Global Land-Use Issues

Keith L. Kline
Virginia H. Dale
Robin Graham

Oak Ridge National Laboratory

5th Annual Forum of the California Biomass Collaborative
Bioenergy Sustainability and Lifecycle Analysis
May 29, 2008
Sacramento, California

Research supported by the Department of Energy's Office of the Biomass Program
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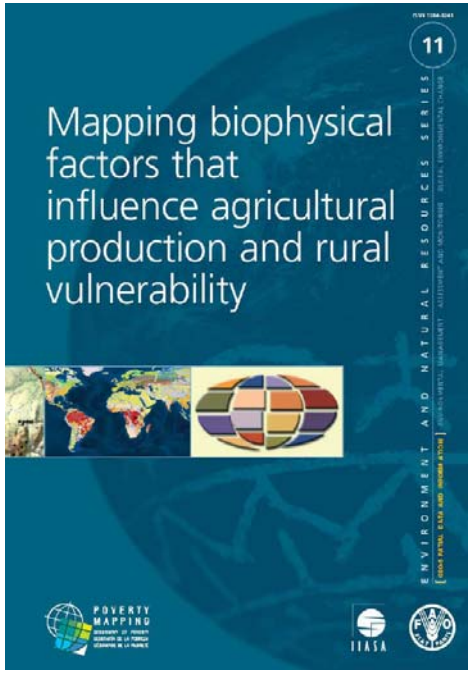
Outline – Global Land Use Issues

- **Land: How much? What type? Where?**
- **What drives land-use change (LUC)?**
- **How can we address it equitably?**
- **Challenges for LCA**



Biofuel Feedstock Assessment for Selected Countries ORNL 2008

Key points

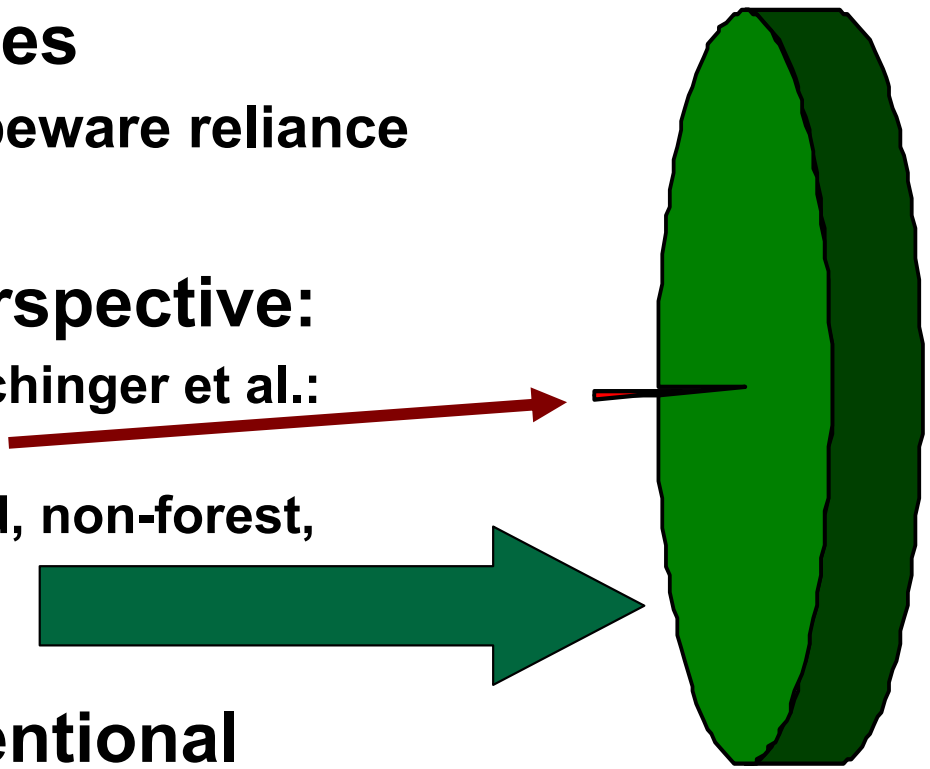
- **Land is available for agric. expansion without clearing new forest**
- **Yet, forest clearing continues.**
- **Critical to understand LUC -- complex, dynamic, *process* - largely independent of crop markets**

Key Points, continued

- **Effective Strategies to address LUC**
- **Bioenergy: an incredible *opportunity***
  - **constructive scrutiny**
  - **certification schemes**
  - **more sustainable land use**
  - **Win-Win potential for emissions, energy security, food security, development**

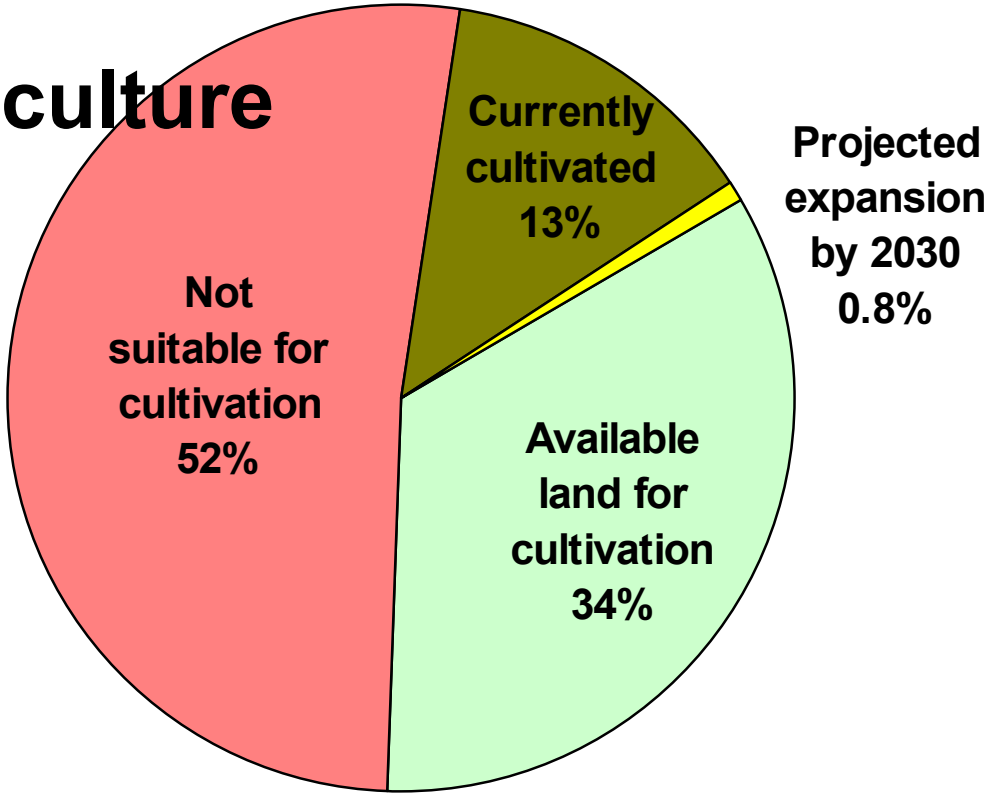
Key points: LUC and Life Cycle Assessment

- **LCA modeling results highly sensitive to LUC assumptions, baseline projections, scale**
- **Uncertainties and challenges**
  - **LUC <> land cover change (beware reliance on remote sensing)**
- **Research, data -- put in perspective:**
  - **LUC impact postulated by Searchinger et al.: 108 thousand km sq**
  - **Underutilized, frequently burned, non-forest, "available/suitable" agric lands: 30 - 40 million km sq**
- **Lack of evidence for conventional wisdom on 'indirect impacts'**



How much agricultural land is available? Various studies

- **World soils assessment (USDA 1999): up to 71 m km^2**
- **FAO 2002, 'World Agriculture towards 2015/2030'**
  - **Total suited ≈ 40 – 70 m km^2**
  - **Currently cultivated ≈ 12 – 20 m km^2**
  - **Available for expansion ≈ 50 m km^2**
  - ***Food, feed, fiber demands by 2030 require ≈ 1.2 m km^2 expansion***
  - **Still available after 2030 ≈ 20 – 49 m km^2**

