

25 YEARS OF LAND CHANGE SCIENCE IN THE NASA LAND-COVER/LAND-USE CHANGE PROGRAM

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The Foundations of the LCLUC Program and its Inception

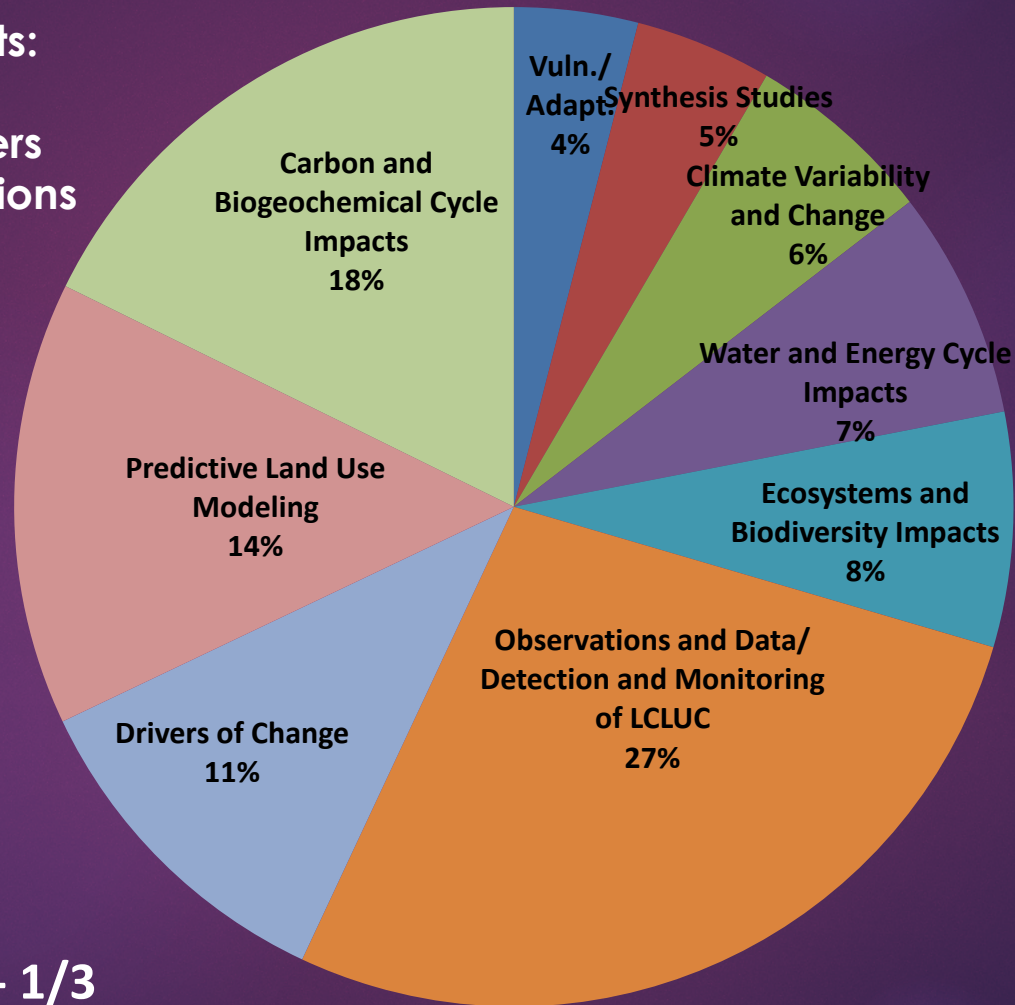
- ▶ 1990 NASA Landsat Pathfinder initiated
- ▶ 1990 IGBP-DIS – global data sets (AVHRR 1km Land Cover)
- ▶ 1994 IGBP/IHDP Land Use/Cover Change (LUCC) program officially launched
- ▶ First NASA LCLUC program round of proposals: 1996
- ▶ First LCLUC Science Team Meeting 1997

https://lcluc.umd.edu/sites/default/files/lcluc_documents/Justice%20LCLUC20.pdf

LCLUC Program Content

25-yr Program stats:

- >300 projects
- >800 researchers
- >1000 publications



Impacts - 1/3

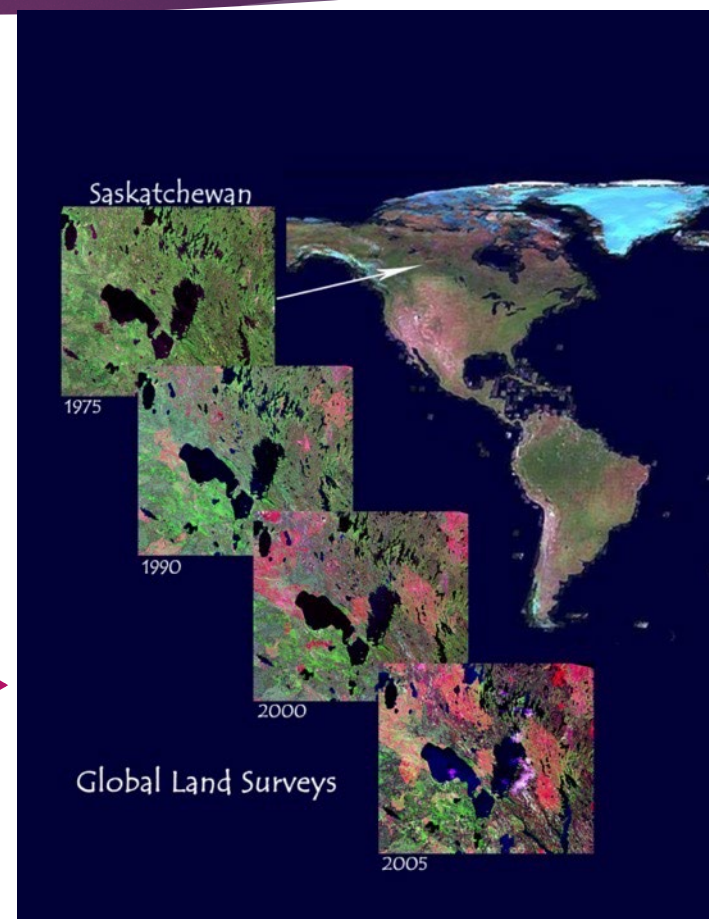
Monitoring - 1/3

Synthesis, other - 1/3

NASA LCLUC-USGS Global Land Survey (GLS) Data Sets

Prior to Free Availability of Landsat Data

- For global assessments of land-cover change (e.g., FAO's FRA)
- Global cloud-free, georectified Landsat (5+7)-based datasets centered on 1975, 1990, 2000, **2005**, and **2010**
 - EO-1 ALI data were used for mosaics over small islands
 - 1 scene per epoch at the peak of vegetation → 30-m global mosaic
- Paper describing GLS-2005 published in P&RS Journal 2008 with a cover image →
- Available for download via GLOVIS/EarthExplorer at USGS free of charge
- Remote Sensing of Environment, 2013, **Assessment of the NASA-USGS Global Land Survey (GLS) datasets**, Gutman et al.

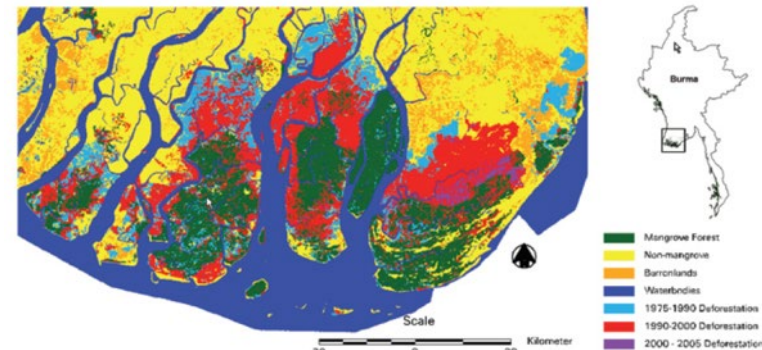


Progression of fires scars in central Canada

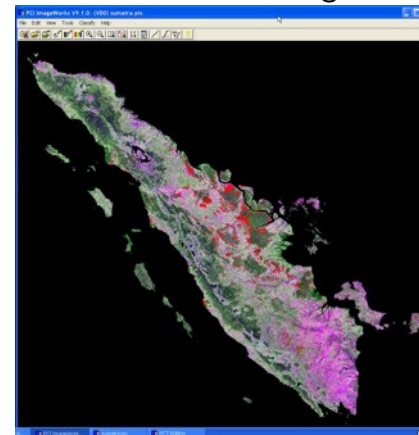
GLS - Enabling Regional Studies by LCLUC Science Projects

- Chander, G. (USGS EROS) - Sensor cross-calibration
- Davis, B. (NASA SSC) - Sensor intercomparison for land cover
- Giri, C. (USGS EROS) – Monitoring Tropical Mangrove Forests
- Masek, J. (GSFC) – North American Forest Disturbance
- Skole, D. (MSU) – Tropical Forest Cover Change
- Townshend, J. (UMD) – South America Forest Cover Change
- Xiao, X. (UNH) – Land Cover Products for Monsoon Asia
- Hansen, M. (SDSU) – Forest Cover in Humid Tropics

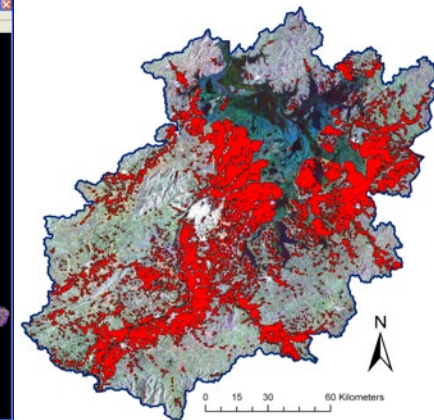
Reminder: Landsat data were not free yet!



Giri: Mangrove Loss, 1975-2005



Hansen: Humid tropical forest cover and change, Sumatra, Indonesia 1999-2009



Xiao: Paddy rice, water and wetlands in Poyang Lake, China

LCLUC Unique in NASA integrating Social Science

- ▶ **Human Dimensions have an important role in LCLUC**
- ▶ **Social and Economic science research includes**
 - ▶ **impacts of changes in human behavior on LCLUC**
 - ▶ **impacts of LCLUC on society**
 - ▶ **adaption to climate change of land-use systems**
- ▶ **The Socio-Economic component has been a mandatory part of all LCLUC proposals, unless otherwise stated in the solicitation**

LCLUC Synthesis: the Early Years



Jack Mustard



Ruth DeFries



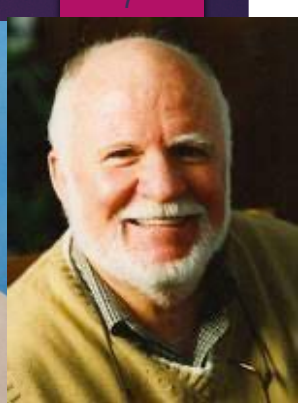
Tom Fisher



Emilio Moran



Ron Rindfuss



Billy Turner

- Case studies over the world
- Synthesis
 - Patterns to processes
 - Disturbances and feedbacks
 - Trajectories and projections

