Modeling woodfuel environmental impacts in dynamic landscapes

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MoFuSS v1.0 Training Course 2016

El Jadida, Morocco September 3-4

www.mofuss.unam.mx/course-2016/

How sustainable is traditional woodfuel consumption?

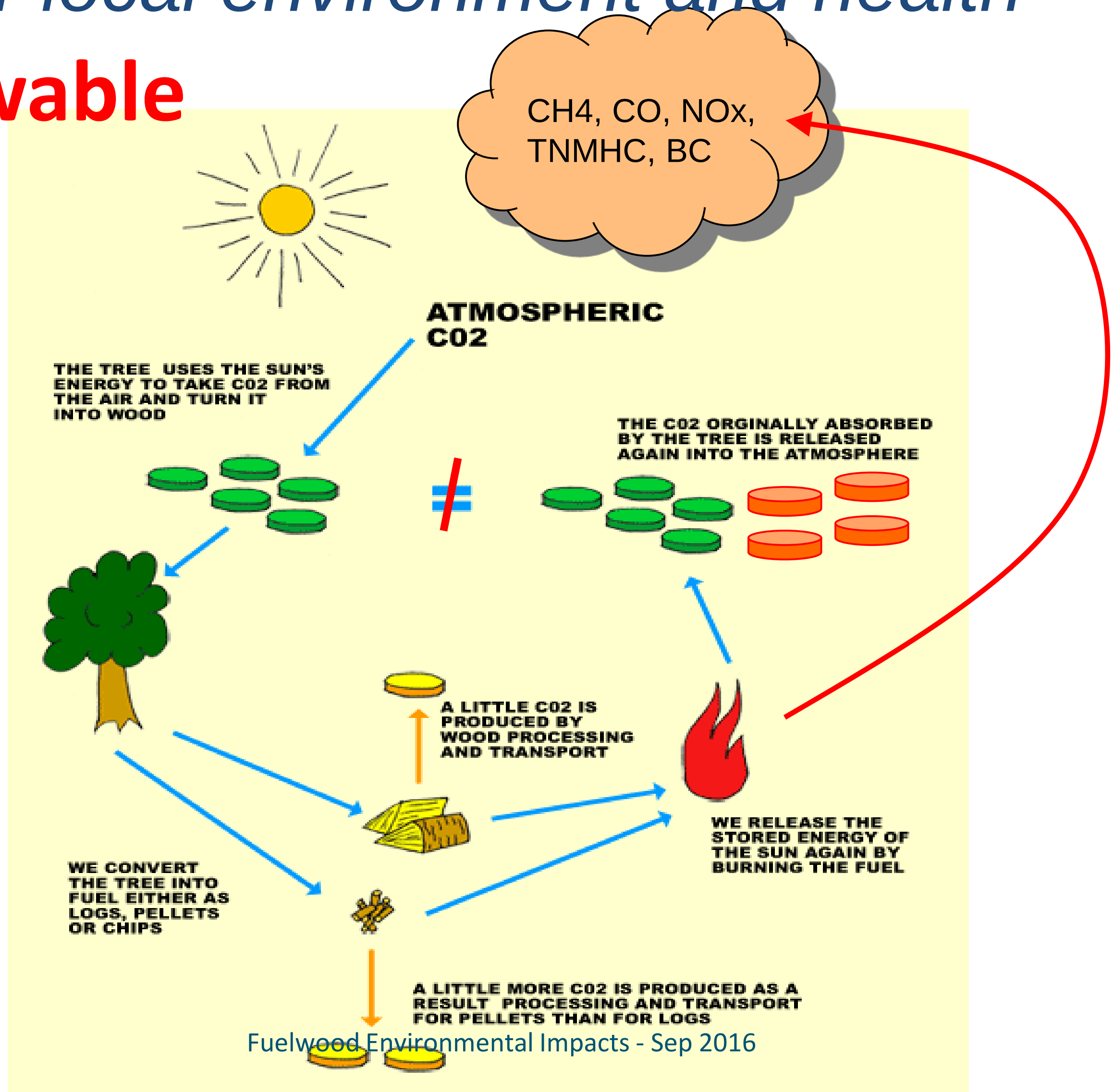
Woodfuel is fuelwood(or firewood) and charcoal

Outline of presentation

- *Renewable* vs not *non-renewable*
- How can we tell if traditional woodfuels are a driver of land change?
- Some precisions on the importance of *spatial* and *temporal* scales
- Short overview of the project that gave origin to this particular model

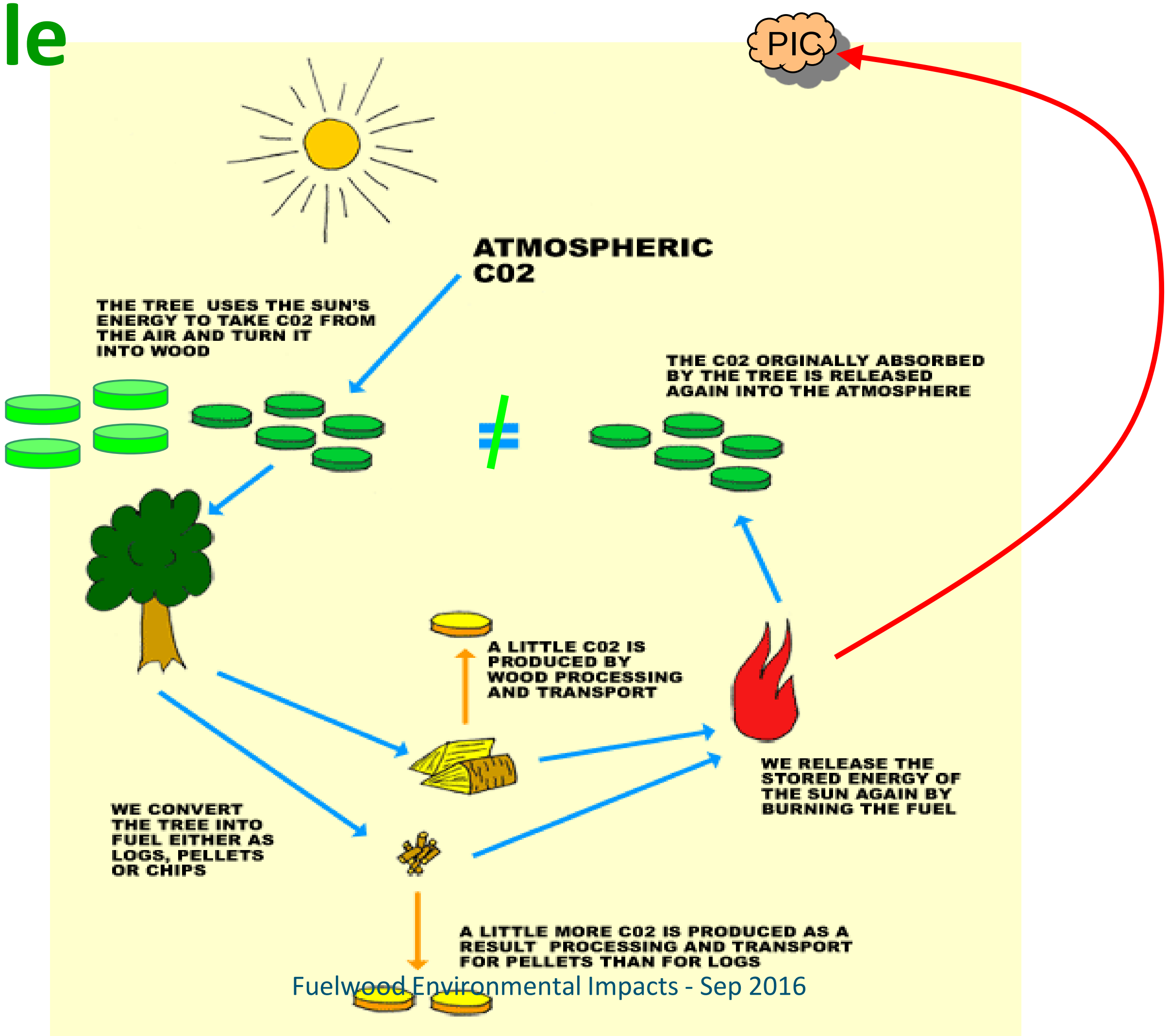
"…in terms of biomass" – due to an emphasis in climate change over local environment and health

Non-renewable



"…in terms of biomass" – due to an emphasis in <u>climate change</u> over local environment and health

Renewable



Woodfuels…

…the **other energy crisis** (Eckholm, 1975)

…a **major driver** of environmental degradation (de Montalembert & Clement, 1983).

…**seldom create problems of such a magnitude**…so as to require major interventions…(Arnold, et. Al, 2006)

…causing **severe deforestation** (e.g. Singh, et al., 2010) …or **habitat degradation** (e.g. Ahrends, et al., 2010; Ryan, et al., 2012).

…have very **limited impact** (e.g. Hansfort & Mertz, 2011)

We might sum up current understanding this way…

In certain areas and under certain conditions, woodfuel exploitation can contribute to deforestation and forest degradation

A. Ghilardi

Motivating questions

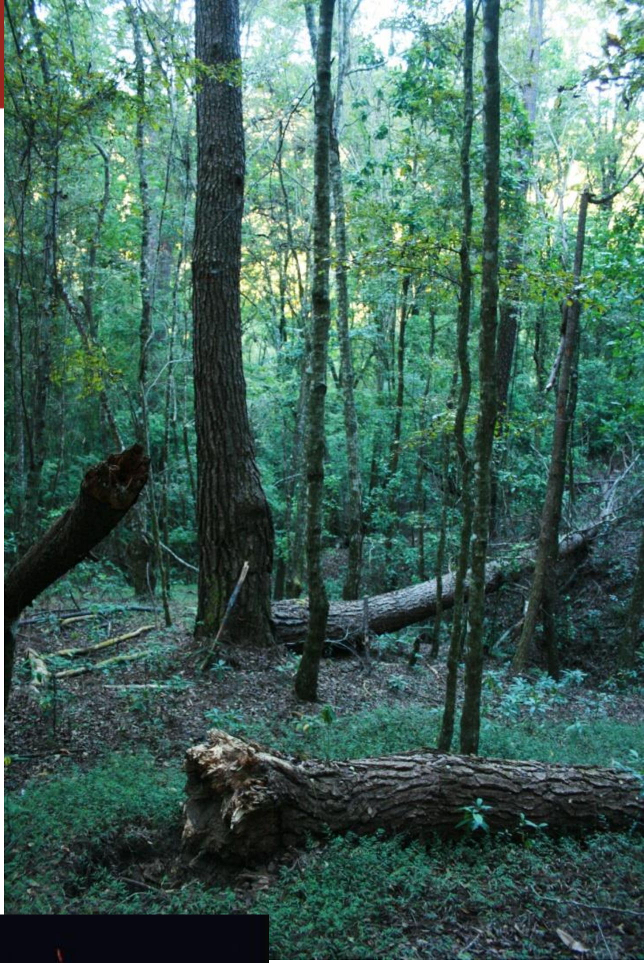
- Under what conditions is woodfuel exploitation sustainable?
    - Can we quantify sustainability in this context?
- Can efficient cookstoves (or fuel switching) reduce deforestation and forest degradation?