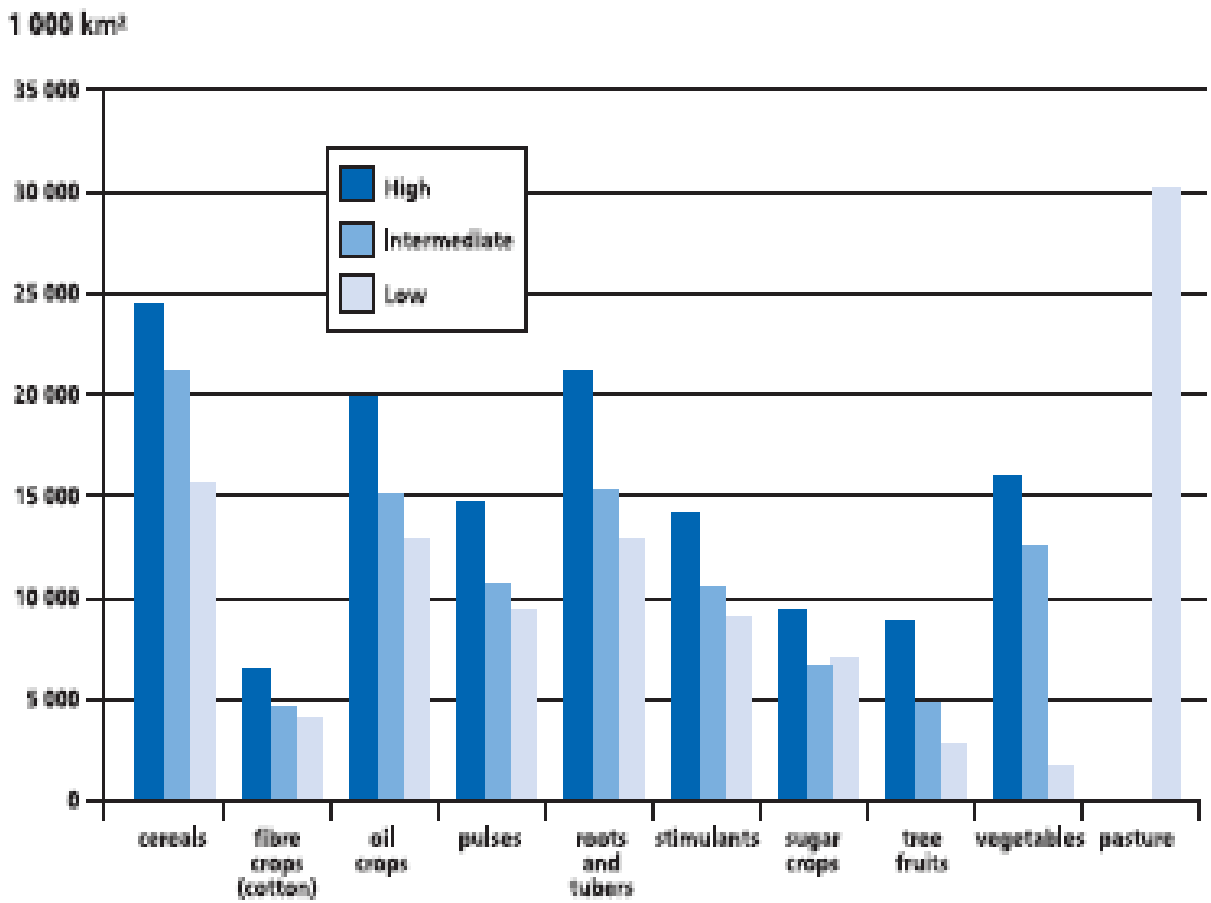


Where are the forests?

Biophysical factors for rural ag (2007)

- **Analyzed environmental constraints to rain-fed agriculture**
  - **Rural land only: 126 m km sq**
  - **Excluded >25 m km sq for forests, etc.**
- **"Available" land ≈ 101 m km sq**
- **Assessed**
  - **soils**
  - **climate**
  - **slope**
  - **land use**
  - **tech**
  - **inputs**

Rural land area with medium high to very high suitability for rainfed crops, by crop group, with low, intermediate and high level of inputs, and pasture at low level of inputs

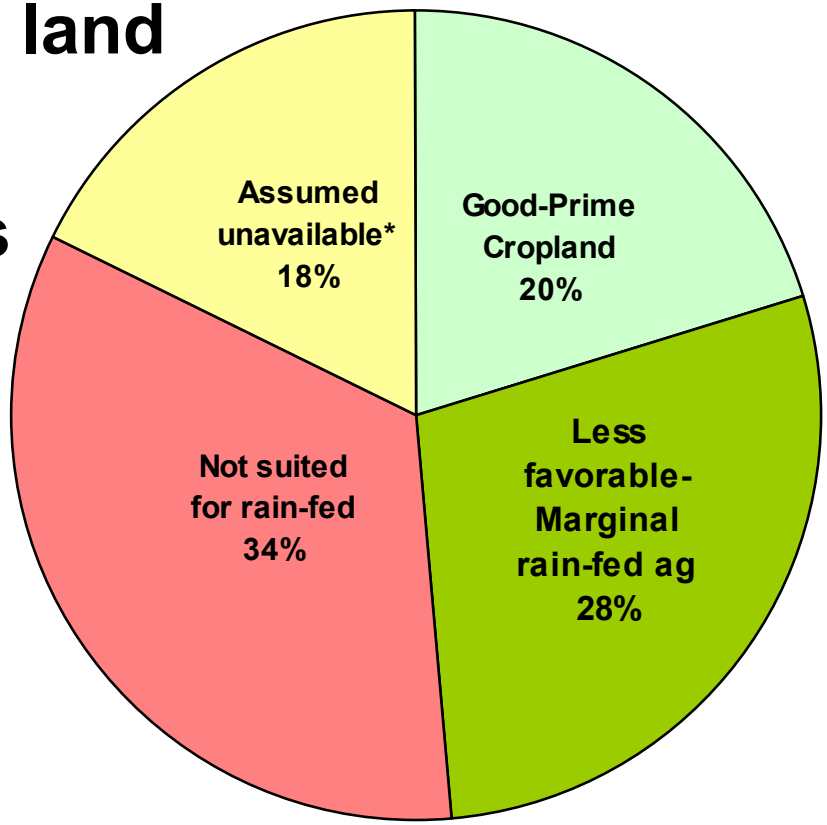


Focus on vulnerability; excluded current irrigated lands

Source: FAO-IIASA, 2007: Mapping biophysical factors that influence agricultural production and rural vulnerability

Lots of land is available

- **Good – Highly suited productive land ≈ 26 m km^2**
- **Less favorable for rain fed crops ≈ 36 m km^2**
- **Using a fraction (30%) of total available**
- **Result similar to prior studies**
  - **ample area available for rain-fed agriculture ≈ 62 m km^2**
- **No *need* to convert forest at this scale**
  - **Best lands not evenly distributed**

