest carbon stocks and emissions in the Amazon” (*Proc. Natl. Acad. Sci. USA* 107:16738–16742, 2010)

G. Bennett & N. Carroll, *Gaining Depth: State of Watershed Investment* (Ecosystem Marketplace, 2014)

J. Busch & J. Engelmann, “The future of forests: emissions from tropical deforestation with and without a carbon price, 2016-2050” (Working Paper 411, Center for Global Development, 2015)

FAO, *Global Forest Resources Assessment 2010: Main Report* (UN Food and Agriculture Organization, Rome, 2010)

FAO, *State of the World’s Forests 2012* (UN Food and Agriculture Organization, Rome, 2012)

L. Gibson et al., “Primary forests are irreplaceable for sustaining tropical biodiversity” (*Nature* 478:378-381, 2011)

D.A. Miteva, S.K. Pattanayak, and P.J. Ferraro, “Evaluation of biodiversity policy instruments: what works and what doesn’t?” (*Oxford Review of Economic Policy* 28:69–92, 2012)

S.K. Pattanayak and R.A. Kramer, “Worth of watersheds: a producer surplus approach for valuing drought mitigation in Eastern Indonesia” (*Environment and Development Economics* 6:123-146, 2001)

S.L. Pimm et al., “The biodiversity of species and their rates of extinction, distribution, and protection” (*Science* 344, 2014)

P. Potapov et al., “Mapping the world’s intact forest landscapes by remote sensing” (*Ecology and Society* 13:51, 2008)

K.A. Schwabe et al., “Creation of Malaysia’s Royal Belum State Park: a case study of conservation in a developing country” (*Journal of Environment and Development* 24:54–81, 2015)

R. Tropek et al., “Comment on ‘High-resolution global maps of 21st-century forest cover change’” (*Science* 344: 981, 2014)

J.R. Vincent, “Impact evaluation of forest conservation programs: benefit-cost analysis, without the economics” (*Environmental and Resource Economics*, 2015)

J.R. Vincent et al., “Valuing water purification by forests: an analysis of Malaysian panel data” (*Environmental and Resource Economics*, 2015)

J.R. Vincent et al., “Developing countries may be willing to pay to protect their own tropical rainforests” (*Proc. Natl. Acad. Sci. USA* 111: 10113–10118, 2014)

Thank you!