A. Ghilardi

Landscapes, where human-environment interactions occur, are inherently *dynamic*

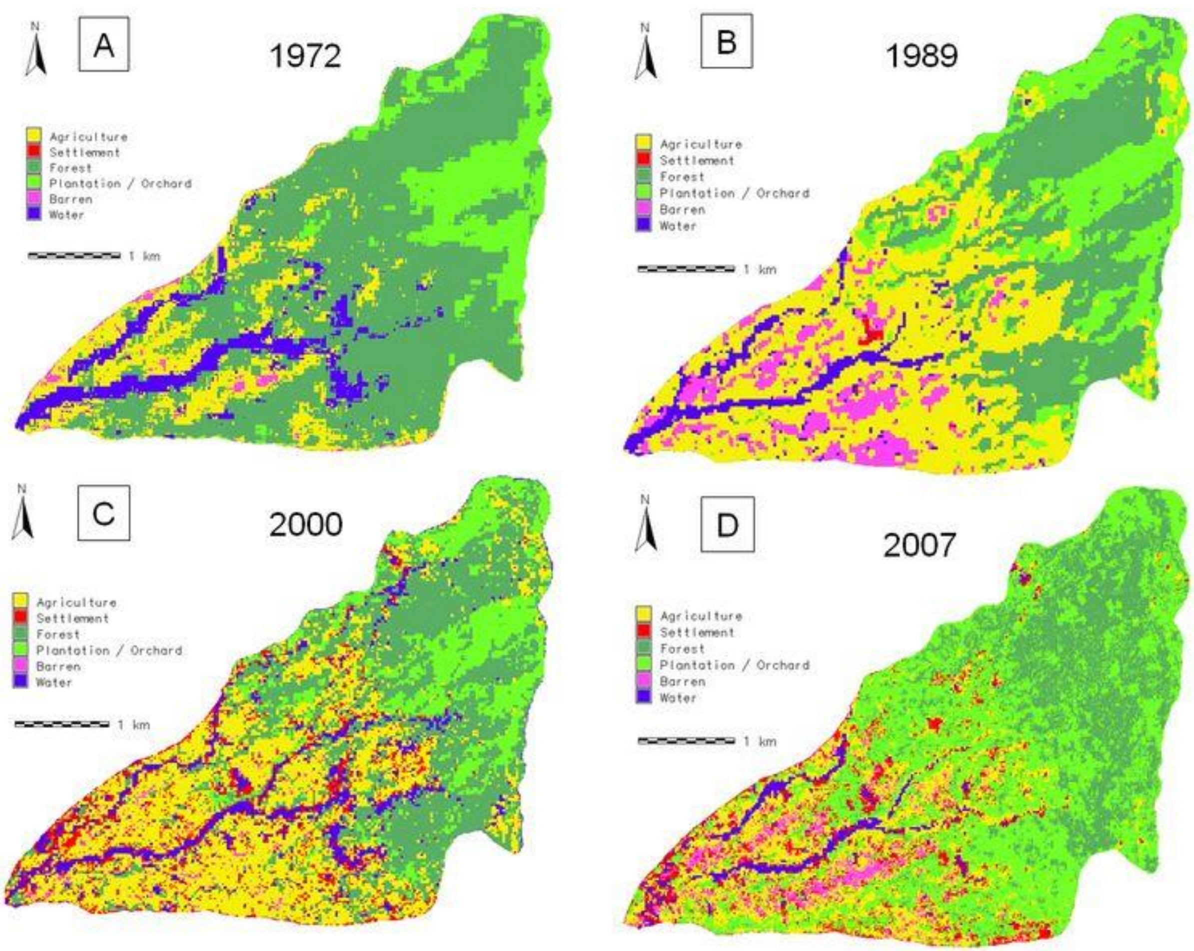
- Meaning they change in time

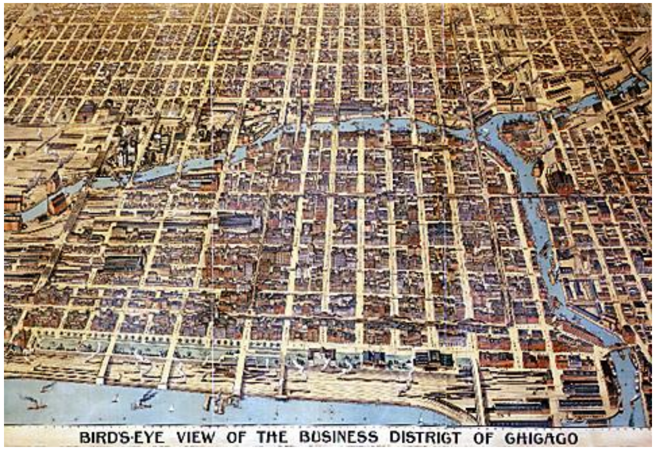
Naturally dynamic…



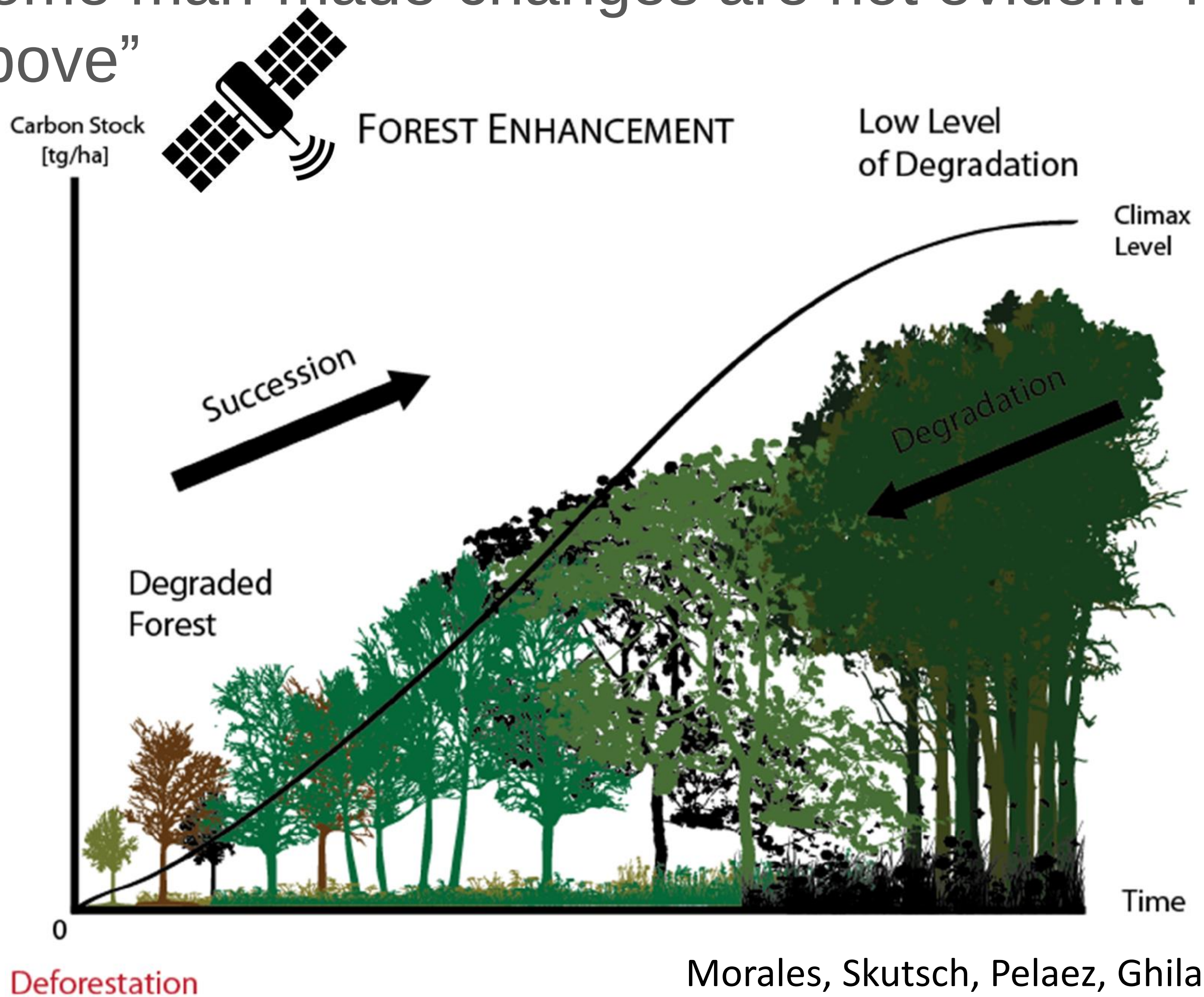
Ghilardi, Pelaez et al., 2013, Tech Rep

… and man-made dynamic



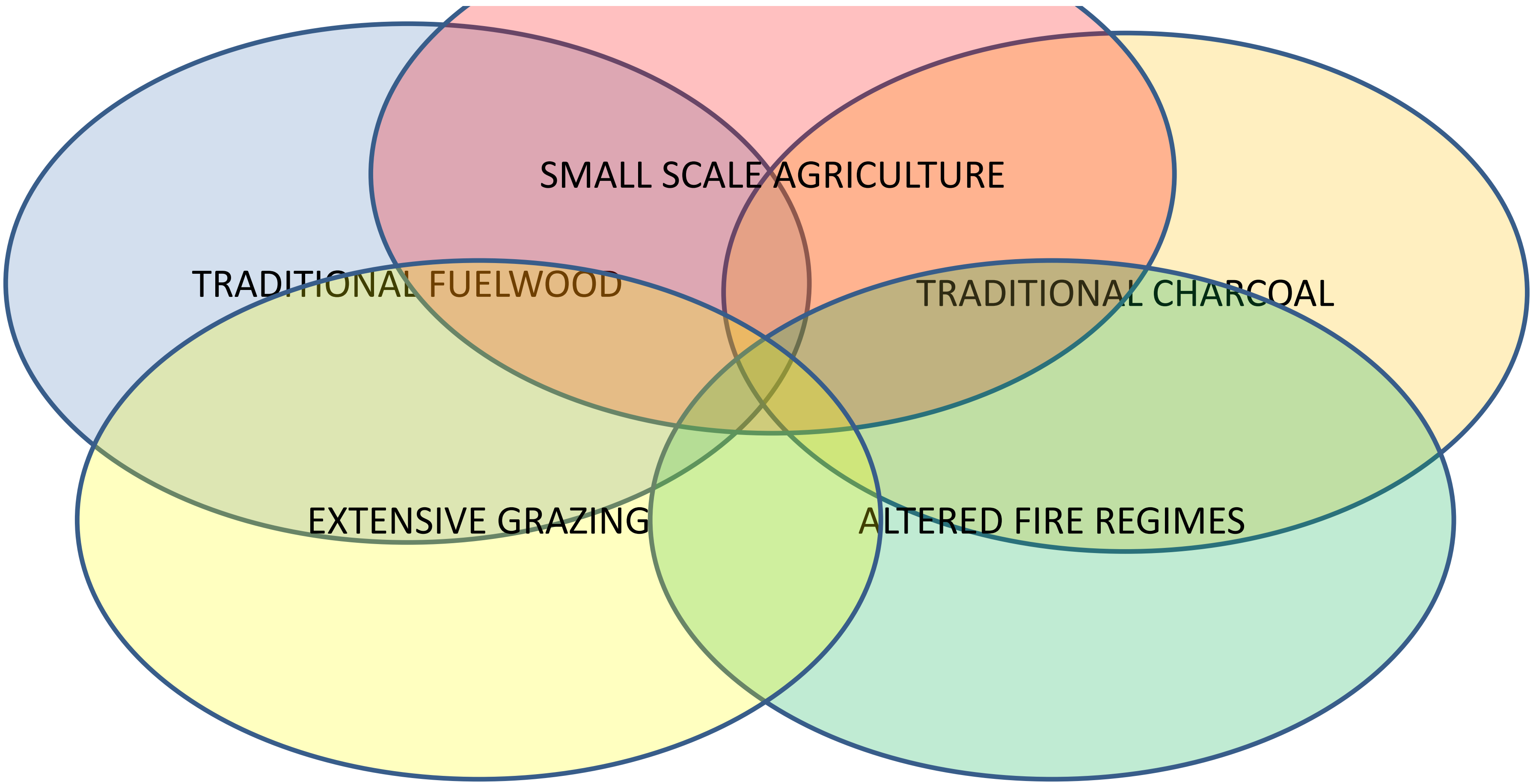


Some man-made changes are not evident “from above”



Morales, Skutsch, Pelaez, Ghilardi, *et al* 2014

So, how can we tell when traditonal woodfuels are a driver of land change?



Previous works examples:
Land change ←→ woodfuels

Spatially explicit

Fig. 6.31. Fuelwood surplus and deficit areas. Three strata with different population density, according to Watson (1976), are outlined.

e.g. Katrina Olson, 1981, Lund University

Temporal simulations

A dynamic model of deforestation arou

production cost and demand for charcoal. The exploited area forms a wedge, which expands

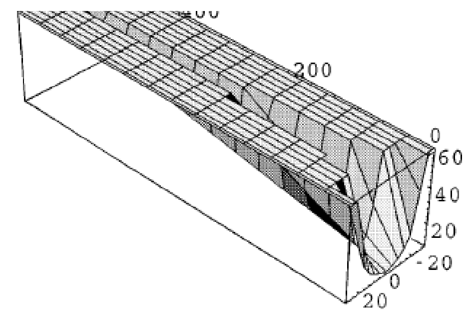


FIG. 3. Woodland degradation when harvesting costs vary with standing volume. Standing volume (vertical axis) as a function of distance from Dar es Salaam (origin at the lower right of the surface) along tarred and dirt road (horizontal axes).

e.g. Hofstad, 1997, J. Environ. Econ. Manag

Fewer attemps have been “spatio-temporal”

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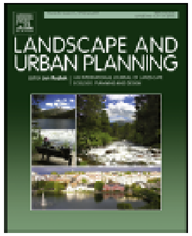

is one in many

Spatial and temporal patterns of fuelwood collection in Wolong Nature Reserve: Implications for panda conservation

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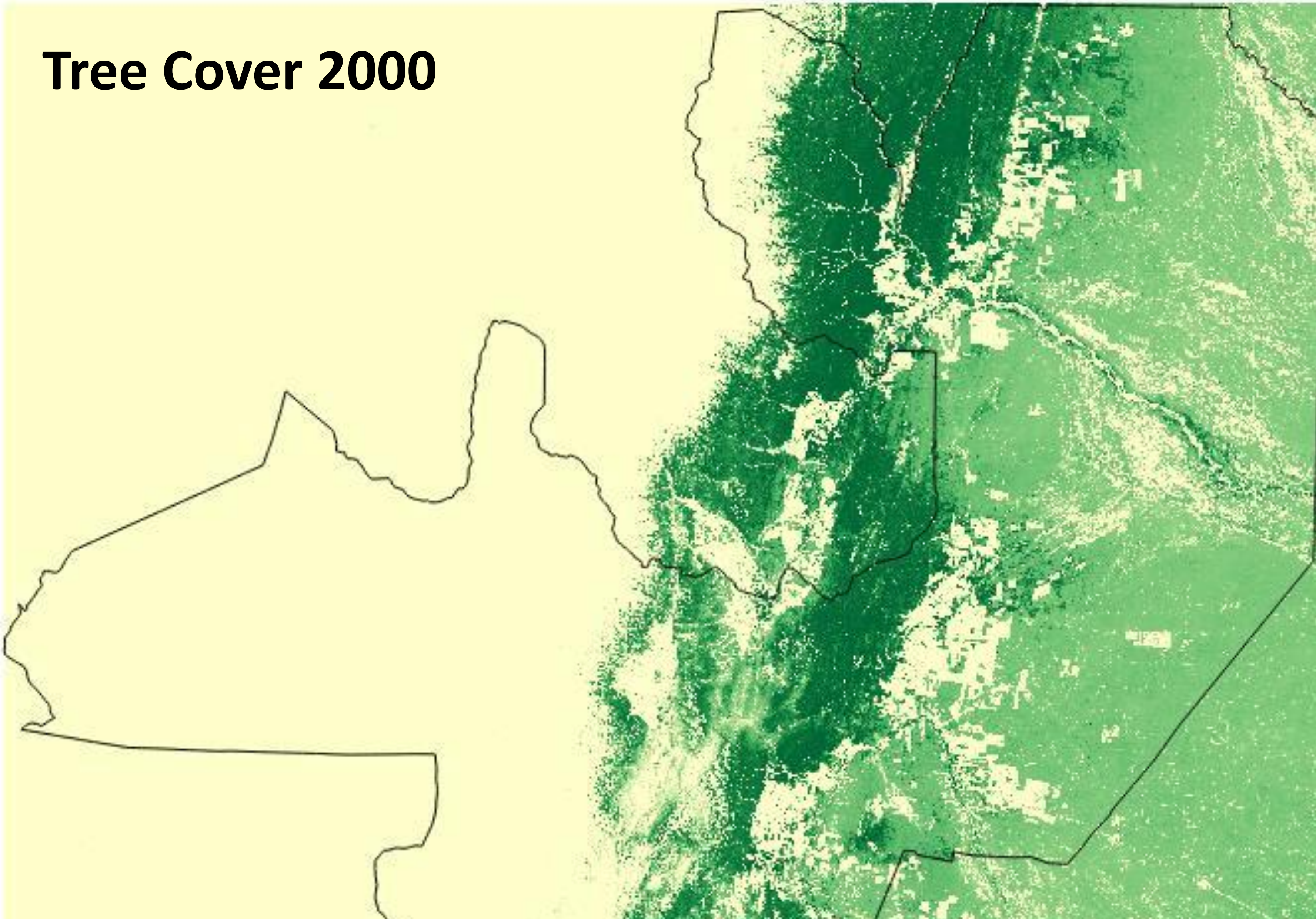
Time matters! **Two** important reasons:

- First of all: *space* is important because woodfuel supply and demand relations are "place-based".
- Why adding *time* could improve spatially explicit estimations?

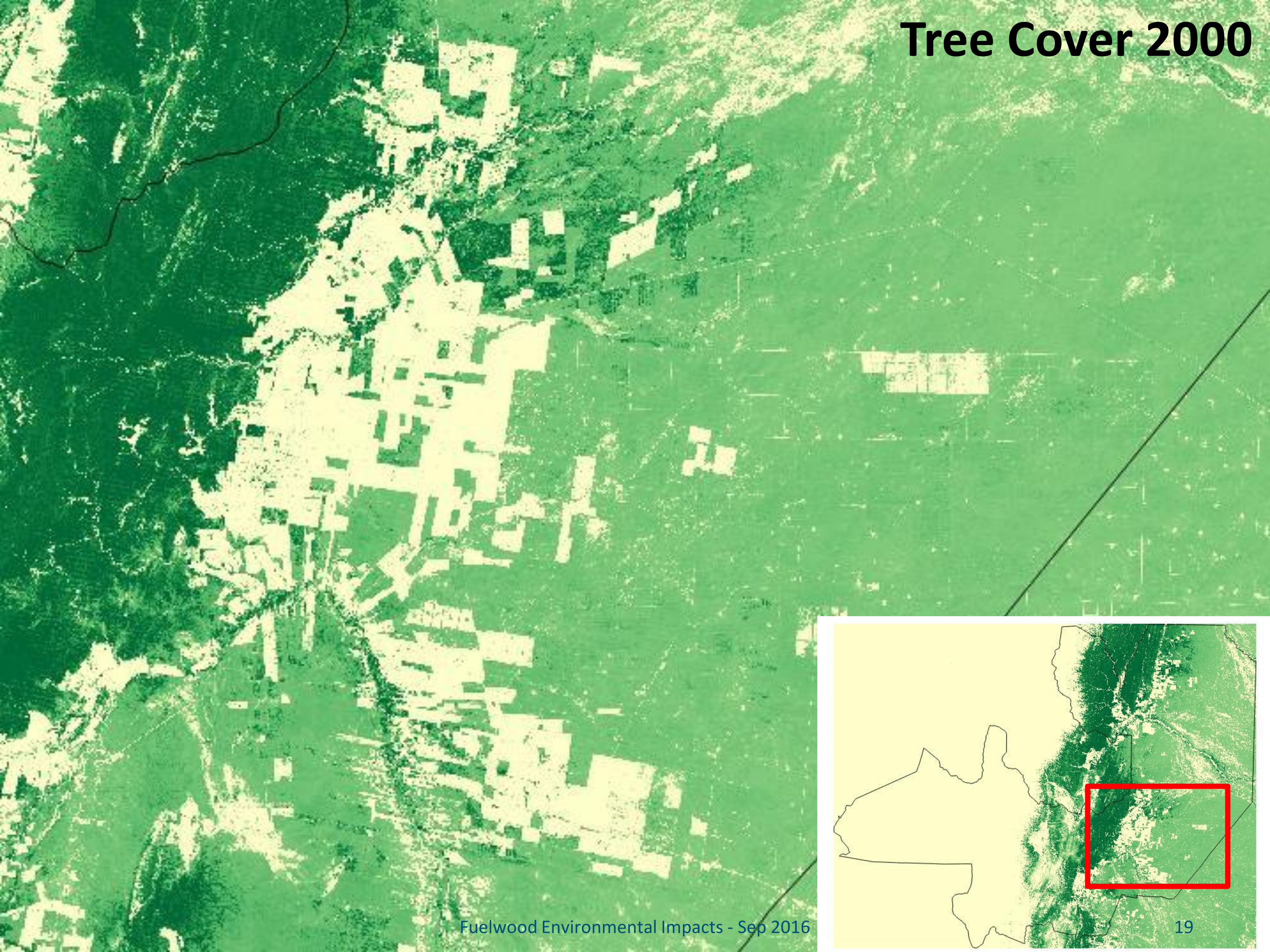
Reason #1: Landscapes, where human-environment interactions occur, are inherently ***dynamic***

- Let's see and example:

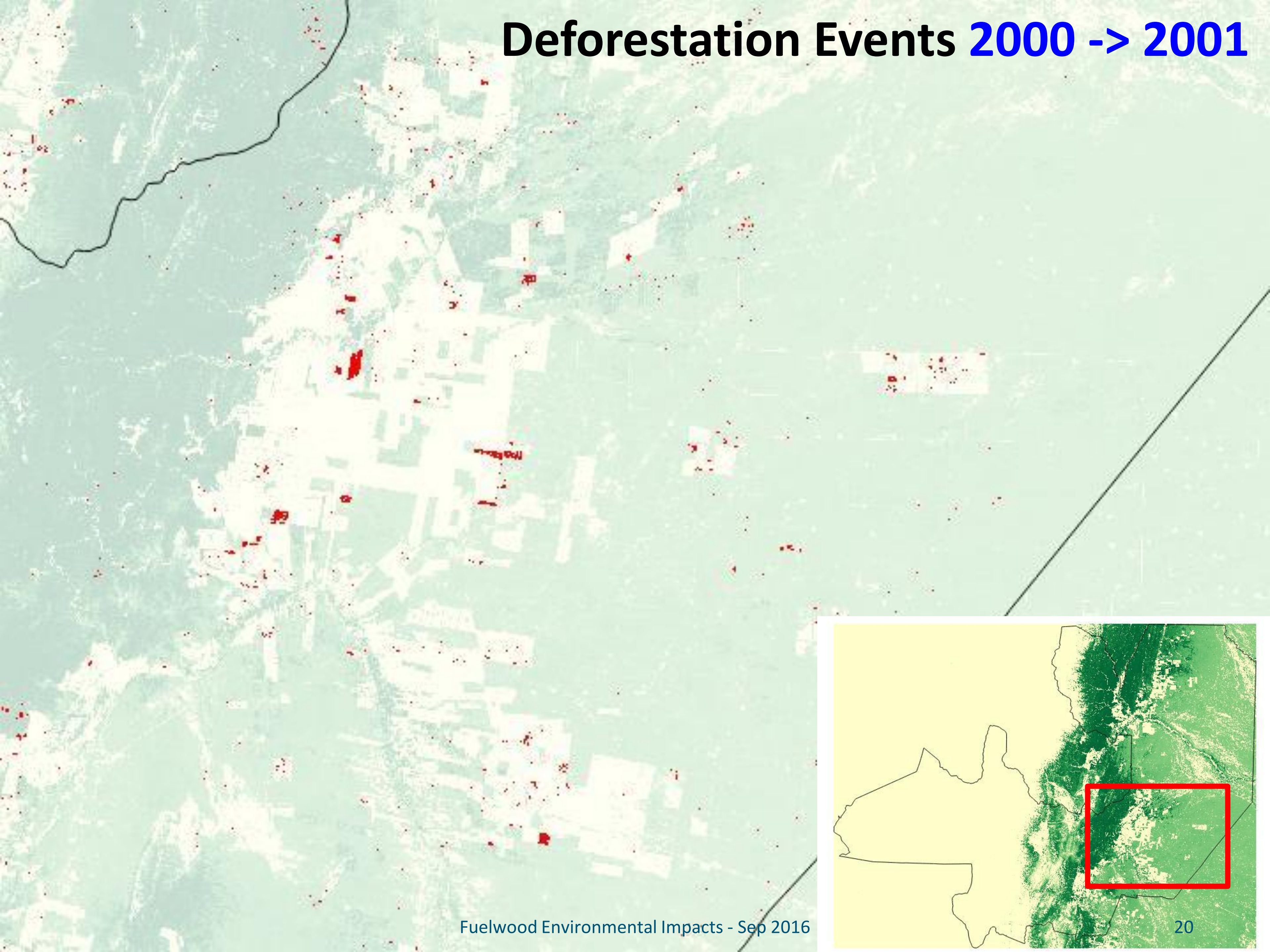


Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. **"High-Resolution Global Maps of 21st-Century Forest Cover Change."** Science 342 (15 November): 850–53.