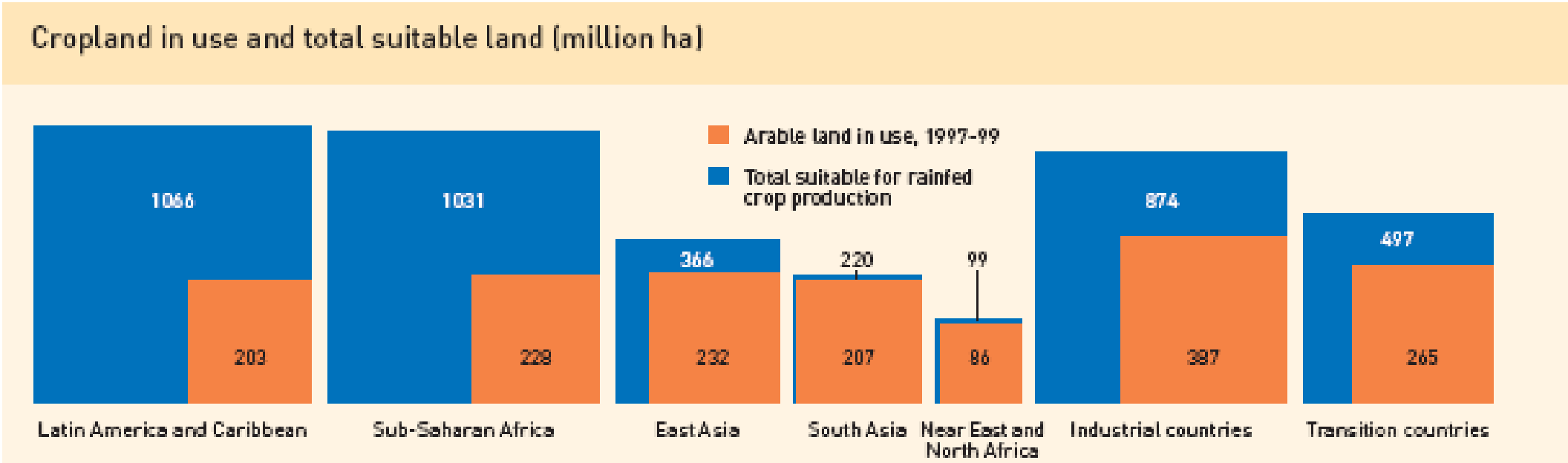


Where is available land?

Percent of total "rural" area under study = 126 m km sq
Data source: FAO-IIASA, 2007: Mapping biophysical factors that influence agricultural production and rural vulnerability

Where is land available?

- **Majority "available" in just seven nations, 4 in Latin America and 3 in Africa**
  - **Issues of governance, development, poverty**
  - **Degrading land productivity from fire, poor management**
- **Expansion of cultivated cropland is small, falling rate over time relative to population. Why?**



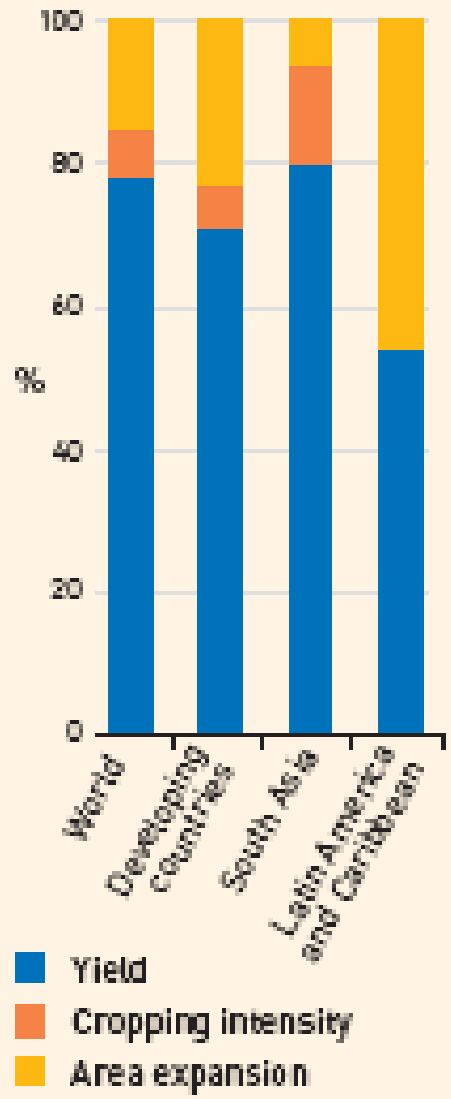
Source: FAO 2002. Tally here for "suitable" = 42 m km2. Total "in use" = 16 (m km sq)

Sources: FAO data and Fischer et al. (2000)

Increasing yields
Shifting croplands

- **More people fed from less and less land**
  - **>80% of production growth from yields, intensity (chart)**
  - **Most available land underutilized**
  - **US reduced cropland by 44 million acres (1982-1997), increased output**
- **Cultivated land at point in time = fraction of total available**
  - **84% of major crop systems are based on shifting agriculture (MEA 2005)**
    - **Forest margins Africa, Asia, Latin America**
    - **Low productivity**

Sources of growth in production, 1961 to 1999



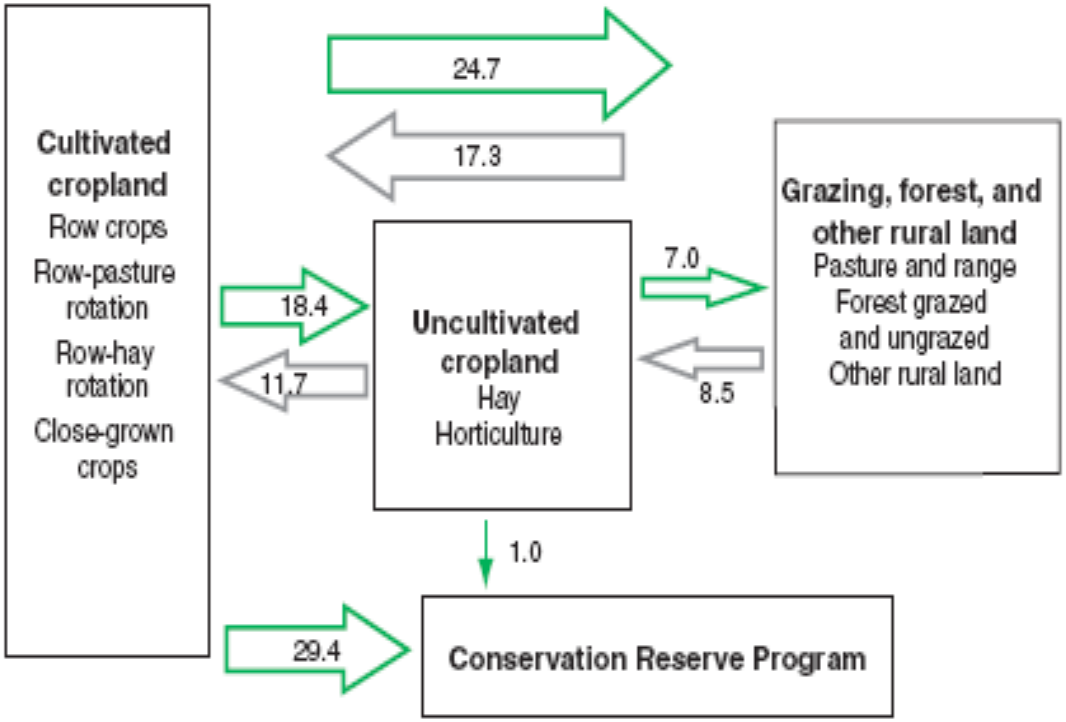
Source: FAO data

LUC process: separate from, far ahead of, broader scale than cultivation

FAO 2002

Land Use Change

- **Meta analysis* of 150 empirical studies concludes: no single cause**
  - **Local patterns, interacting factors**
  - **Land-use in constant flux, multi-directional**
  - **Gross versus net change (results depend on when, where measured)**



Example: shifting US ag land use. USDA maintains extensive data sets to complement remote sensing

- Net gain in forest and less intensive uses (1982-97)

