The background of the slide is a high-angle aerial photograph of a dense forest. The trees are numerous and closely packed, creating a textured pattern of green and yellowish-green shades. The lighting suggests it might be late afternoon or early morning, with some areas of the forest appearing darker than others.

# **Far Flung Forest Landscapes in the Anthropocene**

## **Structural analysis of China's embodied forest network**

Matthew Kekoa Lau (Ph.D.)

Chinese Academy of Sciences and Harvard University





*forests*

# Biodiversity and Conservation in Forests

Edited by

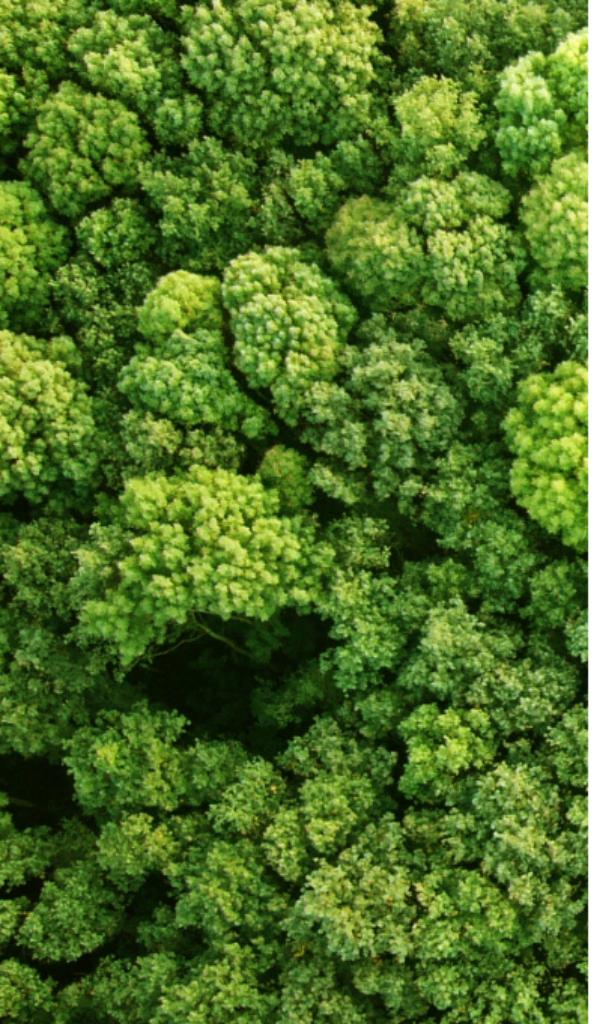
Diana F. Tomback

Printed Edition of the Special Issue Published in *Forests*

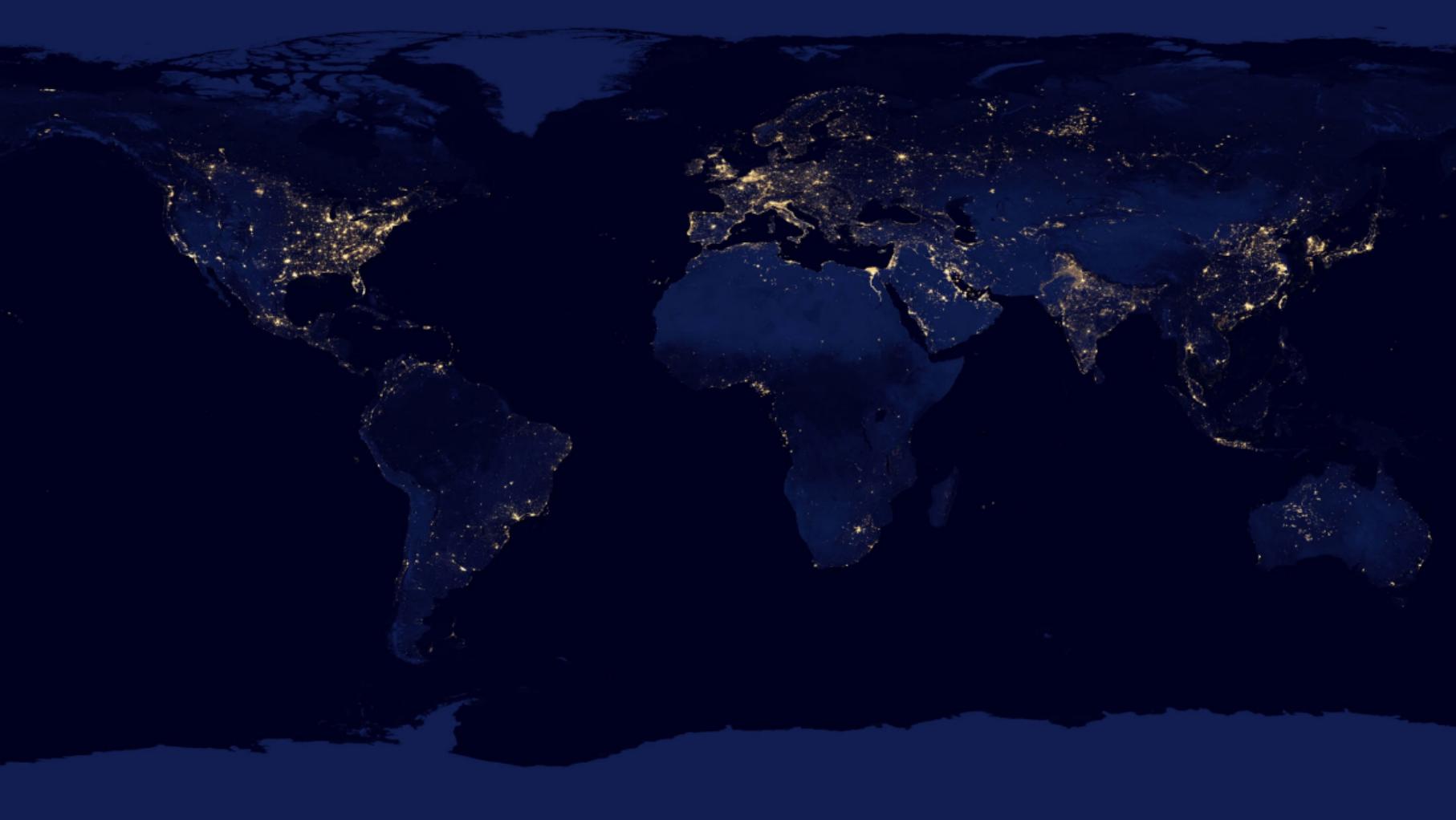
[www.mdpi.com/journal/forests](http://www.mdpi.com/journal/forests)





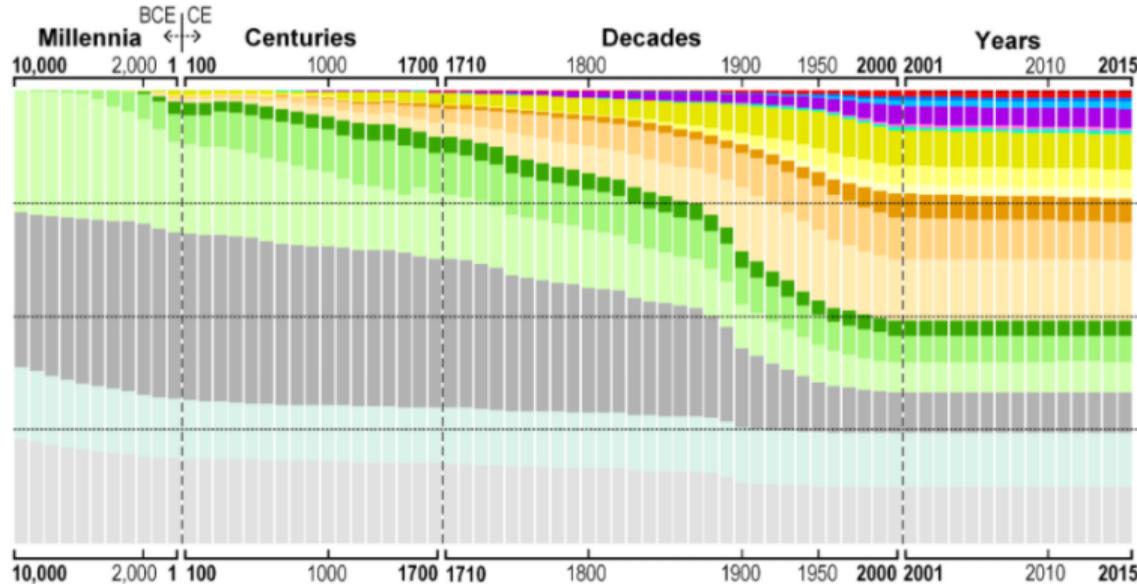






# Anthropogenic biomes: 10,000 BCE to 2015 CE

Changes in anthrome classes as % global land area



## Used

### Dense Settlements

- Urban
- Mixed settlements

### Villages

- Rice villages
- Irrigated villages
- Rainfed villages
- Pastoral villages

### Croplands

- Residential irrigated croplands
- Residential rainfed croplands
- Populated croplands
- Remote croplands