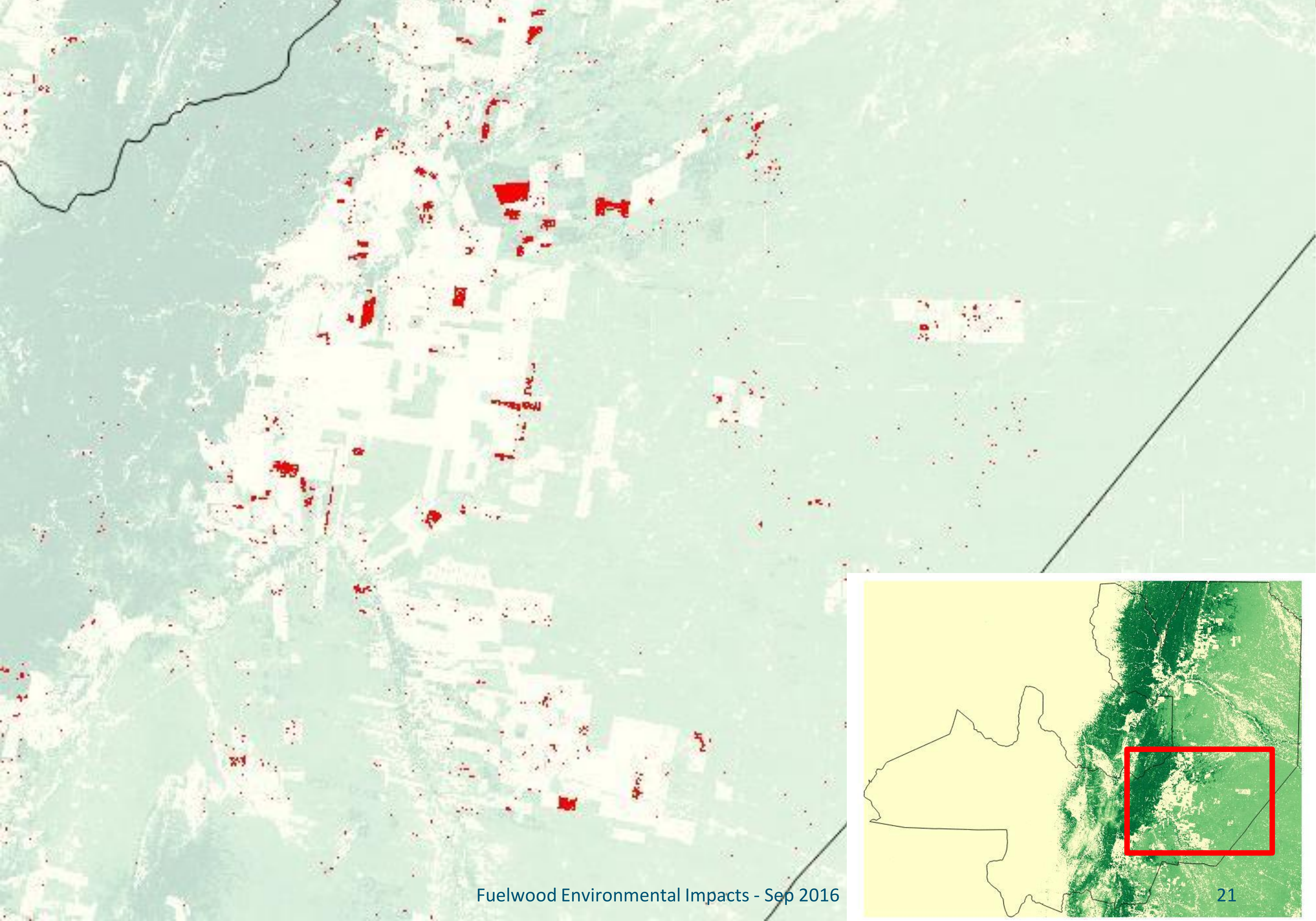
Tree Cover 2000



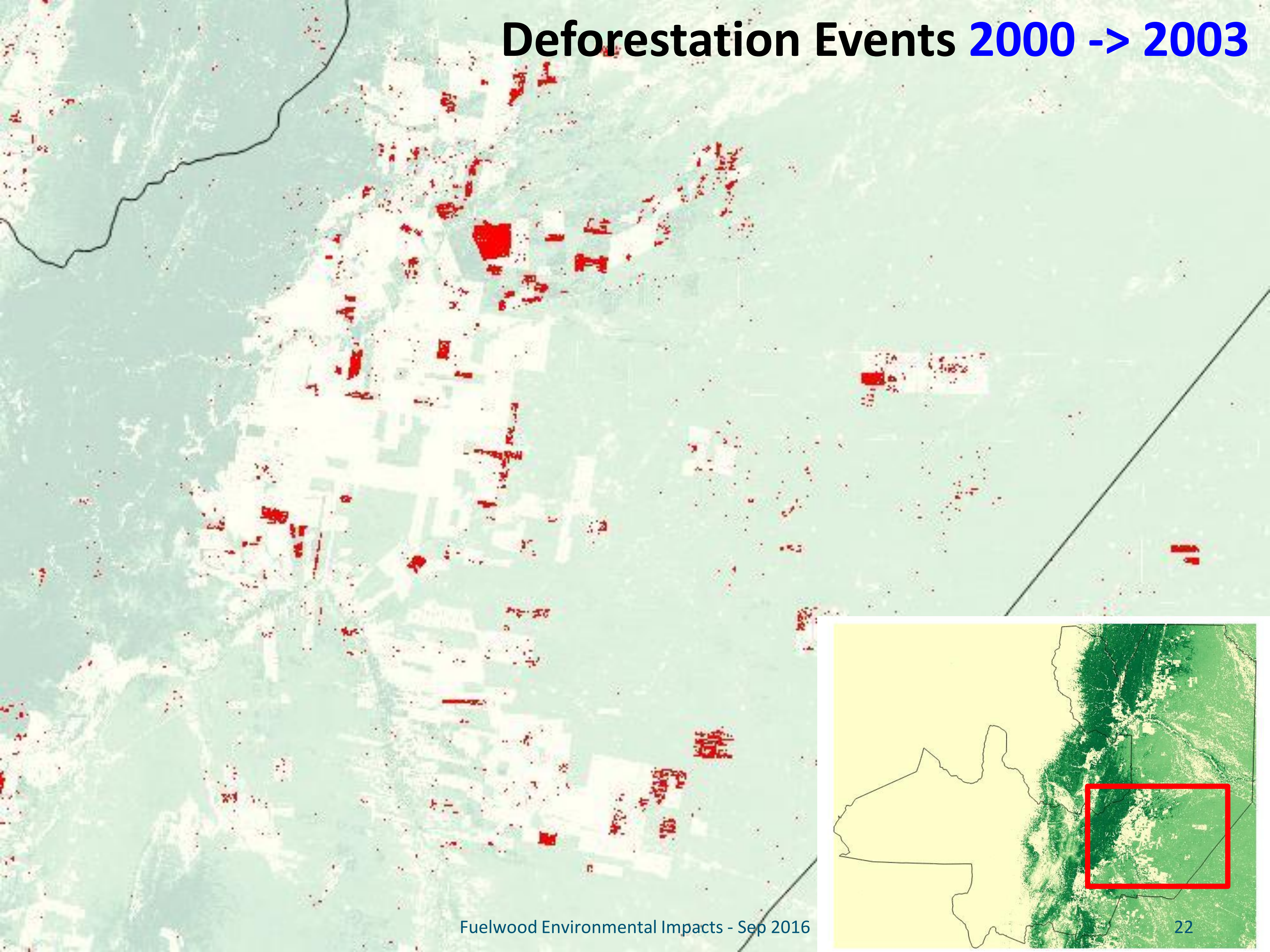
Deforestation Events 2000 -> 2001



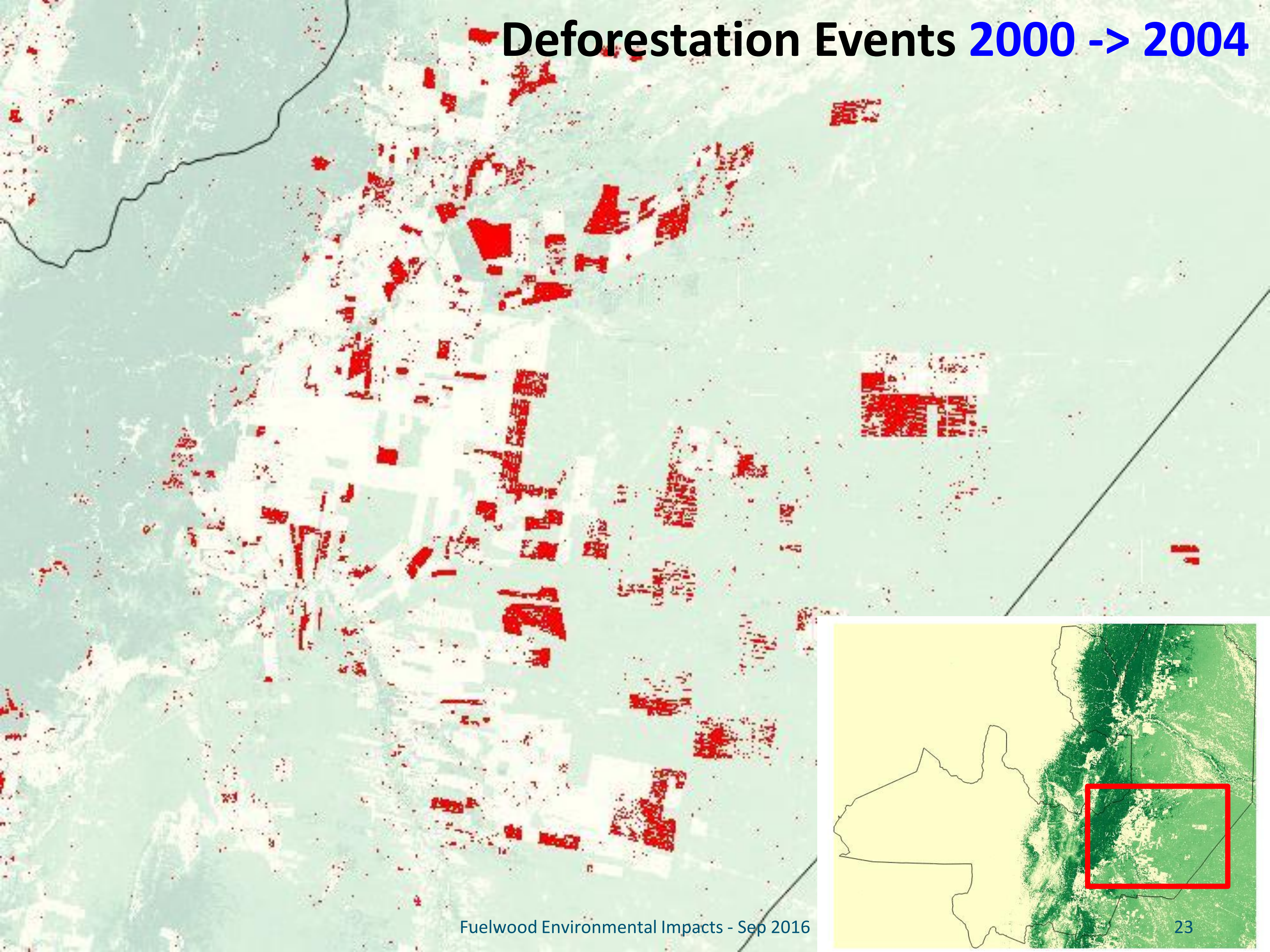
Deforestation Events 2000 -> 2002



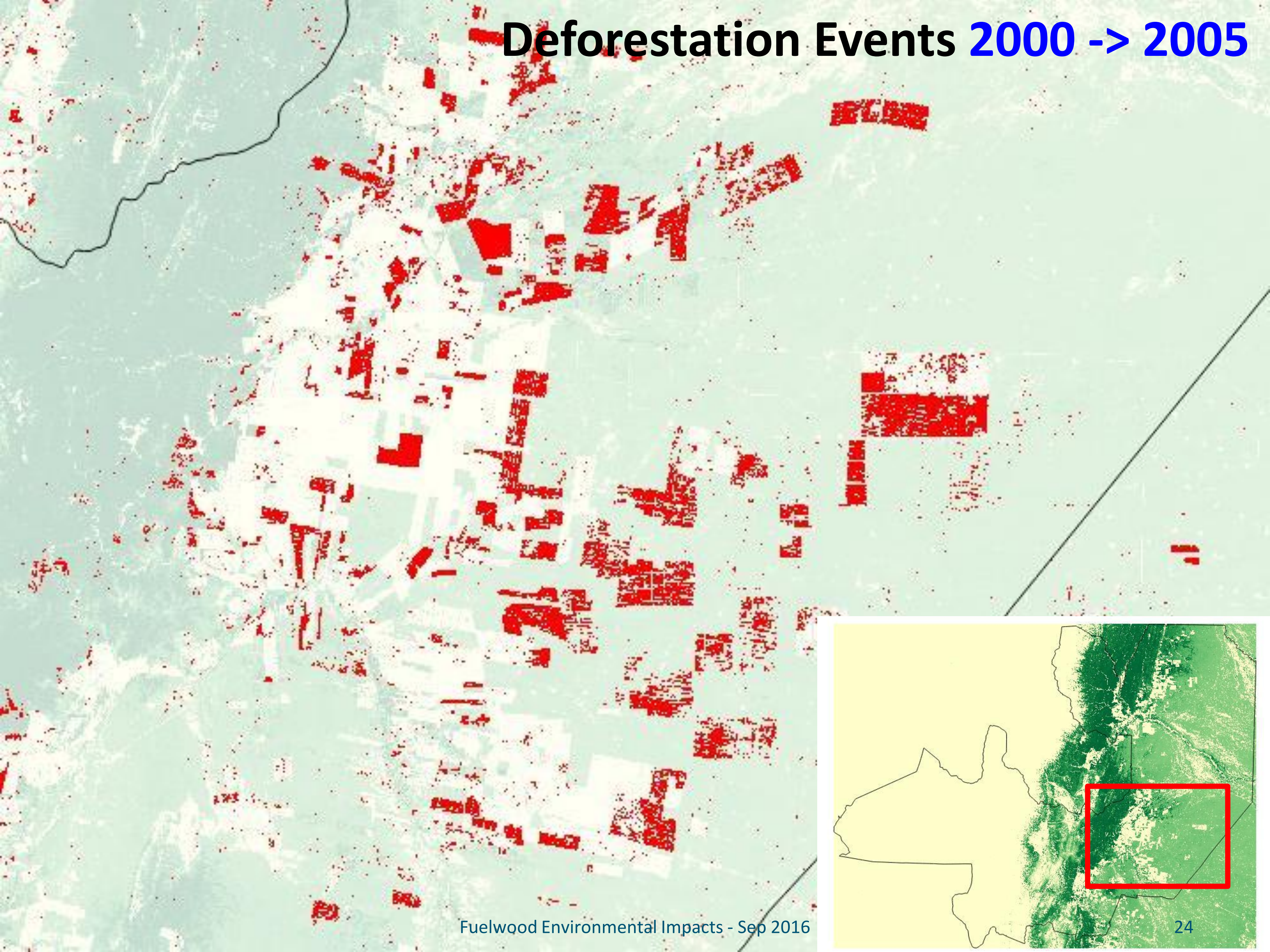
Deforestation Events 2000 -> 2003



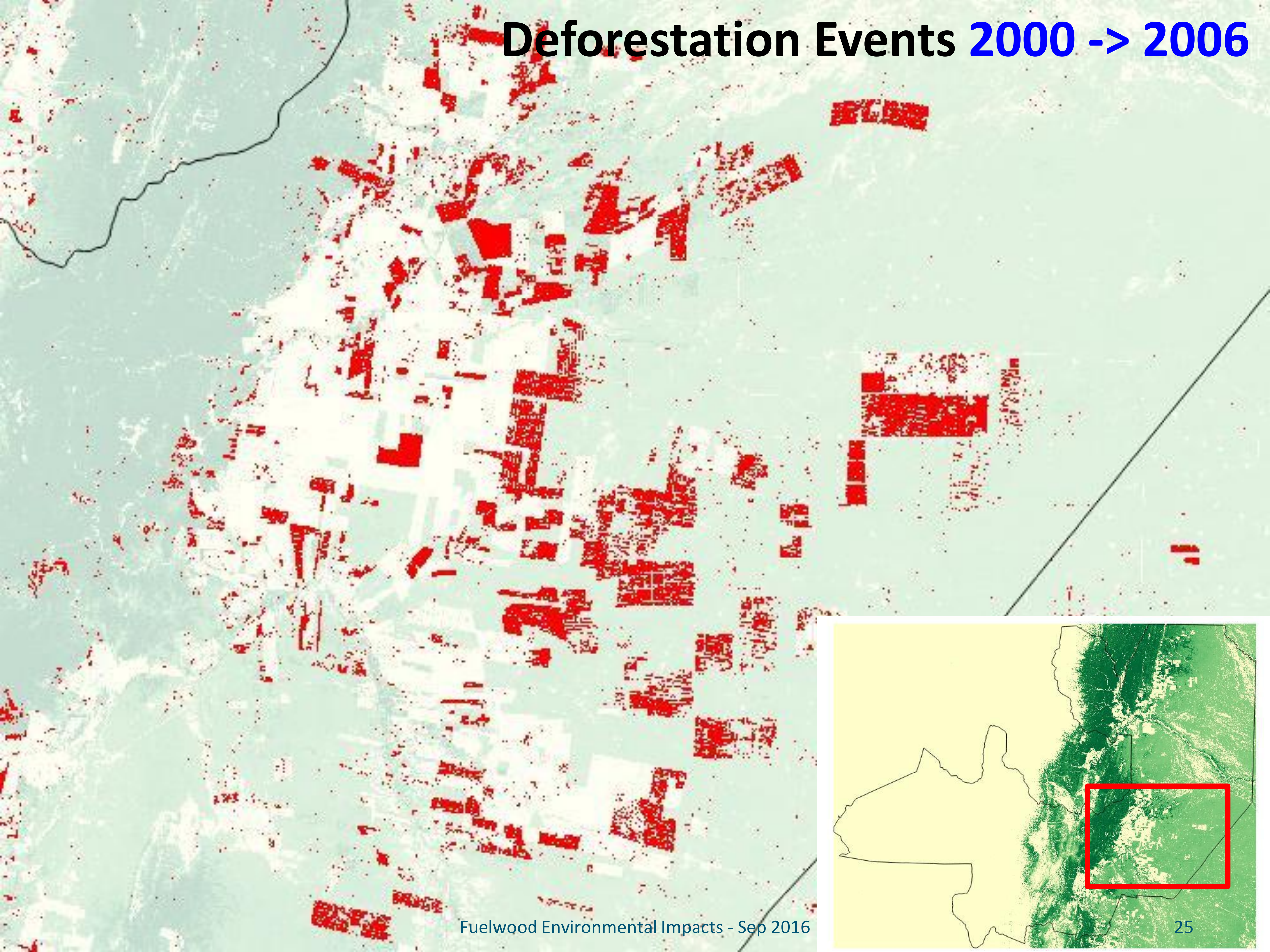
Deforestation Events 2000 -> 2004



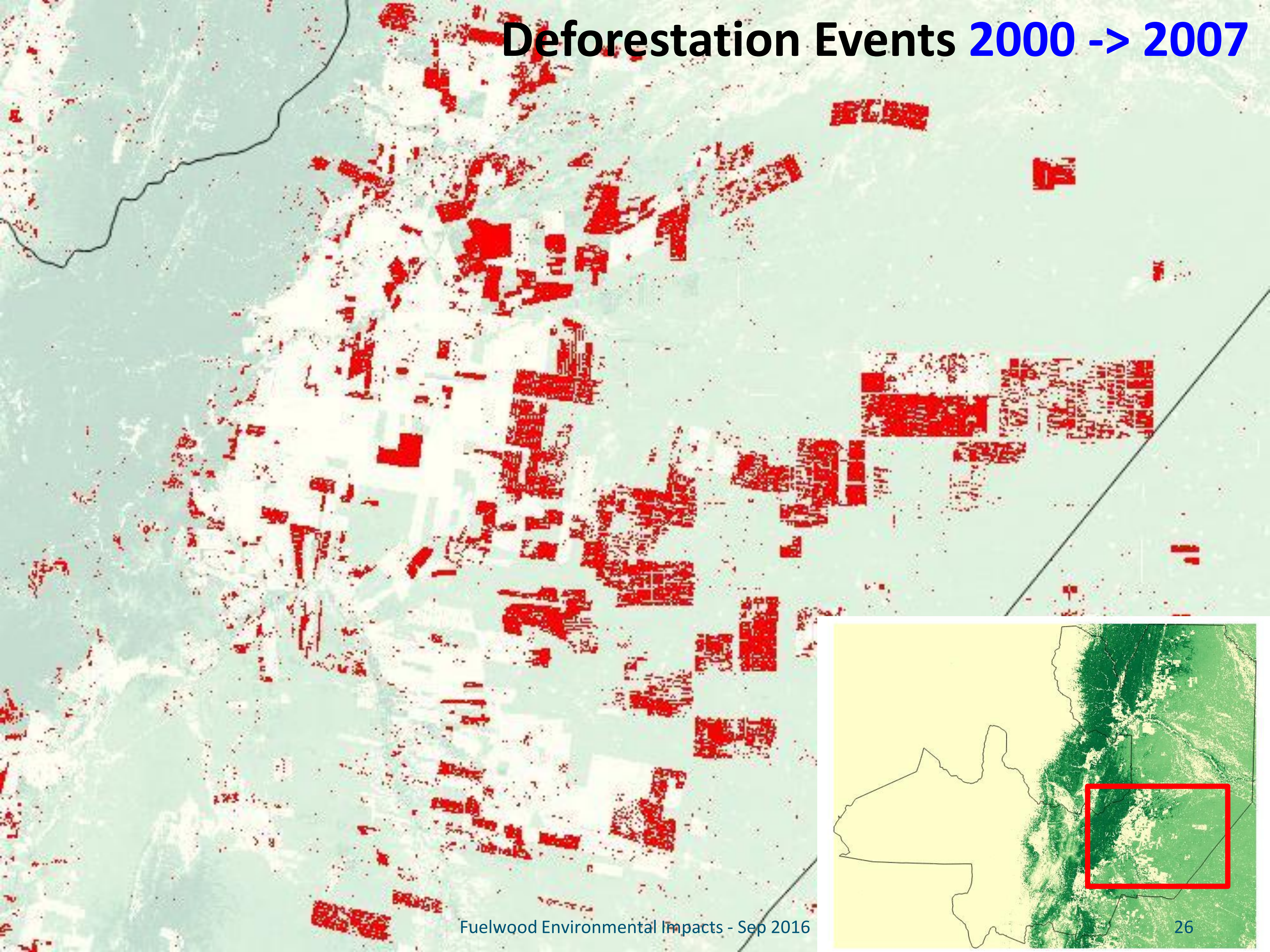
Deforestation Events 2000 -> 2005



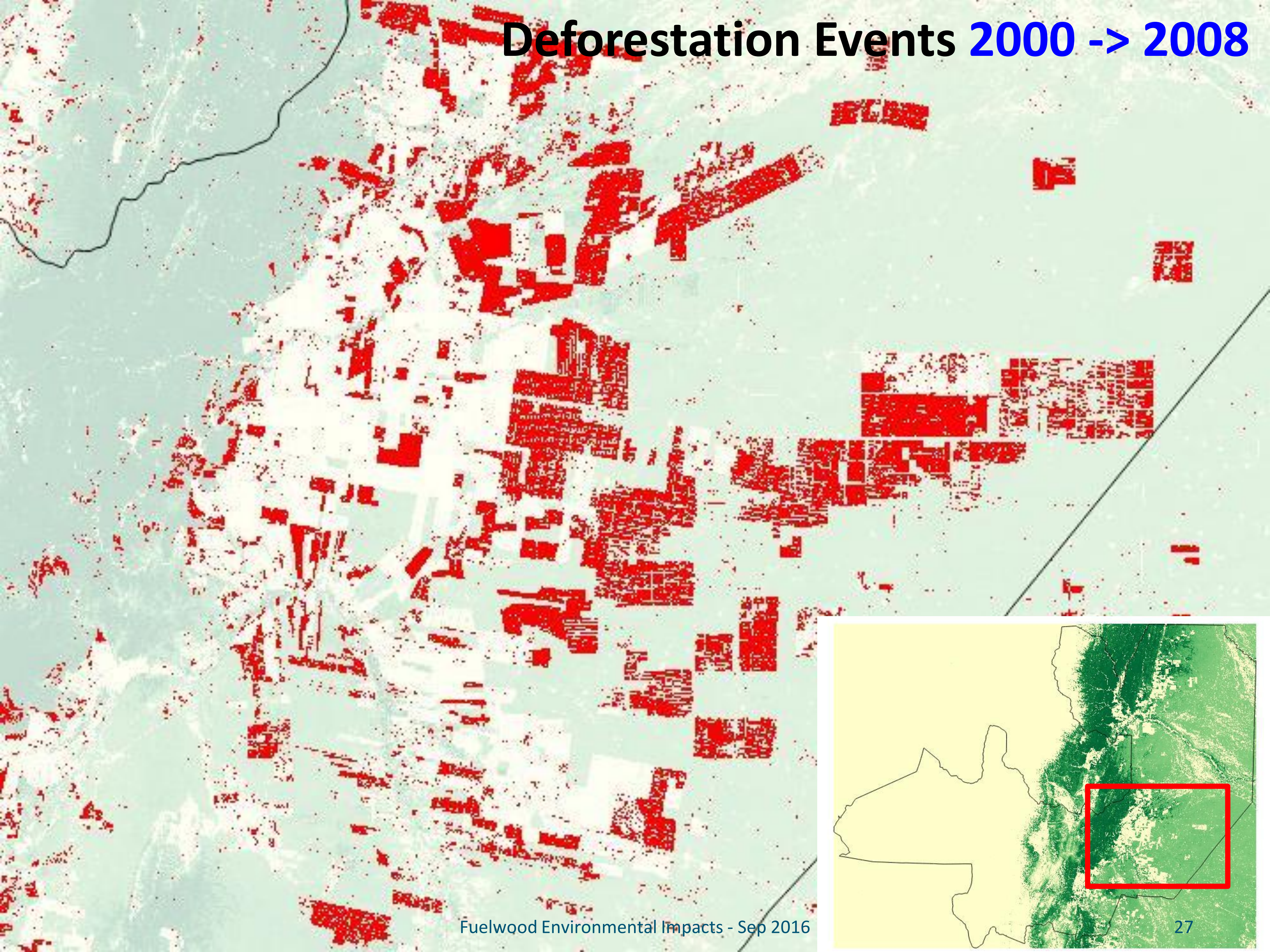
Deforestation Events 2000 -> 2006



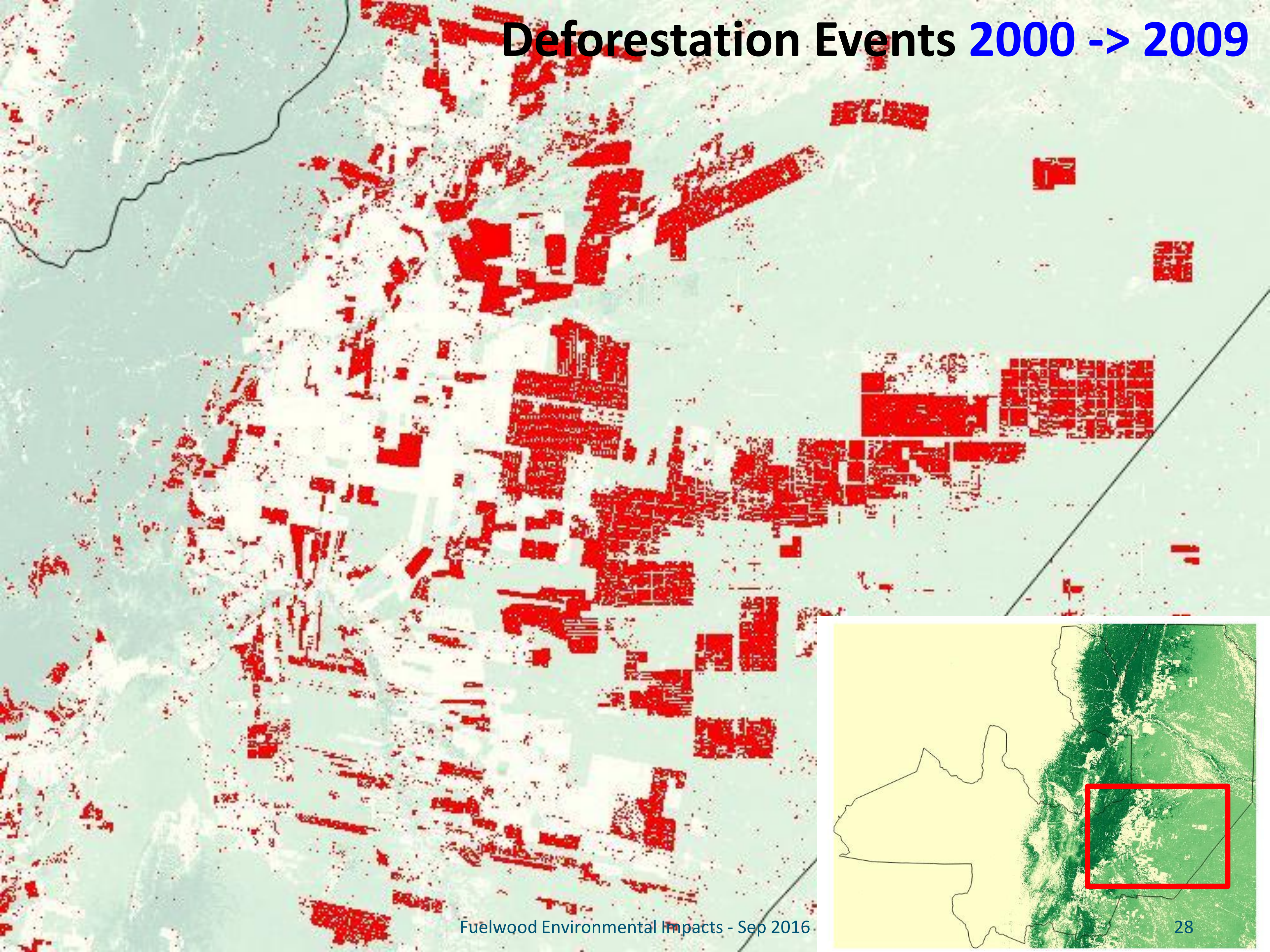
Deforestation Events 2000 -> 2007



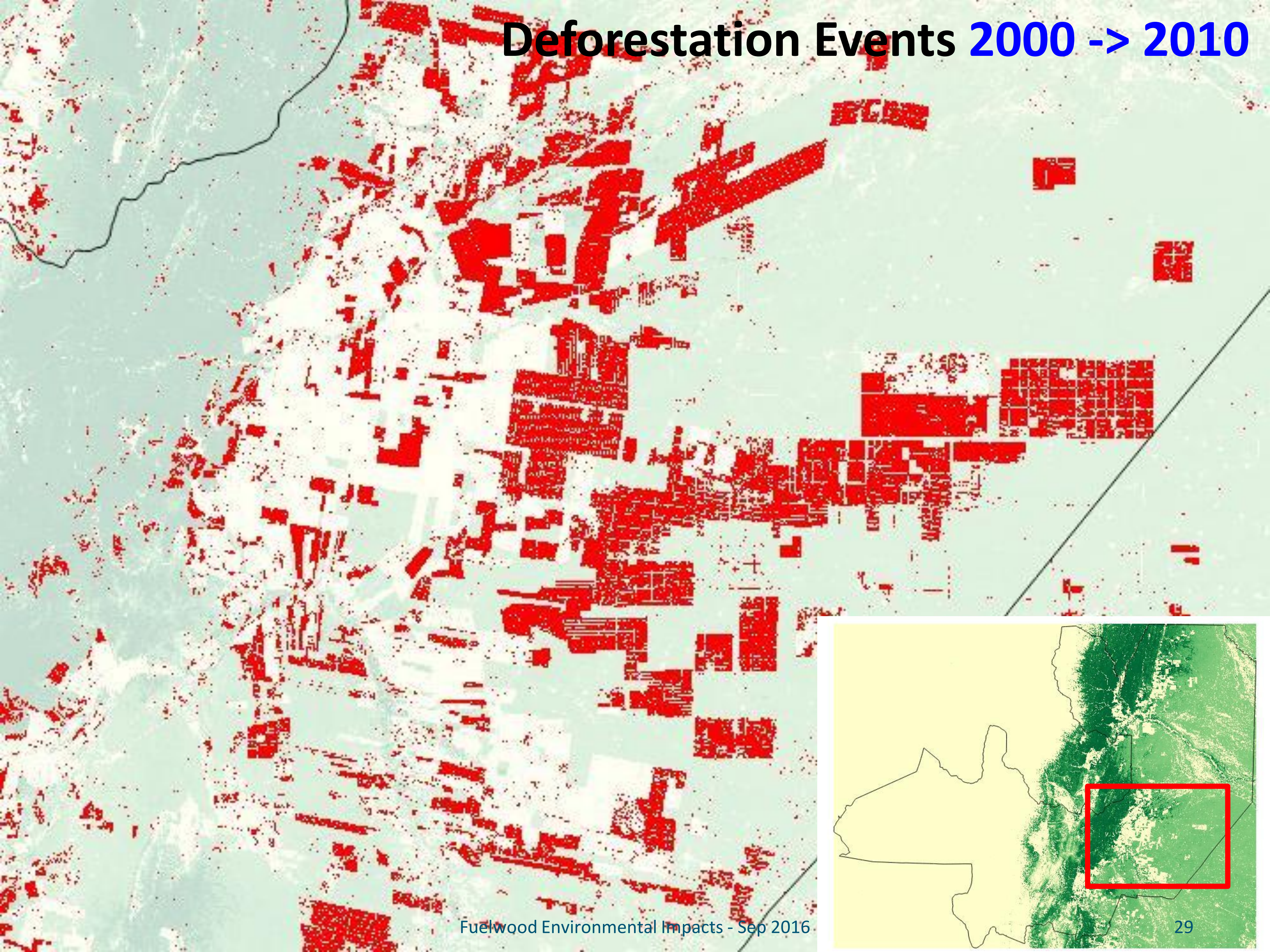
Deforestation Events 2000 -> 2008



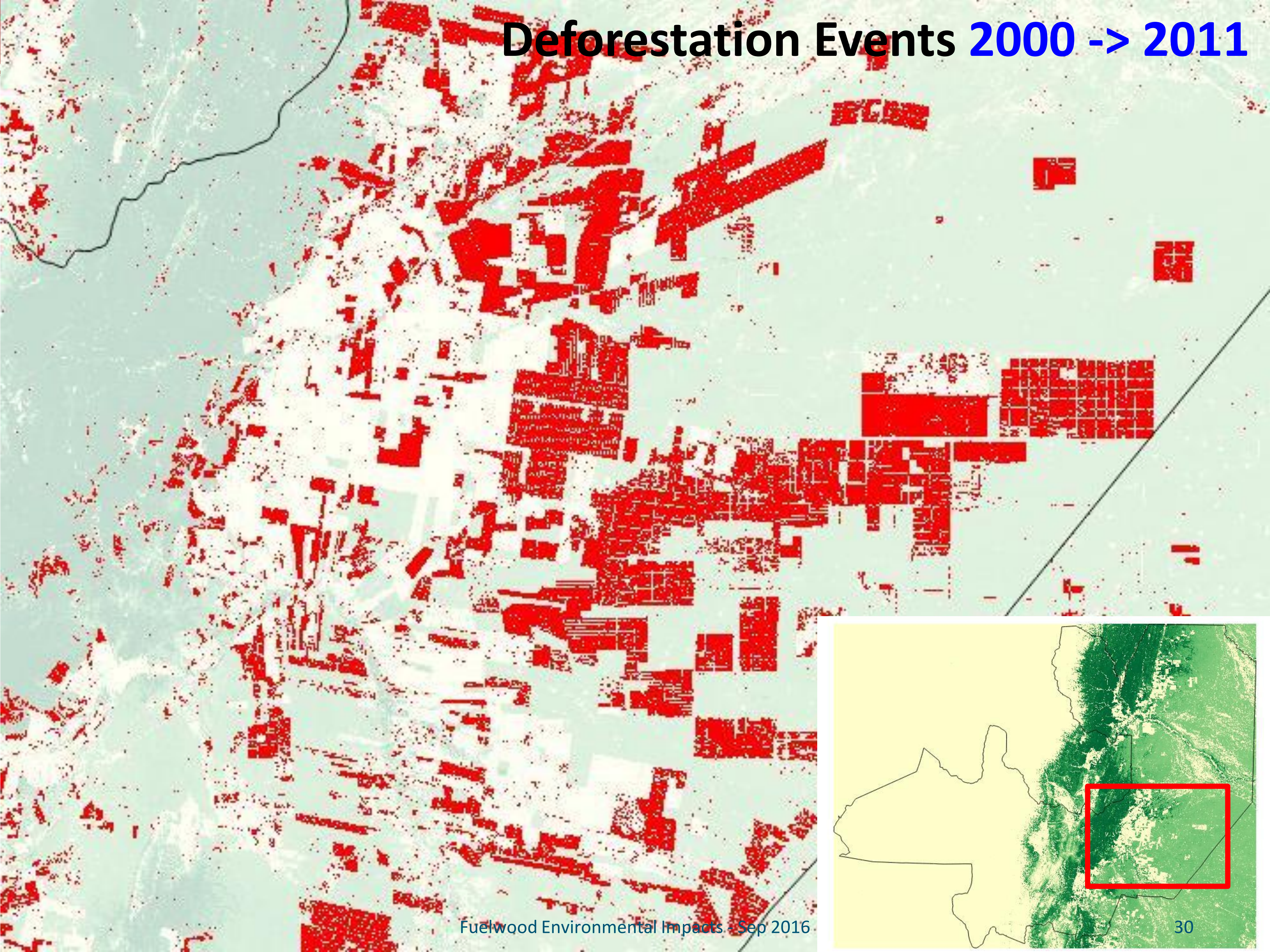
Deforestation Events 2000 -> 2009



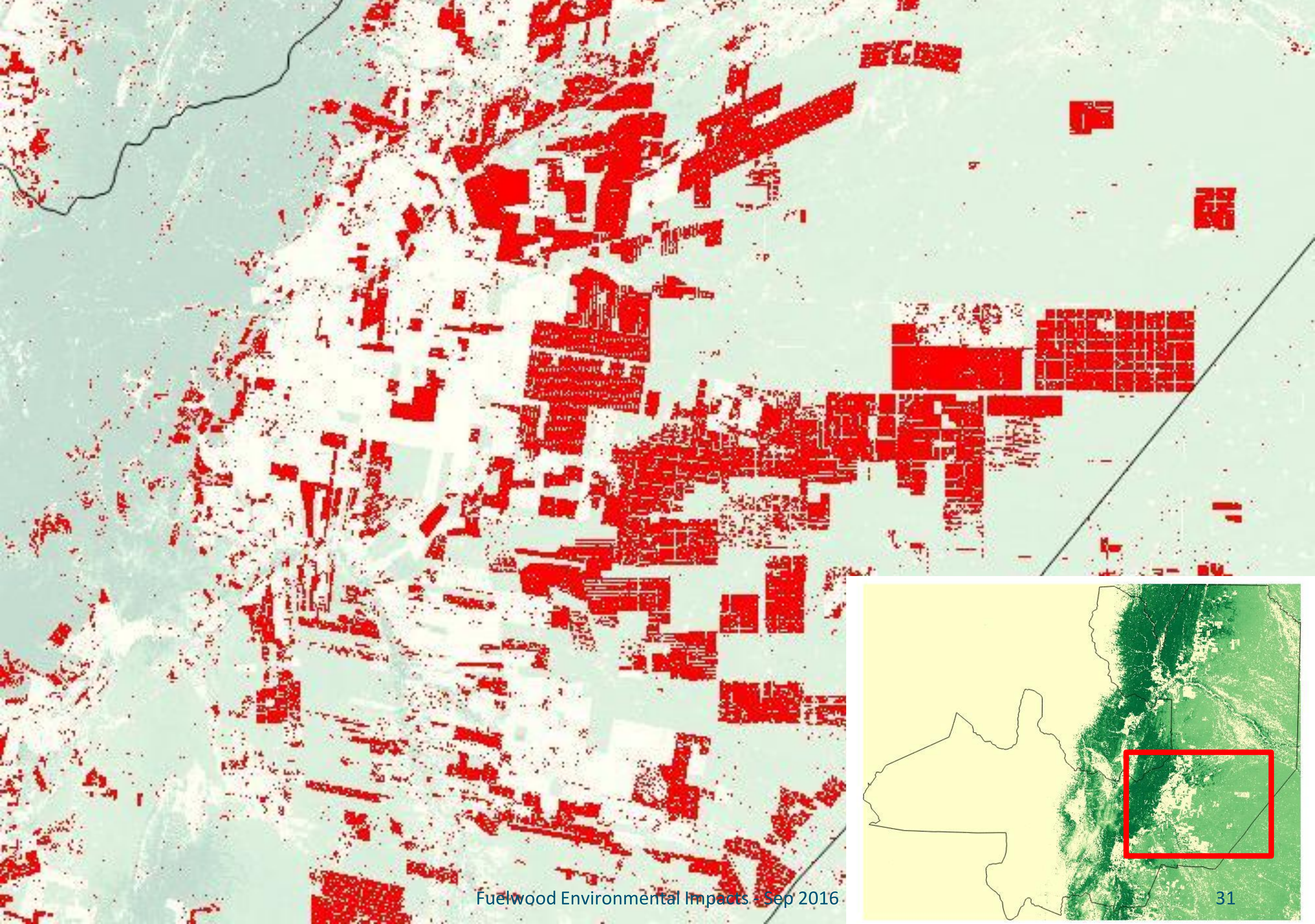
Deforestation Events 2000 -> 2010



Deforestation Events 2000 -> 2011