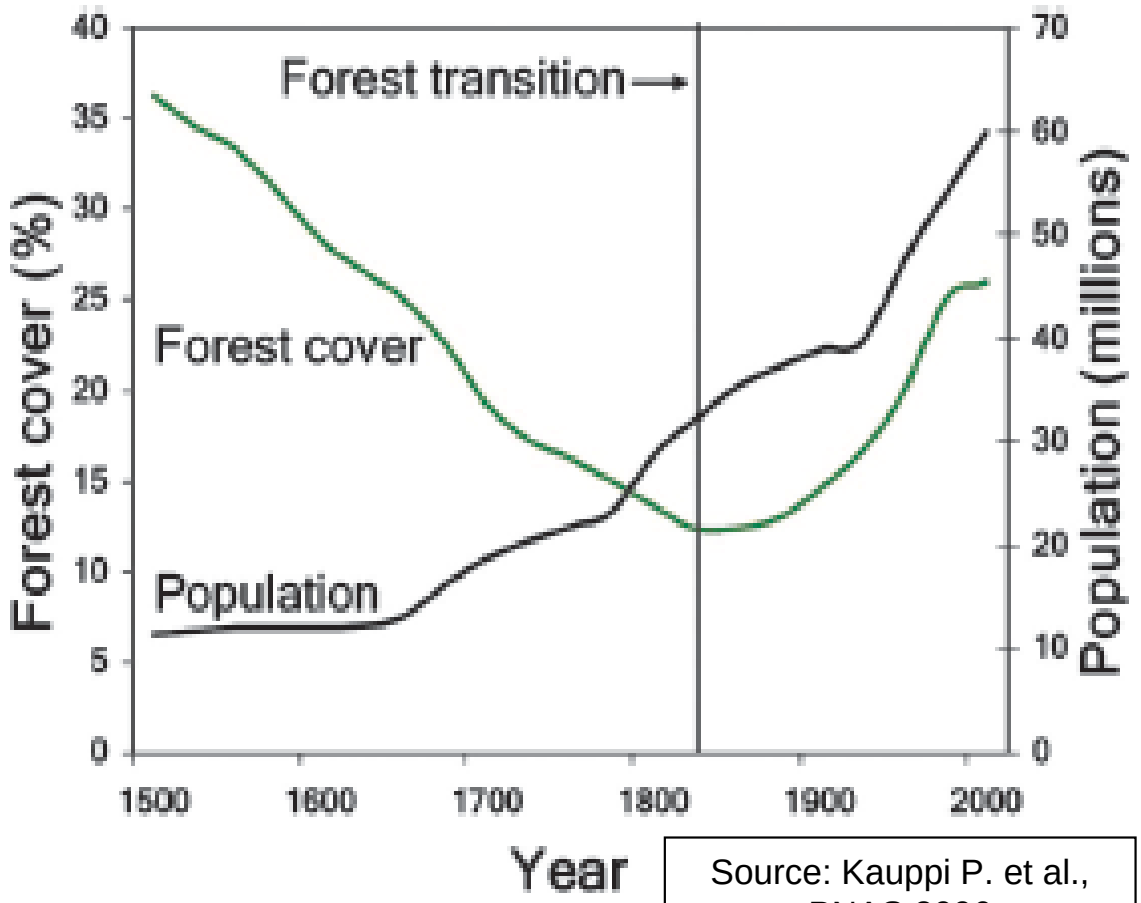
- Results are time, scale sensitive

Illustration of land cover and land-use shifts in US. 1982-1997. USDA 2006: Environmental Effects of Agricultural Land-Use Change: the Role of Economics and Policy

* See references for Geist and Lambin

Change follows predictable patterns

- **Classic 'Mather' curve**
- **Land-use change; independent of specific crop**
- **Many developing nations have made made the 'turn'**
- **At given point in time, land cover may show loss or recuperation**
  - **Scale dependent**



Source: Kauppi P. et al., PNAS 2006

- Applies to developed and less developed countries
- Different nations, different stages – equity issue?

Process – common trends

- **The "forest transition"**
- **Among 50 nations with extensive forests per FAO 2005 Global Forest Assessment:**
  If annual per capita GDP is > $4,600, forest biomass stocks were increasing
- **US example, state scale (map)**

How does this process typically proceed?

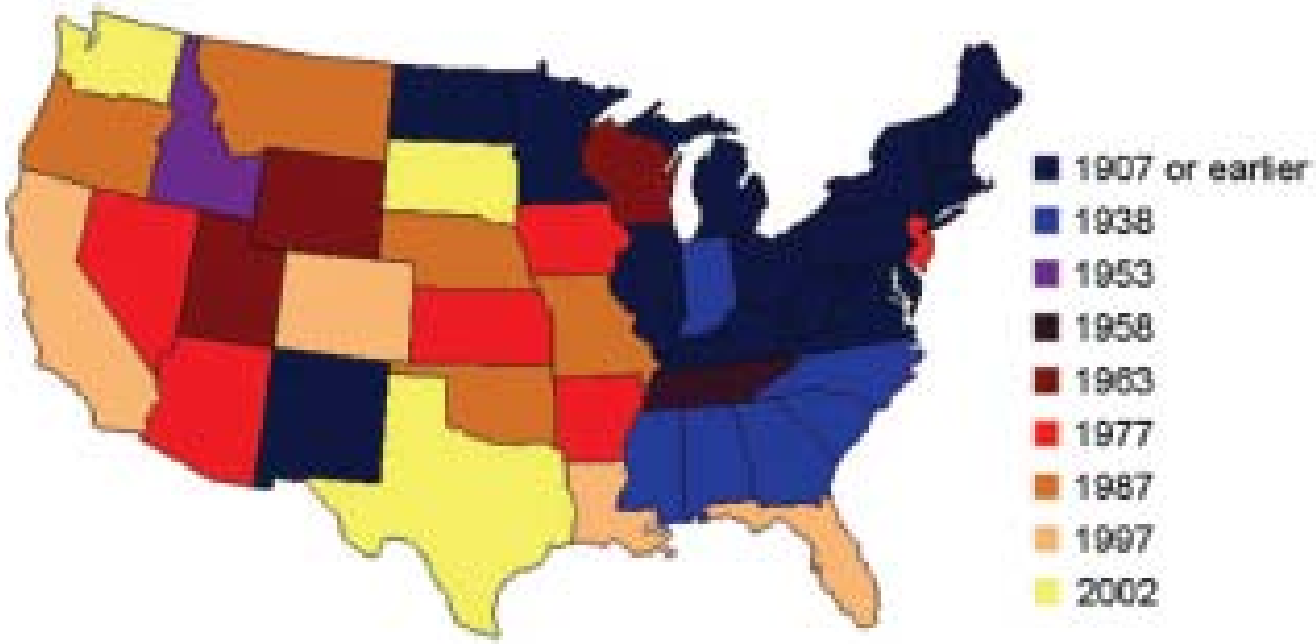
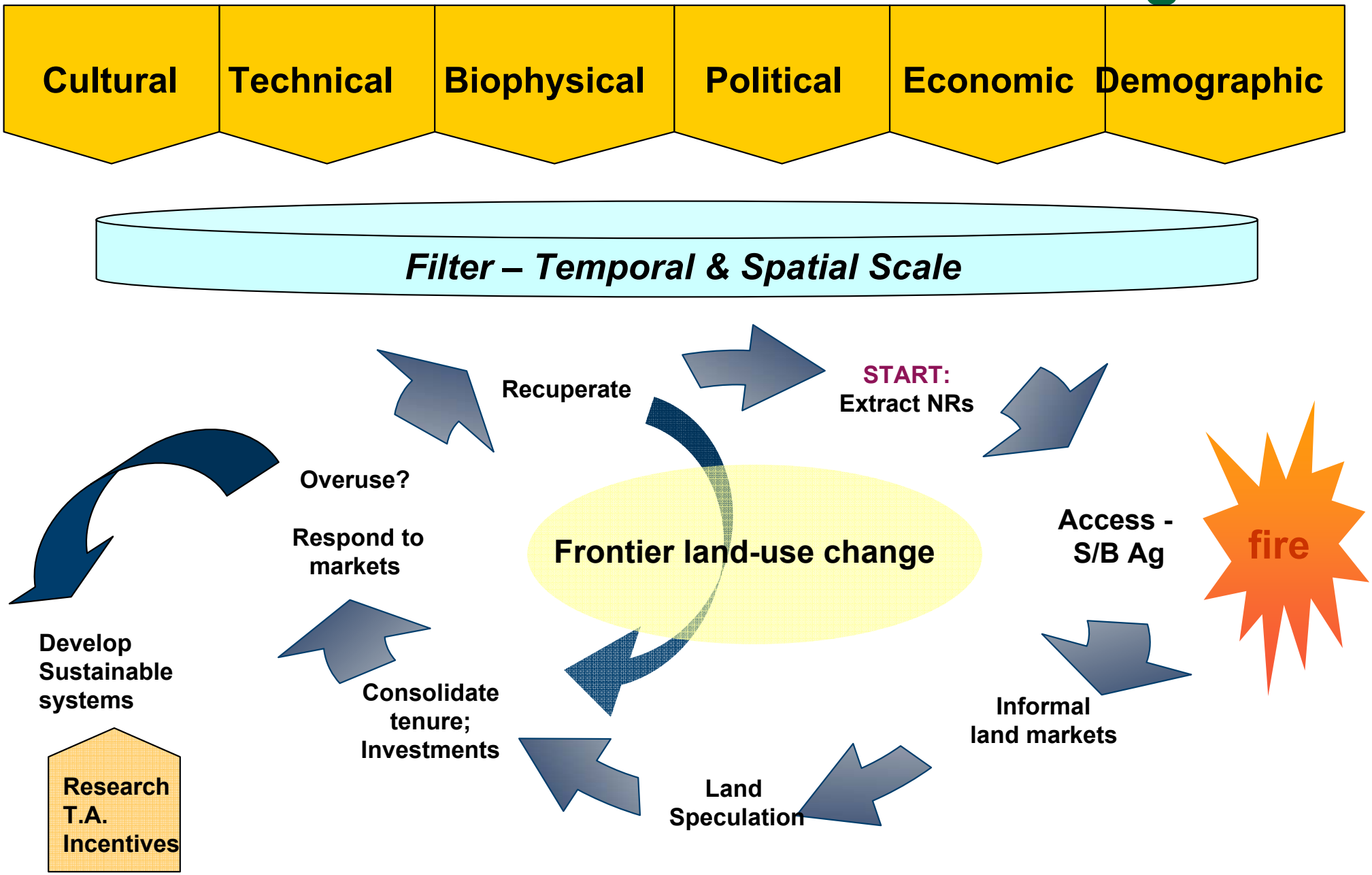


