Mapping Industrial Forests in Tropical Monsoon Asia

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Acknowledgement:

A network of international collaborators for studying in tropical monsoon Asia

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Why care about industrial forests?

*Increasing tropical forests converted into industrial forests*
Most of the global forest conversion from natural to industrial forests happened in tropical monsoon Asia.

e.g.,
~90% global palm oil
~97% global natural rubber production

(Li and Fox, 2012)

(Muller, 2012)
Rubber plantation expansion in tropical monsoon Asia

Some facts

- >95% of global rubber plantations from Southeast Asia
- Rubber production increased by more than 1,500% from 1961-2011
- By 2020, almost 640,000 hectares of protected areas will be converted to rubber trees

(Ahrends et al., GEC 2015)

Soil erosion, Biodiversity loss, Carbon stock decrease, Local climate change

However, industrial forest maps are very limited
to map the major industrial forest plantations in tropical monsoon Asia and quantify their changes
From forest mapping to industrial forest mapping

Effort 1: Forest mapping
Effort 2: Industrial forest mapping
Effort 3: Individual plantation type

Forest map
Industrial forests
Natural forests
Rubber
Oil Palm
Eucalyptus
......
Evergreen
Deciduous
Great discrepancy in existing global forest maps (Sexton et al., Nature Clim Chang 2015)

Previous satellite-based estimates of global forest area range from $32.1 \times 10^6$ to $41.4 \times 10^6$ km$^2$

How well existing forest maps support conservation policy?

Uncertainty in forest baseline

Fig. 2. Trends in global forest area 1990–2015 in Forest Resources Assessments (FRAs) 2000–2015.


(Keenan et al., FEM, 2015)
How well existing forest maps support conservation policy?

- A continued **sharp decrease of net forest area losses** with -3.3 Mha/yr from *ca.* 2010 to *ca.* 2015, mainly in the tropics.
  
  ---- *FAO FRA 2015*

- Tree cover **loss is rapidly accelerating** in the tropics in 2014.
  
  ---- *WRI/GFW 2015*

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**Uncertainty in forest dynamics**

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**Baseline Map of Carbon Emissions from Deforestation in Tropical Regions**

Nancy L. Harris,1,4 Sandra Brown,1 Stephen C. Hagen,2 Sassan S. Saatchi,3,4 Silvia Petrova,1 William Salas,2 Matthew C. Hansen,2 Peter V. Potapov,5 Alexander Lotsch5

30% of previously published estimates for an overlapping time period. The largest source of uncertainty in our analysis is the estimates of gross forest-cover loss across large regions. This

(Harris et al., Science 2012)
Objective 1: Improve forest maps through integration of optical and microwave images

- Existing forest mapping efforts are generally based on optical RS.
- Advantages of L-band PALSAR has been recognized, but limitedly used due to data availability.

Hypothesis: Inclusion of both forest structure and canopy information will help to improve forest mapping

- Optical RS: sensitive to vegetation/foliage cover
- L-band PALSAR: sensitive to structure (e.g., tree height, biomass) and vegetation/surface moisture conditions
Cloud-free PALSAR based forest mapping (Ver_0)

- **L-band PALSAR**
- **Decision Tree**
- **Global Geo-Referenced Field Photo Library**
- **PALSAR-based forest cover map**

(Dong et al., RSE, 2012;)
(Dong et al., Plos One, 2014)
Improved PALSAR+Optical RS based forest mapping (Ver_1)

PALSAR-based Forest Layer

Max NDVI-based Vegetated Layer

Forest Map

A. PALSAR FNF

B. NDVI_{max}

C. Forest map

(Qin et al., Scientific Report, 2016)
Objective 2: Identify and map industrial forests through integration of optical and microwave images

**Hypothesis:** Industrial forests/monoculture plantations are featured with structured planting and smooth/uniform canopy, in comparison to complex canopy and multi-layered structure from natural forests
• **Landsat 8, PALSAR 2, Sentinel-1**

• **Common ratios** \((HH/HV^2)\)

• **Vegetation indices** \((NDVI, LSWI, SATVI, \text{and NDTI})\)

• **Texture indices** (gray-level co-occurrence matrix, GLCM), included mean, variance, homogeneity, contrast, dissimilarity, entropy, second moment, and correlation

• **Classification and Regression Tree - Random Forest (CART-RF approach)**

(Torbick et al., Remote Sensing, 2016)
Objective 3: Identify and map individual industrial forest types through integration of optical and microwave images

Hypothesis: Deciduous rubber plantations have unique phenology feature in its canopy, which can be tracked by time series optical images.
Rubber plantation is more distinguishable in the defoliation stage or rapid foliation stage.