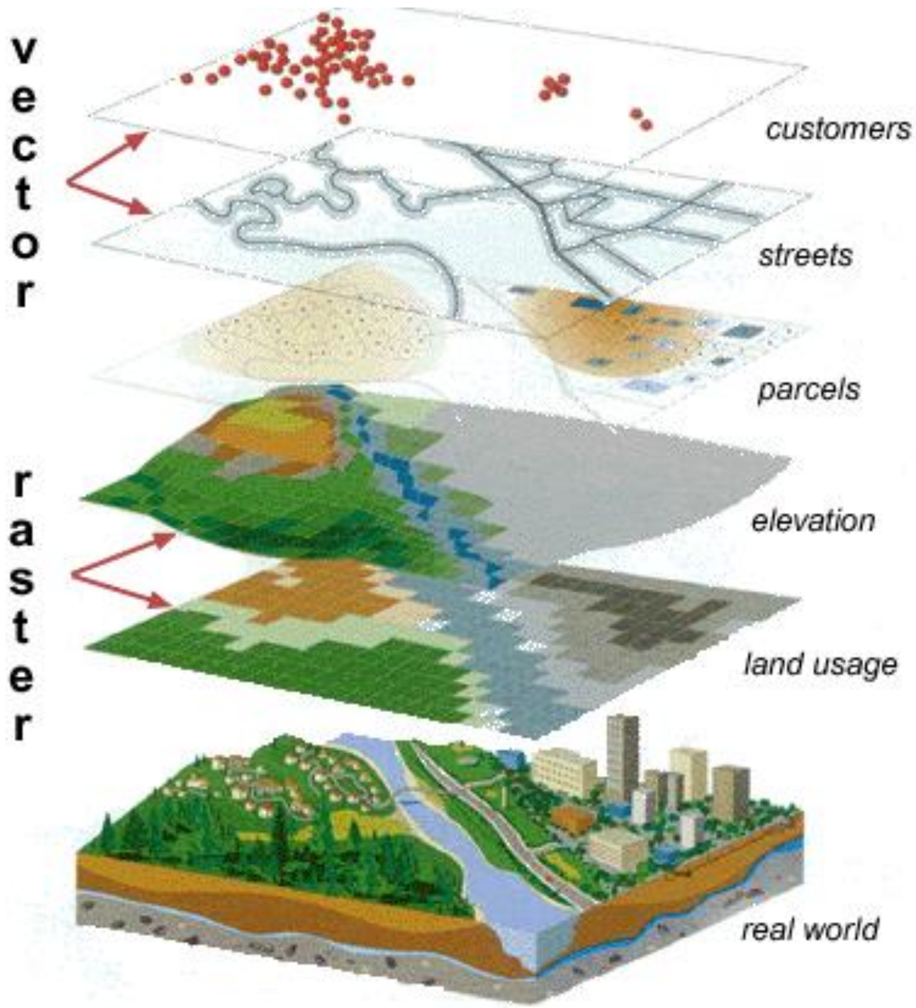
Deforestation Events 2000 -> 2012



Scale matters!

- Reason #2: ***Scaling***
  - Human-environment interactions are known to be complex systems: *"the whole is significantly different from the simple sum of the parts"*
  - Interactions matters, and varying the scale in space, time and complexity can produce different results…
  - **"Scale"** refers to:
    - Resolution: Spatial grain size, time step and degree of complexity of the model
    - Extent: In space, time and n components modeled
- Let's see another grounded example:

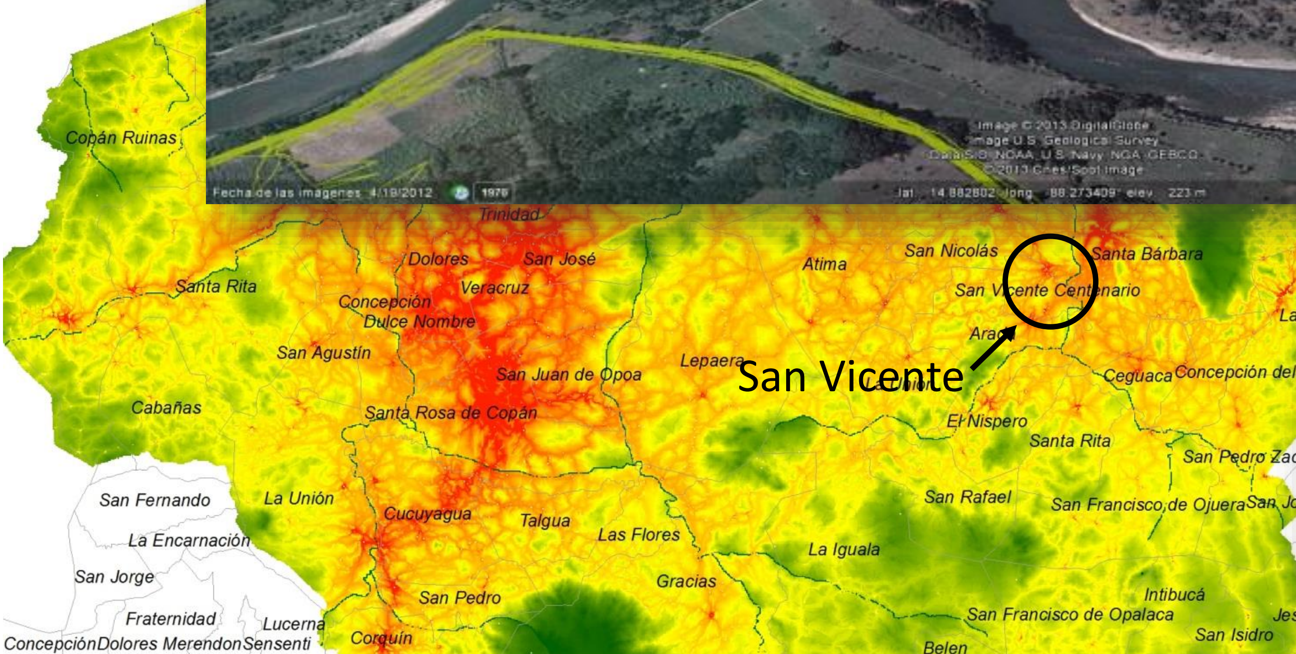
Spatial and temporal scale affects fuelwood collection patterns



- Spatial grain size: most landscape models are based on **geographical raster datasets**.
- "A geographical raster essentially divides a real world place into a grid and assigns some element of the real world to each cell of the grid" *J. Collins-Unruh, Understanding Rasters*