Fig. 2. Forest transitions in the U.S. Dark to light colors indicating the spread of forest transitions from the Northeast, where minimum areas were reported in 1907. The colors indicate the date when the minimum forest area was reported (source, ref. 3).

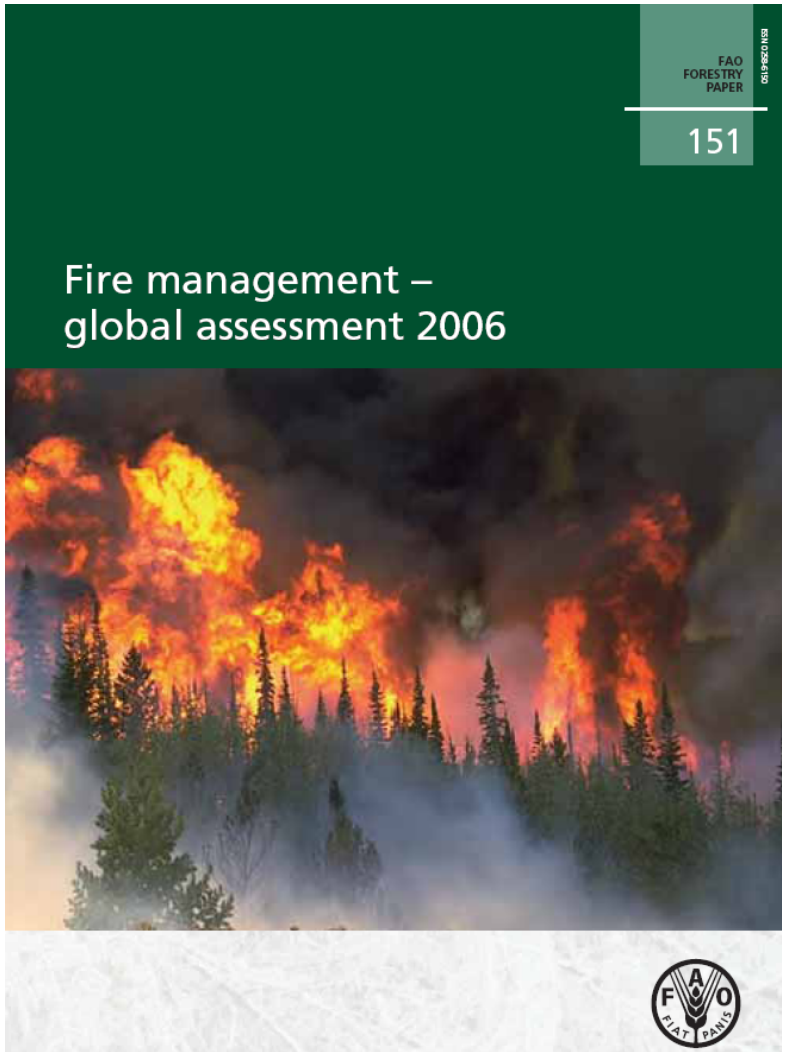
Source: Kauppi P. et al., PNAS 2006

Drivers of frontier land-use change



Fire cannot be ignored

- **Annual burned area 3.5 million km^2/year**
  - **Majority of burning along agricultural frontiers**
  - **Most in poor areas; >40% in Sub-Sahara Africa**
  - **80-95% intentional, human caused**
- **"Carbon debt"**
- **Concerns about growing frequency and intensity in developing nations**

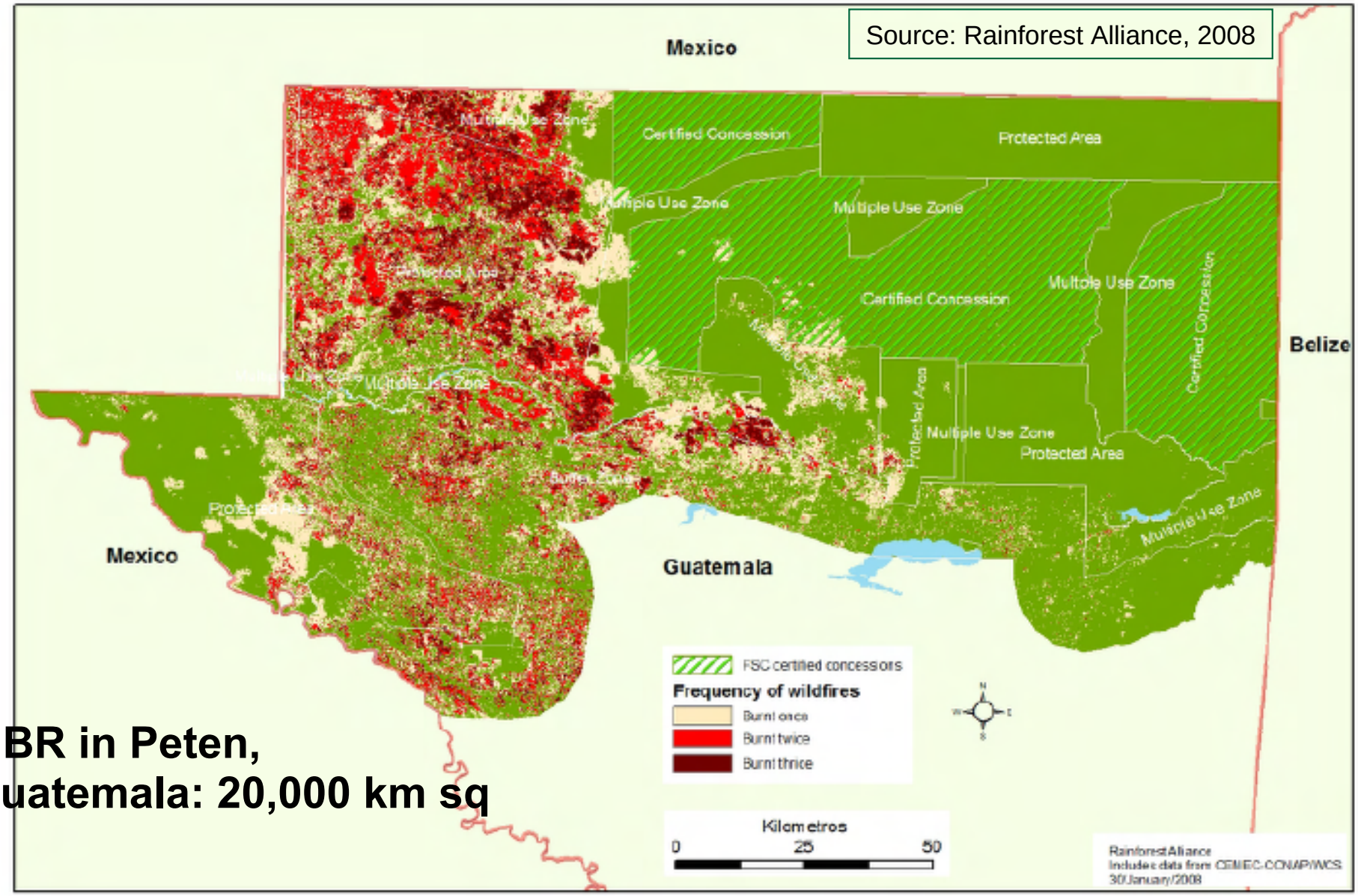


Example: Maya Biosphere Reserve

Map 4. Frequency of wildfires for 2003, 2005 and 2007 fire seasons in the MBR.