The temporal profiles of time series Landsat NDVI, EVI, LSWI and Near-Infrared (NIR) reflectance for (a) rubber plantations, and (b) natural forests.

(Dong et al., RSE, 2013)
Rubber plantation mapping using phenology-based approach

Feature extraction

Time Window Selection: defoliation or rapid foliation stage

Rubber Mapping

(Dong et al., RSE, 2013)
Rubber plantation maps in two rubber production hotspots

Xishuangbanna

Hainan Island

(Kou et al., In Review)  (Chen et al., Int J Appl Earth Obs, 2016)
Rubber plantation stand age mapping

Stand age algorithm

(Kou et al., RS 2015)
Summary of our efforts on forest/plantation mapping

Methodology

- Multi-Sensors
  - Landsat/PALSAR
- Multi-Variables
  - Spectral/Structure/Phenology
- Multi-temporal Data
  - All good observations

Map Products

- Forests
  - Industrial forests
    - Rubber
    - Oil Palm
  - Natural forests
    - Evergreen
    - Deciduous

Applications

- Fragmentation
  - Dong et al., 2014 Plos One
- Biomass
  - Ma et al., In Prep
- Carbon cycle
- Dynamic

- Stand age
  - Dong et al., 2013 RS
  - Chen et al., 2016, JAG; Li et al., 2015 RS
  - Qin et al., 2016, SR
  - Zhai et al., In Revision

- Biodiversity
  - Dong et al., 2012 RS
  - Sheldon et al., 2012 ISPRS P&RS
  - Qin et al., 2015 ISPRS P&RS

- Methodology: Li et al, 2015 RS
- Applications: Dong et al., 2013 RS; Chen et al., 2016, JAG; Li et al., 2015 RS; Qin et al., 2016, SR; Zhai et al., In Revision

- Methodology: Dong et al., 2014 Plos One
- Applications: Dong et al., 2013 RS; Chen et al., 2016, JAG; Li et al., 2015 RS; Qin et al., 2016, SR; Zhai et al., In Revision
Special Issue "Mapping the Dynamics of Forest Plantations in Tropical and Subtropical Regions from Multi-Source Remote Sensing"

A special issue of Remote Sensing (ISSN 2072-4292).

Deadline for manuscript submissions: closed (31 December 2015)

Special Issue Editors

**Guest Editor**
Prof. Xiangming Xiao  
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Interests: applications of remote sensing and GIS in ecosystems science and natural resources; land use and cover changes; ecosystem service assessment; biogeochemistry of terrestrial ecosystems; ecosystem modeling at large spatial scales; integrated impact assessment of climate change; ecology and epidemiology of infectious diseases.

**Guest Editor**
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Interests: land cover and land use change, ecological remote sensing, effects of global change on ecosystem services

Special Issue Information

Dear Colleagues,

...
Remote Sensing of Forests and Plantations in the Tropical and Subtropical Zones I

Friday, 18 December 2015, 08:00-10:00
200F (Moscone West)

Primary Convener:
Xiangming Xiao, University of Oklahoma Norman Campus, Norman, OK, United States

Conveners:
Jinwei Dong, University of Oklahoma Norman Campus, Norman, OK, United States

Chairs:
Xiangming Xiao, Jinwei Dong and Yuanwei Qin, University of Oklahoma Norman Campus, Norman, OK, United States

OSPA Liaisons:
Xiangming Xiao, University of Oklahoma Norman Campus, Norman, OK, United States

