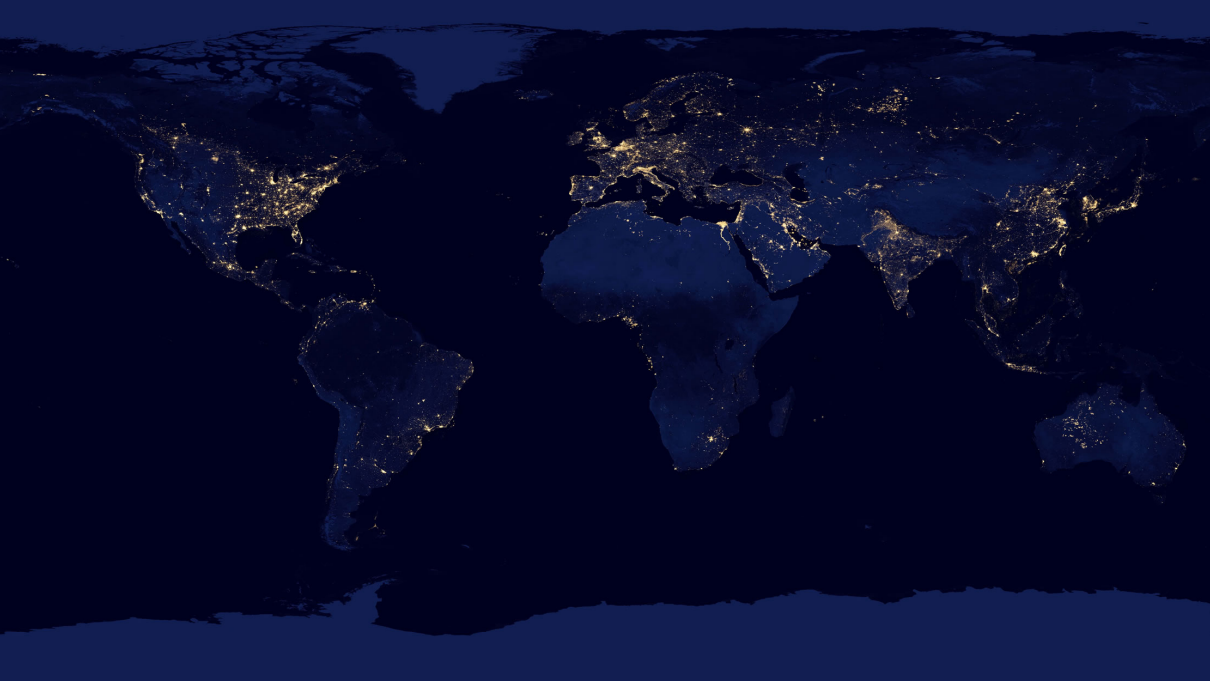
Far Flung Forest Landscapes in the Anthropocene

Structural analysis of China's embodied forest network

Matthew Kekoa Lau (Ph.D.)
Yu Liang, Bo Liu

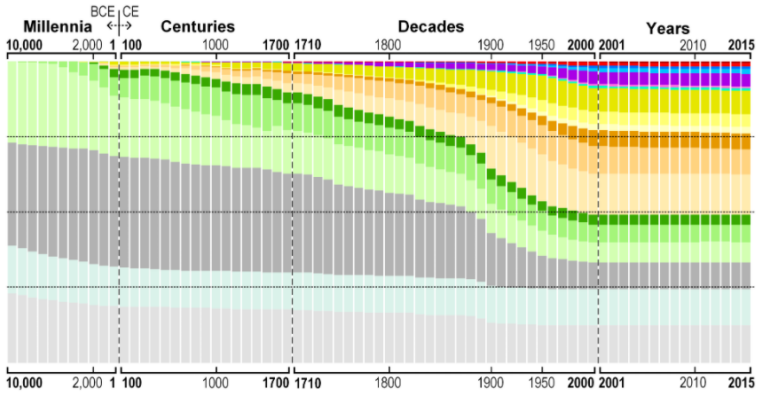
Chinese Academy of Sciences and Harvard University
Email: mk@mklau.info
Website: https://people.fas.harvard.edu/~matthewklau
ResearchGate: Matthew_Lau2

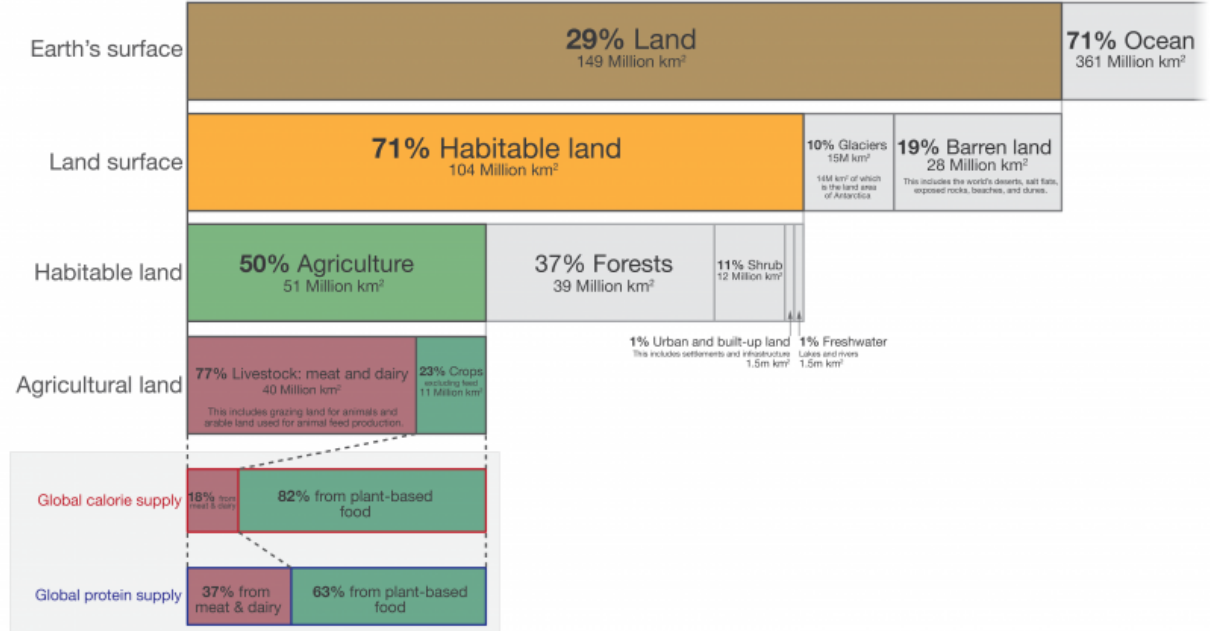

forests
Biodiversity and Conservation in Forests
Edited by
Diana F. Tomback
Printed Edition of the Special Issue Published in Forests
www.mdpi.com/journal/forests
MDPI



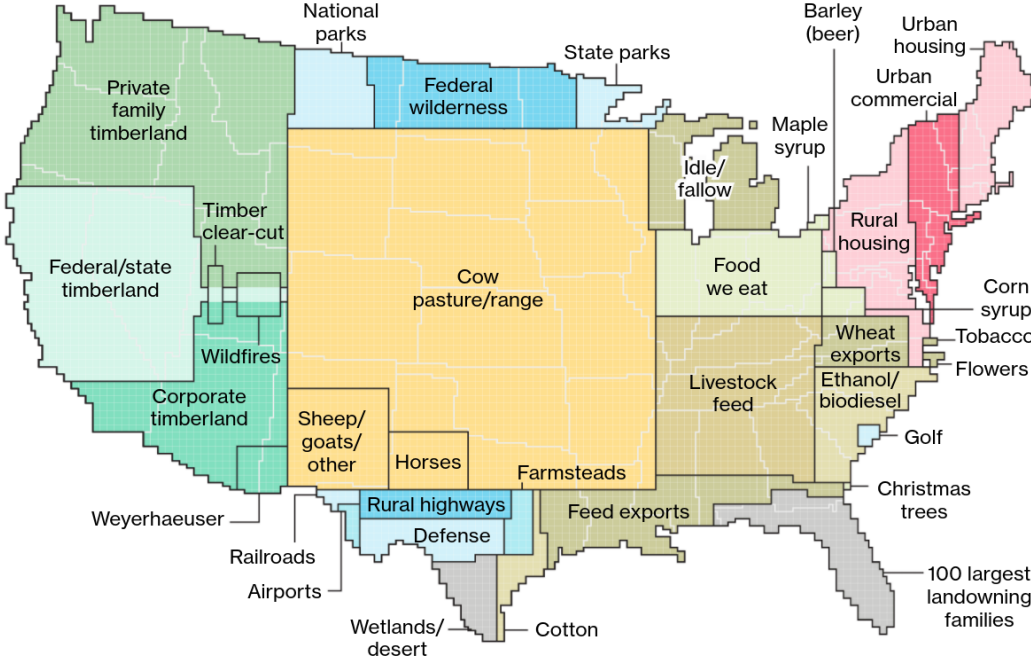
Anthropogenic biomes: 10,000 BCE to 2015 CE