### Rangelands

- Residential rangelands
- Populated rangelands
- Remote rangelands

## Seminatural

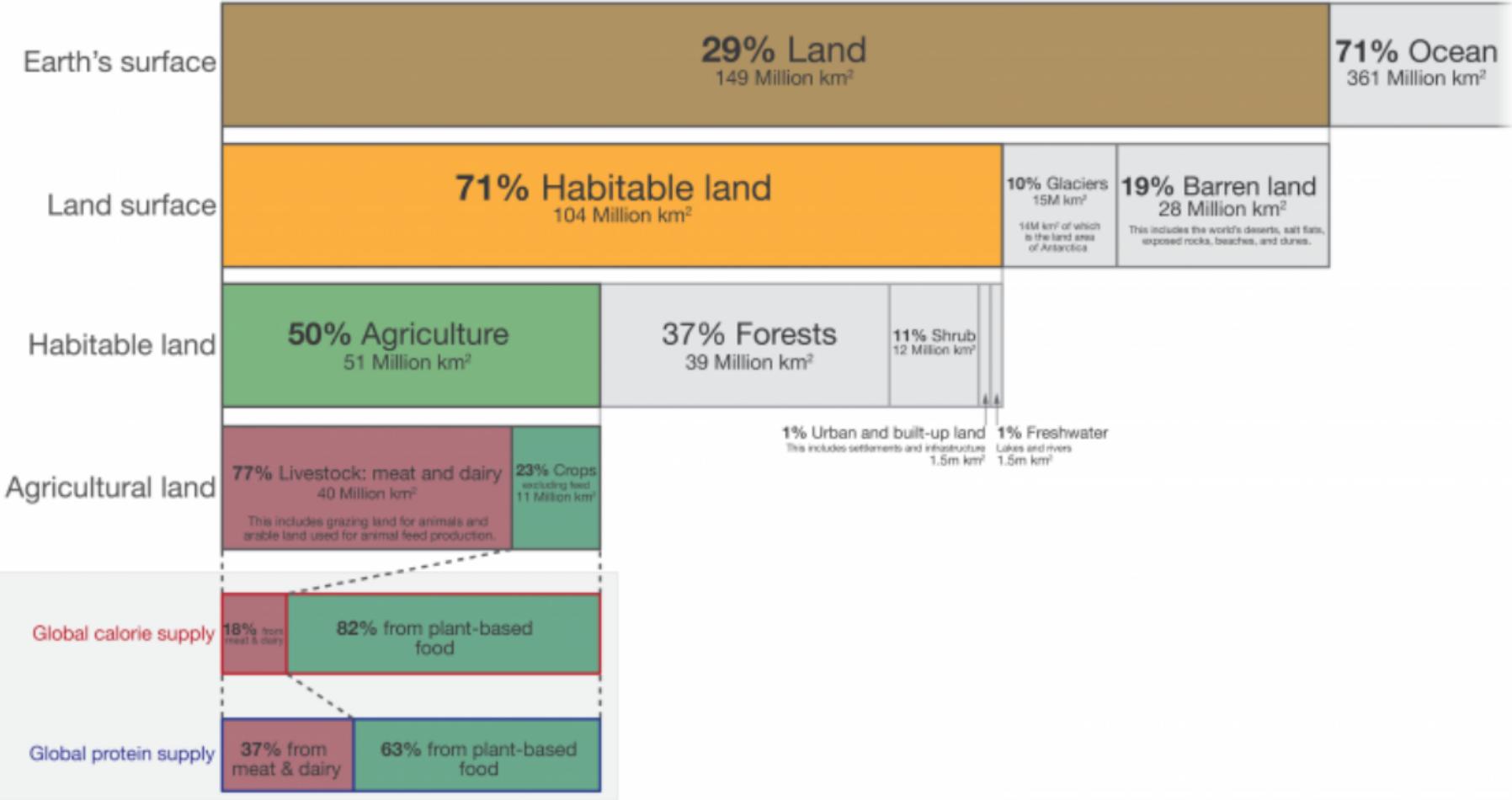
### Seminatural

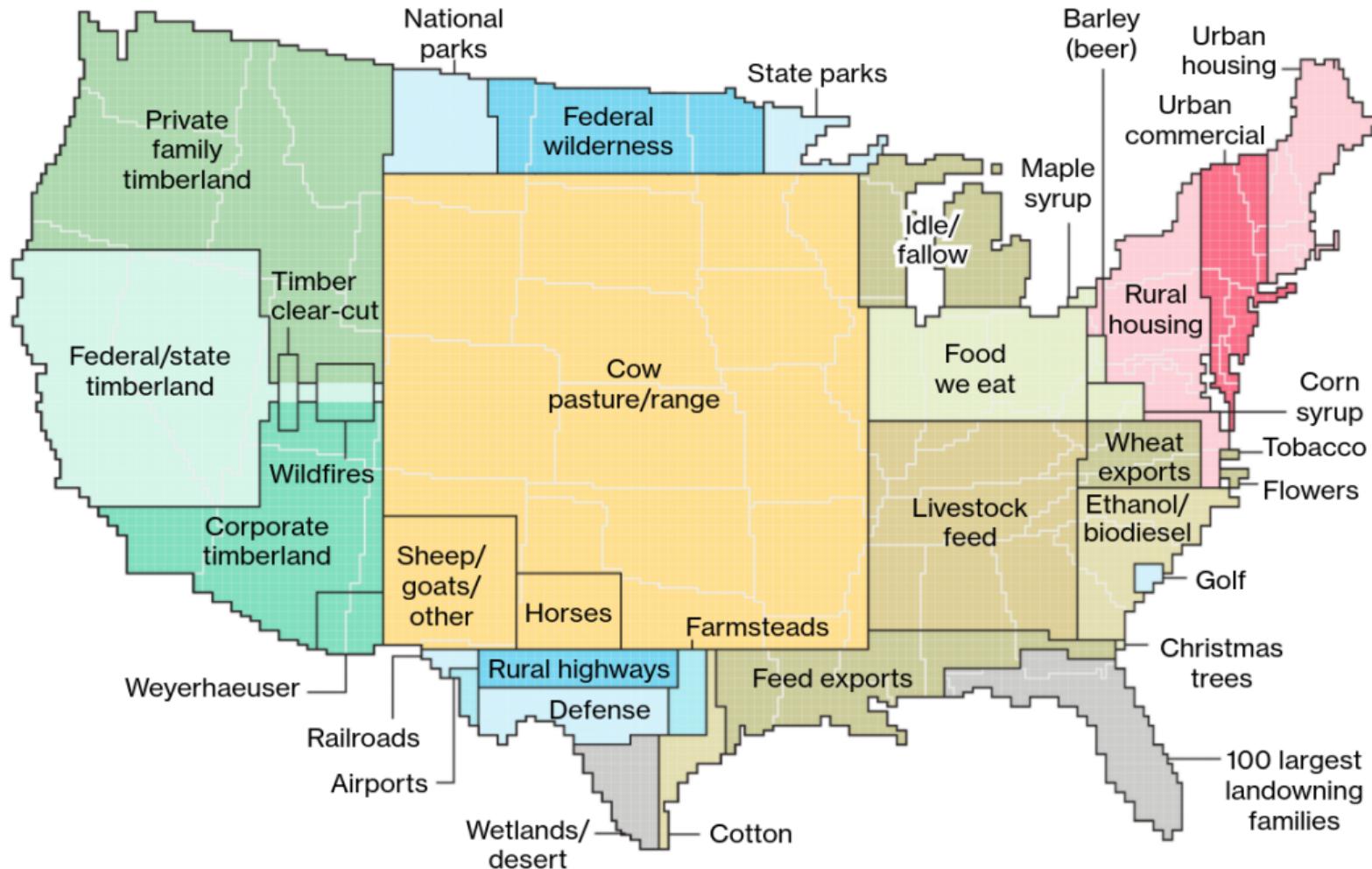
- Residential woodlands
- Populated woodlands
- Remote woodlands
- Inhabited treeless & barren lands