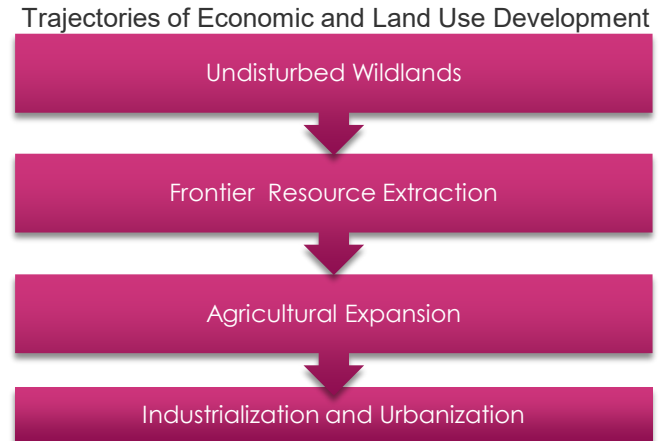
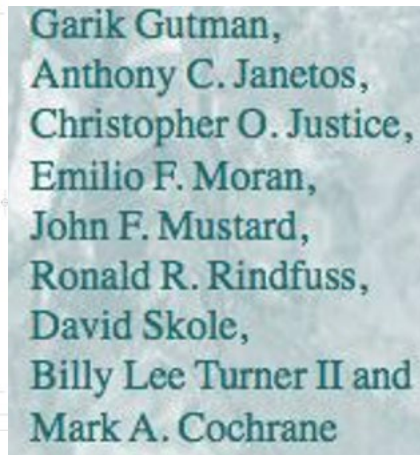
Section V Synthesis and Lessons: Biophysical Change and Beyond

24. **Land-Use and Land-Cover Change Pathways and Impacts**
John F. Mustard, Ruth S. DeFries, Tom Fisher, and Emilio Moran 421

25. **Integrated Land-Change Science and Its Relevance to the Human Sciences**
B. L. Turner II, Emilio Moran, and Ronald Rindfuss 441



The LCLUC milestone: 2004



25 Years of External Linkages: International

- **Global Observations of Forest Cover and Land-use Dynamics (GOFC-GOLD) since 1997**
 - Fire Implementation Team office at UMD funded by LCLUC
 - Regional Information Networks
- **CEOS/GEO**
 - International Working Group on Calibration and Validation
 - Land Surface Imaging (LSI) Constellation Working Group
 - Global Landcover Datasets (SB-02 C1)
- **IGBP/IHDP → Future Earth**
 - Global Land Program (GLP)
 - Some LCLUCers are
 - GLP fellows or Sci Steering Com members or GLP Nodal Coordinators
- **International Regional Initiatives**
 - SAFARI (South Africa)
 - LBA (Amazon)
 - NEESPI (Northern Eurasia)
 - MAIRS (Monsoon Asia)
 - EARSeL (EU Remote Sensing Labs)
 - LULC Special Interest Group
 - Joint biennial workshops
 - **Space Agencies**
 - ESA and worldwide



Ioannis Manakos



Ariane de Bremond Peter Verburg



Francesco Sarti



Olivier Arino



Benjamin Koetz
Earth Observation Applications Engineer

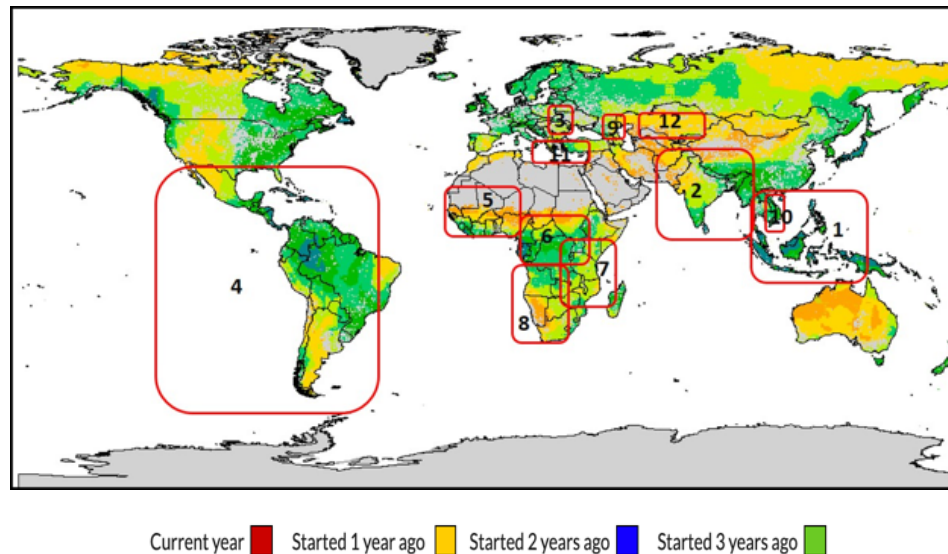
25 Years of GOFC-GOLD Program Support

Fostering International Coordination and Cooperation on Observations
for Land Cover, Forest and Fire Monitoring

LCLUC Support of GOFC Chairs

- John Townshend
- Tony Janetos
- Chris Justice
- Support for US GOFC Co-Chairs Land Cover (Skole) and Fire (Roy)

- LCLUC Support of the Fire Office
- LCLUC Support of Regional Networks via START
- LCLUC Support for GOFC Fellowships



LCLUC International Regional Initiatives

- **SAFARI (South Africa)**



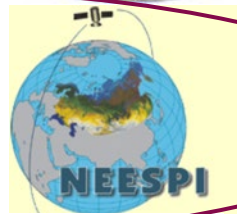
- 3-year project, began in August 1999
- studied the environment of southern Africa
- LCLUC: burning of African forests & savanna
- Goal: to explore how emissions affect phenomena ranging from regional crop productivity to global climate change.