Changes in anthrome classes as % global land area



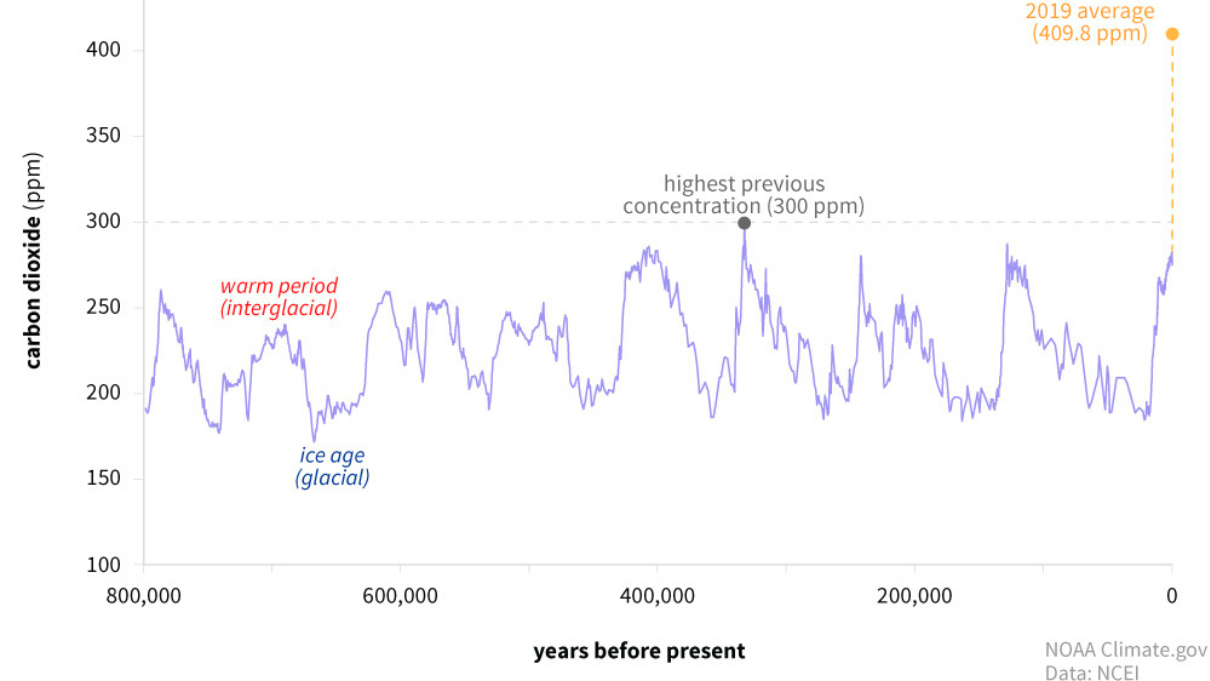


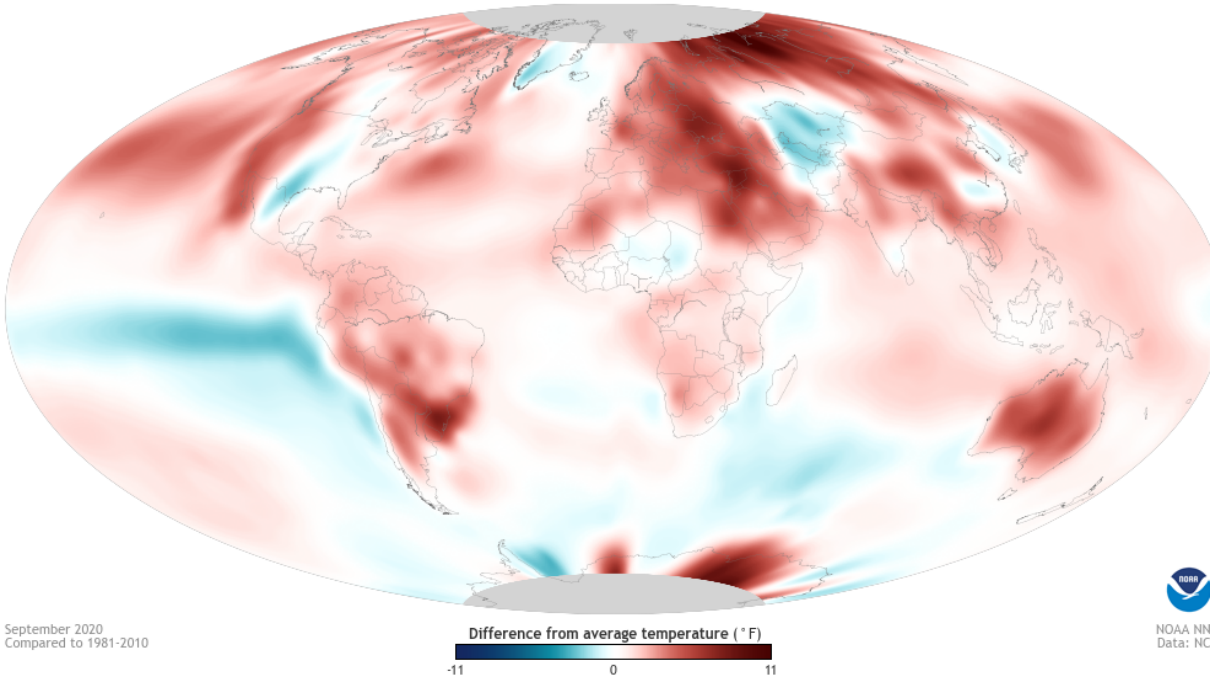
Data source: UN Food and Agriculture Organization (FAO)

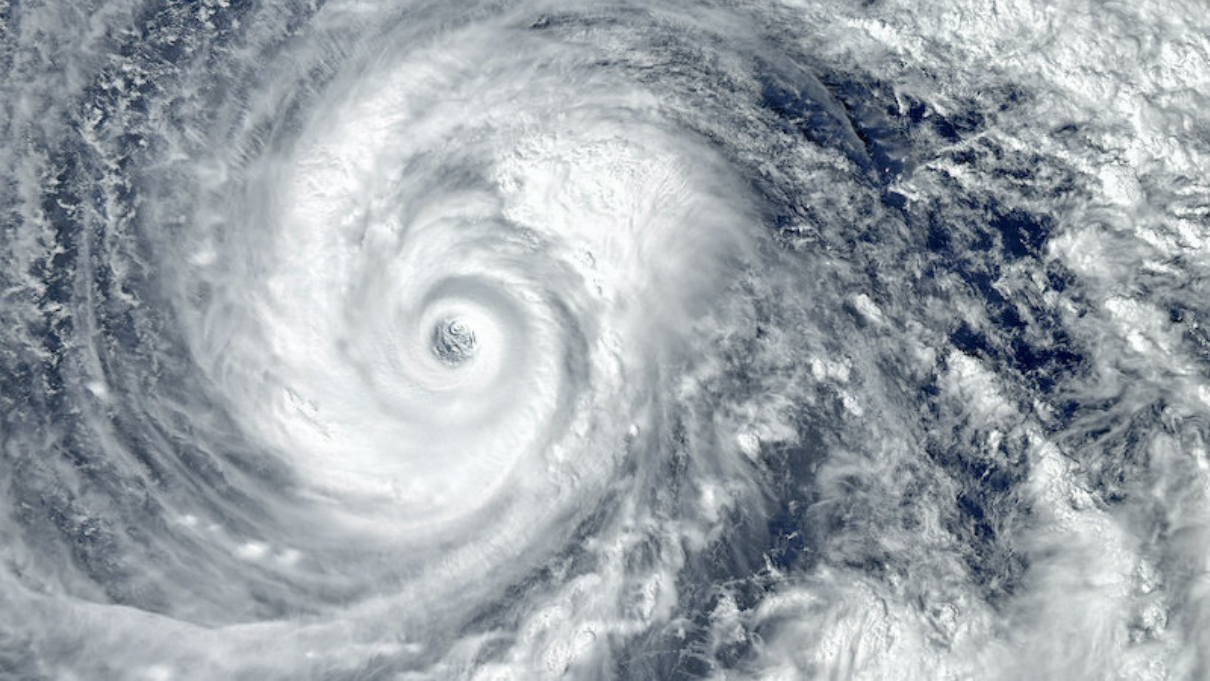

National parks
Barley (beer)
Urban housing
State parks
Urban commercial
Private family timberland
Federal wilderness
Maple syrup
Idle/ fallow
Timber clear-cut
Rural housing
Federal/state timberland
Cow pasture/range
Food we eat
Corn syrup
Wheat exports
Tobacco
Wildfires
Flowers
Livestock feed
Ethanol/ biodiesel
Corporate timberland
Sheep/ goats/ other
Golf
Horses
Farmsteads
Christmas trees
Weyerhaeuser
Rural highways
Feed exports
Railroads
Defense
100 largest landowning families
Airports
Wetlands/ desert
Cotton