## Wild

### Wildlands

- Wild woodlands
- Wild treeless & barren lands
- Ice, uninhabited







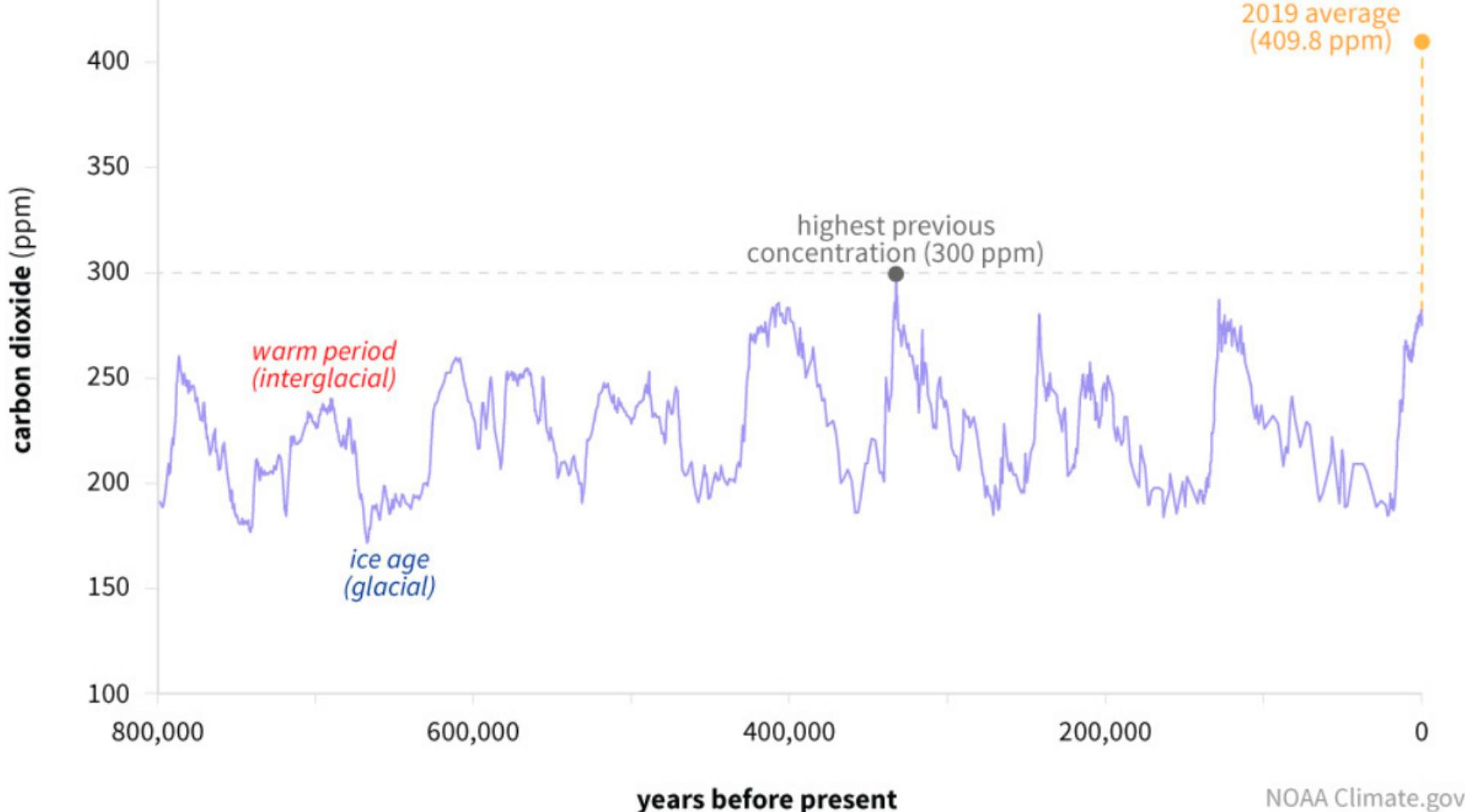


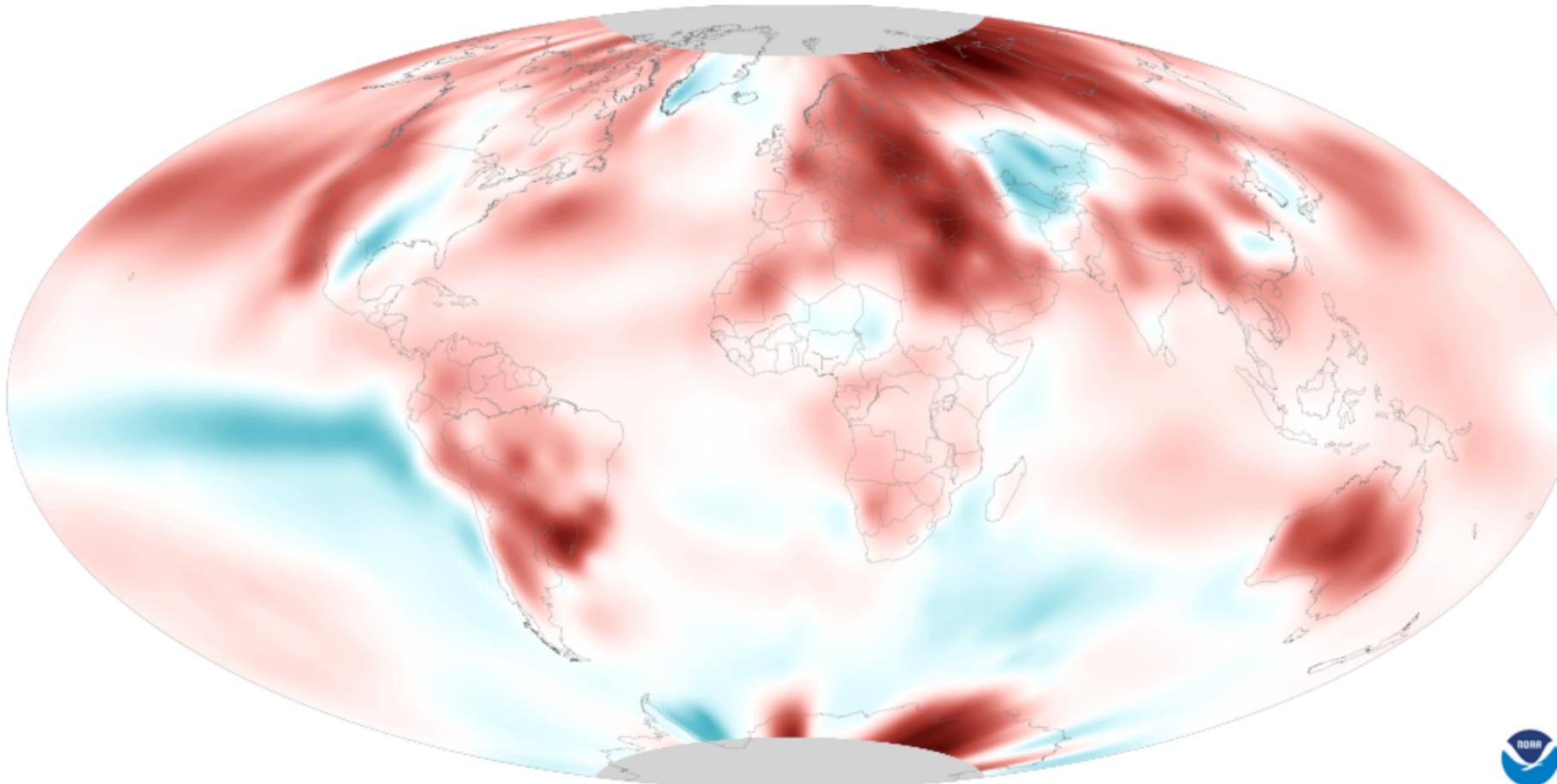




ECLIPSE Ice Drill







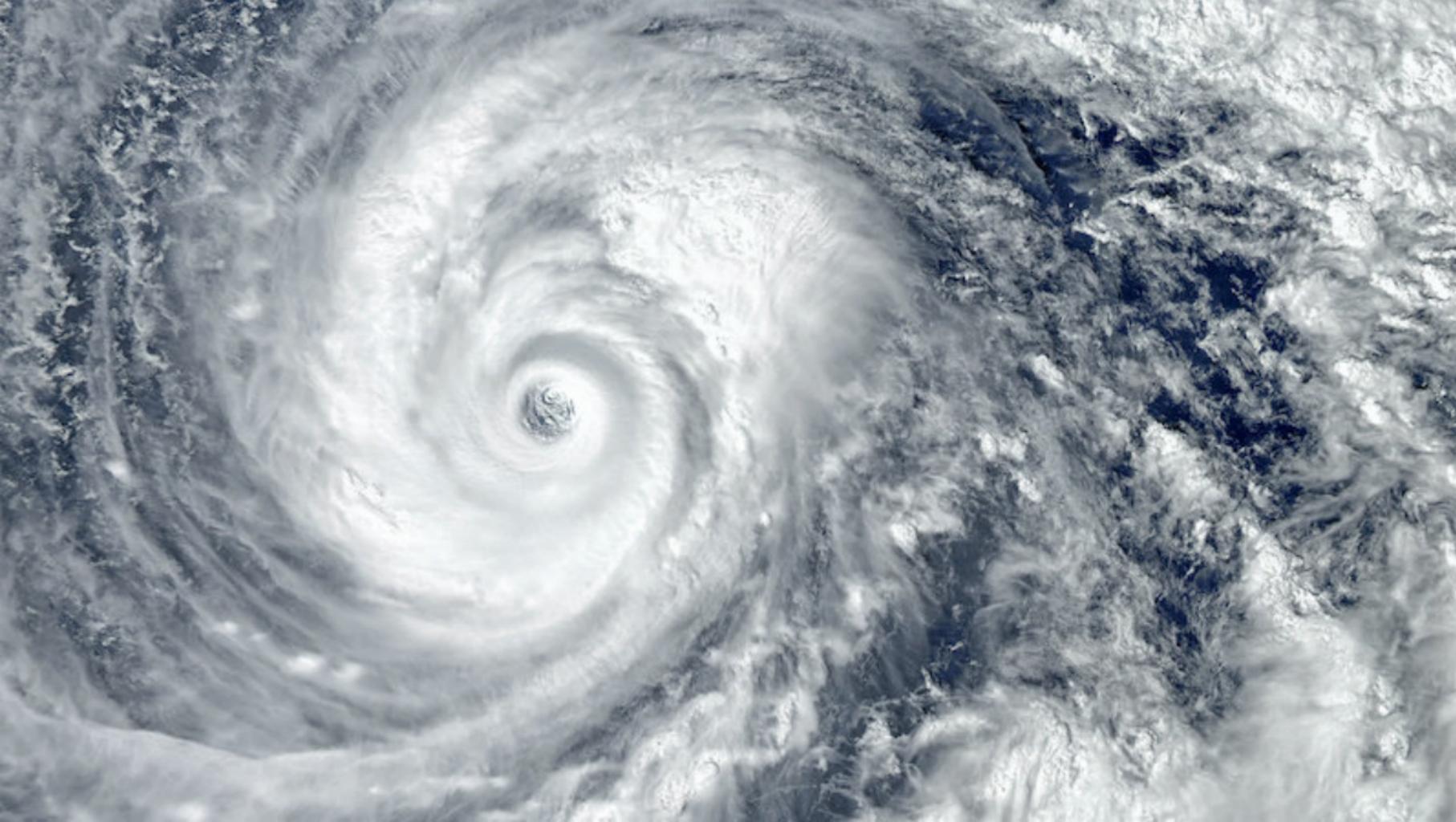
September 2020  
Compared to 1981-2010

Difference from average temperature ( °F)