- **LBA (Amazon)**



- Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA): 1998-2006
- LBA-Eco: Field campaign in several sites to help answering questions on forest conversion, re-growth, selective logging, and the sustainable land use in Amazonia

- **NEESPI (Northern Eurasia)**



- The Northern Eurasia Earth Partnership Initiative (NEESPI) 2006-2016.
- Currently, Northern Eurasian Future Initiative (NEFI) a regional component of Future Earth

- **MAIRS (Monsoon Asia)**



- The MAIRS programme (Monsoon Asia Integrated Regional Study) 2006-2016
- Currently, Monsoon Asia Integrated research for Sustainability - part of Future Earth

- **SARI (South/Southeast Asia)**

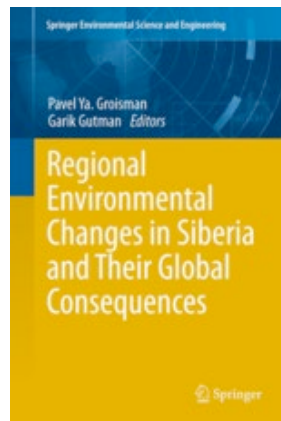


- South/Southeast Asia Research Initiative (SARI) 2014-2024
- LCLUC interactions on climate, water resources, biodiversity, atmosphere, vulnerability, impacts and adaptation issues

NASA NEESPI and SARI Science



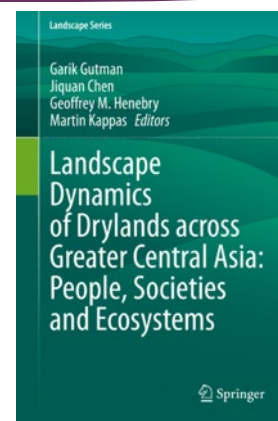
Springer 2010
Arctic



Springer 2012
Siberia

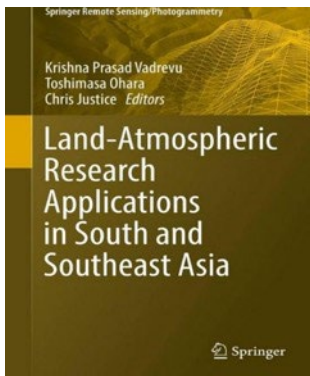


Springer 2017
Eastern Europe

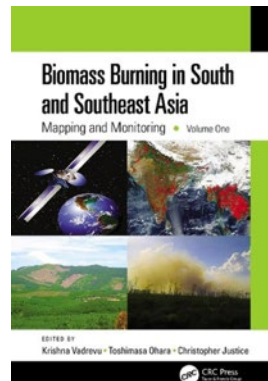


Springer 2020
Central Asia

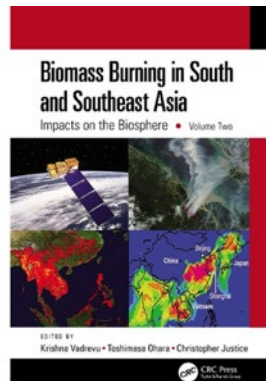
Northern Eurasia
> 750 scientists from 200 institutions in 30 countries
with > 170 projects
80 Ph.D. students
>1500 papers



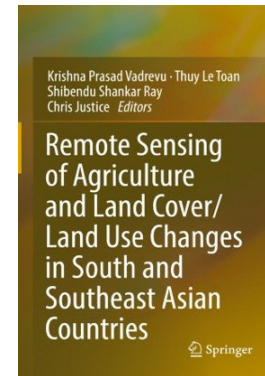
Springer 2018



CRC Press, 2021



CRC Press, 2021

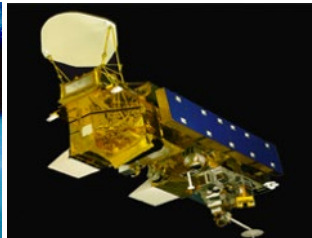
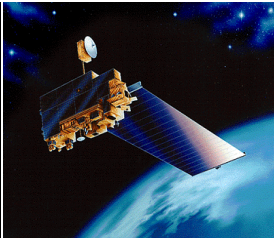
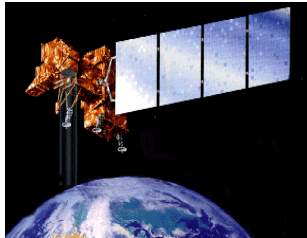


Springer 2022

South/Southeast Asia
> 250 scientists from >150 institutions in 15 countries
with > 25 projects
12 special issues
>250 papers

NASA LCLUC-Relevant Missions: 25 years of Remote Sensing

Systematic Missions - Observation of Key Earth System Interactions



Landsat 5 & 7
3/1/84 & 4/15/99

Terra
12/18/99
ASTER

← MODIS →

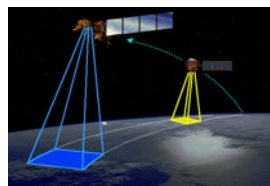
Aqua
5/3/02

Suomi-NPP
10/28/11
VIIRS

Landsat 8
2/11/13

Landsat 9
9/27/21

Exploratory Missions – Exploration of Specific Earth System Processes and Demonstration of Technologies