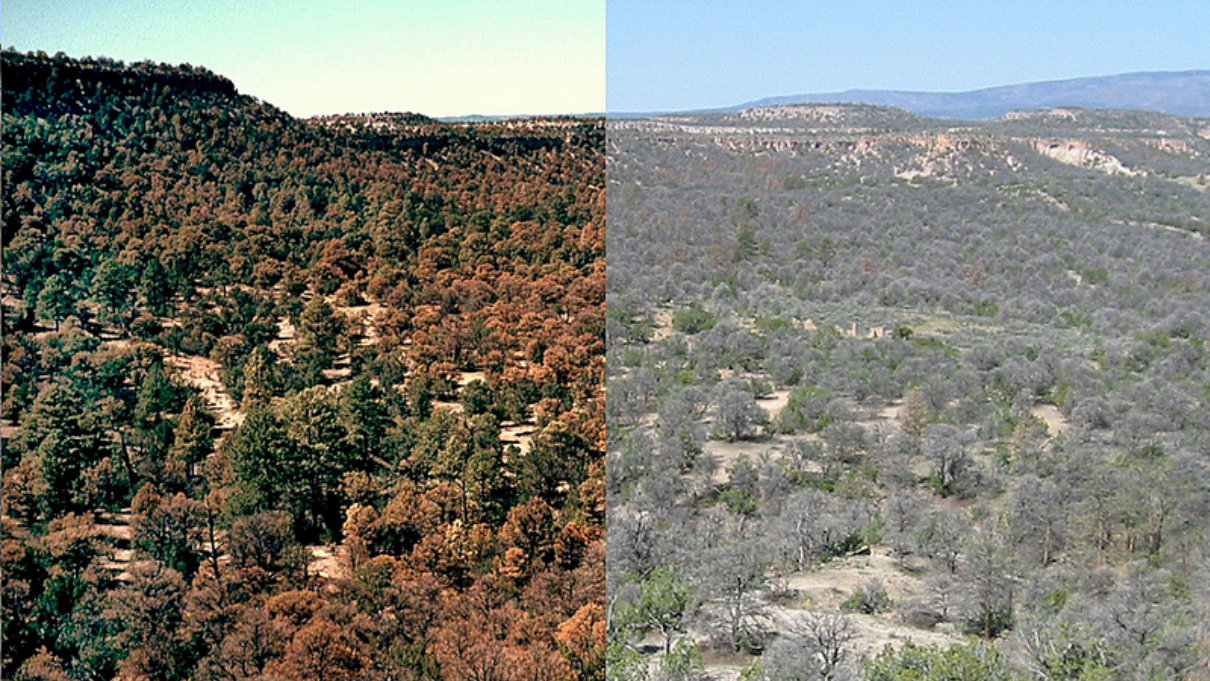

A LA MARINE

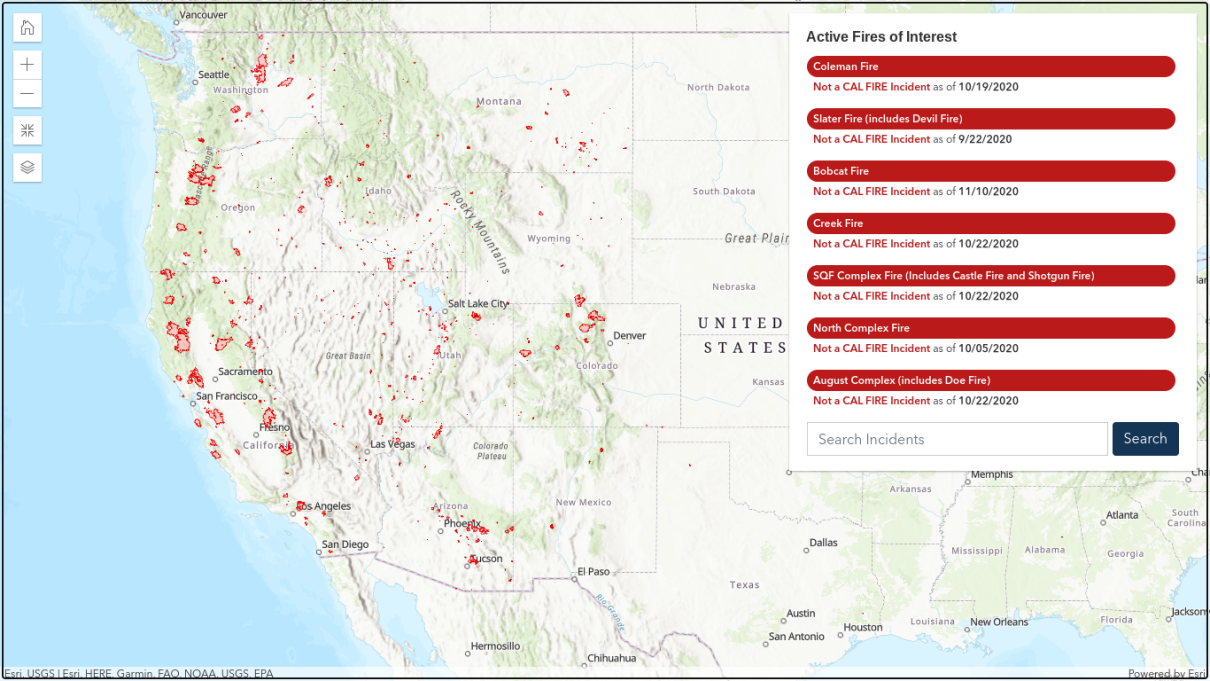

ECLIPSE Ice Drill

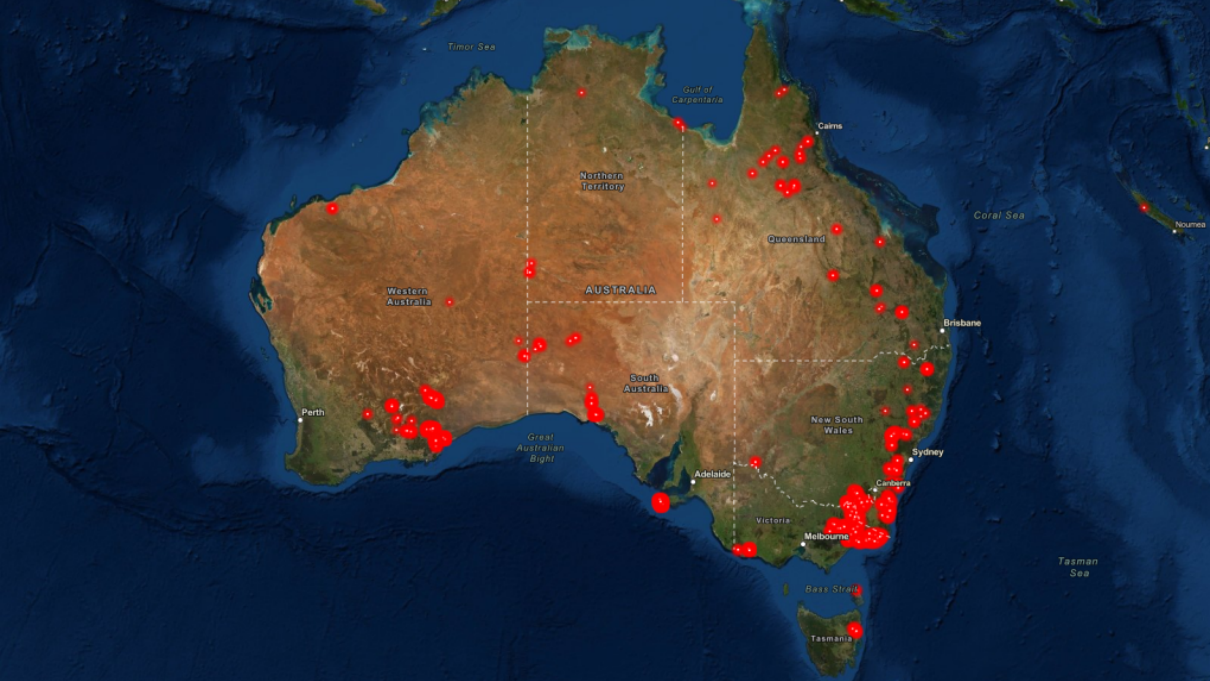

2019 average
(409.8 ppm)
highest previous
concentration (300 ppm)
warm period
(interglacial)
ice age
(glacial)
carbon dioxide (ppm)
400
350
300
250
200
150
100
800,000
600,000
400,000
200,000
0
years before present
NOAA Climate.gov
Data: NCEI


September 2020
Compared to 1981-2010
Difference from average temperature (°F)
-11
0
11
NOAA NN
Data: NC






Active Fires of Interest
Coleman Fire
Not a CAL FIRE Incident as of 10/19/2020
Slater Fire (includes Devil Fire)
Not a CAL FIRE Incident as of 9/22/2020
Bobcat Fire
Not a CAL FIRE Incident as of 11/10/2020
Creek Fire
Not a CAL FIRE Incident as of 10/22/2020
SQF Complex Fire (Includes Castle Fire and Shotgun Fire)
Not a CAL FIRE Incident as of 10/22/2020
North Complex Fire
Not a CAL FIRE Incident as of 10/05/2020
August Complex (includes Doe Fire)
Not a CAL FIRE Incident as of 10/22/2020
Search Incidents
Search
Vancouver
Seattle
Washington
Montana
North Dakota
Oregon
Idaho
Rocky Mountains
Wyoming
South Dakota
Great Plains
Nebraska
Salt Lake City
Denver
UNITED
STATES
Great Basin
Utah
Colorado
Kansas
Sacramento
San Francisco
Fresno
California
Las Vegas
Colorado Plateau
Memphis
Arkansas
Los Angeles
Arizona
New Mexico
Phoenix
Atlanta
South Carolina
San Diego
Dallas
Mississippi
Alabama
Georgia
Tucson
El Paso
Texas
Austin
Houston
Louisiana
New Orleans
Florida
San Antonio
Hermosillo
Chihuahua
Esri, USGS | Esri, HERE, Garmin, FAO, NOAA, USGS, EPA
Powered by Esri


Timor Sea
Gulf of Carpentaria
Cairns
Northern Territory
Coral Sea
Noumea
Queensland
AUSTRALIA
Western Australia
Brisbane
South Australia
Perth
New South Wales
Great Australian Bight
Sydney
Adelaide
Canberra
Victoria
Melbourne
Tasman Sea
Bass Strait
Tasmania

Forests in the Anthropocence

- Forests are changing from human impacts

Forests in the Anthropocence

- Forests are changing from human impacts
- Large direct and indirect effects of land-use

Forests in the Anthropocence

- Forests are changing from human impacts
- Large direct and indirect effects of land-use
- How do we address indirect and systems-level effects?