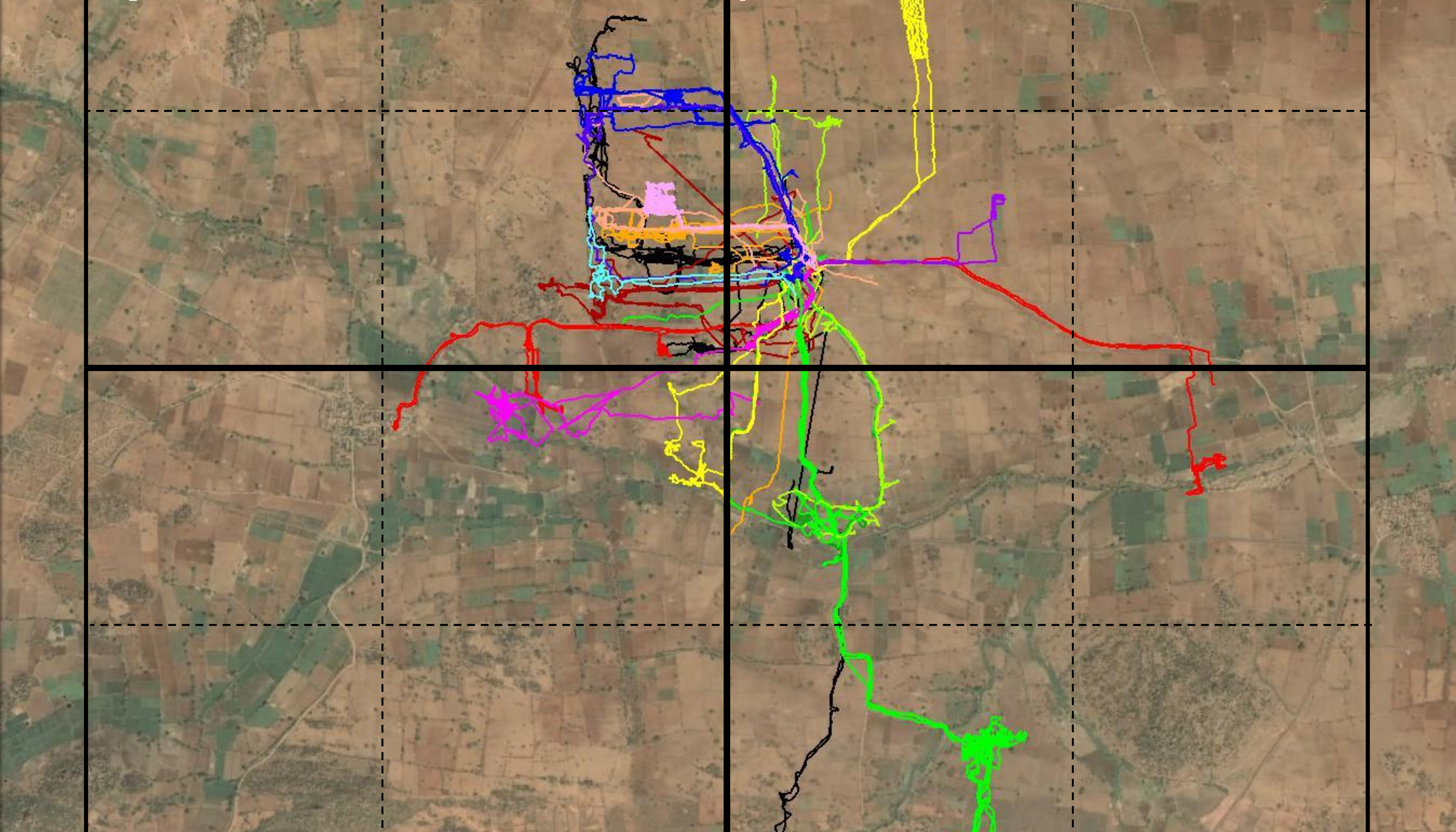
#MoFuS


Image © 2013 DigitalGlobe
Image U.S. Geological Survey
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 Cnes/Spot Image
Fecha de las imágenes: 4/18/2012
1970
lat 14.882802° long -88.273409° elev 223 m


Copán Ruinas
Trinidad
Dolores
San José
Atima
San Nicolás
Santa Bárbara
Santa Rita
Veracruz
Concepción
Dulce Nombre
San Vicente Centenario
San Agustín
San Juan de Opoa
Lepaera
San Vicente
Ceguaca
Concepción del
Cabañas
Santa Rosa de Copán
El Níspero
Santa Rita
San Pedro Zaca
San Fernando
La Unión
Cucuyagua
Talgua
San Rafael
San Francisco de Ojuera
La Encarnación
Las Flores
La Iguala
San Jorge
Gracias
San Pedro
Intibucá
Fraternidad
Lucerna
San Francisco de Opalaca
Concepción
Dolores Merendon
Sensenti
Corquín
San Isidro
Belen