Shuttle Radar Topography Mission
2/11/02
Space Shuttle Endeavour

Earth Observing EO-1
ALI (predecessor of Landsat-8)
Hyperion – first hyperspectral in space
11/21/00-3/30/2017

ECOSTRESS (thermal IR)
GEDI (Lidar)
DESIS (Hyperspectral)

International Space Station (ISS)

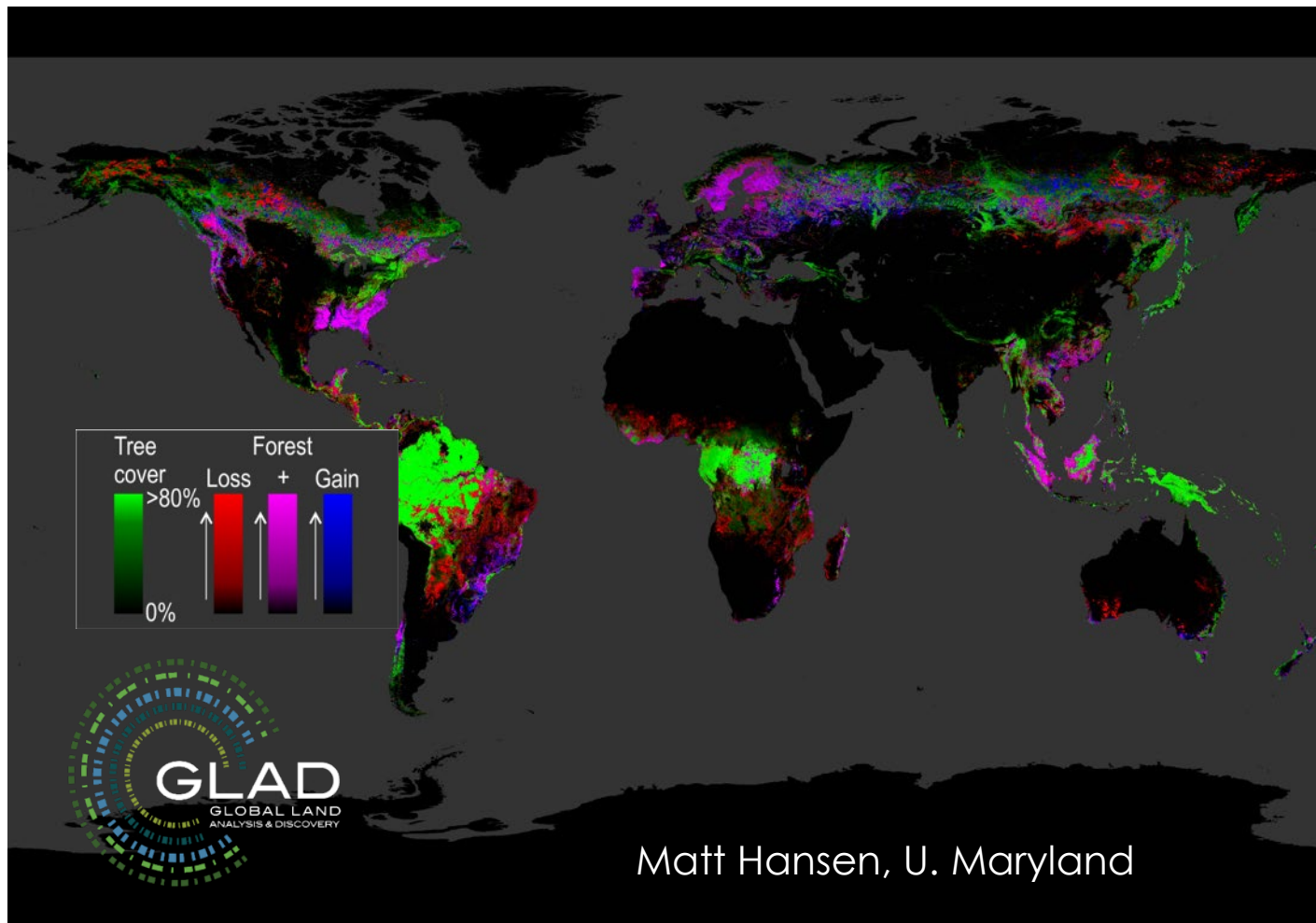
BUILDING ON THE LANDSAT LEGACY

Landsat is a USGS/NASA Partnership



Landsat has been the workhorse of the LCLUC Program
Moderate resolution for Land Cover and Change