Today's Talk

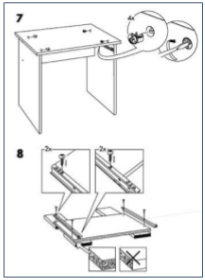
1. Environmentally Extended Economic Models
2. Global Trade Networks of Forest Landscapes
3. China's Domestic Forest Land Network Structure
4. Summary and Conclusions
5. Future Work

Economic Input-Output Models

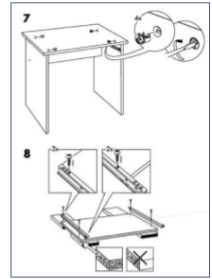

Annie Sloan
LACQUER
a matt water based varnish
mainly for painted floors
1 Litre


Annie Sloan
LACQUER
a matt water based varnish
mainly for painted floors
1 litre

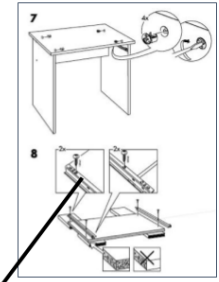

Annie Sloan
LACQUER


7
8


Annie Sloan
LACQUER


7
8


Annie Sloan
LACQUER


7
8

$$X = (I - A)^{-1} Y$$

$$X = (I - A)^{-1} Y$$

- X: total consumption

$$X = (I - A)^{-1} Y$$

- X: total consumption
- A: intermediate consumption

$$X = (I - A)^{-1} Y$$

- X: total consumption
- A: intermediate consumption
- Y: final use

$$X = (I - A)^{-1} Y$$

- X: total consumption
- A: intermediate consumption
- Y: final use
- I: identity matrix

Economic Input-Output Modeling

$$X = (I - A)^{-1} Y$$

- X: total consumption
- A: intermediate consumption
- Y: final use
- I: identity matrix

- Wassily Leontief (1936)
- *Leontief Inverse* $(I - A)^{-1}$ calculates all of the indirect consumption correctly

Economic Input-Output Modeling

$$X = (I - A)^{-1} Y$$

- X: total consumption
- A: intermediate consumption
- Y: final use
- I: identity matrix

- Wassily Leontief (1936)
- *Leontief Inverse* $(I - A)^{-1}$ calculates all of the indirect consumption correctly
- Indirect effects can, and usually are, greater than direct

Economic Input-Output Modeling

$$X = (I - A)^{-1} Y$$

- X: total consumption
- A: intermediate consumption
- Y: final use
- I: identity matrix

- Wassily Leontief (1936)
- *Leontief Inverse* $(I - A)^{-1}$ calculates all of the indirect consumption correctly
- Indirect effects can, and usually are, greater than direct
- Has been influential in ecosystem network analysis

$$X = (I - A)^{-1} Y$$

$$E = F(I - A)^{-1}Y$$

$$E = F(I - A)^{-1}Y$$

- F: environmental inputs

Environmental Extended Input-Output Models

$$E = F(I - A)^{-1}Y$$

- F: environmental inputs
- E: environmental consumption

Environmental Extended Input-Output Models

$$E = F(I - A)^{-1}Y$$

- F: environmental inputs
- E: environmental consumption

- Any environmental (or social) variable can be used

Environmental Extended Input-Output Models

$$E = F(I - A)^{-1}Y$$

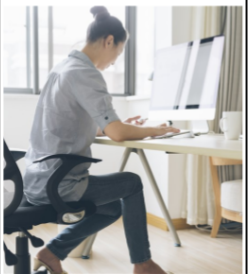
- F: environmental inputs
- E: environmental consumption

- Any environmental (or social) variable can be used
- **Required**: estimate of how much is used by each industrial sector

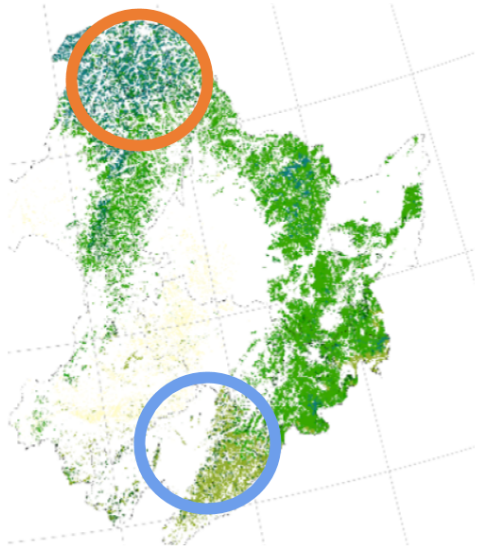
l_i

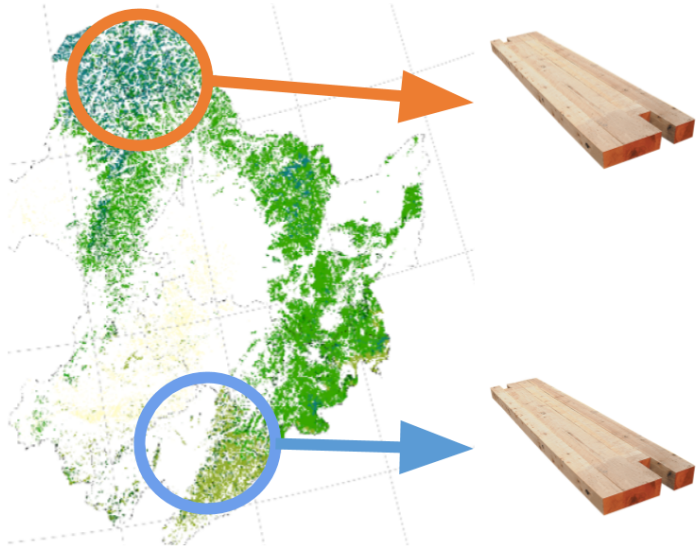
A_{ij}

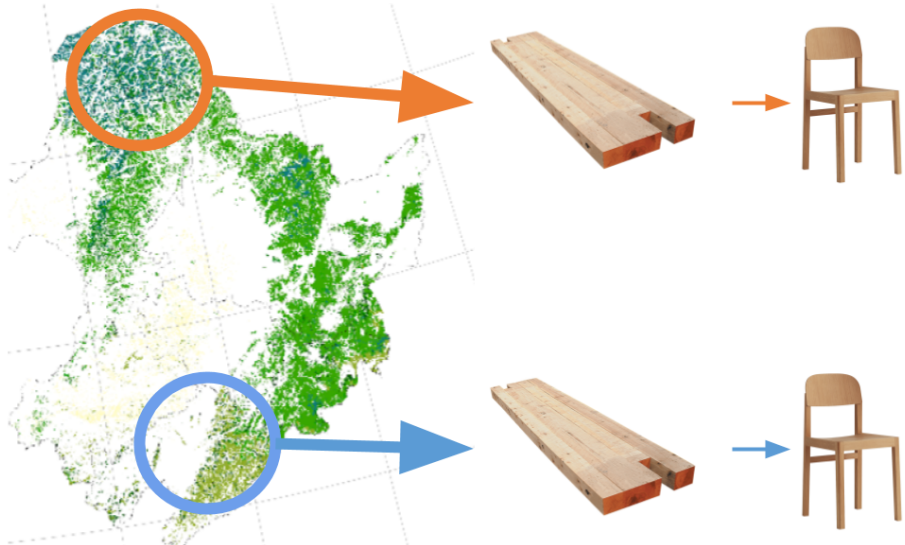
Y_j

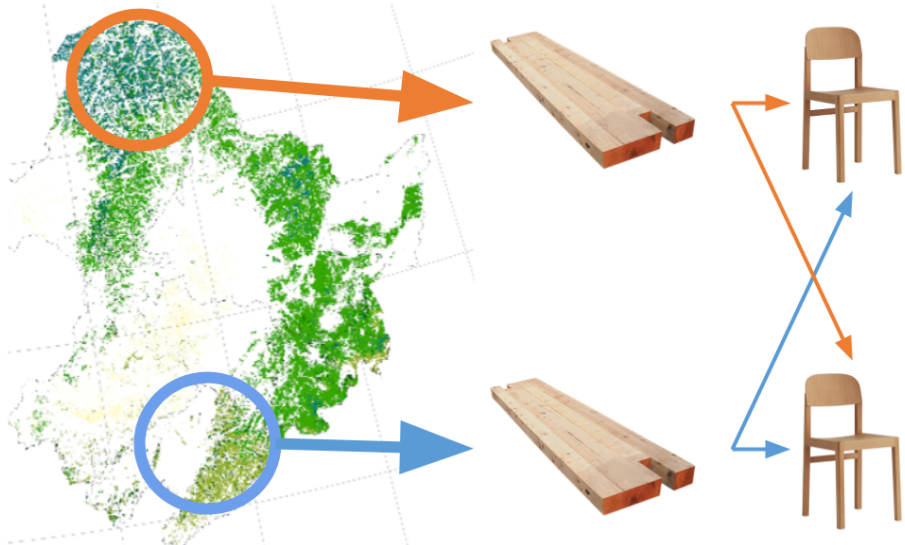


“Multi-Regional” = Spatial Context





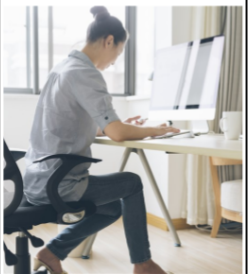




l_i

A_{ij}

Y_j



l_i^r

A_{ij}^{rs}

Y_j^s

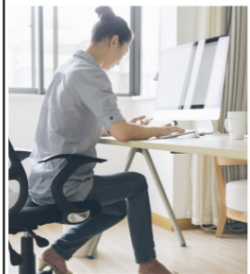


Table 1
The structure of the ecological MRIO account.