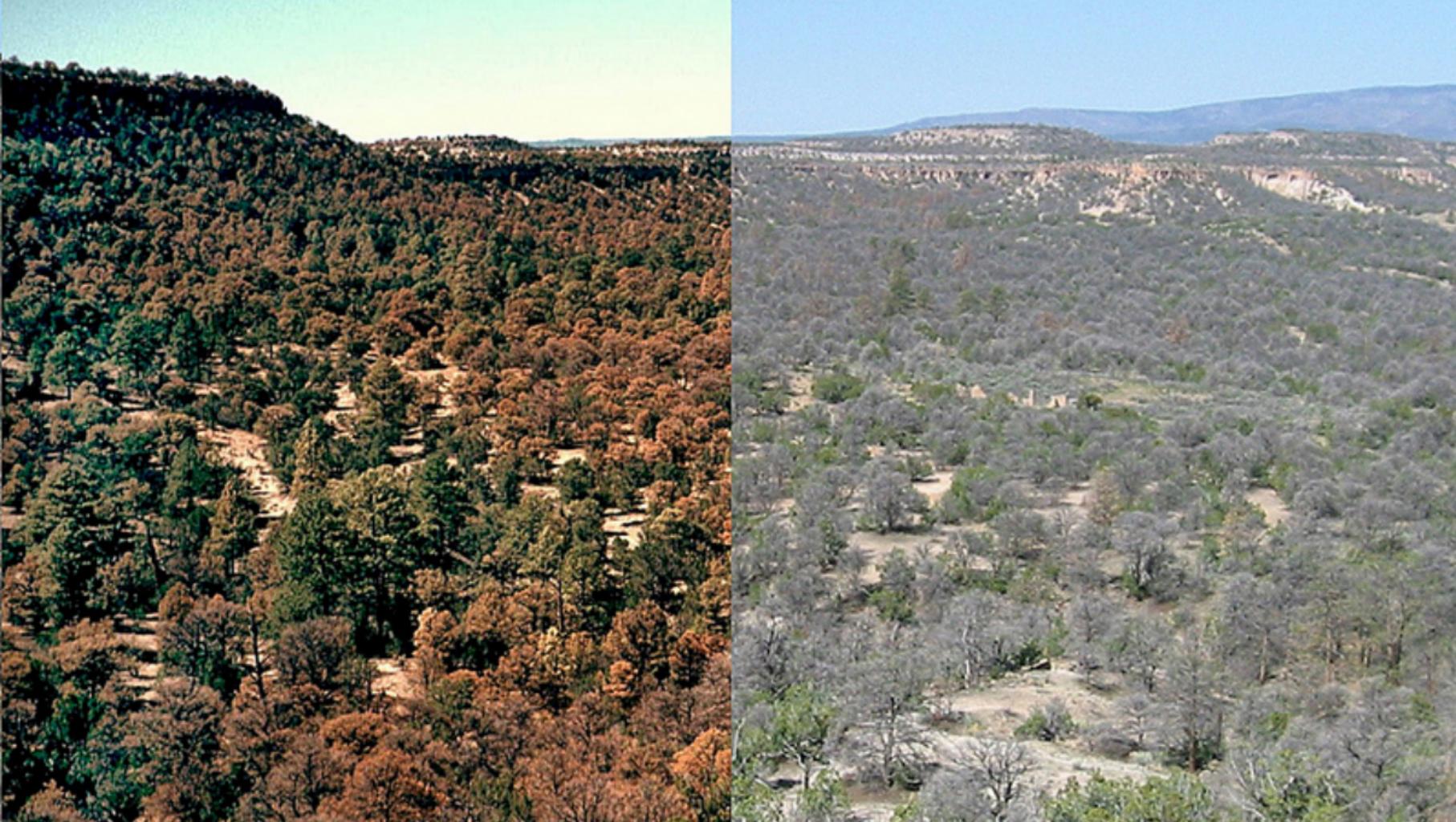
-11 0 11

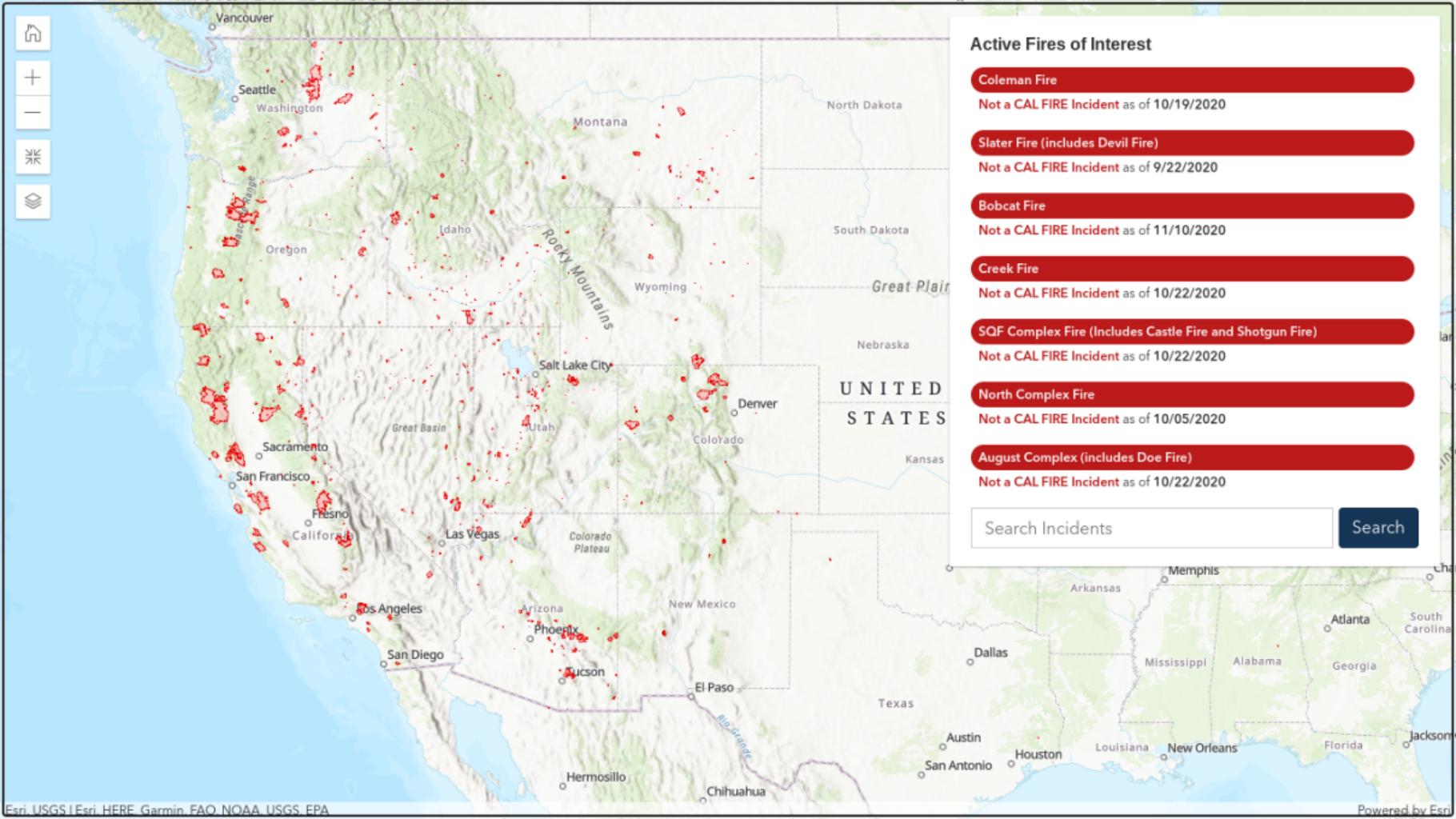


NOAA NN  
Data: NC

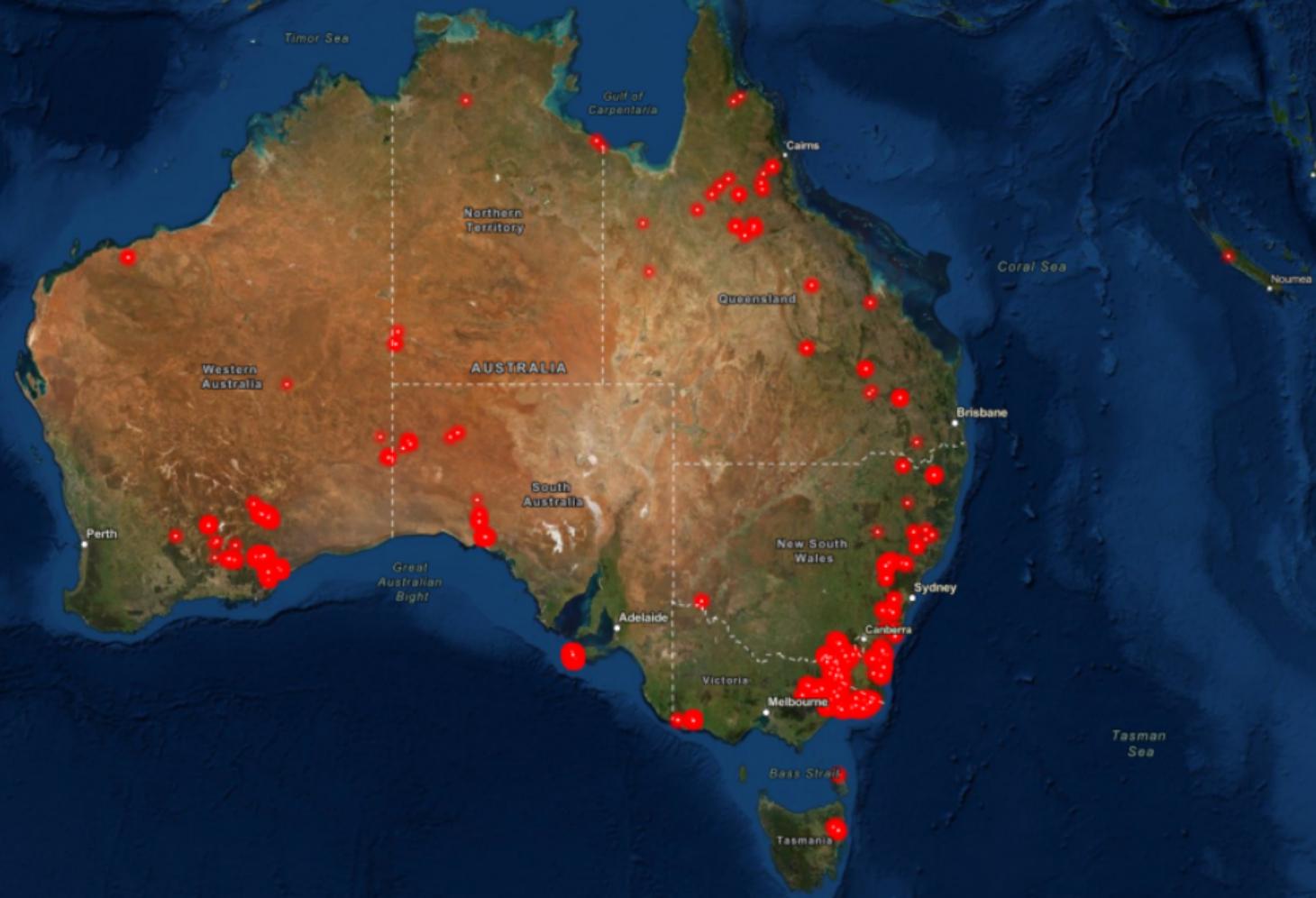












## Forests in the Anthropocene

- Forests are changing from human impacts

## Forests in the Anthropocene

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

## Forests in the Anthropocene

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

- ① Environmental Extended Economic Models
- ② Global Trade Networks of Forest Landscapes
- ③ China's Forest Networks
- ④ Conclusions
- ⑤ Future Work

# Input-Output Models





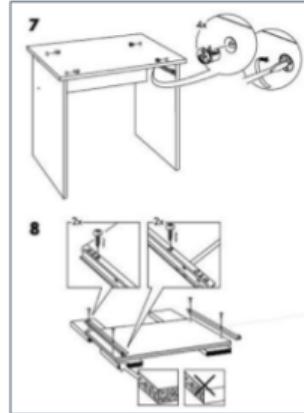


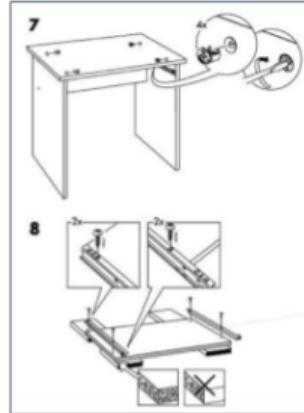


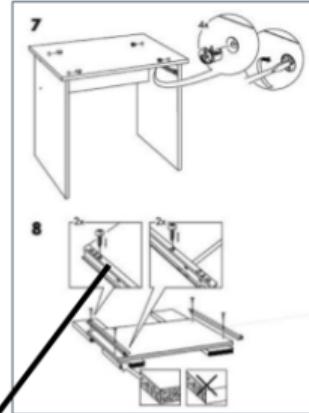












$$X = (I - A)^{-1} Y$$

- Uses a simple subtraction to calculate all of the indirect consumption correctly

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

- Uses a simple subtraction to calculate all of the indirect consumption correctly
- Indirect effects can, and usually are, greater than direct
- Has been influential in ecosystem network analysis

# Environmental Extended Input-Output Models

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

# Environmental Extended Input-Output Models

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

# Environmental Extended Input-Output Models

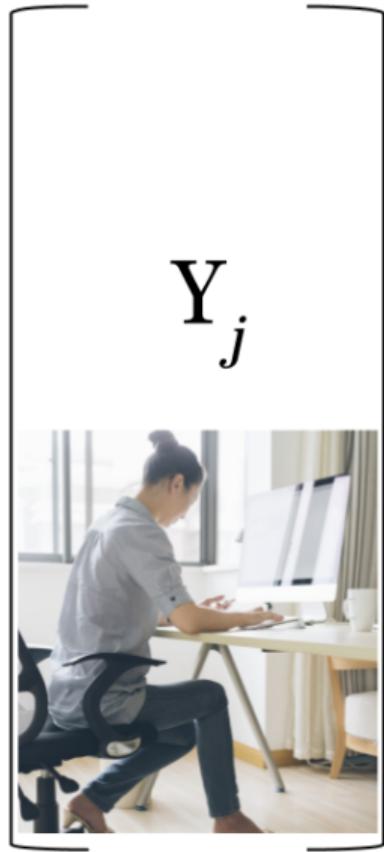
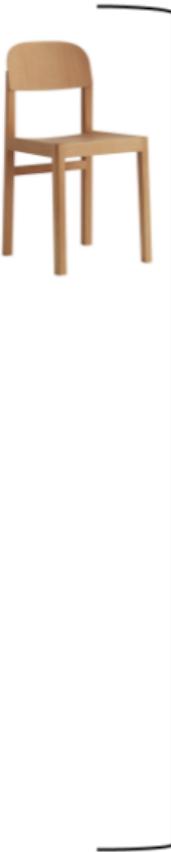
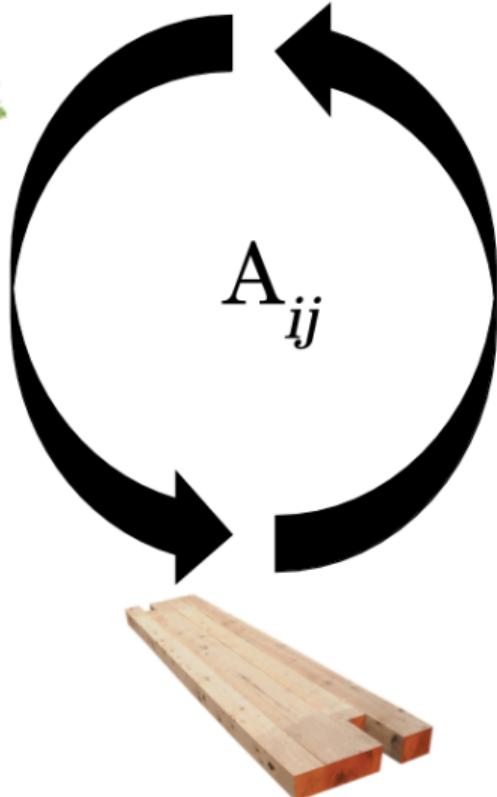
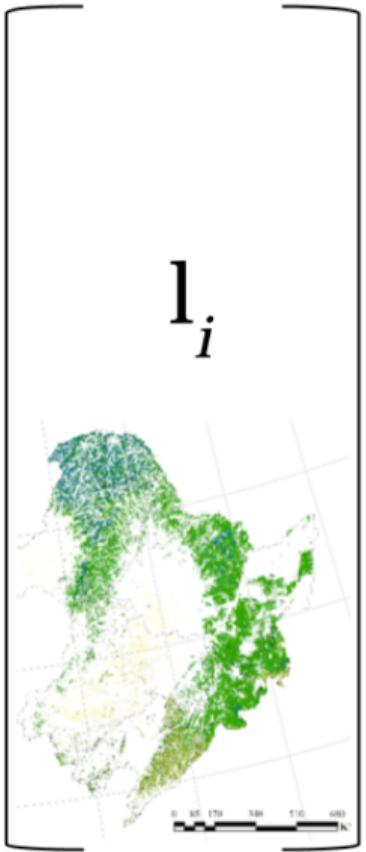
$$X = E(I - A)^{-1} Y$$