Tree Cover Extent and Forest Loss and Gain: 2000-2014



Matt Hansen, U. Maryland

Global cropland extent and change 2000-2020

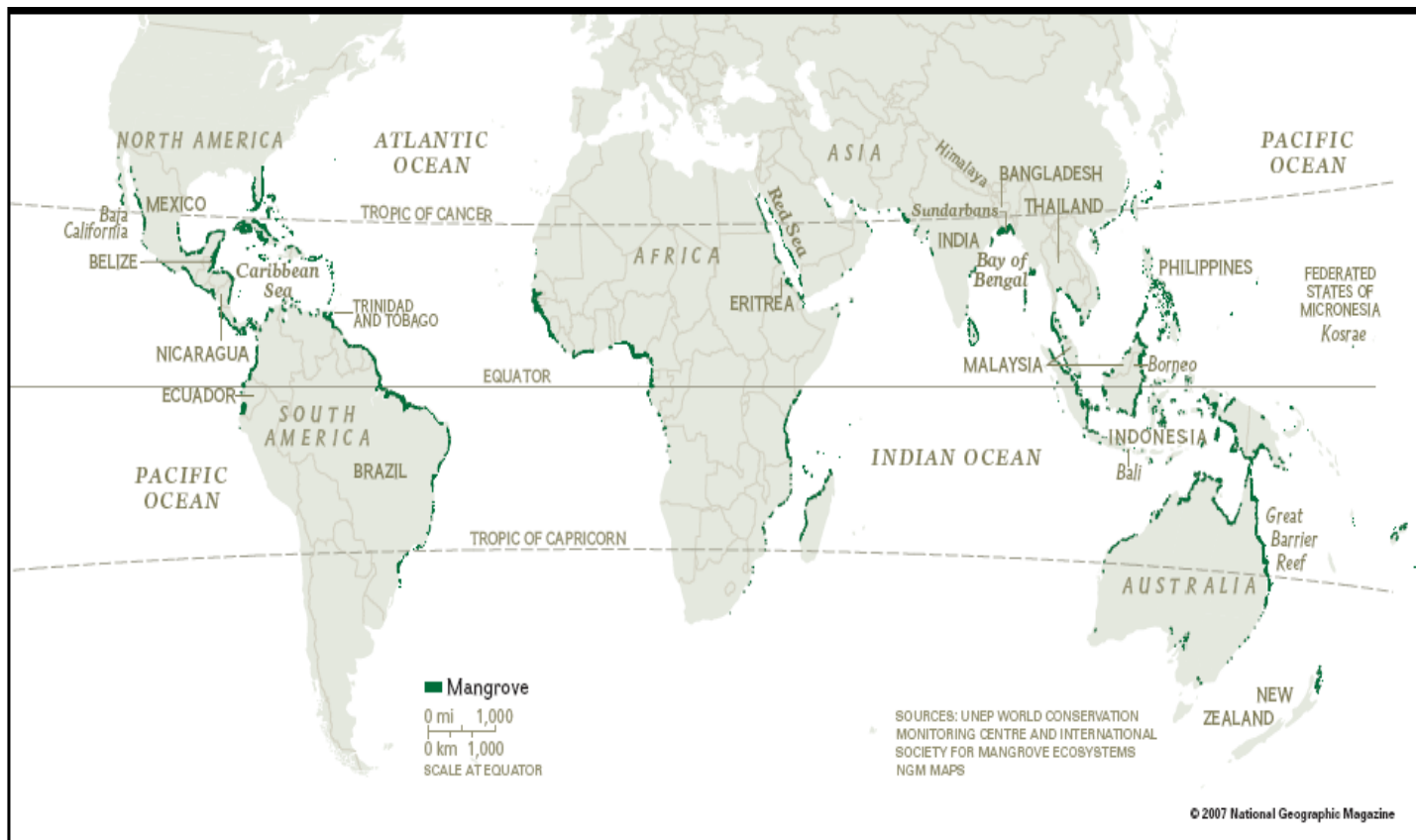
Global cropland expansion in the 21st century

Global cropland dynamics 2000-2019

- Global cropland dynamics 2000-2019:
- Stable cropland
 - Intermittent cropland: 4/5 intervals
 - Intermittent cropland: 3/5 intervals
 - Intermittent cropland: 2/5 intervals
 - Cropland gain in 2004-2007
 - Cropland gain in 2008-2011
 - Cropland gain in 2012-2015
 - Cropland gain in 2016-2019
 - Cropland loss in 2004-2007
 - Cropland loss in 2008-2011
 - Cropland loss in 2012-2015
 - Cropland loss in 2016-2019



Mangroves Extent



Chandra Giri, USGS → EPA

Impervious Surfaces and Settlements Extent



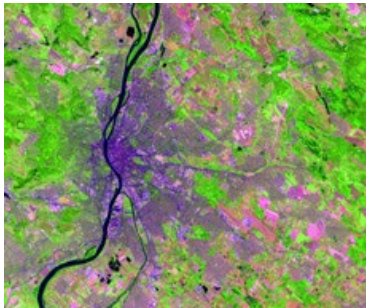
SOCIOECONOMIC DATA AND APPLICATIONS CENTER (SEDAC)

A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS) — Hosted by CIESIN at Columbia University

“The Global High Resolution Urban Data from Landsat data collection contains the two companion data sets produced by