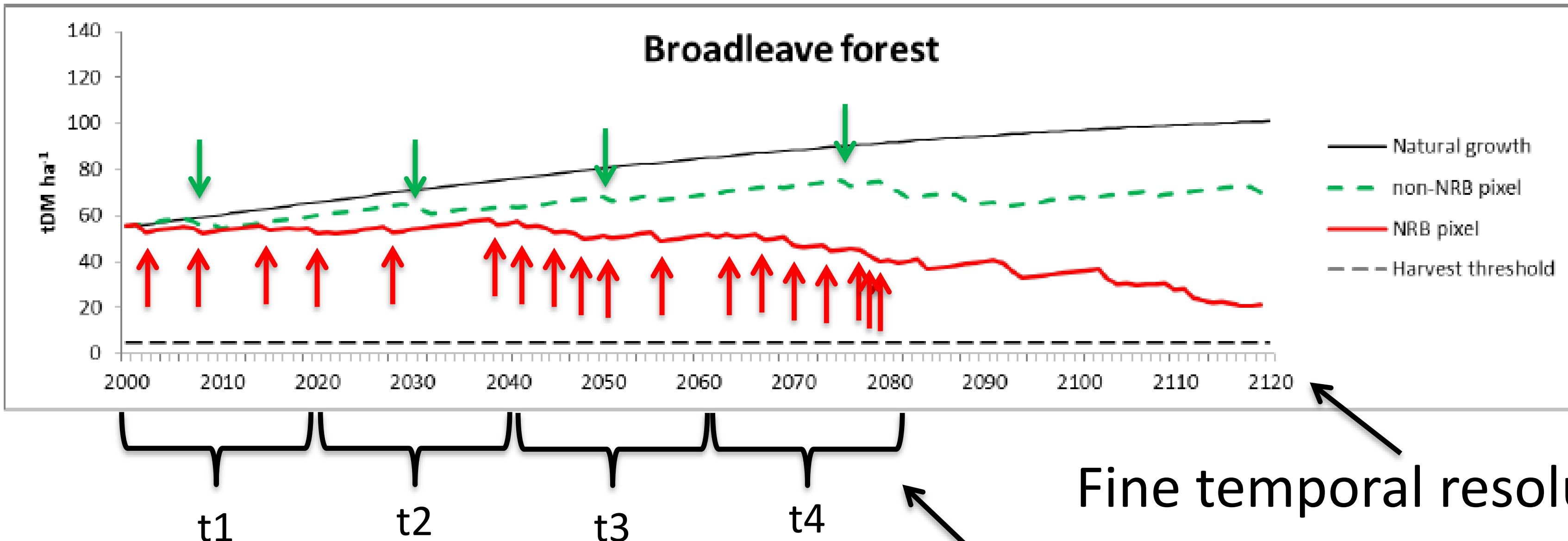

HOLUX
M-241

Spatial scale varies, temporal scale is fixed



Temporal scale varies, spatial scale is fixed

Figure A.5. Temporal projections of supply/demand relations at pixel-level

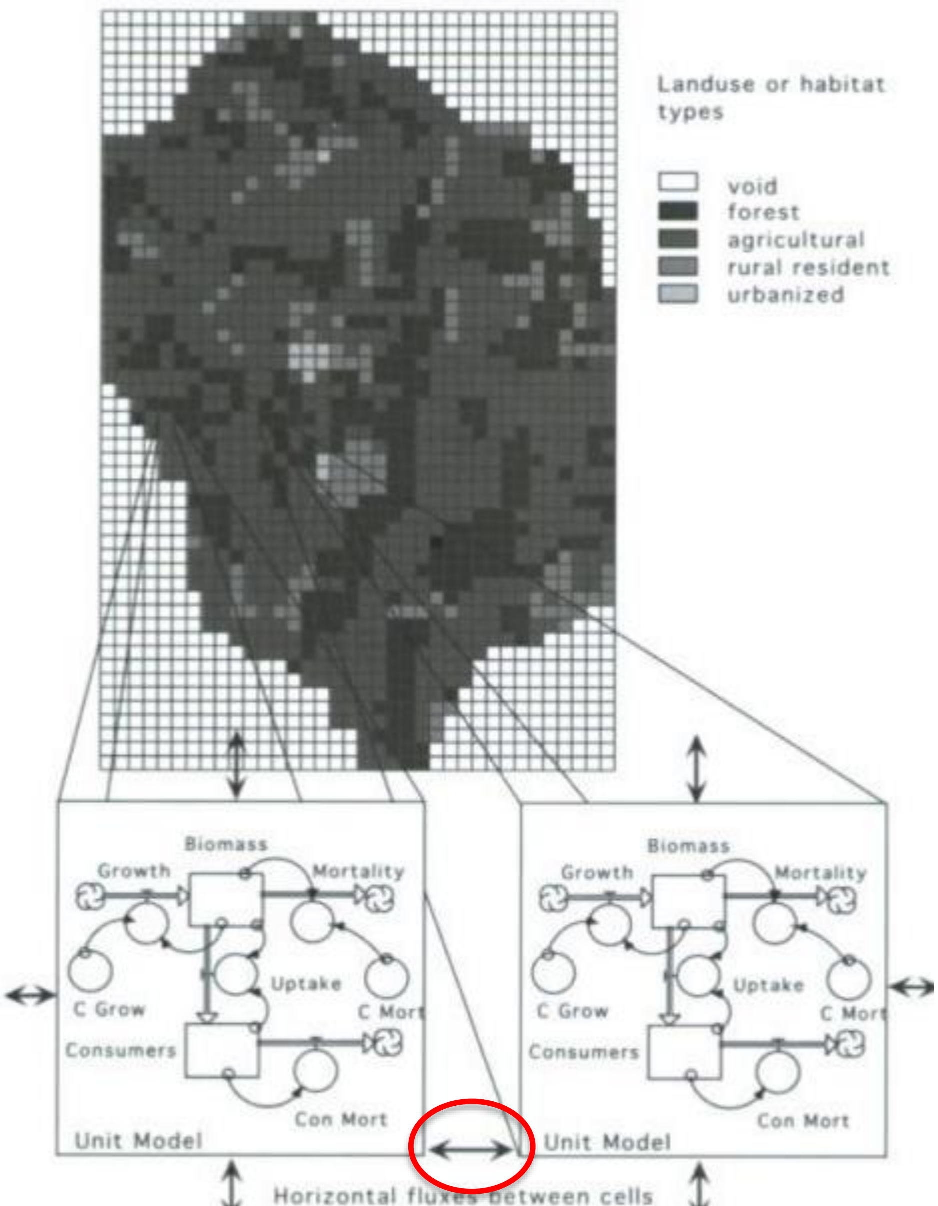


Fine temporal resolution

Coarser temporal resolution

Spatial and temporal scale affects fuelwood collection patterns simulation

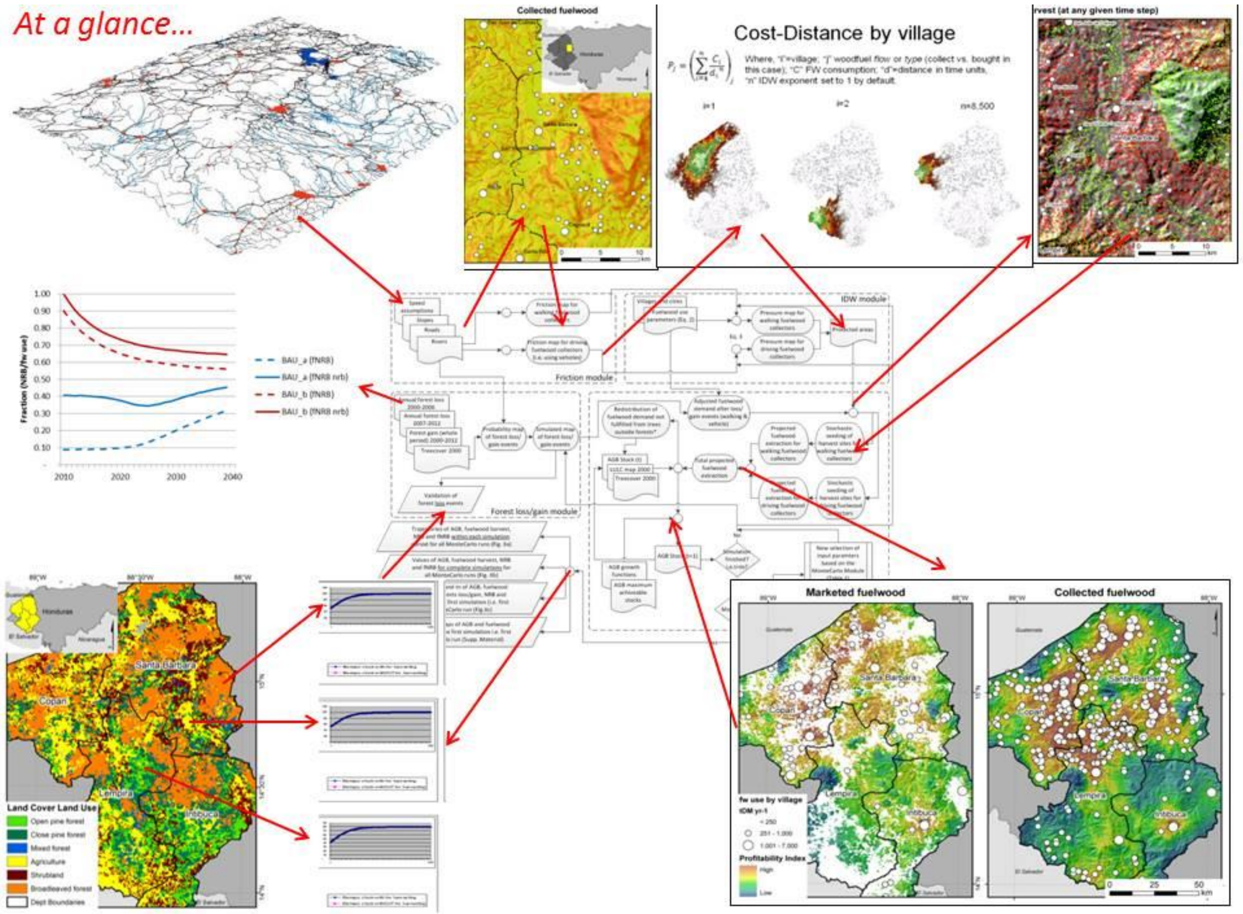
- So, whats the point?
- Spatial and temporal scale affects the **frequency** and **intensity** by which raster cells are harvested.
- And this has implication on the modeled <u>response of the vegetation</u> to the disturb.



- Programming tools available to do it in a fairly easy way.
- Most cutting-edge tools are freeware.
- Many of these tools can be integrated toguether in single models.

Source: Constanza & Voinov 2004

How to include *spatial dynamics* in woodfuel supply-demand analyses?

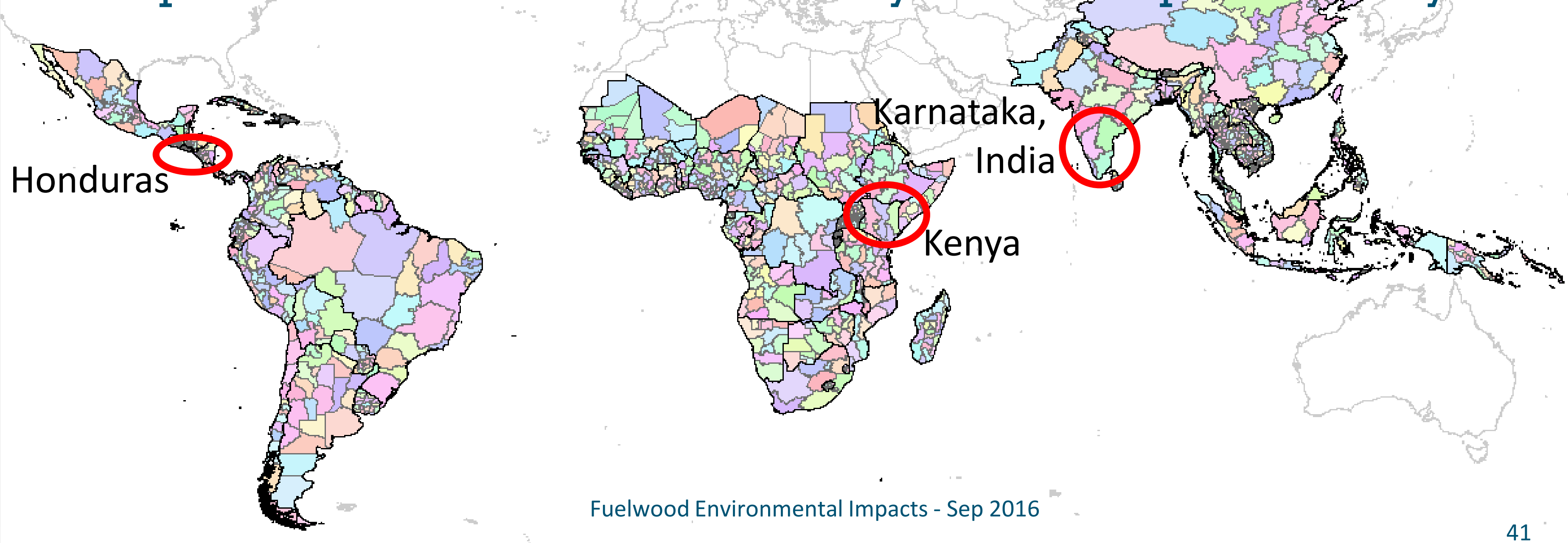


Why we developed this model in the first place?

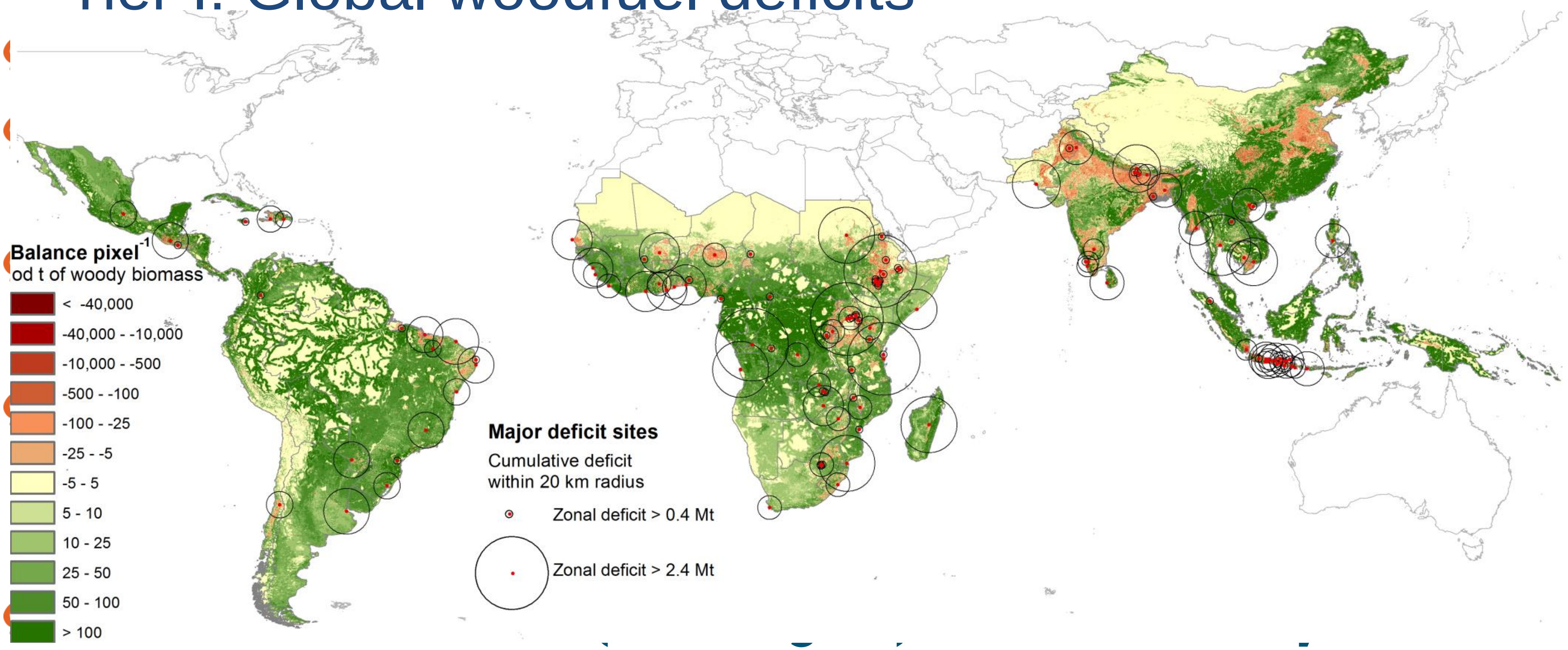
- MoFuSS was developed during one of the Global Alliance for Clean Cookstoves (GACC) projects between 2013-2015: *Geospatial Analysis and Modeling of Non-Renewable Biomass: WISDOM and beyond*.
- It was built for GACC partners and other stakeholders to assess fuelwood-driven degradation in a variety of contexts.

Project objectives

1. Develop spatially explicit estimates of woodfuel demand, supply, and **non-renewable biomass (NRB)** in 88 countries (1482 subnational units analyzed) – Pantropical or **Tier I analysis**.
2. Carry out **national (Tier II)** and **sub-national (Tier III)** analyses in selected **"high-risk" areas** of Africa, Asia, and Latin America.
3. Develop a publicly available **user friendly tool** that GACC partners and others can use to carry out landscape level analyses.