- Any environmental (or social) variable can be used

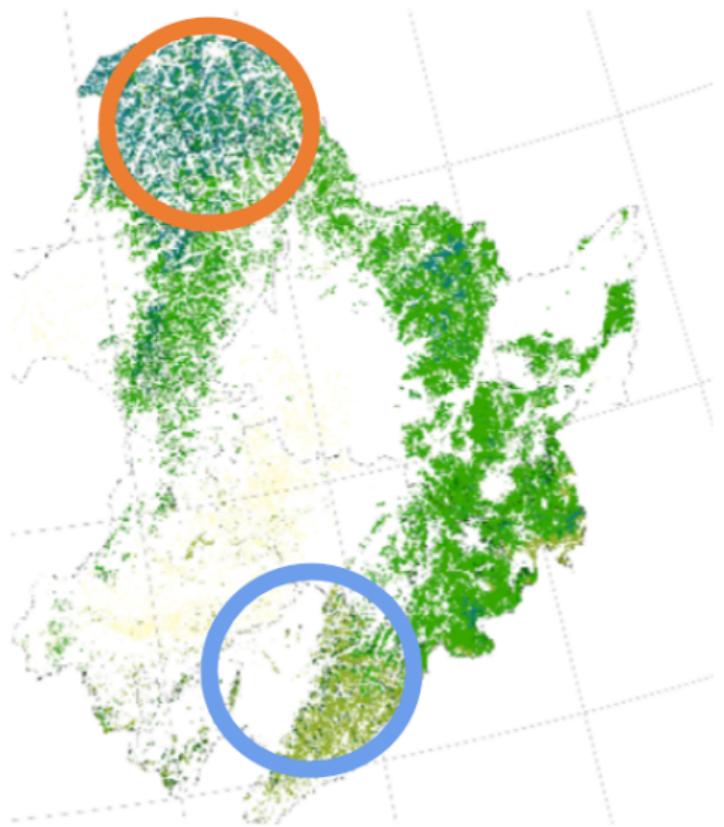
# Environmental Extended Input-Output Models

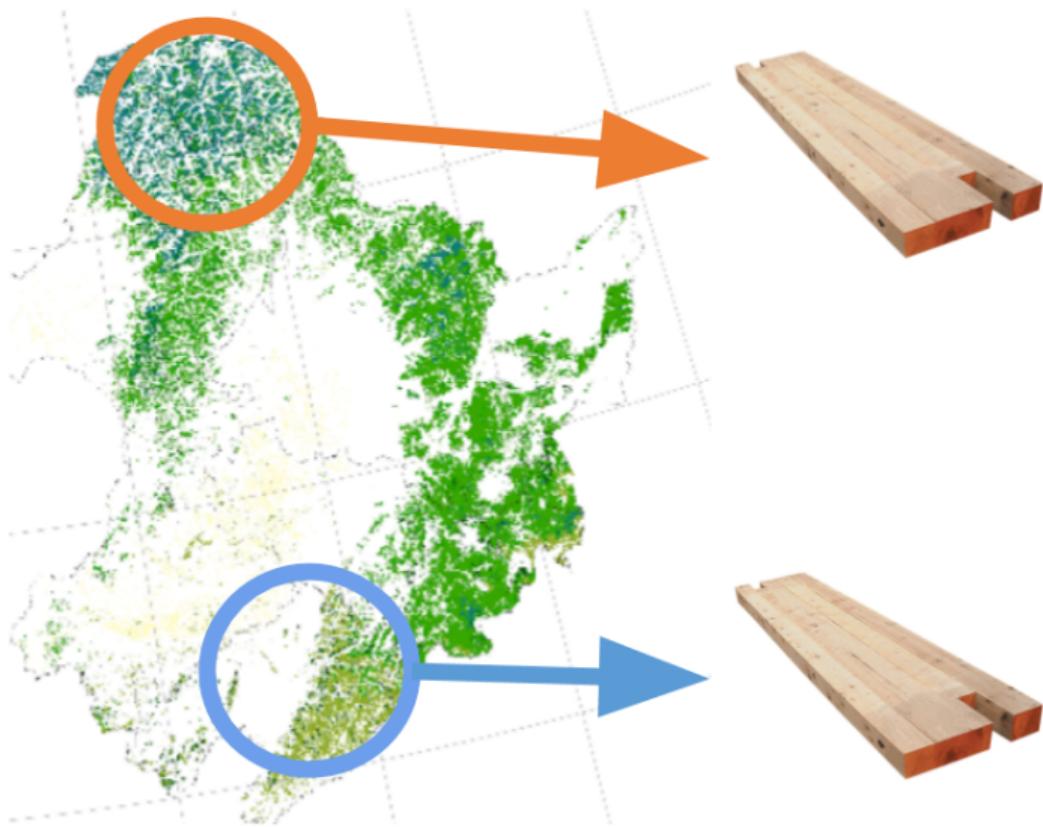
$$X = E(I - A)^{-1} Y$$

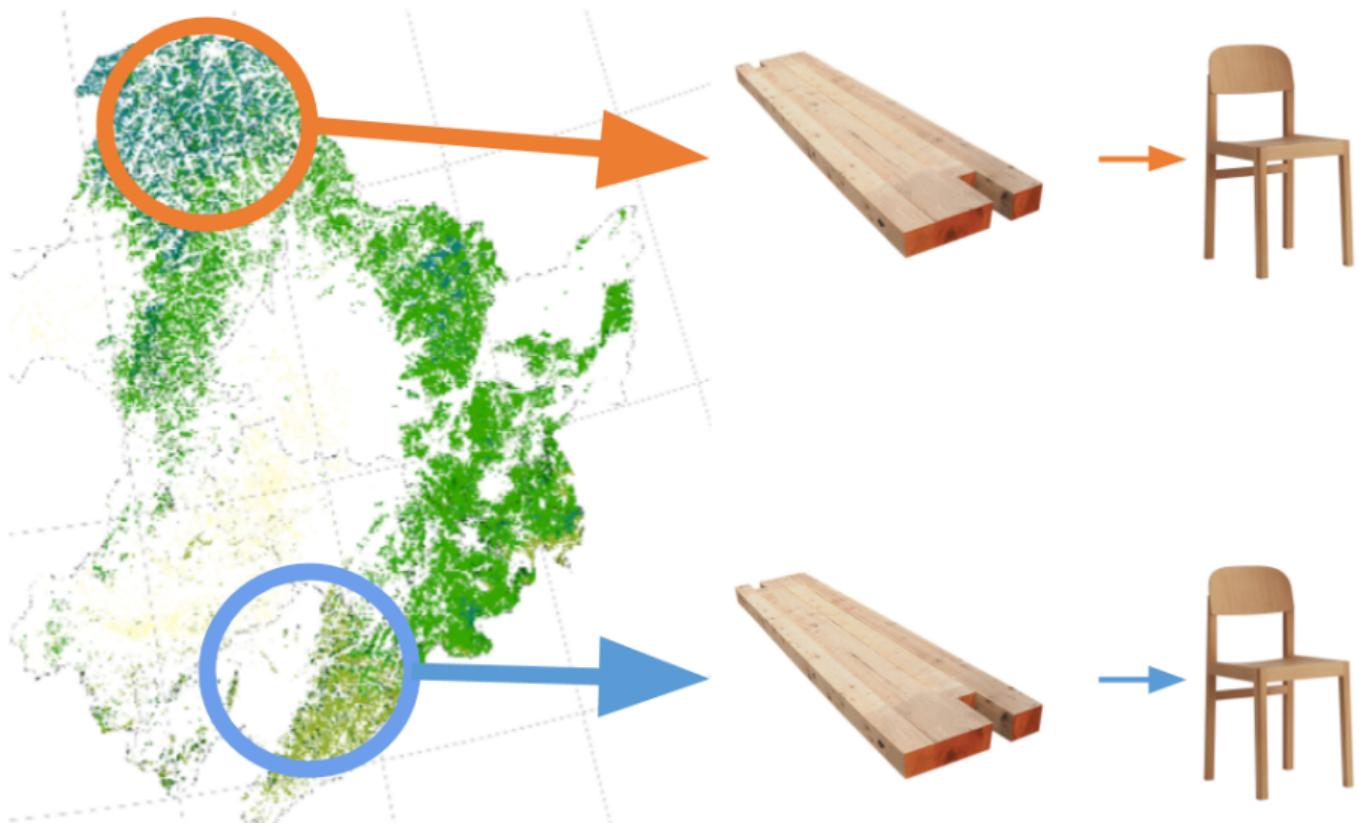
- Any environmental (or social) variable can be used
- **Required:** estimate of how much is used by each industrial sector