Eric Brown de Colstoun, NASA GSFC

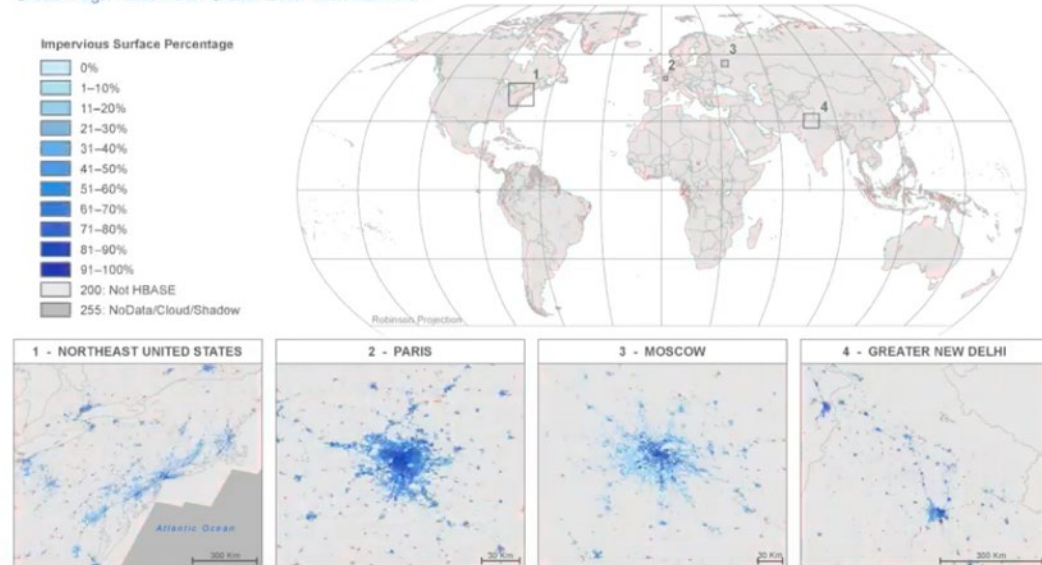
Cheng Huang U. Maryland



Budapest from Landsat (2010)

Global Man-made Impervious Surface (GMIS) Dataset From Landsat, 2010: Impervious Surface Percentage

Global High Resolution Urban Data from Landsat



- LCLUC Global Products (available since 2015)
 - Global Man-made Impervious Surfaces
 - Global Human Built-up And Settlement Extent

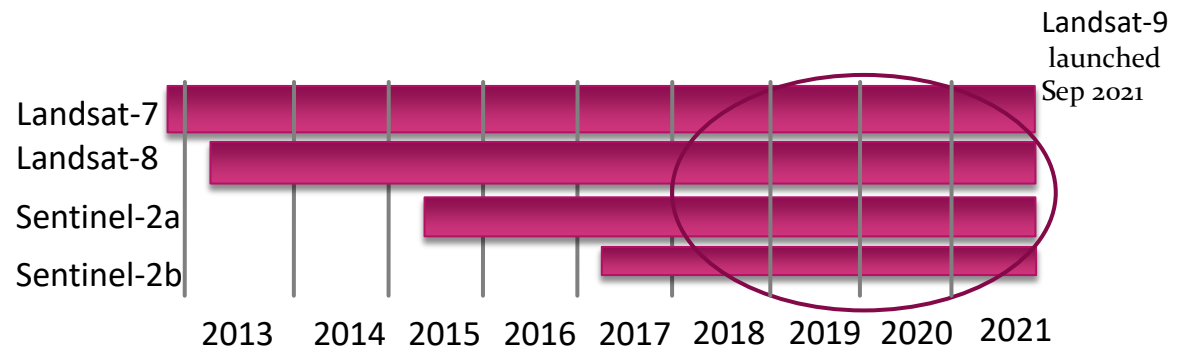
NASA Multi-Source Land Imaging MuSLI: Sentinels to the Rescue!

Merging Sentinel-2 and Landsat data streams provide

< 5-day coverage required for Ag monitoring

- Both sensors have 10-30m coverage in VNIR-SWIR
- Satellite orbits complementary

- launched in Apr 1999
- launched in Feb 2013
- launched in Jun 2015
- launched in Mar 2017



←→ Global ~5 day coverage

←→ Global ~3 day

Synergy of mid-res optical sensor data and active microwave (radar) data

Multi-source Imaging of Infrastructure and Urban Growth Using Landsat, Sentinel-1, -2 and SRTM

PI: C. Small (Columbia Univ.)

Co-I: S. Nghiem (NASA-JPL)

Combine multi-season optical land cover fractions with multi-season microwave backscatter to map impervious surface.

Continuous Substrate Vegetation Dark land cover fractions from standardized spectral mixture model.

Multi-season Substrate moment (Mean/StdDev = μ/σ) distinguishes stable impervious surfaces from variable moisture soils.

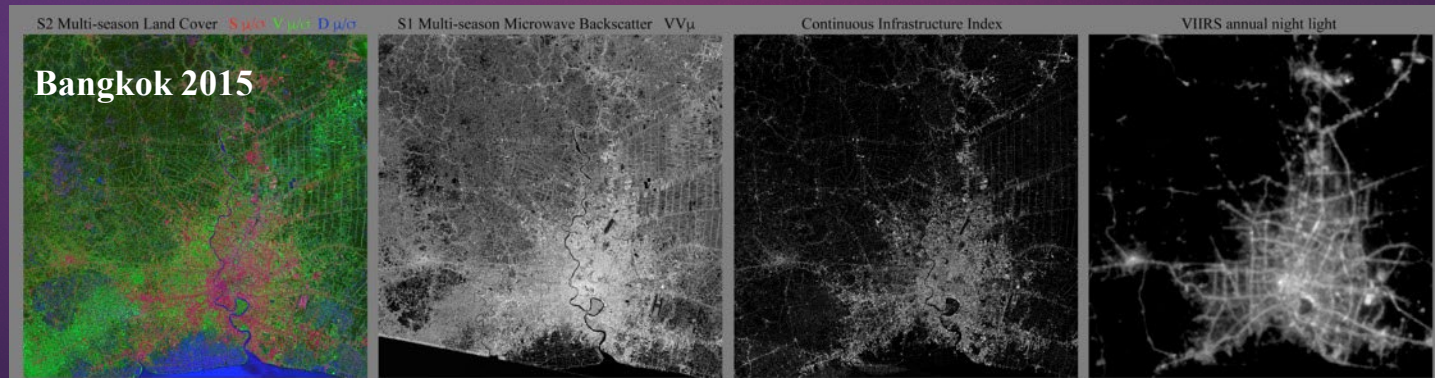
High density of corner reflectors gives persistent high VV backscatter in multi-season mean $VV\mu$