Rainforest Alliance

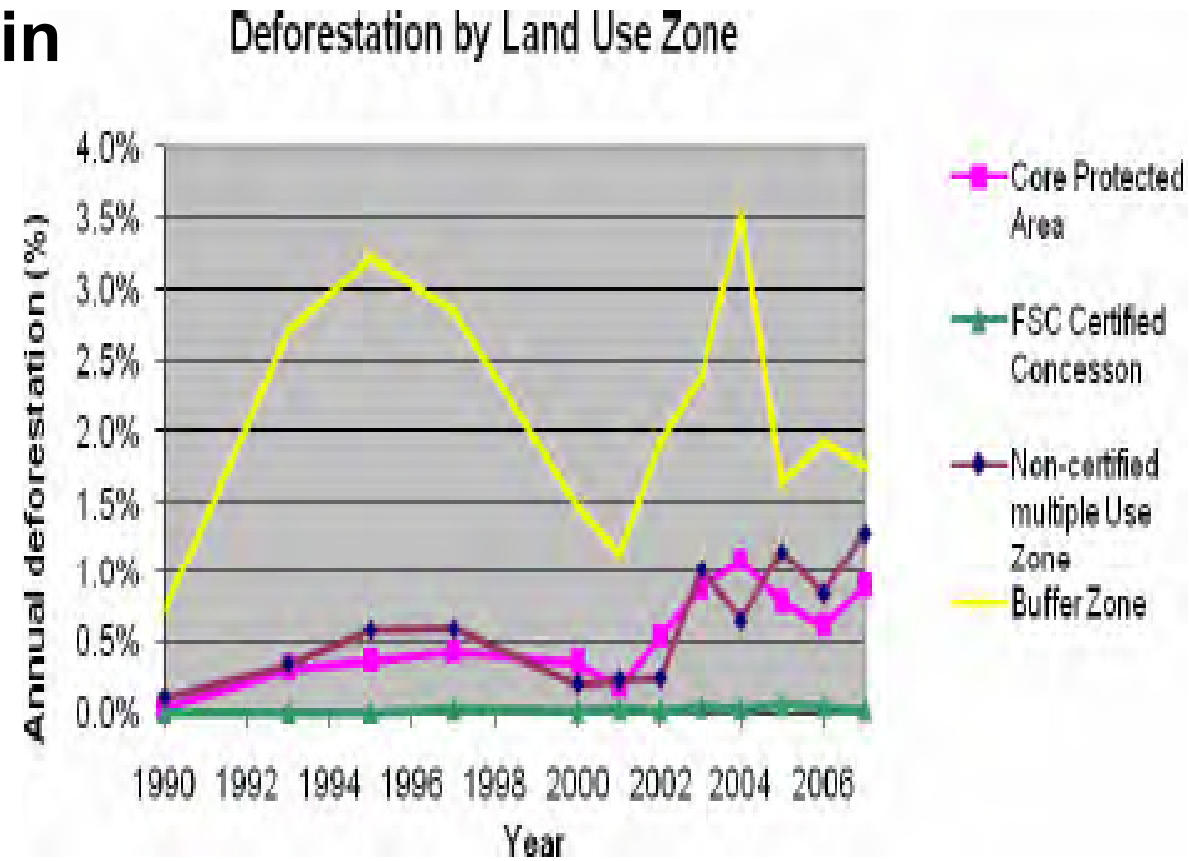
Wildfires - 2003, 2005 & 2007



MBR in Peten, Guatemala: 20,000 km sq

Land cover change, Guatemala MBR example

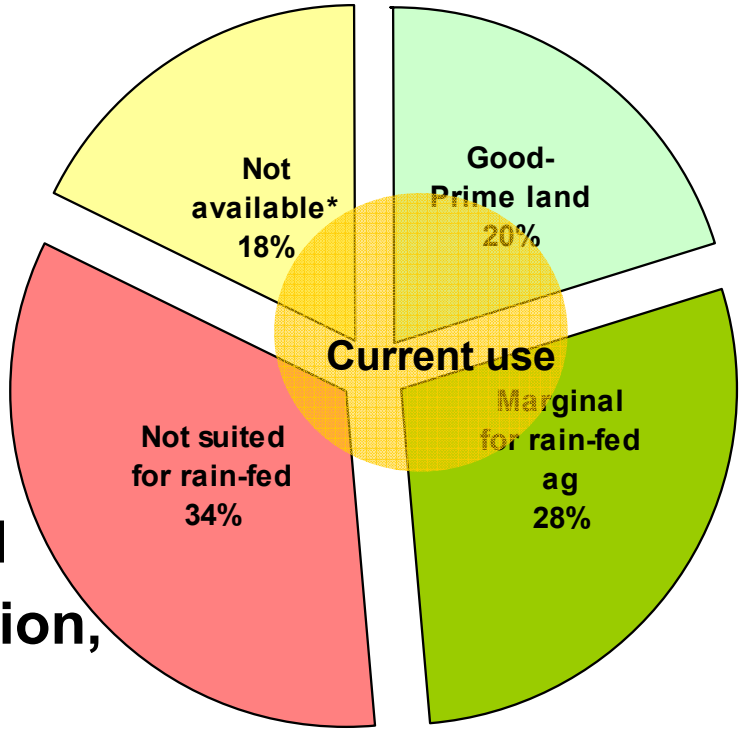
- **Deforestation higher in parks than multi-use zones**
- **Getting incentives right**
  - **Certification can help!**
- **Road access**
  - **predominant factor in deforestation process**
  - **Opened/maintained by petroleum exploration and production operations**
- **Brazil- Marina Silva resigns after losing battle over HYDRO development…**



Graph from Rainforest Alliance, 2008

LUC Issues

- **Overlaps in land classes, uses**
- **Despite large areas "available"**
  - **Forest lands still being converted**
  - **"Unsuited" lands in use**
  - **Official parks and reserves cultivated**
  - **Land degraded by repeated fire, erosion, poor management**



- **Analytical results depend on spatial, temporal scale**
  Selection of parameters dictates outcome
- **Each micro LUC situation distinct – difficult to link micro - macro scales but,**
  (a) some important trends are clear
  (b) LUC can be addressed
  - **focus on local drivers with local people**

Strategies to address biodiversity, tropical deforestation

USAID – Sec. 118/119 FAA:

- Poverty/Governance/Illicit actions: “threats”
- Solutions involve support for:
  - Sustainable production - rural livelihoods (reduce fire)
  - Land Use Plans, Management
  - Land tenure
  - Increase capacity (gov, community) for management, decision making, enforcement
  - Inventory, protect key areas