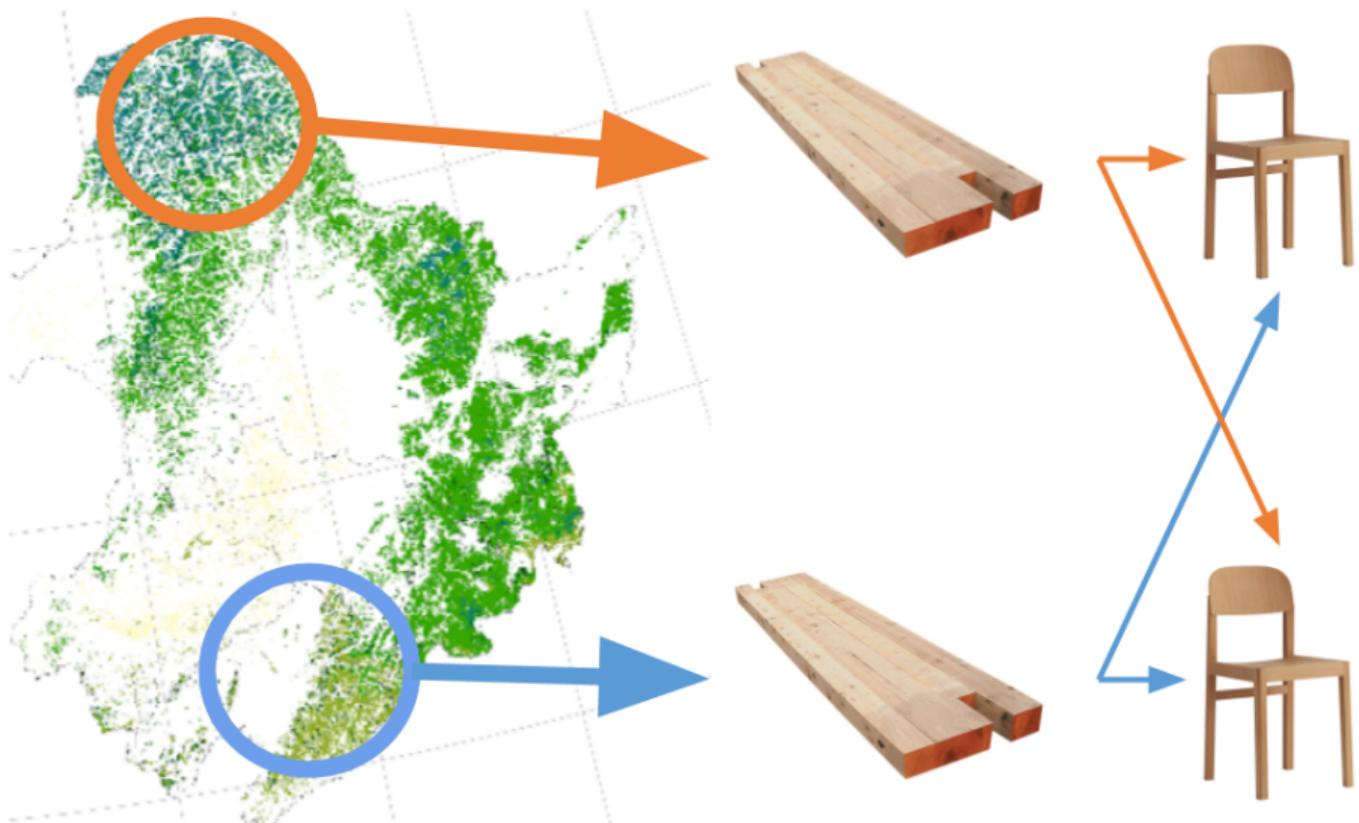


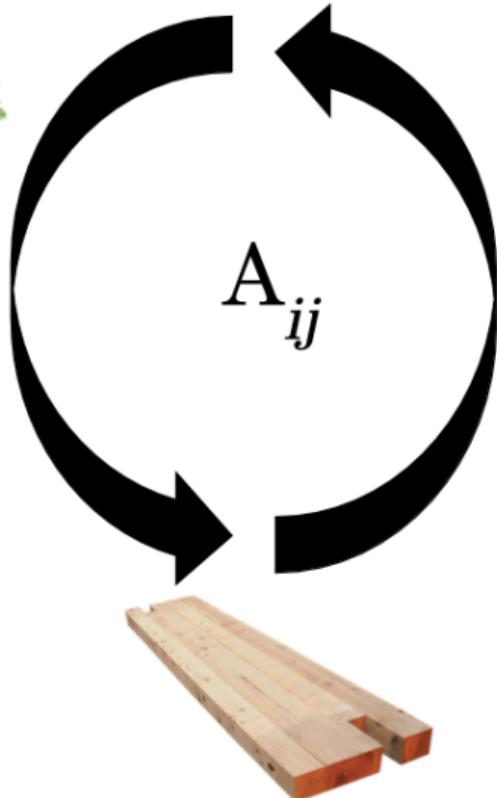
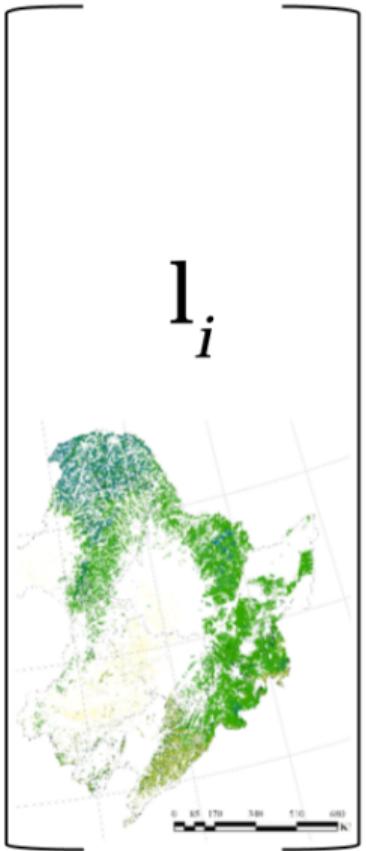
**“Multi-Regional” = Spatial Context**

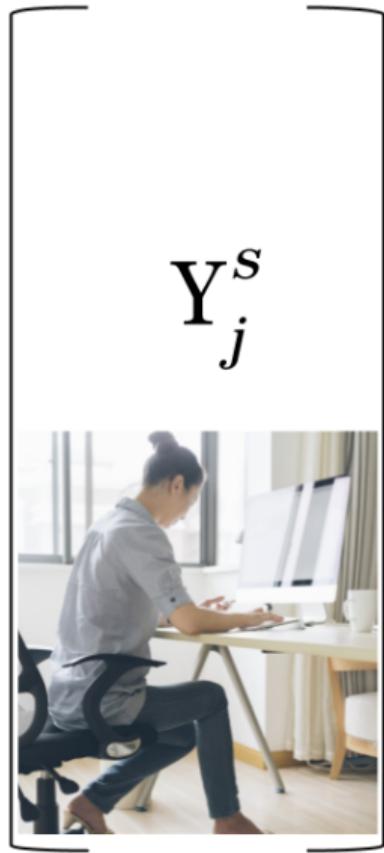
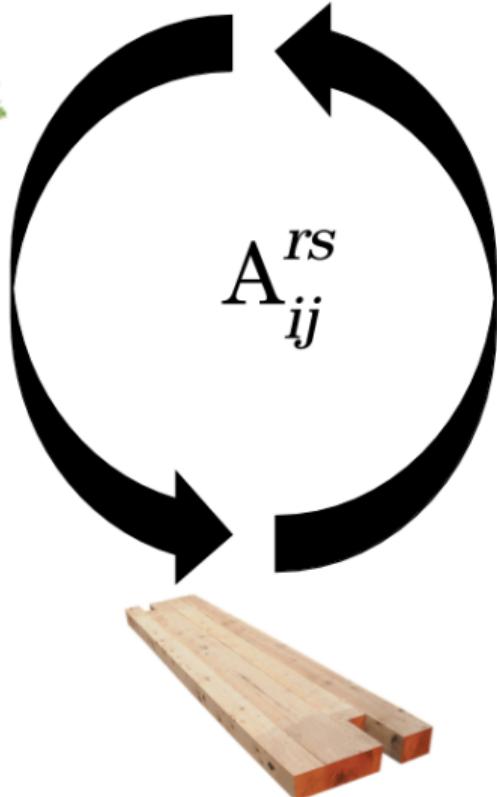












**Table 1**

The structure of the ecological MRIO account.

				Final demand		Region m	Rest of final demand (capital goods)	
				Region 1	...	Household consumption	Government consumption	
				Non-profit institutions consumption	...	...	Non-profit institutions consumption	
Output		Intermediate use		Region 1	...	Household consumption	Rest of final demand (capital goods)	
		Region 1	Region m					
Input		Sector 1	Sector n	Sector 1	...	Sector n	Government consumption	
		...	...	...	...	...	Non-profit institutions consumption	
Sector 1		Sector 1	Sector n	z <sub>ij</sub> <sup>rs</sup>		f <sub>i</sub> <sup>r</sup>		
		...	...	...		...		
Sector 1		Sector 1	Sector n	p <sub>j</sub> <sup>s</sup>		p <sub>j</sub> <sup>s</sup>		
		...	...	...		...		
Sector 1		Sector 1	Sector n	u <sub>j</sub> <sup>s</sup>		u <sub>j</sub> <sup>s</sup>		
		...	...	...		...		
Primary inputs				p <sub>j</sub> <sup>s</sup>		p <sub>j</sub> <sup>s</sup>		
Exogenous environmental inputs				u <sub>j</sub> <sup>s</sup>		u <sub>j</sub> <sup>s</sup>		
Intermediate input								
Region 1		Region 1	Region m					

## A few EE-MRIO Applications

- Global carbon emissions are primarily indirect by developed country consumption (23%) [5]

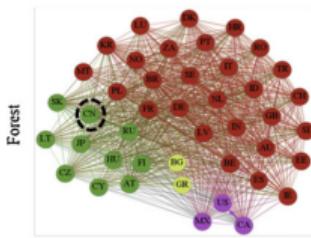
## A few EE-MRIO Applications

- Global carbon emissions are primarily indirect by developed country consumption (23%) [5]
- 17% of biodiversity is embodied in food exported to high income countries [4]

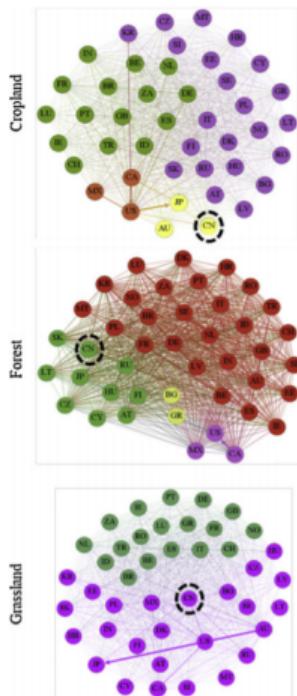
## A few EE-MRIO Applications

- Global carbon emissions are primarily indirect by developed country consumption (23%) [5]
- 17% of biodiversity is embodied in food exported to high income countries [4]
- Tropical forest loss in Brazil driven by conversion to soy exported primarily to China (48.6%) and the USA (72.3%) [6]

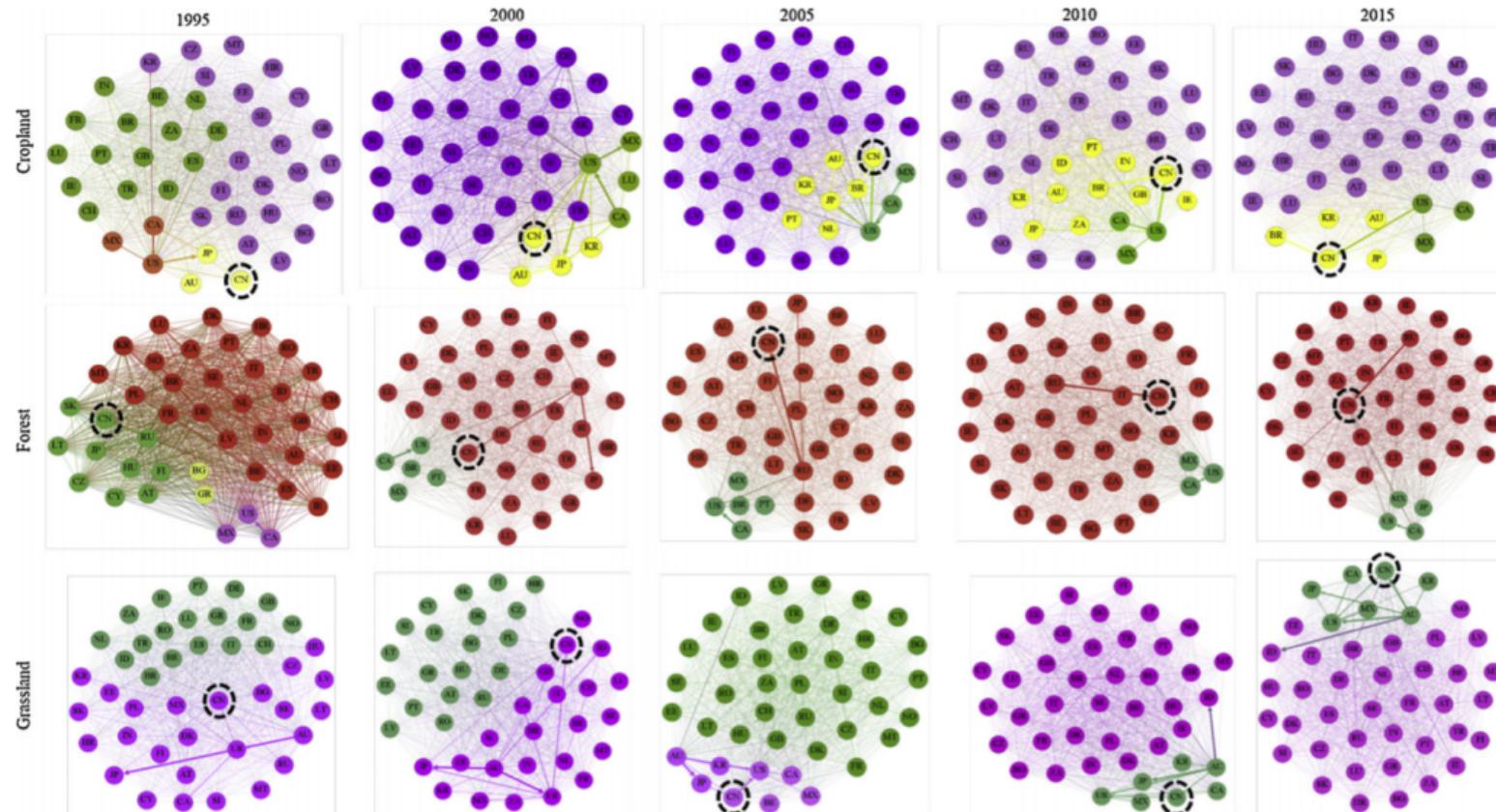
# Global Embodied Landscape Trade Networks