2015 Sentinel-2 SVD μ/σ + Sentinel-1 $VV\mu$

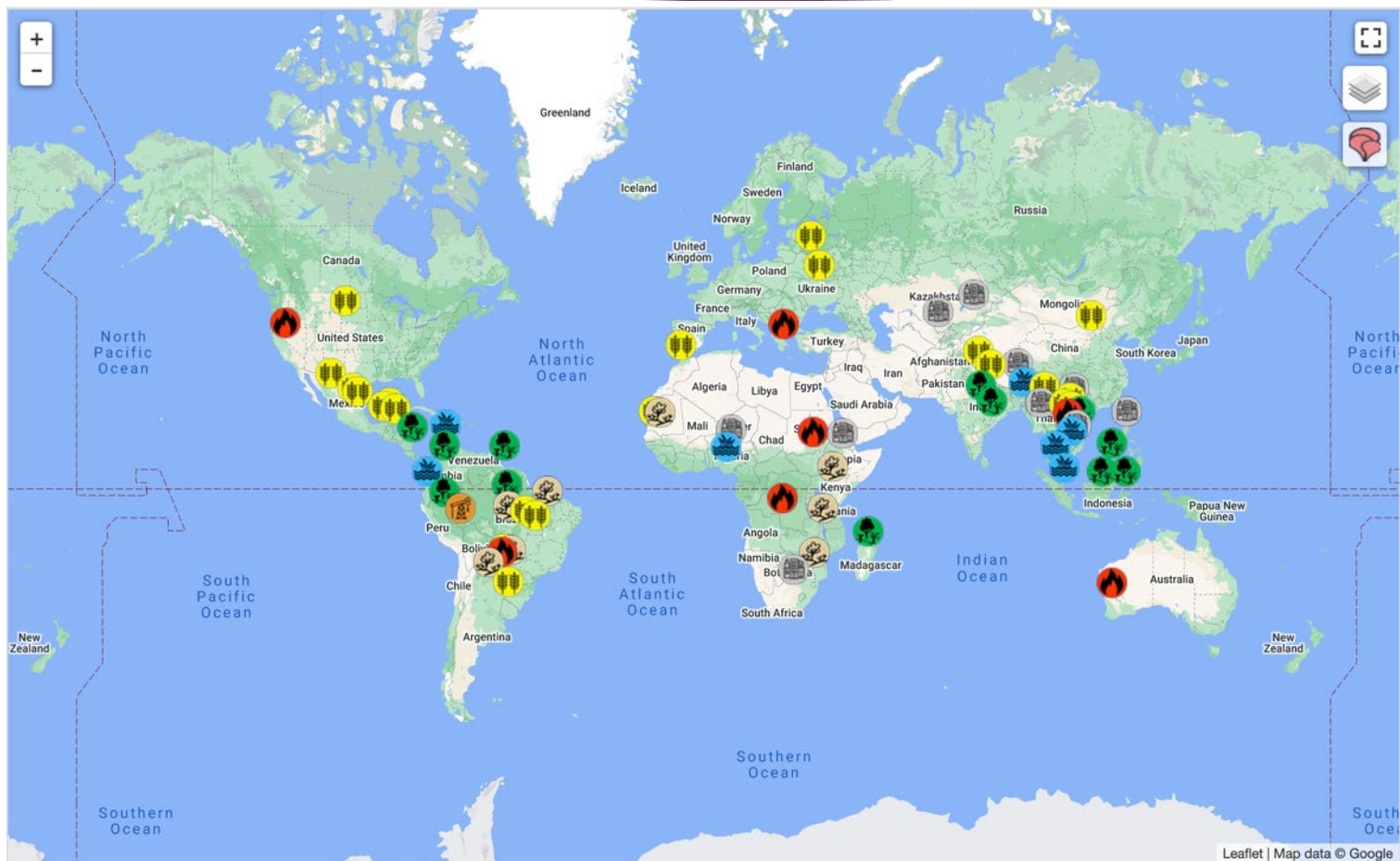
2000 Landsat 7 SVD μ/σ + SRTM $VV\mu$

Continuous Infrastructure Index = $S\mu/\sigma VV\mu$

Comparison of the infrastructure index to the night light for Bangkok clearly distinguishes the built area better than either optical or microwave alone



Most Recent LCLUC Initiative: Hotspots of Land-Use Change



25 Years of LCLUC PROGRAM

Summary of Achievements

The LCLUC Program has

- ▶ **advanced scientific analysis** to areas of the globe where LCLUC is taking place and provided insight into the various impacts of these changes
- ▶ **examined the underlying drivers** of land-use change including socio- economic, political, institutional aspects in diverse regions of the globe
- ▶ **evaluated the role of satellite data** in initiating projections of future regional land-use change
- ▶ **built broad networks** of international scientists that routinely utilize NASA data to monitor regional land-use change
- ▶ **provided the basis for monitoring**, reporting and verification of urban-, forest-, and agricultural cover change in the context of the implementation of Carbon Treaties
- ▶ **created the means to undertake periodic, continuous global assessments** of Land-Cover and Land-Use Change
- ▶ **quantified rapid changes** in the urban built environment, forest cover and agriculture around the globe
- ▶ **provided the primary science rationale** for the Landsat Mission and, more general, Sustainable Land Imaging
- ▶ **developed** global Landsat-based products

Thank You!