08:00 BS1L-01 Dynamics of Industrial Forests in Southeast United States Assessed using Satellite and Field Inventory Data (Invited) (81990)
Chengquan Huang, University of Maryland, Department of Geographical Sciences, College Park, MD, United States and NAPF team

08:15 BS1L-02 Changes in rubber plantation in the cross-border area of mainland Southeast Asia through analysis of PALSAR and time series Landsat images (10275)
Jinwei Dong1, Xiangming Xiao1, Yuanwei Qin1, Banggian Chen2, Weili Kou3, Dai Di4, Geili Zhang4, Yan Zhang4, Yuting Zhou1 and Jie Wang1
1University of Oklahoma Norman Campus, Norman, OK, United States
2Organization Not Listed, Washington, DC, United States
3University of Oklahoma, Norman, OK, United States
4Kunming Institute of Botany, Chinese Academy of Sciences, Kunming, China
5University of Oklahoma, Center for Spatial Analysis, Norman, OK, United States

08:30 BS1L-03 Tropical Forest Biomass Dynamics from X-Band, TanDEM-X DATA (Invited) (83544)
Robert N. Truesdell, NASA Jet Propulsion Laboratory, Pasadena, CA, United States

08:45 BS1L-04 Topographic Distributions of Emergent Trees in Tropical Forests of the Osa Peninsula, Costa Rica (Invited) (79340)
Chris Balzter1,2, Gregory Paul Asner1,3, Philip Taylor4, Rebecca J Cole4, Brooke B Osborne5, Cory C. Cleveland6, Stephen Porter7 and Alan R Townsend8
1Carnegie Institution for Science Washington, Washington, DC, United States
2Carnegie Institution for Science, Department of Global Ecology, Stanford, CA, United States
3University of Colorado at Boulder, Boulder, CO, United States
4University of Hawaii at Manoa, Honolulu, HI, United States
5Brown University, Department of Ecology and Evolutionary Biology, Providence, RI, United States
6University of Montana, Missoula, MT, United States
7Brown University, Providence, RI, United States

09:00 BS1L-05 Reconstructing Land Use History from Landsat Time-Series: Case study of Swidden Agriculture Intensification in Brazil (82925)
Leila Dureaux, Catarina C. Jakovac, Latifa M. Silva and Lamott Kooistra, Wageningen University, Wageningen, Netherlands

09:15 BS1L-06 Tracking Forest Change through 40 Years On Two Continents with the BULC Algorithm and Google Earth Engine (85023)
Jeffrey A Cardille, McGill University, Natural Resources Sciences, Montreal, QC, Canada

09:30 BS1L-07 Using CLASSE to Map Deforestation in Makira Natural Protected Area, Madagascar (79228)
Alison Nicole Thieme1, Sean McCartney1, John Rogan1, Florencia Sangemino1 and David Wilkie1
1Clark University, Worcester, MA, United States
2Wildlife Conservation Society, Bronx, NY, United States
Cal/Val LC database: Global Geo-Referenced Field Photo Library

>150,000 photos

Smartphone Apps
“Field Photo”

(http://www.eomf.ou.edu/photos)

(Xiao et al., EOS, 2011)

Individual photos are linked with time series MODIS data (2000-present)
Summary

• 1. Cloud-free PALSAR data can effectively contribute to the existing forest mapping efforts. For example, the combined Landsat/PALSAR-based forest mapping approach is more robust.

• 2. Unique phenology signature makes rubber plantation identification possible in a simple way; however, its extensive application in other regions and other species should consider different factors.

• 3. Emerging data sources (e.g., Landsat 8, Sentinel-1, Sentinel-2, and PALSAR-1/2) provide unprecedented opportunities for industrial forest mapping; however, new algorithms and computing technologies (e.g., cloud computing) are needed to make full use of these big data.
Work plan in 2016

• 1. Improved forest maps by integrating PALSAR and Landsat/Sentinel-2.

• 2. Extensive application of the rubber plantation approach on tropical monsoon Asia.

• 3. Development of new mapping algorithms for other industrial forest types.

• 4. Enhanced field photo and ground truth data portal (freely open to the public).
Questions?

http://eomf.ou.edu