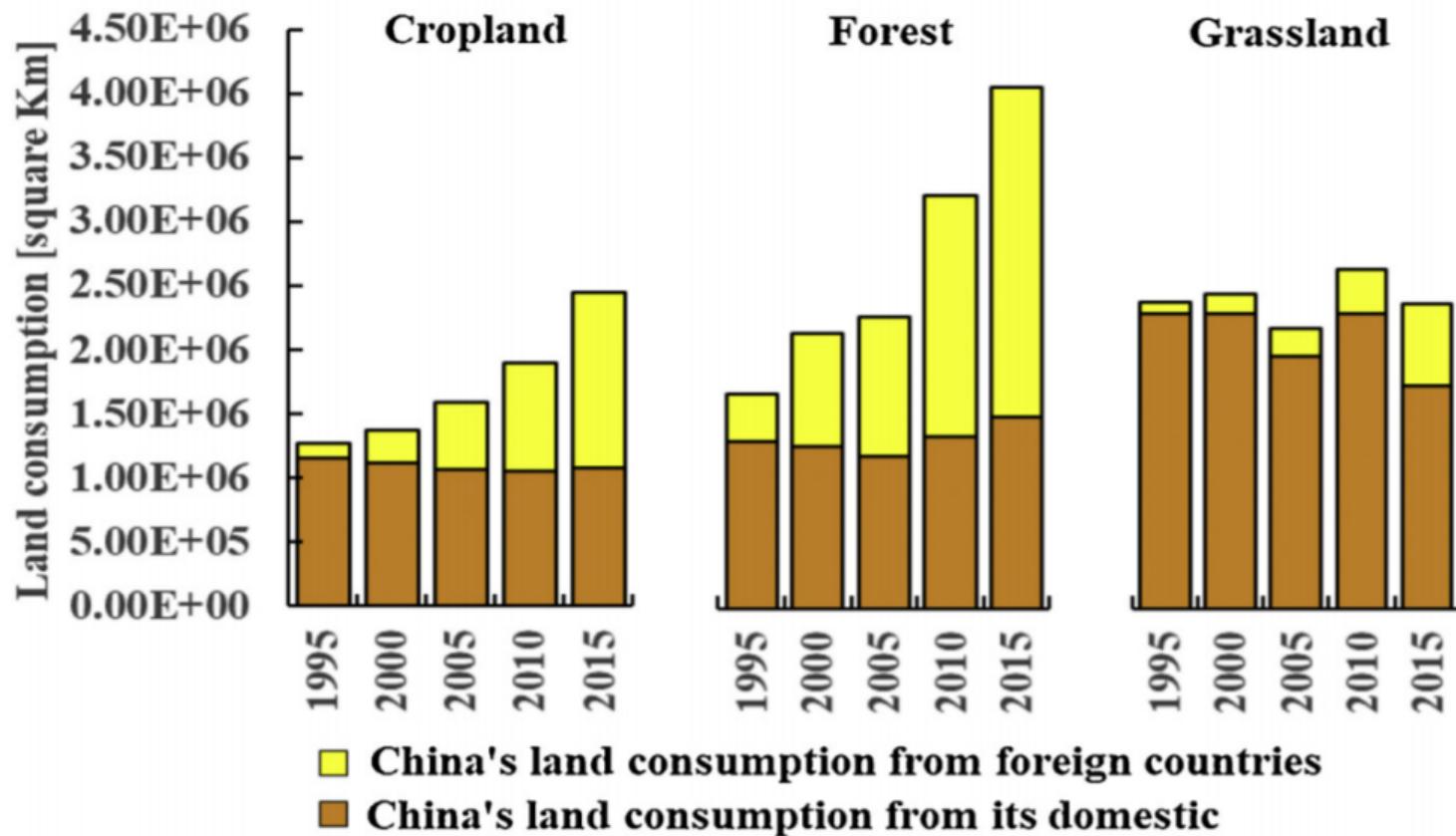


# Global Embodied Landscape Trade Networks



# Global Embodied Landscape Trade Networks





D

## China Imports 2018: Wood (Lumber and Sawn)

Units

Value (US \$)

Weight



Share of global forestry products trade



Scale

5m t

10m t

20m t

Exporter

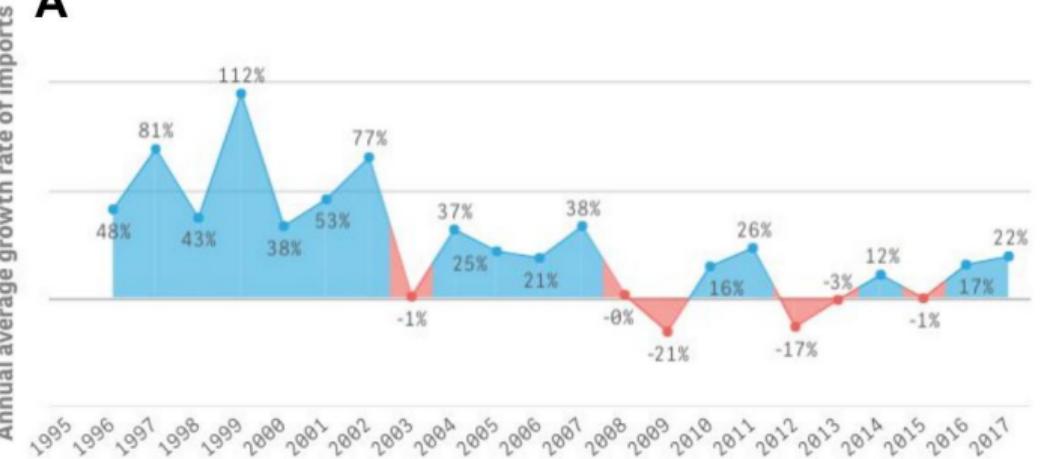
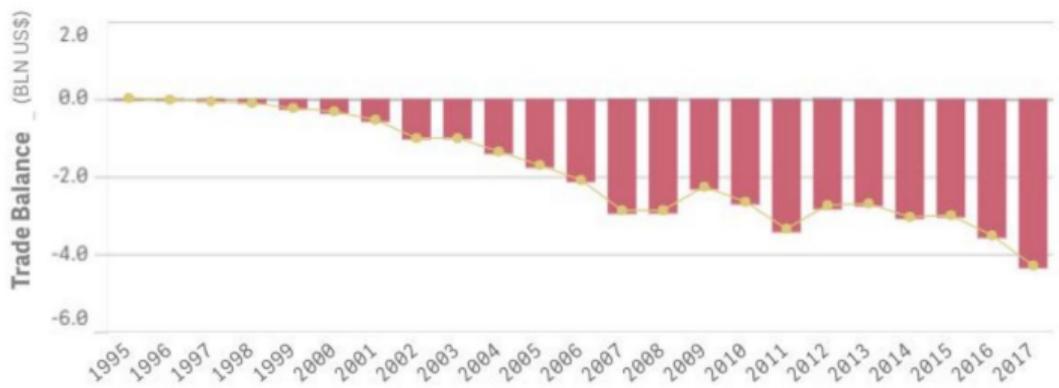
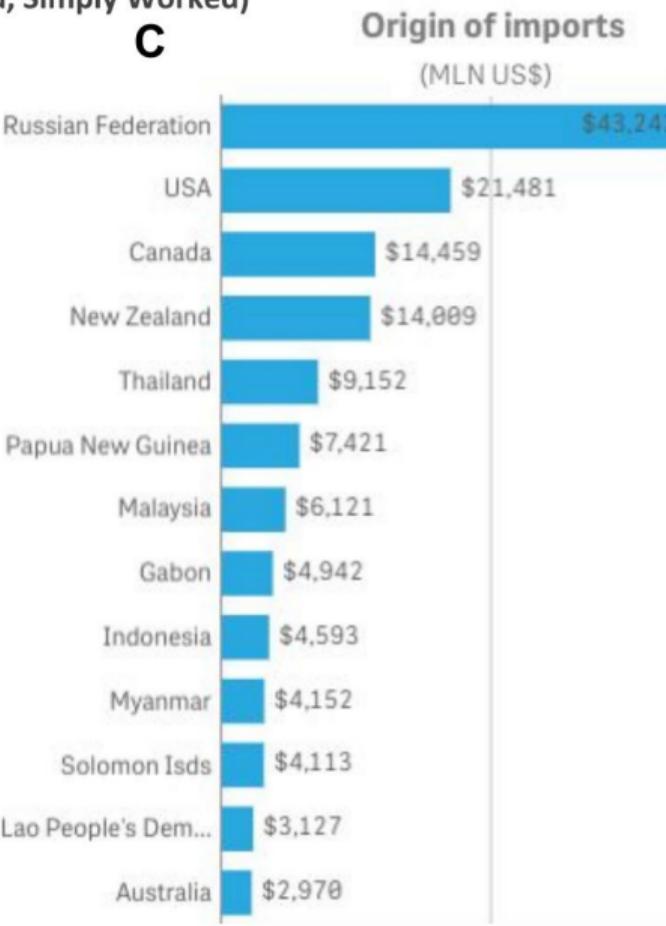
Importer