Tier I: Global woodfuel deficits

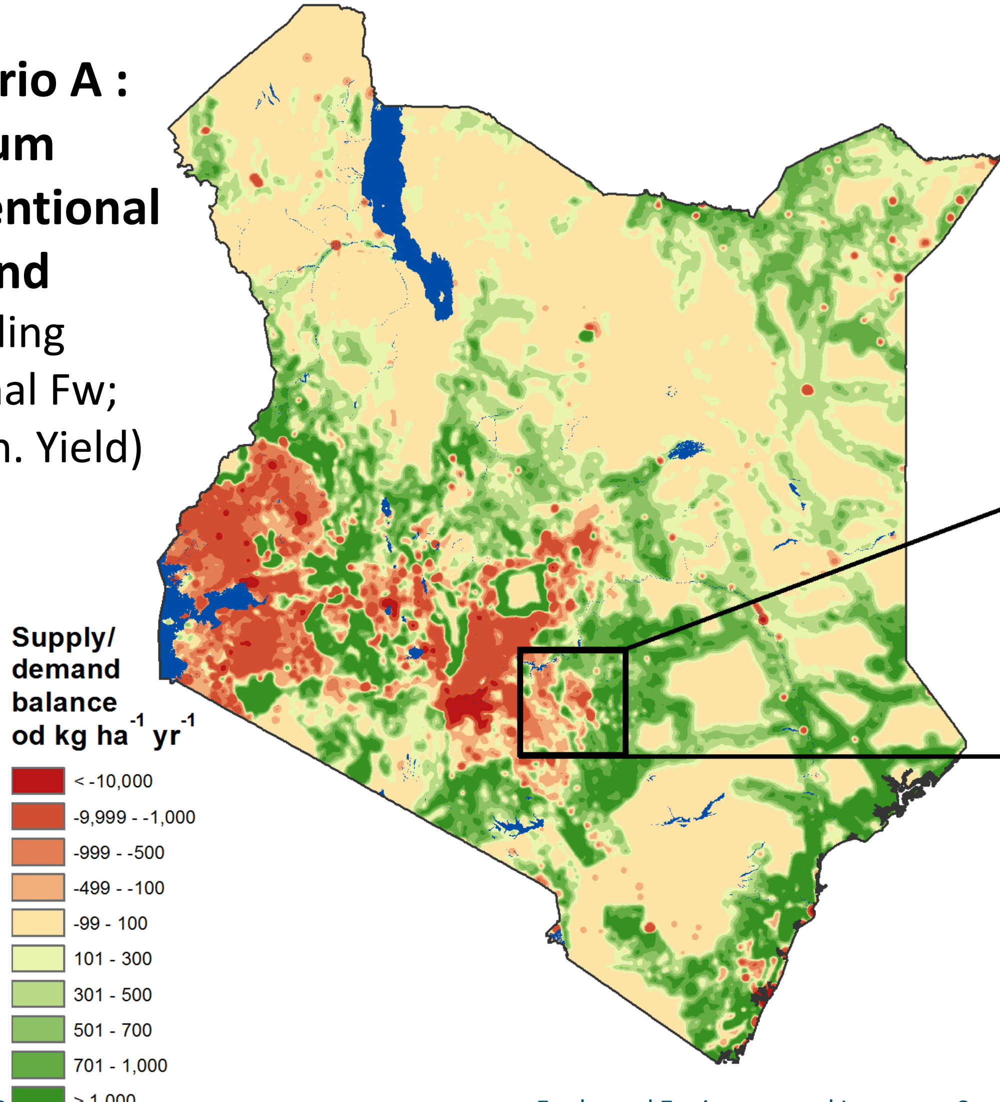


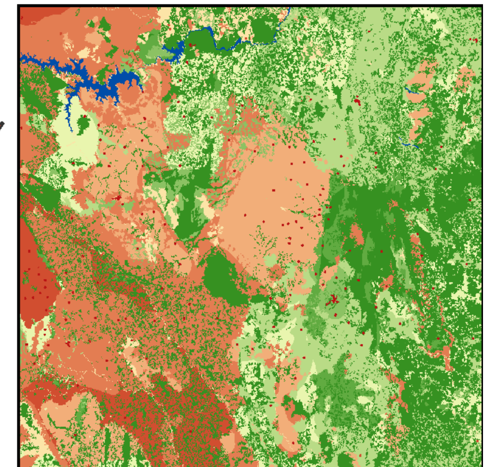
deployed using the best available technology, then emissions would decrease by 100-160 MtCO2e/yr

Source: Bailis, Drigo, Ghilardi, Masera. Nature Climate Change (2015)

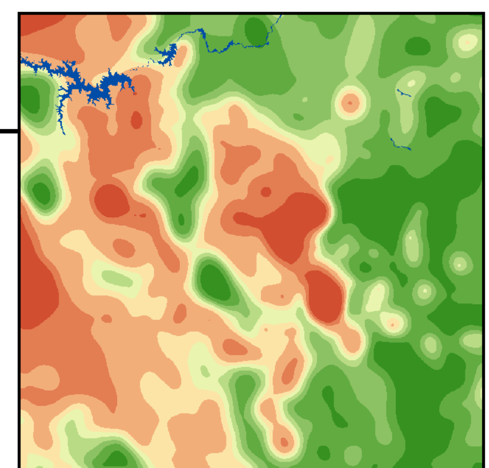
Tier II: National asessments - Kenya

Scenario A : Medium Conventional demand (excluding marginal Fw; 24% Ch. Yield)





Pixel-level balance (1ha)



Local-level balance (context of 6 km)

Tier III: Scope of landscape level analysis

- Built a landscape-level computer model that simulates fuelwood harvesting in space and time, and expected regrowth of the vegetation.
- Use the model to account for savings in non-renewable woody biomass from reduced consumption (due to interventions).

Similarities and differences of Tier III with Tier I & II

Similarities

- Similar inputs
- Spatially-explicit.
- Same principles of supply/demand balance
- Accounts for fuelwood from deforestation.

Differences

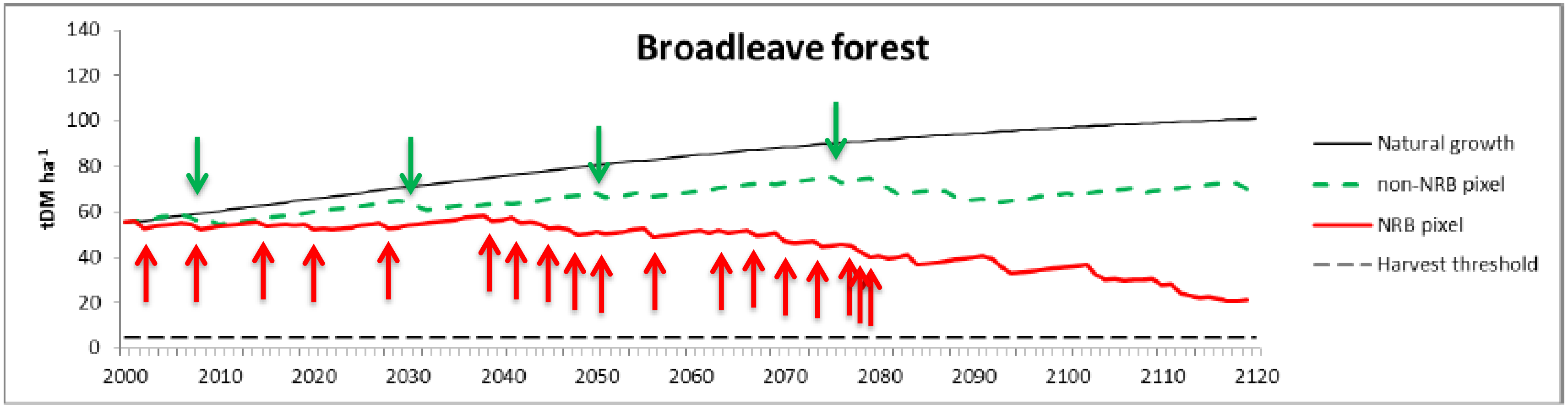
- Dynamic: time-steps allow repeated cycles of harvest and regrowth
- Use biomass growth functions (i.e. CAI)
- Incorporates *uncertainty and stochasticity*
- Unsuitable for very large areas
- Intended as a usable tool for third parties:
  - Built on open or freeware
  - Can run in the "cloud"

Thanks

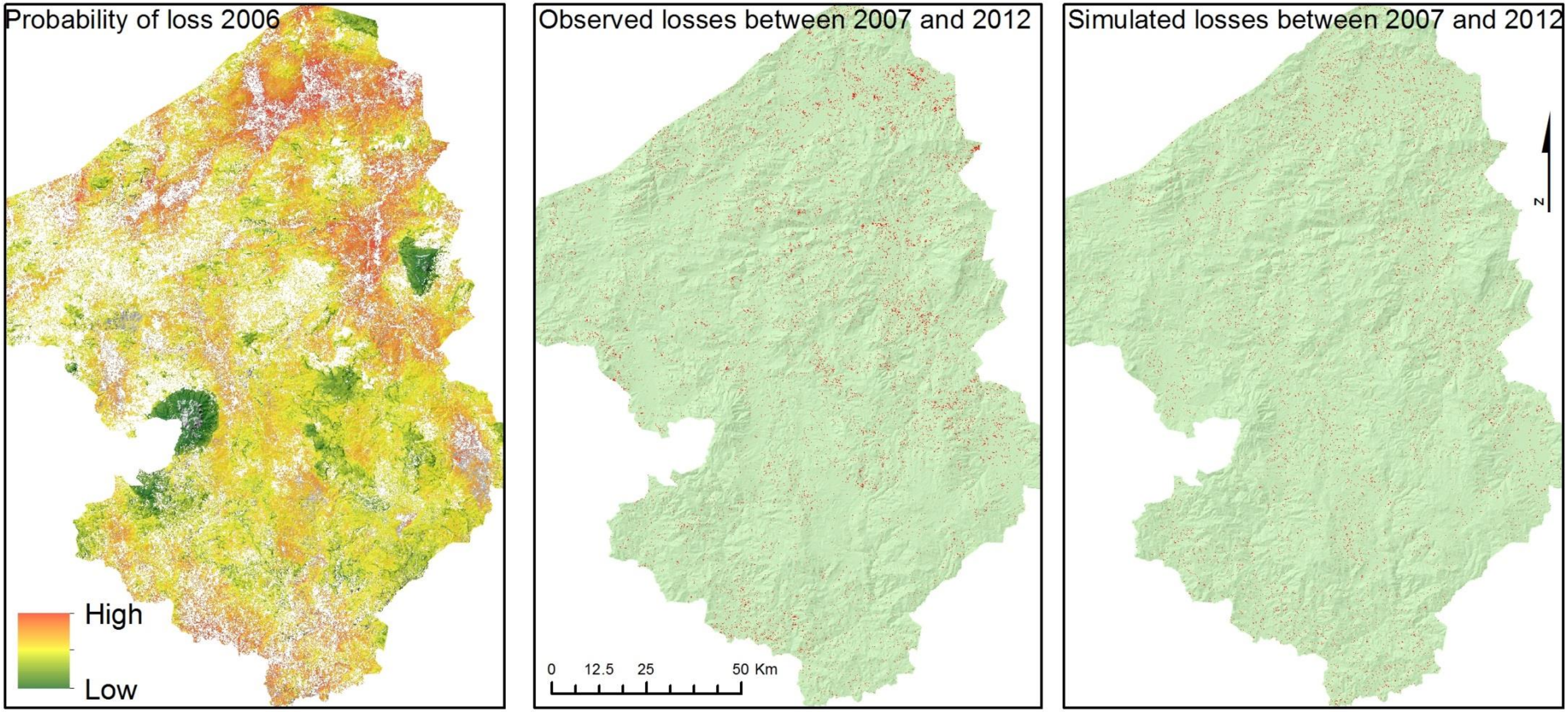
- We will now install MoFuSS in your computers
- Will follow with a short presentation on how the model works
- Then we will run the model

What is the expected “reaction” of vegetation to the distrub

Figure A.5. Temporal projections of supply/demand relations at pixel-level

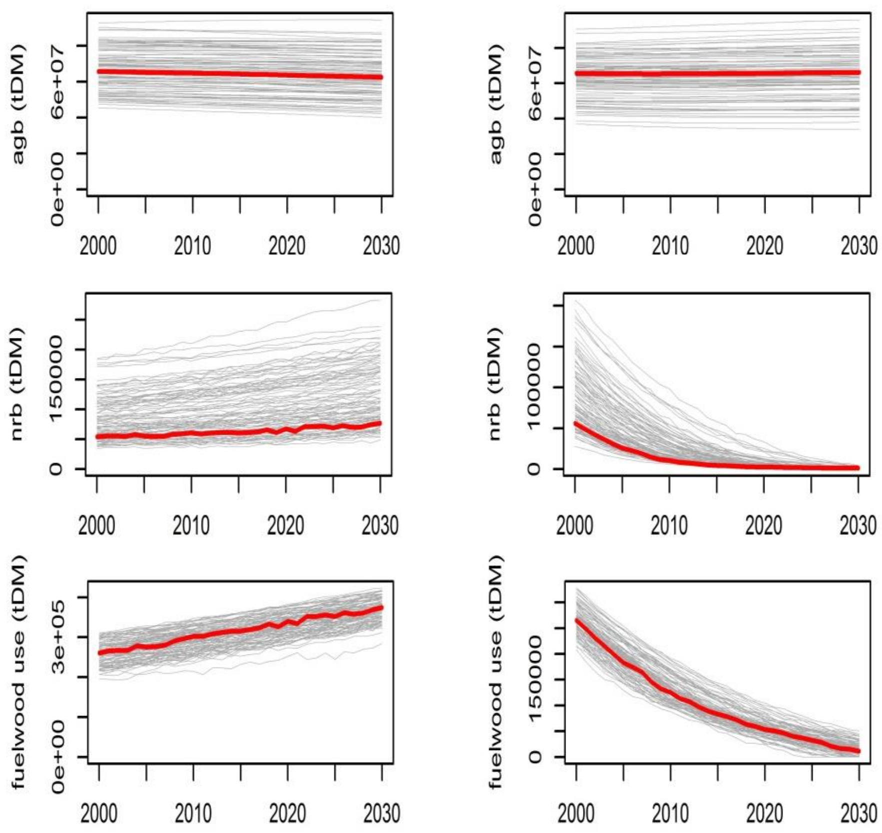


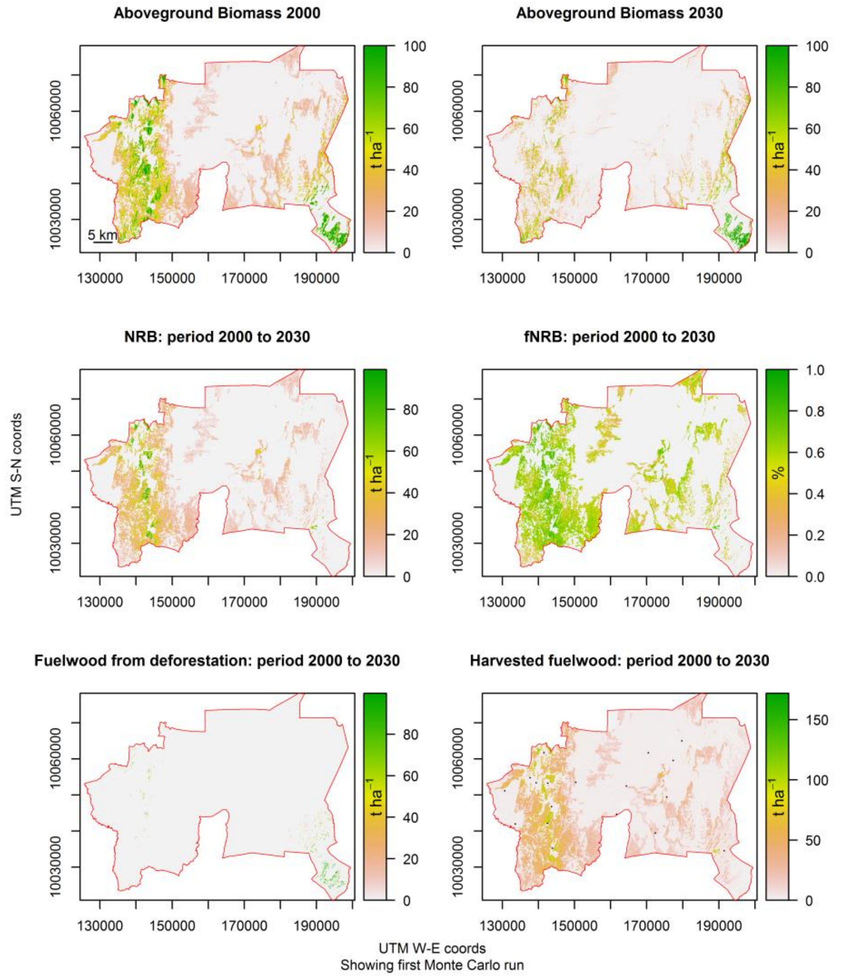
Validated trends in forest loss and gains not necessarily related to woodfuel (Prospective Landscape Simulation submodel)



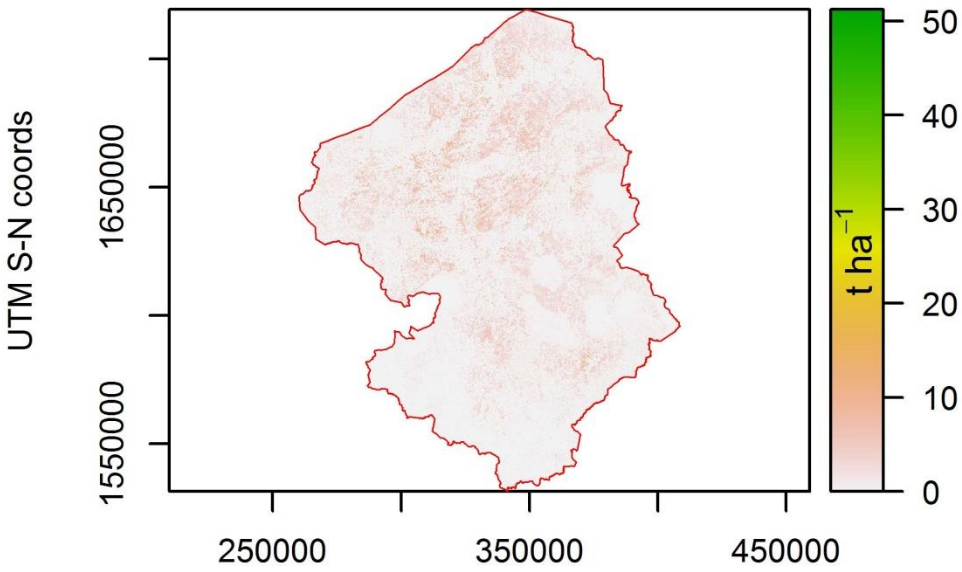
How the relation between wood harvest and vegetation response evolve in a landscape simoultaneously experiencing forest losses and gains

Business as Usual **vs** Clean Cookstoves

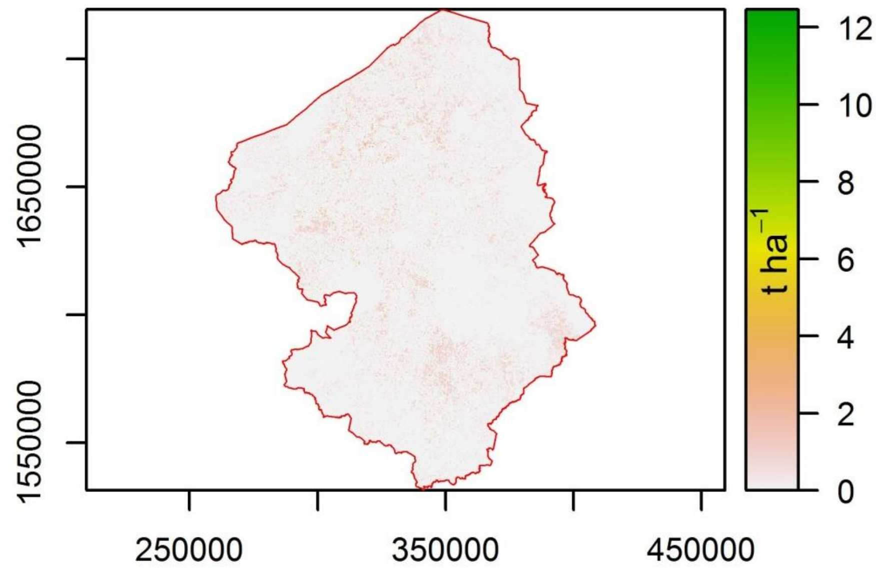




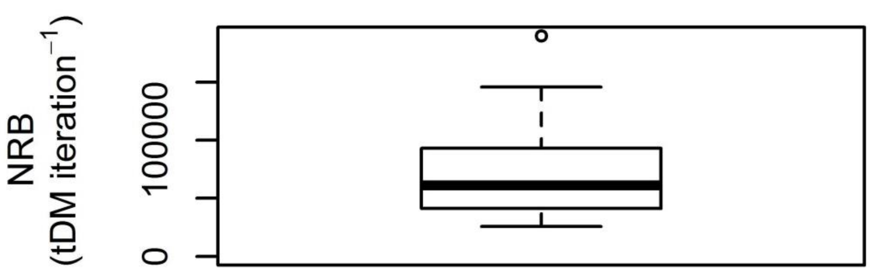
BaU: NRB: period 2000 to 2030



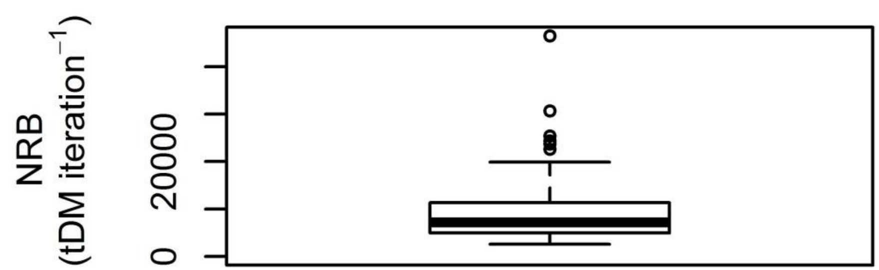
Cookstoves: NRB: period 2000 to 2030



BaU:



Cookstoves:



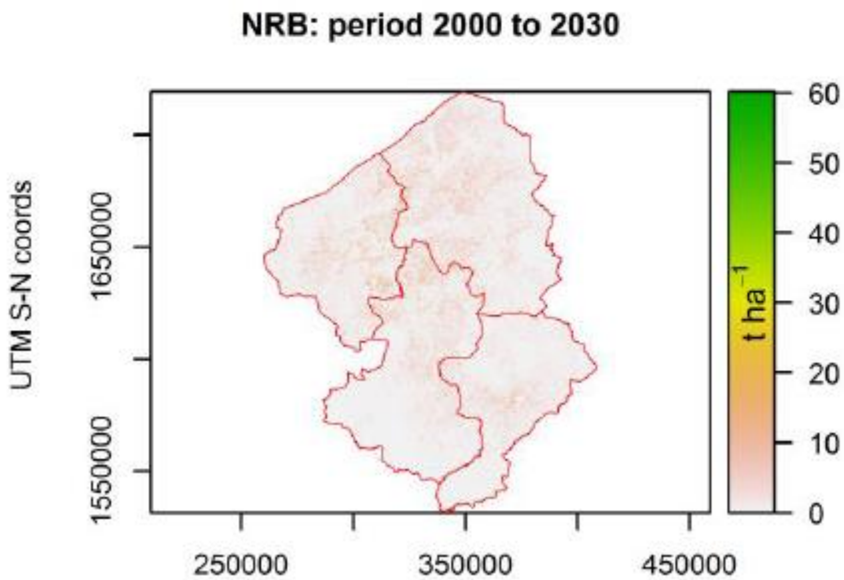
NRBv1.0 produces tables, maps and animations

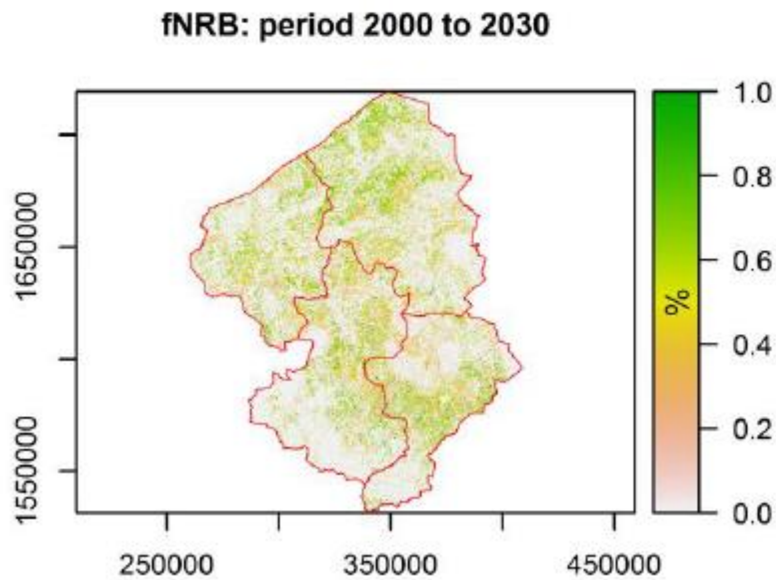
Summary table of key results by administrative unit

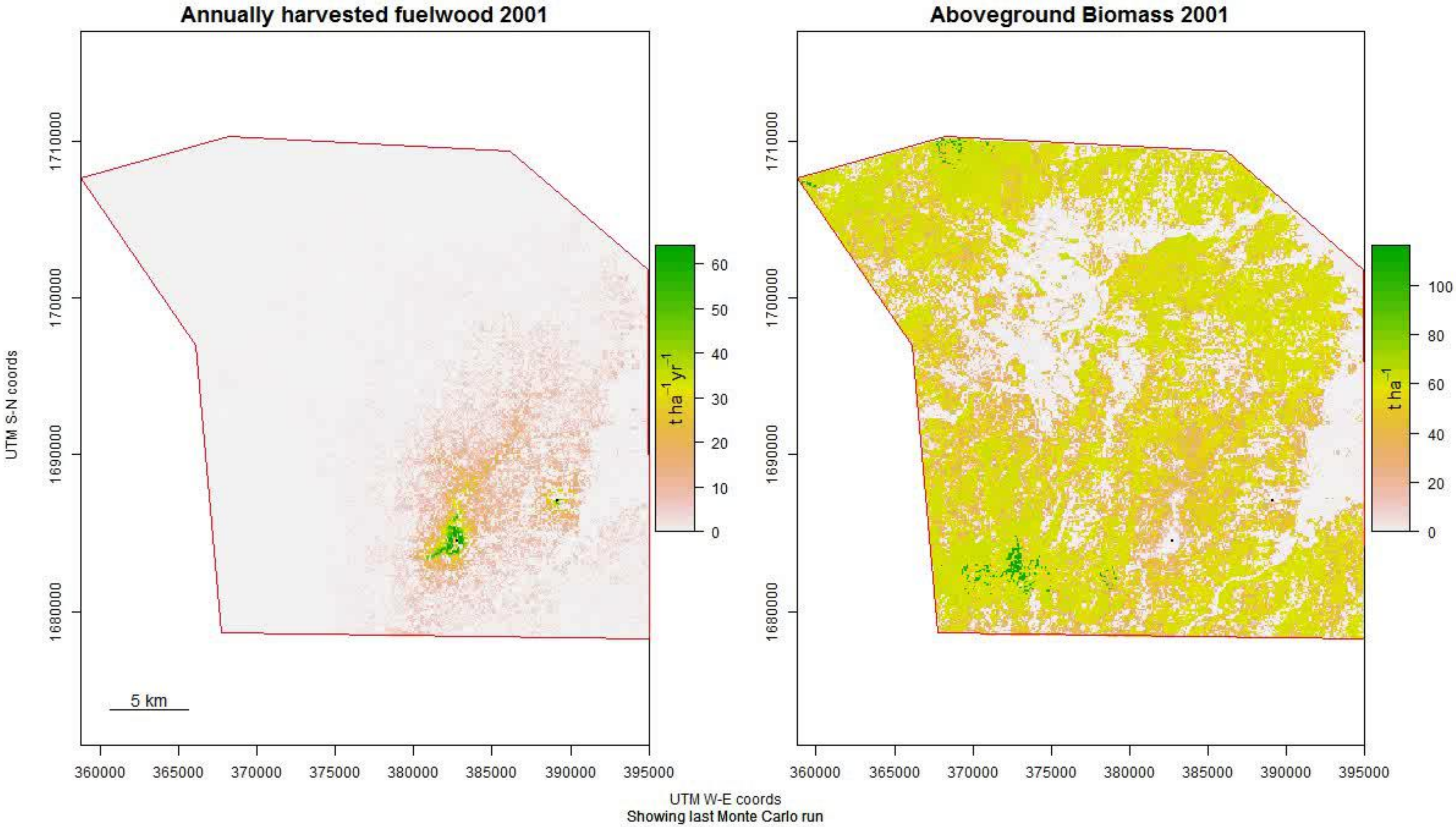
	NOM_MUN.x	NRB_MC_mean	NRB_MC_sd	CON_TOT_MC_mean	CON_TOT_MC_sd	CON_NRB_MC_mean	CON_NRB_MC_sd	fNRB	fNRB_sd	fNRB_nrb	fNRB_nrb_sd
1	Platón Sánchez	26509.14	190.79	38084.16	345.17	36839.24	59.48	0.70	0.01	0.72	0.01
2	Jaltocán	7775.19	459.62	11098.57	36.05	10624.64	338.14	0.70	0.06	0.73	0.07
3	Huejutla de Reyes	53999.44	368.03	85192.20	388.64	78686.61	1145.10	0.63	0.01	0.69	0.02
4	Huazalingo	1490.96	207.87	8843.66	45.20	6700.07	647.45	0.17	0.14	0.22	0.17
5	Atlapexco	1130.20	279.92	5695.52	99.10	4368.91	133.09	0.20	0.25	0.26	0.25
6	Chiconamel	1733.38	133.49	2681.17	90.71	2575.84	99.95	0.65	0.08	0.67	0.09
7	Chalma	22355.90	990.83	31591.36	418.97	30378.05	857.12	0.71	0.05	0.74	0.05
8	Chiconamel	17007.43	310.82	23424.19	1.26	22687.65	292.42	0.73	0.02	0.75	0.02
9	San Felipe Orizatlán	27854.90	1126.65	47628.07	270.61	44371.54	1056.53	0.58	0.04	0.63	0.05

Note:
NRB_MC_mean and NRB_MC_sd are average and standard deviation of NRB values for all Monte Carlo realizations per choosen administraive unit.
CON_TOT_MC_mean and CON_TOT_MC_sd are average and standard deviation of fuelwood use for all Monte Carlo realizations per choosen administraive unit.
CON_NRB_MC_mean and CON_NRB_MC_sd are average and standard deviation of fuelwood use driving degradation for all Monte Carlo realizations per choosen administraive unit.
fNRB and fNRB_sd are the fraction of non−renewable biomass and its standard deviation respectively for all Monte Carlo realizations per choosen administraive unit.
fNRB_nrb and fNRB_nrb_sd are the fraction of non−renewable biomass and its standard deviation respectively, but only accounting for fuelwood use driving degradation.

Table automatically generated by NRBv1.0, but the script producing this table is still in its Beta version






Annually harvested fuelwood 2001
Aboveground Biomass 2001
UTM S-N coords
1710000
1700000
1690000
1680000
5 km
t ha^{-1} yr^{-1}
60
50
40
30
20
10
0
t ha^{-1}
100
80
60
40
20
0
360000
365000
370000
375000
380000
385000
390000
395000
UTM W-E coords
Showing last Monte Carlo run

Conclusions from Version 1.1:
Expected outcomes and relevance of results

- Allows to compare BaU vs Intervention scenarios in terms of environment degradation risk and GHG emissions.
- From a Climate Finance perspective, the model allows project developers to come up with their own estimates over their area of interest.
- Possibility of calibration-validation-simulation (In principle).
- Easy to explore sensitivity.
- Other aspects of woodfuels impacts can be eventually assessed: local environment, energy povety, health.

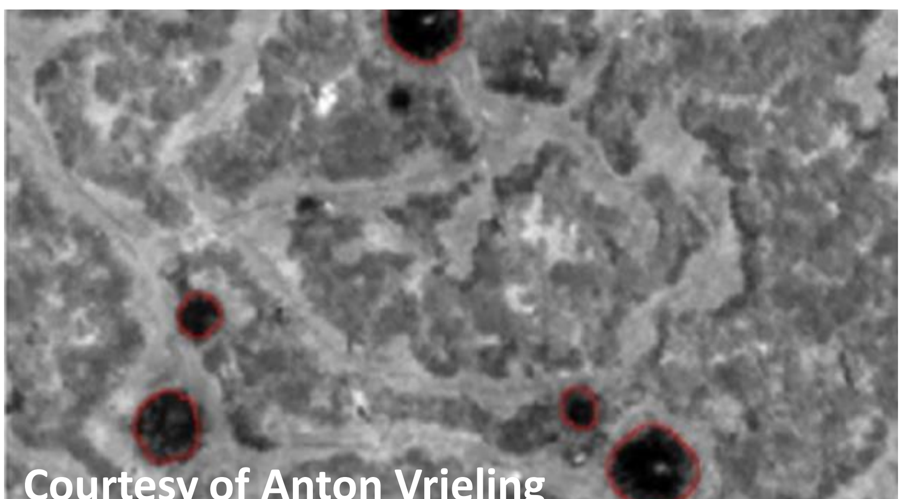
Where is research and development heading in the next few years?

1. Validation using **independent** datasets is becoming increasingly doable and required by specialized peers.

2. Analyze multiple drivers in ensemble (i.e. simoultaneously): complexity of models is increased considerable.

3. Making modeling tools available, aplicable and affordable to non-technical practitioners in the need of cuantitative frameworks and results.

Validation: High resolution imagery is now available for the past 5-10 years

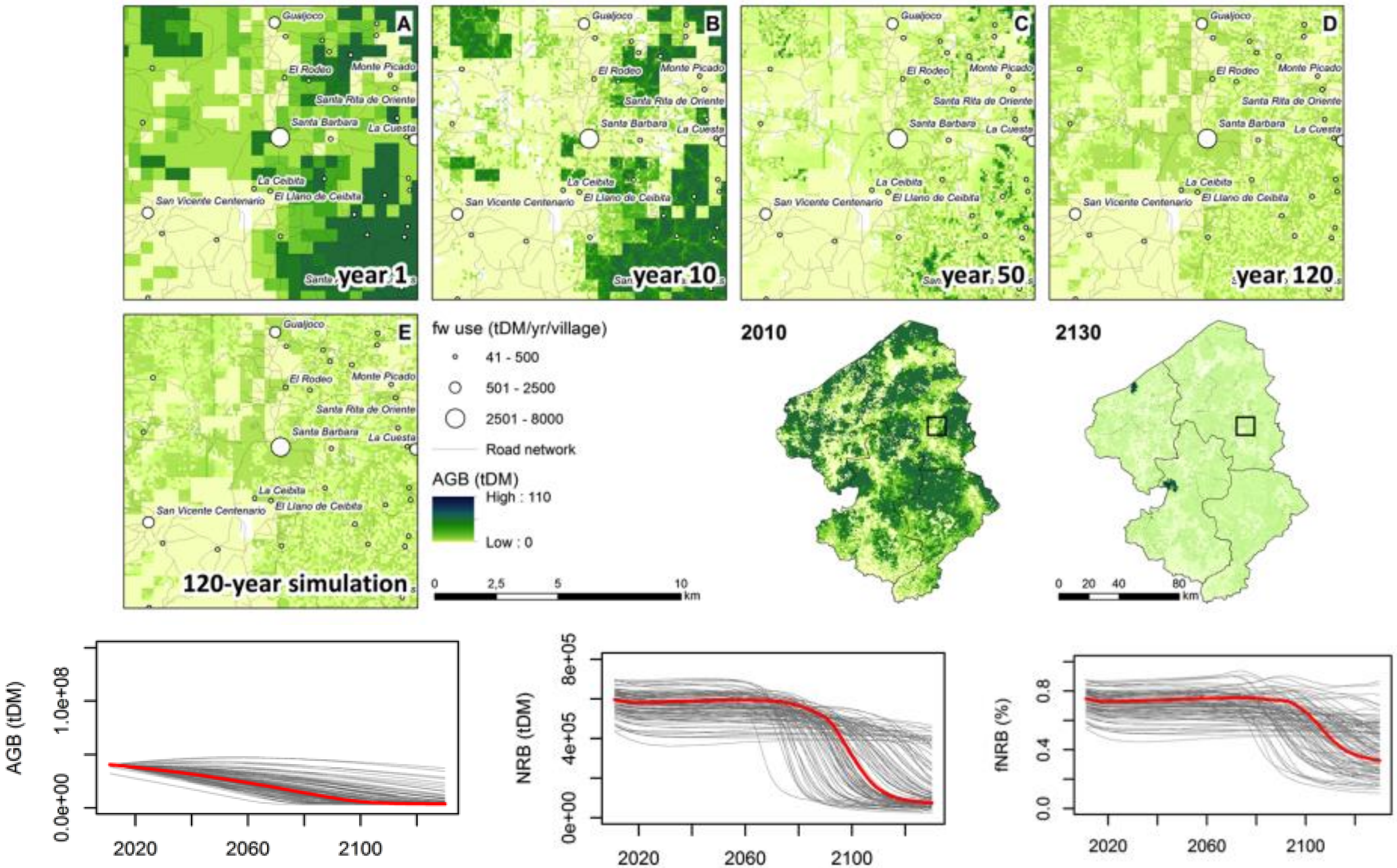


Courtesy of Anton Vrieling

Recent work on space-time simulations of socio-environmental systems include tools designed to study complex systems such as:

- Genetic algorithms (e.g. Yu and Wei, 2012; Stange et al., 2011; Wendt et al., 2010).
- Neural networks (e.g. Gil-Tena et al., 2010; Li et al., 2010; Maeda et al., 2009).
- Celullar automata (Mahiny and Gholamalifard, 2007).
- Network theory (Yang et al., 2010

Exploring complex behaviour in non-linear systems



Make **TOOLS, not results,** usable by a wide range of practitioners and government officials

e.g. MoFuSSv2.0 (UNAM-SEI) wish list for 2017:

- User-friendliness:
  - Automatic reports
  - Easy "one-click" instalation
  - Manuals
  - Video tutorials and training webinars
  - Worldwide default datasets and parameters
  - A growing community of users
- Improved features:
  - Optimization algorithms to inform about cookstove deployment strategies
  - Multiple LULCC transitions
  - *…we have many more here, some of them already being worked on…*
- Validation
  - Good-practice guidance for independent validation of results
- Dream on features
  - Coupled to behavioural change modeling


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Image U.S. Geological Survey
© 2013 Cnes/Spot Image
lat 14.882602 long 88.273409° elev 223 m