Output / Input			Intermediate use							Final demand								
			Region 1			⋯	Region m			Region 1				⋯	Region m			
			Sector1	⋯	Sector n	⋯	Sector1	⋯	Sector n	Household consumption	Non-profit institutions consumption	Government consumption	Rest of final demand (capital goods)	⋯	Household consumption	Non-profit institutions consumption	Government consumption	Rest of final demand (capital goods)
Intermediate input	Region 1	Sector1	z_{ij}^{rs}							f_i^r								
		⋯																
		Sector n																
	⋯																	
	Region m	Sector1																
		⋯																
		Sector n																
Primary inputs			p_j^s															
Exogenous environmental inputs			u_j^s															

Environmental Extended Multi-Regional Input-Output Models

- Many products are made from other products, so indirect use matters

Environmental Extended Multi-Regional Input-Output Models

- Many products are made from other products, so indirect use matters
- Input-output modeling provides a framework to account for this

Environmental Extended Multi-Regional Input-Output Models

- Many products are made from other products, so indirect use matters
- Input-output modeling provides a framework to account for this
- Environmental multipliers allow us to calculate “embodied” ecological variables

Environmental Extended Multi-Regional Input-Output Models

- Many products are made from other products, so indirect use matters
- Input-output modeling provides a framework to account for this
- Environmental multipliers allow us to calculate "embodied" ecological variables
- Spatially explicit data allows us to regionalize our models

Environmental Extended Multi-Regional Input-Output Models

- Many products are made from other products, so indirect use matters
- Input-output modeling provides a framework to account for this
- Environmental multipliers allow us to calculate "embodied" ecological variables
- Spatially explicit data allows us to regionalize our models

$$E_j^s = F_i^r (I - A_{ij}^{rs})^{-1} Y_j^s \tag{1}$$

- Global carbon emissions are primarily indirect by developed country consumption (23%) [2]

A few EE-MRIO Applications

- Global carbon emissions are primarily indirect by developed country consumption (23%) [2]
- 17% of biodiversity is embodied in food exported to high income countries [1]

A few EE-MRIO Applications

- Global carbon emissions are primarily indirect by developed country consumption (23%) [2]
- 17% of biodiversity is embodied in food exported to high income countries [1]
- Tropical forest loss in Brazil driven by conversion to soy exported primarily to China (48.6%) and the USA (72.3%) [3]

Global Embodied Landscape Trade Networks

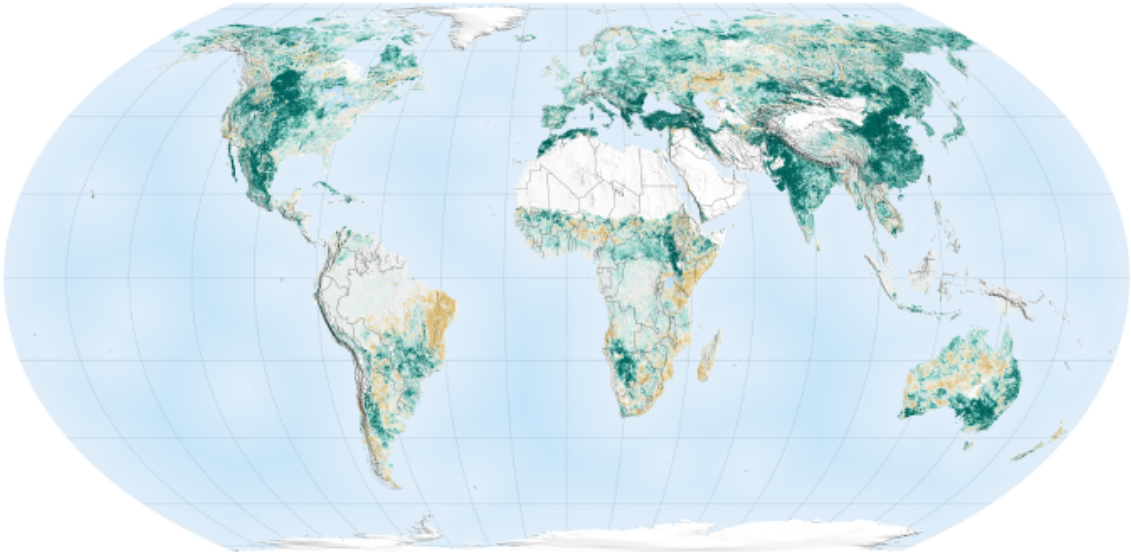
- What is the current state of forested landscapes

Global Embodied Landscape Trade Networks

- What is the current state of forested landscapes
- How does this relate to current patterns of landscape trade?

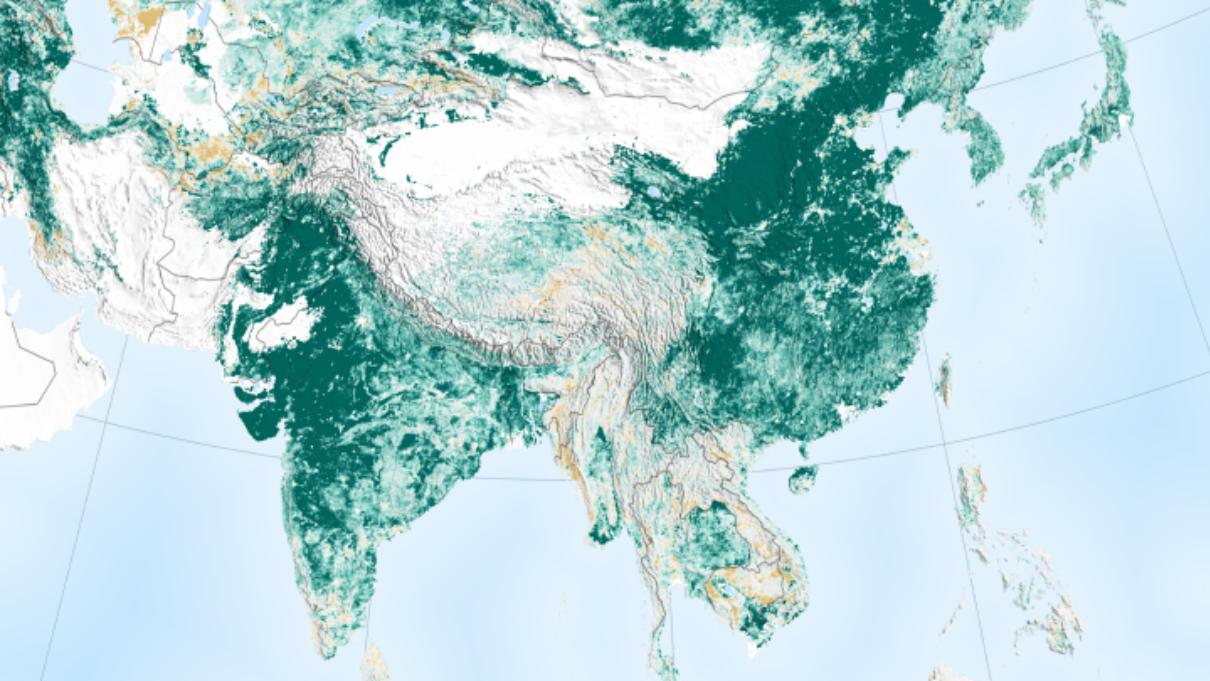
Global Embodied Landscape Trade Networks

- What is the current state of forested landscapes
- How does this relate to current patterns of landscape trade?
- What is the role of China, which is a globally dominant economic consumer and producer?