Free Zones

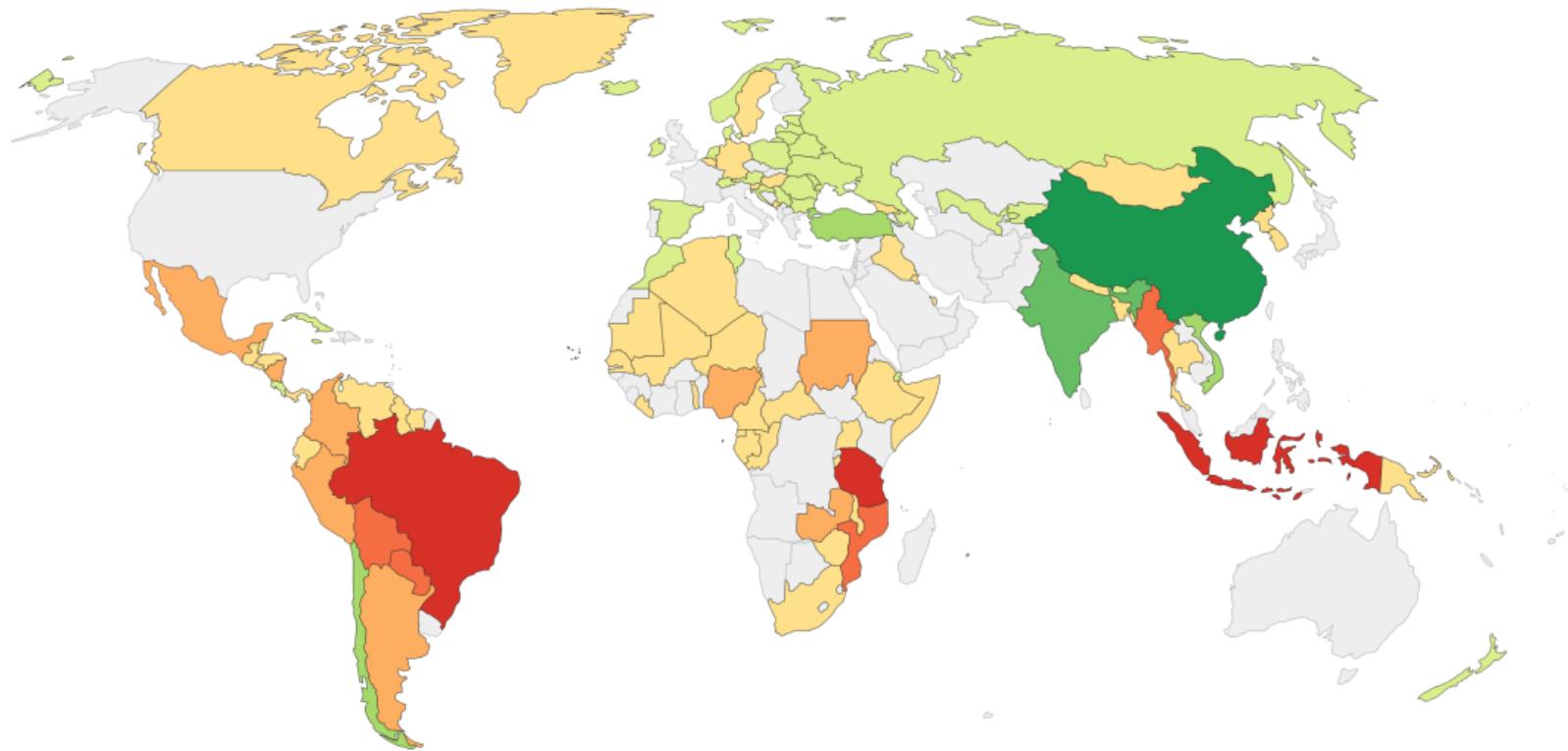


SOURCE: Chatham House Resource Trade Dashboard

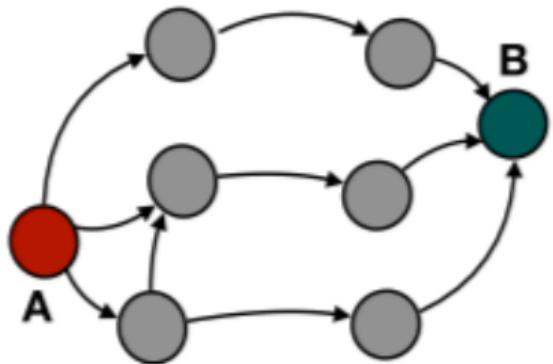
# China Imports: Wood Products (Rough Squared, Simply Worked)

**A****B****C**

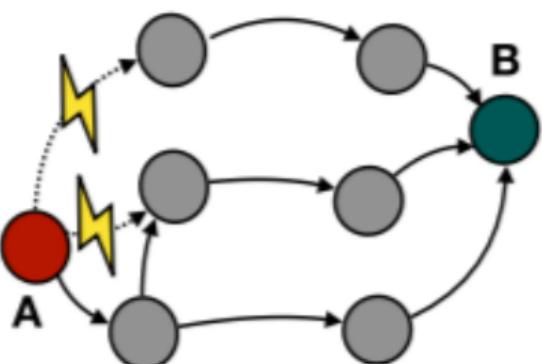
SOURCE: United Nations Commodity Trade Dashboard (2020)



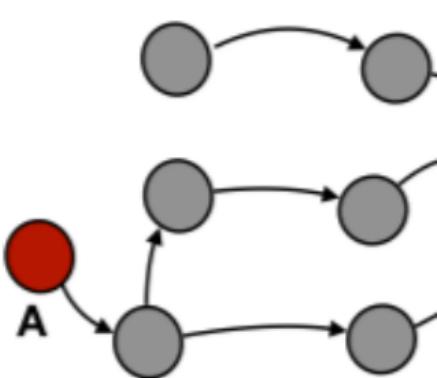
# Redundancy ~ Efficiency



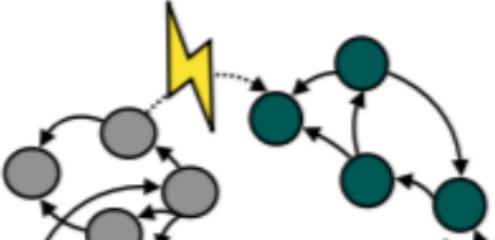
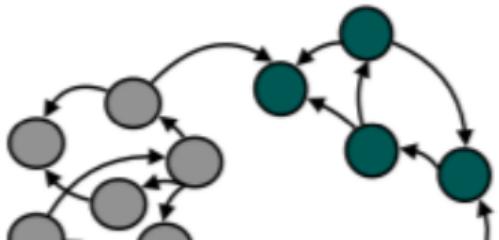
Redundant pathways between  
A and B



Shock in the system



Perseverance of pathw  
between A and B



$$H = - \sum_{i=1}^n p_i \ln(p_i)$$

$$\Psi = -k \sum_{i=1}^{nn} \sum_{j=1}^{nn} \frac{T_{ij}}{T_{..}} \ln\left(\frac{T_{ij}^2}{T_{i..} T_{..j}}\right)$$

has been a widely used approach in the literature as it takes into consideration both variety and balance (Sterling, 2010). It is defined as:

$$H = -\sum_i p_i \ln(p_i)$$

Here  $p_i$  indicates the proportion of category  $i$  within the total categories. The above formula can be rewritten in terms of systems process as:

$$H = - \sum \frac{T_{ij}}{T_{..}} \ln \frac{T_{ij}}{T_{..}}$$

Where,  $T_{ij}$  represents the effect that element  $i$  has on element  $j$  and the period signifies summation over that index.

From the above formulas it is evident that a higher value of  $H$  indicates

and conditional entropy of a network system (Rutledge et al., 1976; R.E. Ulanowicz & Norden, 1990) is used to define redundancy ( $\psi$ ) as:

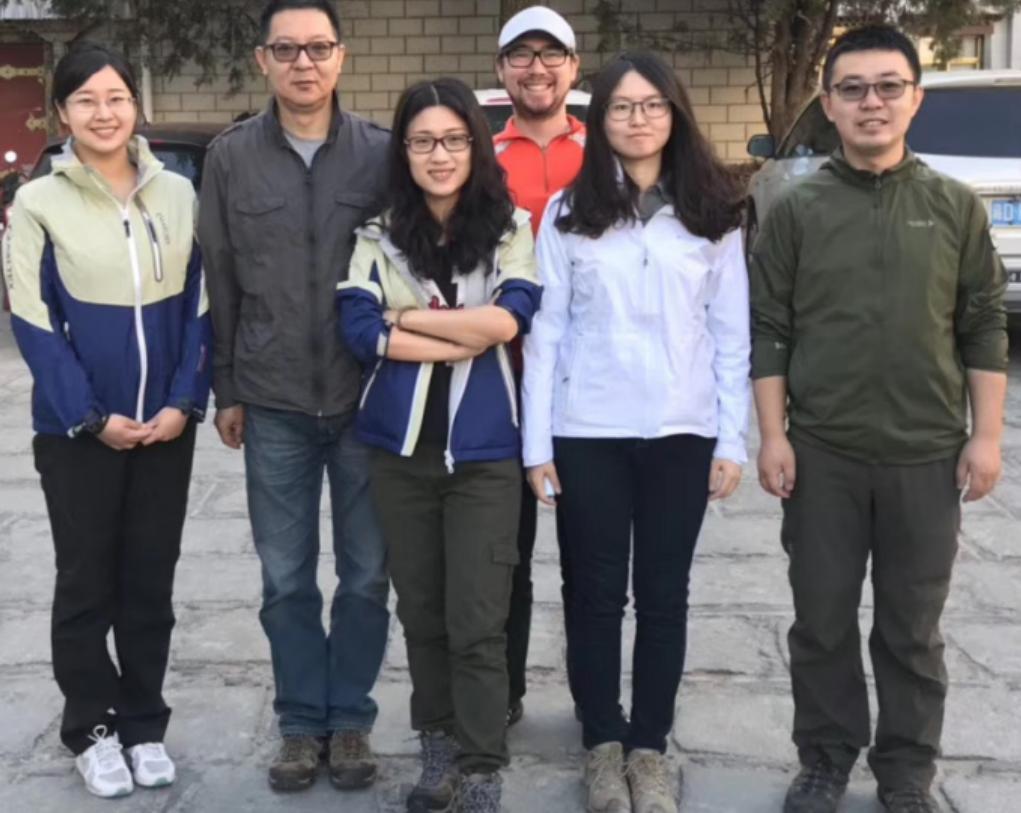
$$\psi = -k \sum_{i,j} \frac{T_{ij}}{T_{..}} \ln \frac{T_{ij}^2}{T_{i..} T_{..j}}$$

Here,  $T_{ij}$  is the flow from node  $i$  to node  $j$ ,  $T_{i..} = \sum_j T_{ij}$  is the total flow leaving node  $i$ ,  $T_{..j} = \sum_i T_{ij}$  is the total amount of medium entering node  $j$  and the sum of all flows in the system,  $T_{..} = \sum_{ij} T_{ij}$ , is known as the “total system throughput” (TST).

Redundancy refers to the replication of pathways, functions, or compo-



























林芝

LIN ZHI





后院  
车库

WiFi

严厉

自然保护区  
杨尚昆  
一九八九年





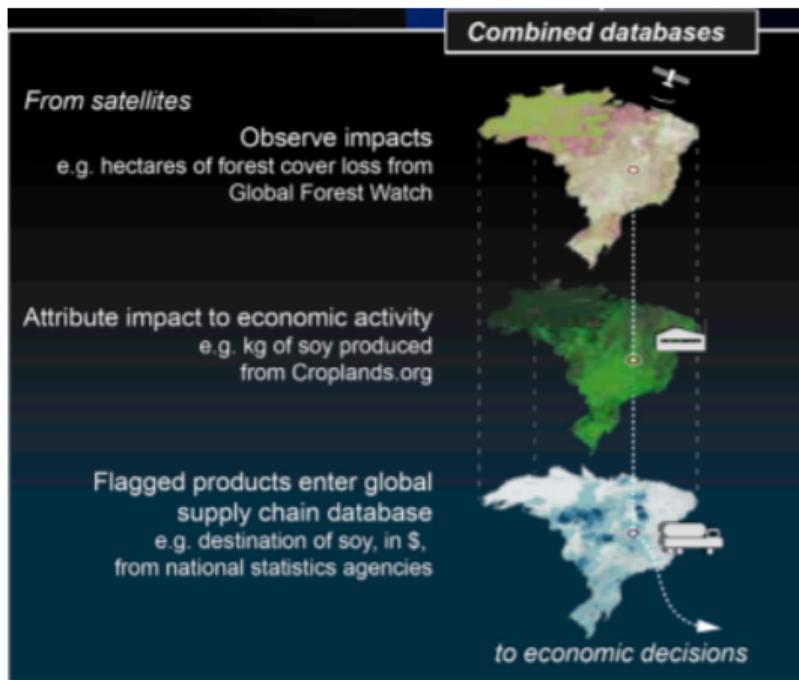
# **China's Forest Networks: Global**

# China's Forest Networks: Domestic/Local

- Localization of resource consumption increases modularity
- This is line with recent observations of the benefits of empowering local communities for forest restoration
-

## Future Work

# Future Work



## Cool Projects to Check Out

- [www.globalcanopy.org](http://www.globalcanopy.org) - Financial Sector Transparency
- [www.fineprint.global](http://www.fineprint.global) - Product Sourcing Analysis
- [trase.earth](http://trase.earth) - Stakeholder and Investor Information

## Acknowledgements



[1] [2] [3] [7]

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-  D. Schaffer-Smith, S. A. Tomscha, K. J. Jarvis, D. Y. Maguire, M. L. Treglia, and J. Liu.  
Network analysis as a tool for quantifying the dynamics of metacoupled systems: An example using global soybean trade.  
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