Strategies to address deforestation

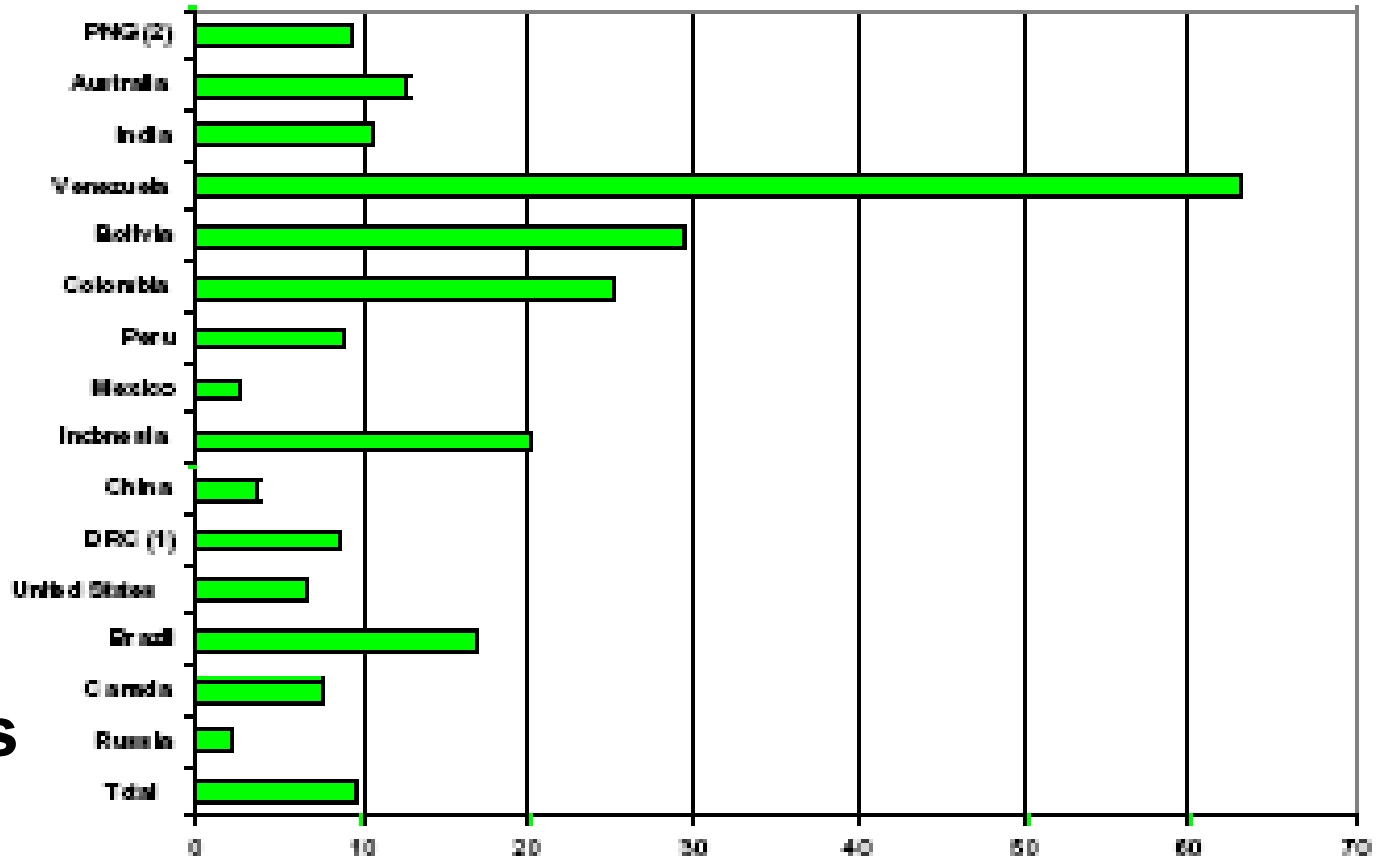
CSD (May 2008): Need investment in agric., especially more sustainable production

USAID – SE Asia:

- **Shared vision among stakeholders based on valid, relevant information (land-use plans)**
- **Political will, clear rules, sustained commitment**
- **Participatory and transparent governance of the resource (tenure clarity)**
- **On-the-ground presence**
- **Public-Private Partnerships**

Leading strategies to address deforestation

- **Get incentives "right"**
- **TNC (Brazil)**
  - **increase crop yields**
  - **enforce laws and regulations**
- **Sound familiar?**
- **Forest nations ≈ large areas "protected" ≈ high bioenergy crop potential**



(1) Democratic Republic of the Congo (Zaire), (2) Papua New Guinea

Figure 11: Top 15 countries protection status of the world remaining closed forests (percent).

Source: UNEP Assessment of Status of World's Remaining Forests

Models using Life Cycle Analysis

- **Do data support a 'zero-sum' game to allocate indirect land use change to biofuels?**
- **How does market uncertainty affect land use? (more annual crops, less perennials?)**
- **What would be impact on LUC if RFS were revoked? If only "non-forest" lands are eligible?**
- ***Inaction* ≈ continue trend of rapid land conversion, forest loss.**
- **Can we use best available management practices, move forward constructively?**

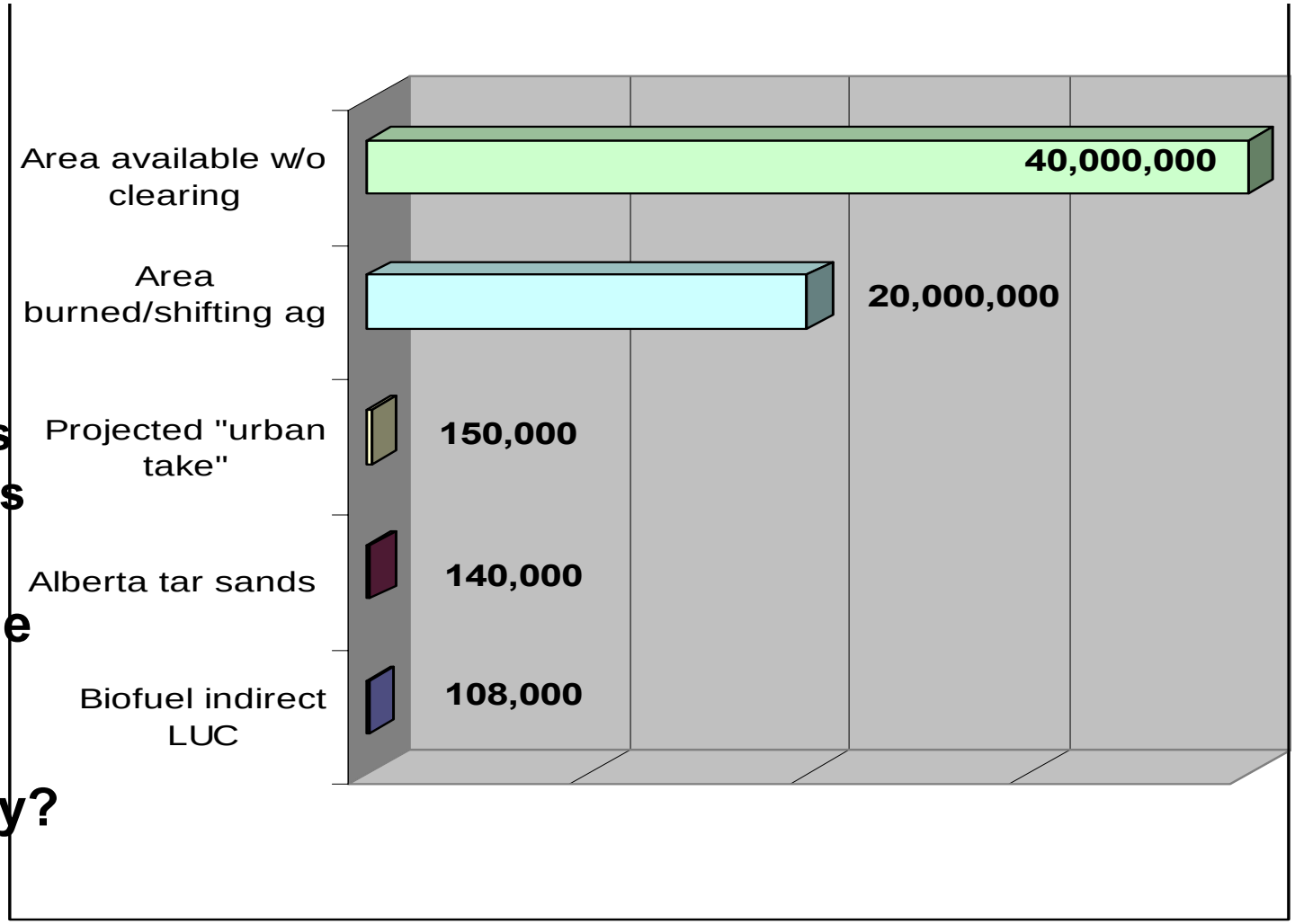
Land Use Change, Biofuels & LCA

- **Feb 2 2008 *Science* reports[1] claim biofuels cause high greenhouse gas emissions due to *land-use change*.**
- **Agreement**
  - **When land is cleared, carbon released**
  - **Effects of clearing are significant**
  - **Global demand for food increasing**

[1] "Land Clearing and the Biofuel Carbon Debt" (J. Fargione *et al.*) and "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases through emissions from Land Use Change" (T. Searchinger et al.)