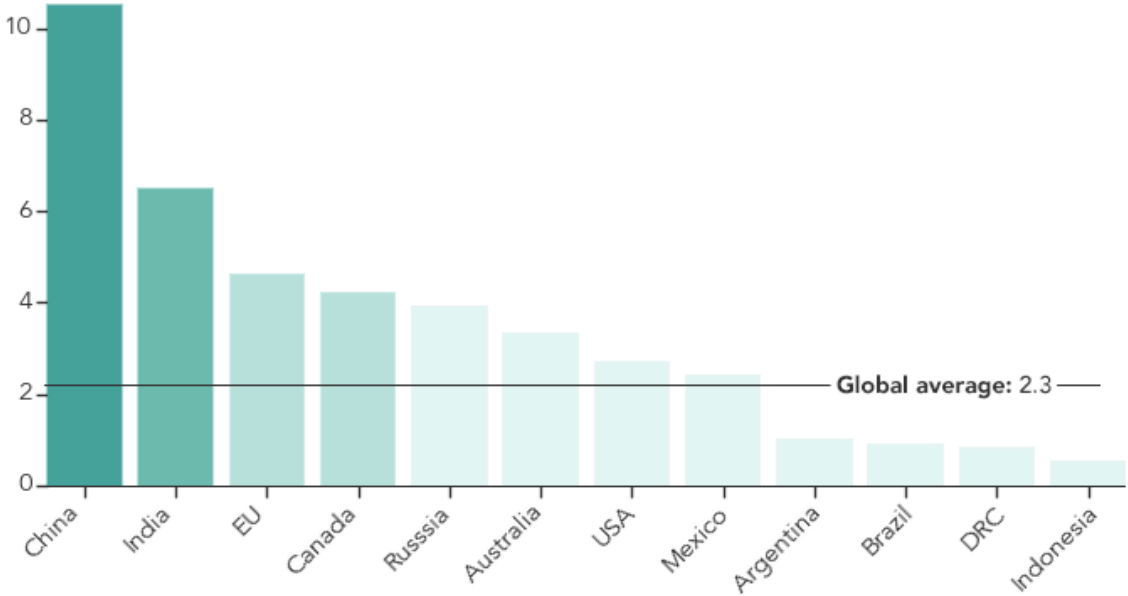
Trend in Annual Average Leaf Area (% per decade, 2000-2017)

≤-8	-4	0	4	8	12	≥16



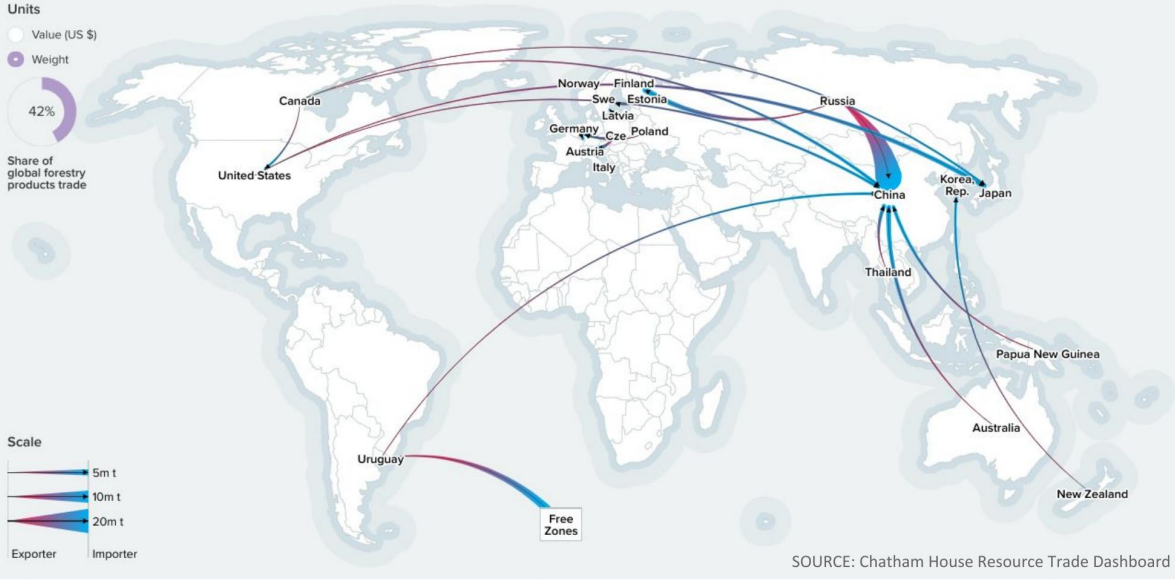
China and India Lead in Greening Due to Human Activity

Change in Leaf Area (% per decade)



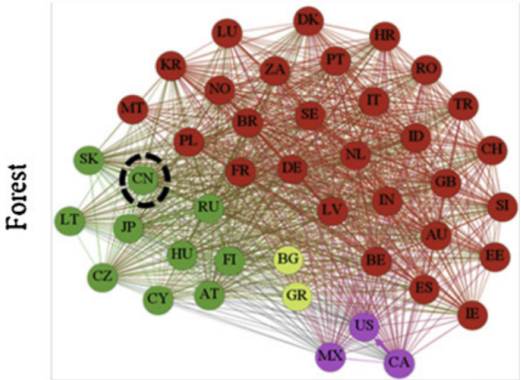
D

China Imports 2018: Wood (Lumber and Sawn)

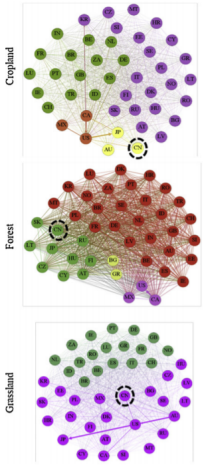


SOURCE: Chatham House Resource Trade Dashboard

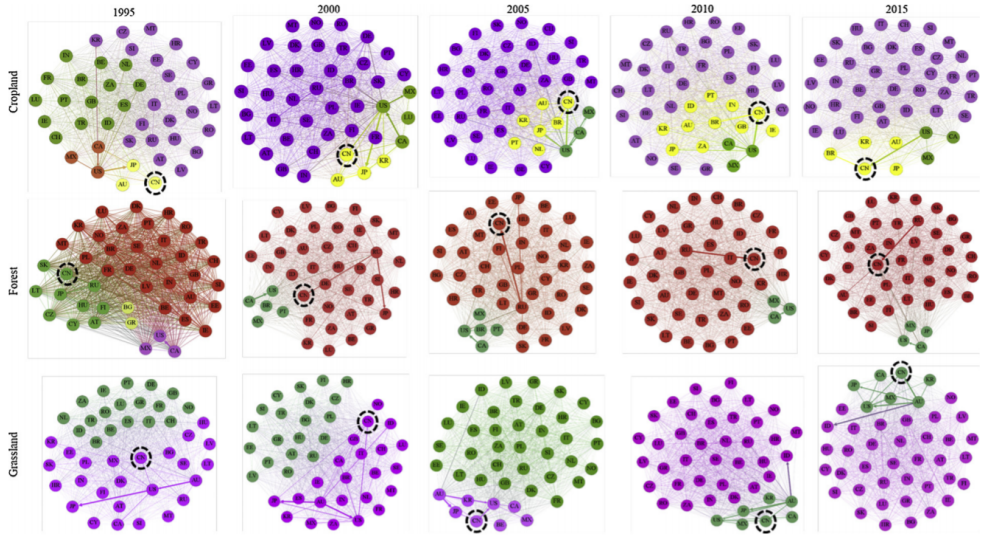
Global Embodied Landscape Trade Networks (Tian et al. 2019)



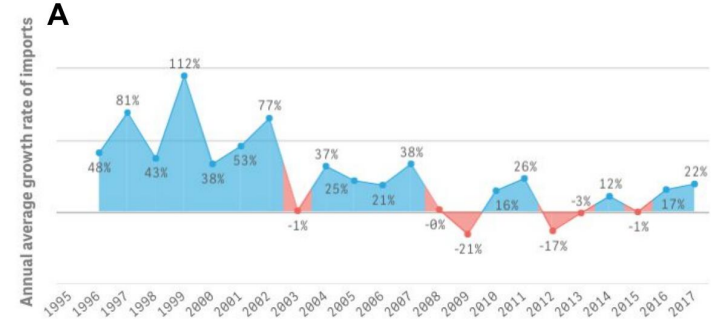
Global Embodied Landscape Trade Networks (Tian et al. 2019)

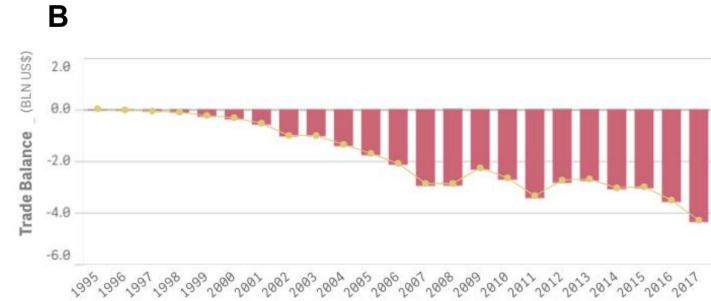


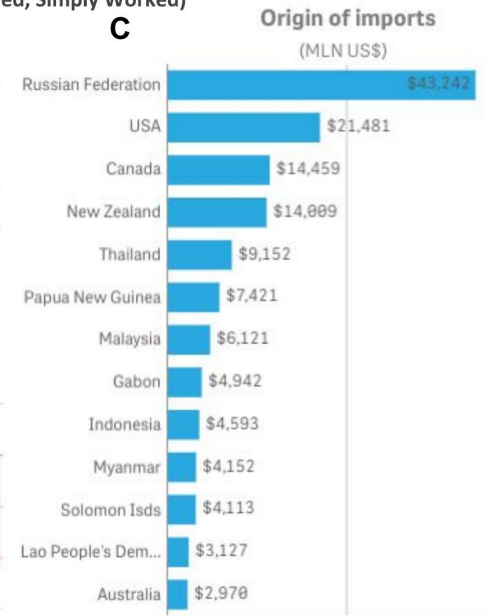
Global Embodied Landscape Trade Networks (Tian et al. 2019)



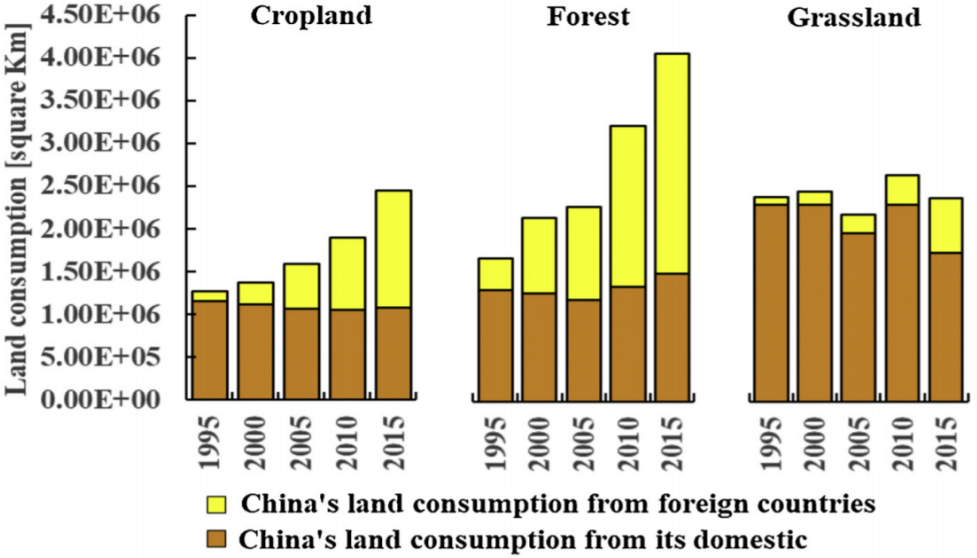
China Imports: Wood Products (Rough Squared, Simply Worked)

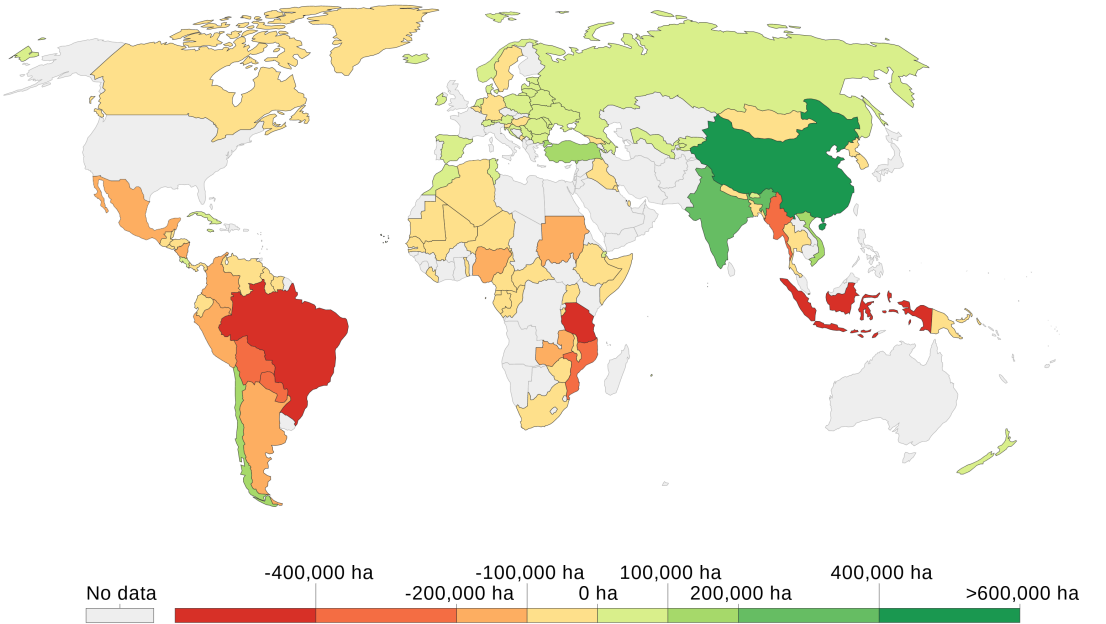






SOURCE: United Nations Commodity Trade Dashboard (2020)


Land consumption [square Km]
4.50E+06
4.00E+06
3.50E+06
3.00E+06
2.50E+06
2.00E+06
1.50E+06
1.00E+06
5.00E+05
0.00E+00
Cropland
Forest
Grassland
1995
2000
2005
2010
2015
China's land consumption from foreign countries
China's land consumption from its domestic



Source: UN Food and Agriculture Organization (FAO). Forest Resources Assessment.

Global Embodied Landscape Trade Networks

- The Earth is getting greener, due in large part to forests in China

Global Embodied Landscape Trade Networks

- The Earth is getting greener, due in large part to forests in China
- This greening is in part the result of national forest policy driven shifts in forest use

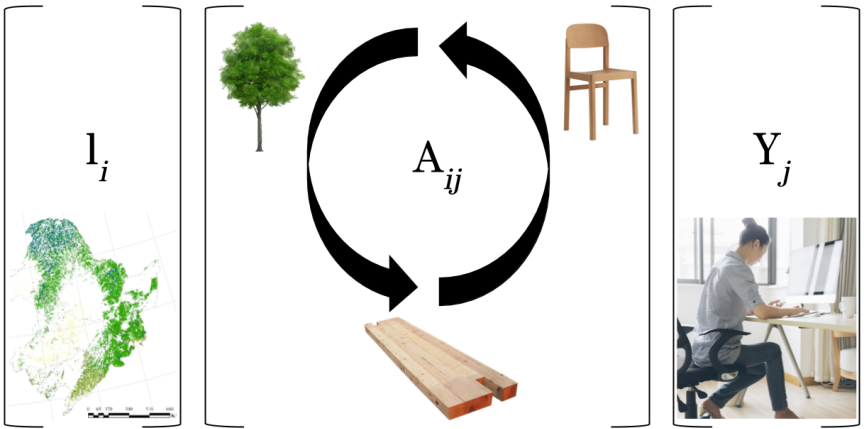
Global Embodied Landscape Trade Networks

- The Earth is getting greener, due in large part to forests in China
- This greening is in part the result of national forest policy driven shifts in forest use
- These shifts have concommitantly resulted in expansion of imports and deforestation through global trade networks

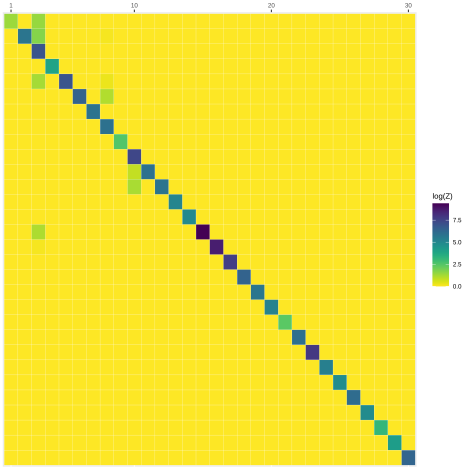
Global Embodied Landscape Trade Networks

- The Earth is getting greener, due in large part to forests in China
- This greening is in part the result of national forest policy driven shifts in forest use
- These shifts have concommitantly resulted in expansion of imports and deforestation through global trade networks
- China is a dominant direct and indirect consumer of domestic and global forested lands

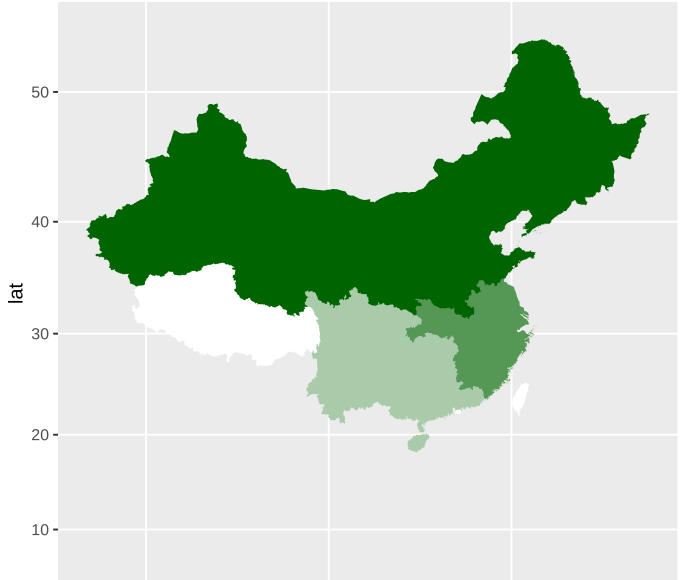
Network Structure of China's Domestic Forest Lands