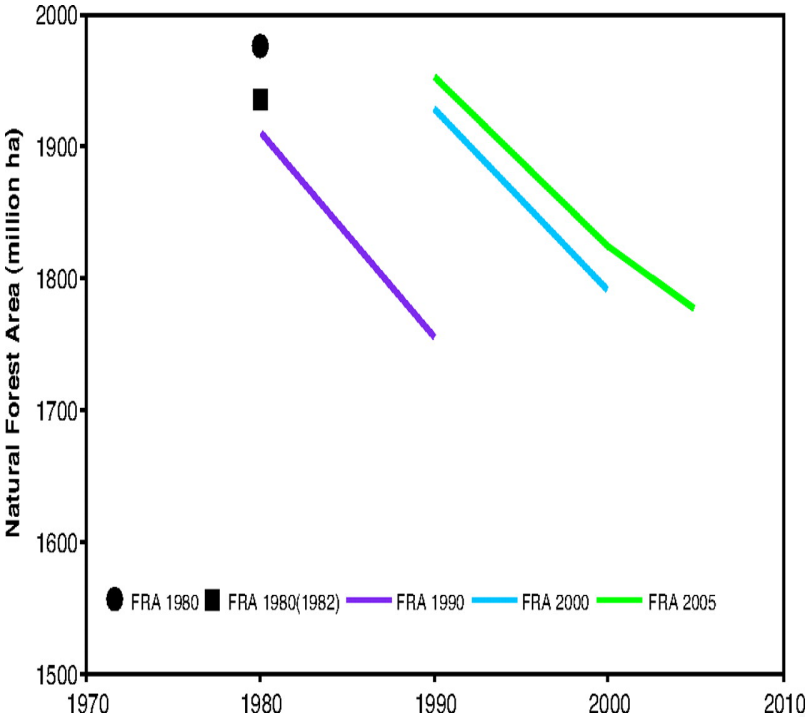
Review numbers in perspective

- **Available, underutilized, "suitable" for rain-fed agriculture lands**
- **LCA (Searchinger et al.) postulated 108,000 km2 indirect impact**
  - **Less than one percent of land cleared, available**
- **Reasonable? Causal relationship?**
- **Urban/built-up consuming cropland around globe**
  - **permanent loss**
  - **Increasing rates**
- **Other energy sources→ change more permanent**
- **Should all LUC be treated equally?**



Uncertainty: land use versus land cover

- **Remote sensing *interpretations* ~ apparent land cover**
  - **Ground truth required - costly and difficult**
  - **Errors common, significant**
- **Remote sensing can reflect data where something changed, given spot in time, not *why*.**
- **Land-use more difficult to verify**
- **Large scale remote sensing often misrepresents land-use, especially "pasture" (Morton 2006 example)**



Grainger (PNAS 2008). Large contradictions in forest area reported. Consistent and reliable trend analysis using remote sensing is difficult. No apparent decline in "moist forests" – this may be due to influence of errors, methods and "forest return" effect.

What is planted responds to crop markets *after* LUC process is advanced

- **Justification for assumed indirect impact?**
- **Single citation*: study not designed to identify causal factors of land clearing**
  - **focused on land classification *after* deforestation**
  - **focused on large scale changes only, assuring omission of small precursors**
  - **problem with "pasture" – adjusted data to fit conclusion**
  - **Correlation versus causation**
- **Reliance on satellite imagery does not assess *why* changes occurred**

* "Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon" (D.Morton *et al.*) PNAS 2006.

Alternate LCA conclusions possible

- **Biofuels can:**
  - **Reduce recurring use of fire and GHG emissions**
  - **Reduce pressure to clear more land**
  - **Improve soil carbon**
- **But - must be done sustainably**
- **Certification schemes likely to play instrumental future role – challenge to 'keep it simple,' low cost and reliable**

Recap: Land-use change and associated carbon emissions are complex

- **Driven by**
  - **Interactions among cultural, technological, biophysical, political, economic, and demographic forces**
- **Not singular events**
  - **Shifting land use mosaics**
  - **Recurring fires in agricultural frontiers, increasing extent and intensity**
- **Essential to understand the forces behind land-clearing and fires to reduce emissions**

Conclusions

- **No 'one size fits all'**
  - **Adapt sustainability criteria to local conditions**
- **Opportunities!!**
  - **SEKAB example**
  - **Link energy policy with development goal**
  - **Certification**
- **Learn from experience**
  - **Use clear, simple, technical standards**
  - **CDM, credit issues**
- **Develop partnerships**
  - **win-win for environment, food/fuel security, social benefits**

Focus on LUC? Or "Sustainable use" w/ safeguards for biodiversity and ecosystem services WATER

Thank you

Selected References:

Land Available:

- FAO & IIASA (2007). "Mapping biophysical factors that influence agricultural production and rural vulnerability."
- MEA (2005). Millennium Ecosystem Assessment, See Assessment Report Chapter 26 on cultivated systems. http://www.millenniumassessment.org/en/Condition.aspx
- FAO (2002). Food and Agriculture Organization of the U.N., Rome, 2003. "World Agriculture: toward 2015/30, an FAO perspective."
- USDA (1999). http://soils.usda.gov/use/worldsoils/papers/pop-support-paper.html
- SAGE U Wisconsin2008: http://www.sage.wisc.edu/pubs/articles/M-Z/Monfreda/MonfredaGBC2008.pdf

Land-Use Change

- Kauppi, P.E. et al., Proc. Nat. Acad. Sci. U.S.A. 103, 17574 (2006). "Returning forests analyzed with the forest identity."
- Geist H.J., et al., BioScience 52, 143 (2002)
- Lambin E. et al., Global Env. Change 11, 261 (2001). "The causes of land-use and land-cover change: Moving beyond the myths".
- USDA 2006. Environmental Effects of Agricultural Land-Use Change: The Role of Economics and Policy

Fire and Forest cover:

- FAO 2006. "Forest Resource Assessment, 2005" http://www.fao.org/forestry/fra2005/en/
- Giglio L. et al., Atmos.Chem. Phys., 6, 957 (2006).
- Tansey et al (2004) J.Geophys. Res., 109 (global burned area assessments)
- FAO 2007: ftp://ftp.fao.org/docrep/fao/009/A0969E/A0969E02.pdf Forestry Paper 151. FAO, Rome, 2007 "Fire management – global assessment 2006. A thematic study…"
- UNEP (2001). An Assessment of the Status of the World's Remaining Closed Forests. UNEP/DEWA/TR 01-2 http://na.unep.net/publications/closedforest.pdf

Others:

- EEA Core Set of Indicators (CSI) Standard indicator 014 (urban take).
- Commission on Sustainable Development sixteenth session, 5-16 May, 2008
- Kline et al., Biofuel feedstock assessment for selected countries. ORNL TM2007/224; February 2008.
- USAID 118/119 ReportsAfrica: http://www.encapafrica.org/bioformatrix.htm
  ANE: http://www.usaid.gov/our_work/environment/compliance/ane/118.htm
  LAC: http://www.usaid.gov/locations/latin_america_caribbean/environment/118_119.html