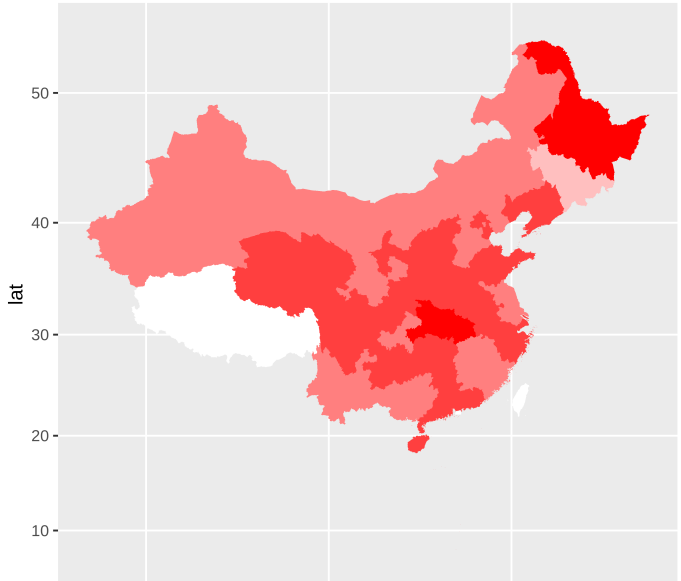
Network Structure: Highly Localized Direct Use



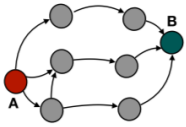
Network Structure: Three Modules



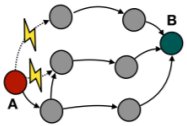
Network Structure: Dominated by Two Provinces



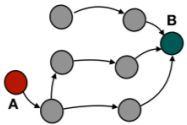
Network Structure to Dynamics



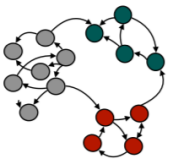
Redundant pathways between A and B



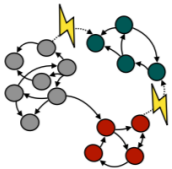
Shock in the system



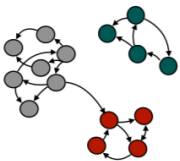
Perseverance of pathway between A and B



Modular network

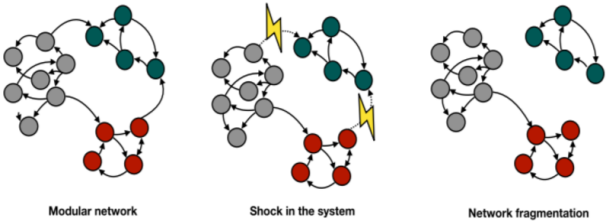


Shock in the system

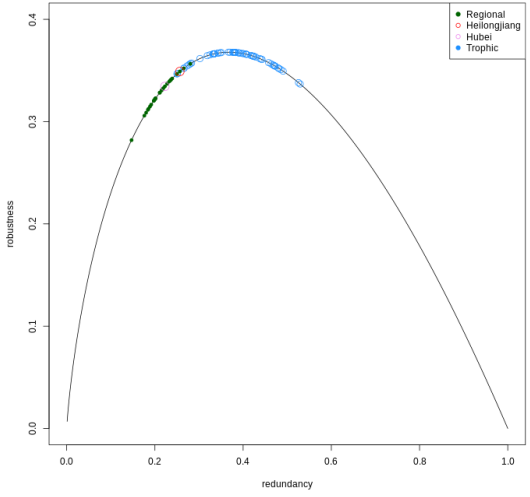


Network fragmentation

Network Structure to Dynamics



Network Structure to Dynamics



Summary and Conclusions

- The effects of the anthropocene has been globalization of economies and de-stabiliziation of the environment

Summary and Conclusions

- The effects of the anthropocene has been globalization of economies and de-stabiliziation of the environment
- China is a driver of forest dynamics globally with increasing imports of forested landscapes from foreign countries

Summary and Conclusions

- The effects of the anthropocene has been globalization of economies and de-stabiliziation of the environment
- China is a driver of forest dynamics globally with increasing imports of forested landscapes from foreign countries
- China's domestic forest landscape network structure is highly modular relative to provincial industries and nationally modular at a broad regional scale (north, south and west)

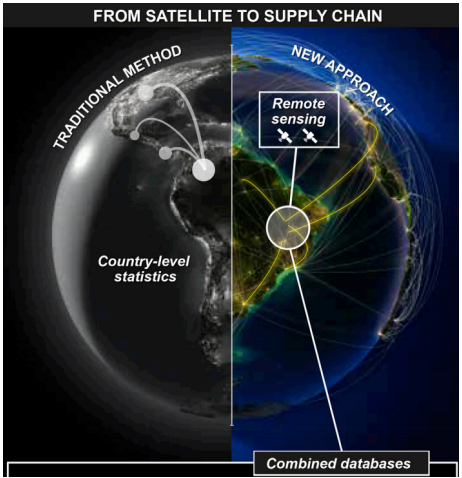
Summary and Conclusions

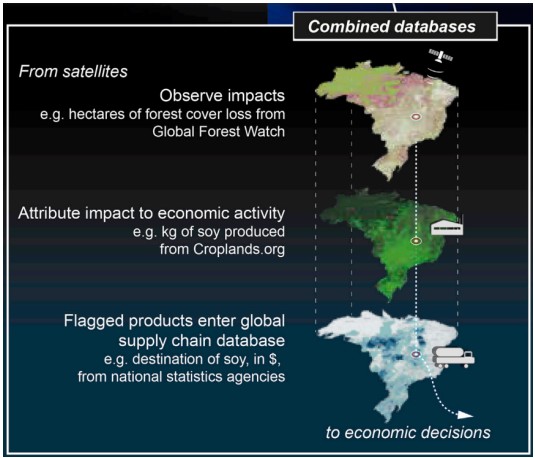
- The effects of the anthropocene has been globalization of economies and de-stabiliziation of the environment
- China is a driver of forest dynamics globally with increasing imports of forested landscapes from foreign countries
- China's domestic forest landscape network structure is highly modular relative to provincial industries and nationally modular at a broad regional scale (north, south and west)
- The provincial industries that rely on forest landscapes are potentially sub-optimally structured relative to food-webs

Summary and Conclusions

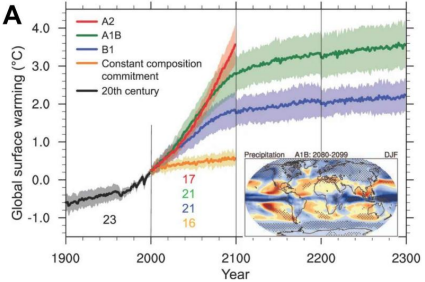
- The effects of the anthropocene has been globalization of economies and de-stabiliziation of the environment
- China is a driver of forest dynamics globally with increasing imports of forested landscapes from foreign countries
- China's domestic forest landscape network structure is highly modular relative to provincial industries and nationally modular at a broad regional scale (north, south and west)
- The provincial industries that rely on forest landscapes are potentially sub-optimally structured relative to food-webs
- **Take-Home**: structural analysis of global and domestic networks provide a necessary insight into human impacts on Earth, suggesting the need/opportunity for international coordination in environmental issues.

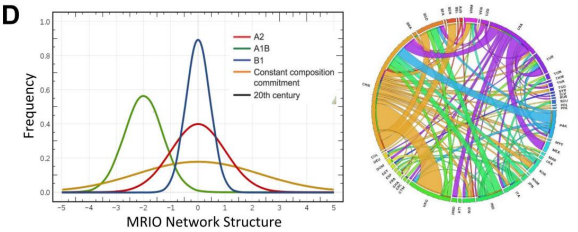
Future Work: CAS Grant (2021-2023)

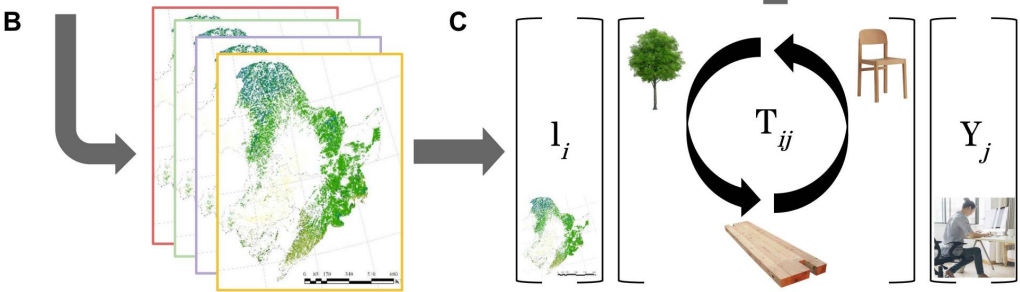




Future Work: CAS Grant (2021-2023)







Cool Projects to Check Out

- `www.globalcanopy.org` - Financial Sector Transparency
- `www.fineprint.global` - Product Sourcing Analysis
- `trase.earth` - Stakeholder and Investor Information

Acknowledgements

References I

A. Chaudhary and T. Kastner.

Land use biodiversity impacts embodied in international food trade.
Global Environmental Change, 38:195 – 204, 2016.

B. Liddle.

Consumption-based accounting and the trade-carbon emissions nexus.
Energy Economics, 69:71 – 78, 2018.

D. Schaffer-Smith, S. Tomscha, K. Jarvis, D. Maguire, M. Treglia, and J. Liu.

Network analysis as a tool for quantifying the dynamics of metacoupled systems: An example using global soybean trade.
ECOLOGY AND SOCIETY, 23:3, 10 2018.

Far Flung Forest Landscapes in the Anthropocene

Structural analysis of China's embodied forest network

Matthew Kekoa Lau (Ph.D.)
Yu Liang, Bo Liu

Chinese Academy of Sciences and Harvard University
Email: mk@mklau.info
Website: https://people.fas.harvard.edu/~matthewklau
ResearchGate: Matthew_Lau2