

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

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

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- Intro/Context
  - Forests are globally important
  - Anthropocene effects
  - Global forest loss and gain and change
    - Global greening = India(Agriculture) + China(Forests)
- Economics\*Ecology = Landscape Extended Models
- Network Analysis of China's Greening
  - Global Scale
  - Local Scale
    - Landscape = Chen 2019
    - Resilience Analysis of China's Forest LE-MRIO
- Conclusions and Future Work
- Acknowledgements

# Overview

## Globally Forests are Important

- biodiversity
- water and nutrient cycling
- carbon storage
- resources(wood, food)
- culturally

# The Anthropocene

- Humans = dominant global impact -> Anthropocene
- Global = Climate Change
- Indirect Effects Significant

# In the Anthropocene, Economy is Global Ecology

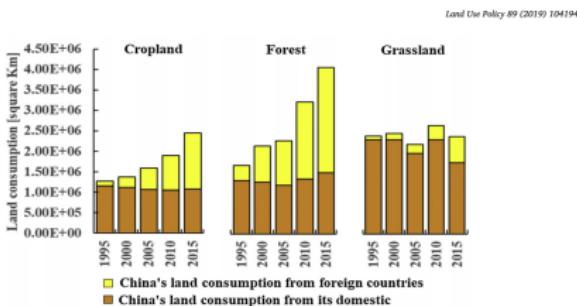
- Economic trade data is a window into human impacts
- Brief history of IO and ENA analyses
- Global Trade Models
- Trade Networks  $\text{MRIO} = \text{Sectors} + \text{Regions}$
- Environmental Extensions
- Forested Landscapes and Embodied Trade Networks

## Interactions/Trade = Complex Systems

- Indirect effects and The far reach of the city
- Complex systems = many players and indirect effects matter (surprising)

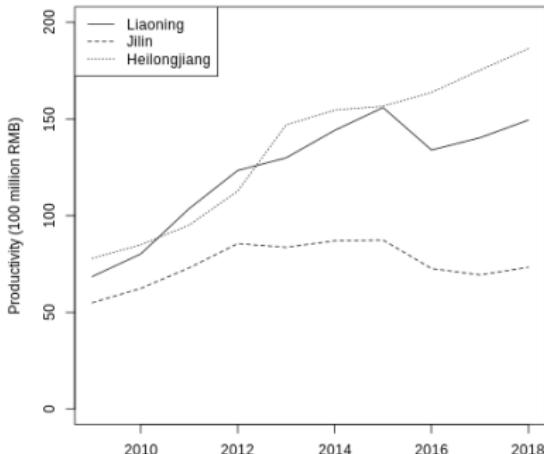
# A little money moves a lot of forest.

- Tian et al. 2019 showed that China consumes an equivalent amount of domestic cropland as forest land, on the order of  $10^6 \text{ km}^2$ .
- Looking at the domestic landuse productivity data for China, forests have the lowest monetary productivity.
- Thus, per unit monetary output a relatively larger amount of forest land is used.

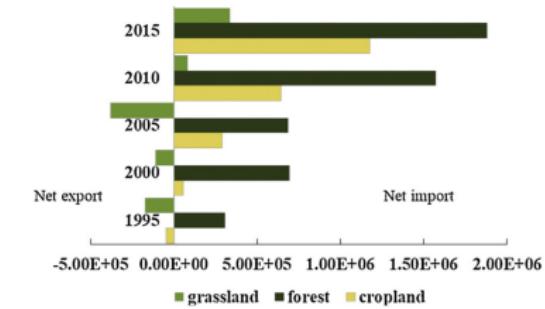


# A little money moves a lot of forest.

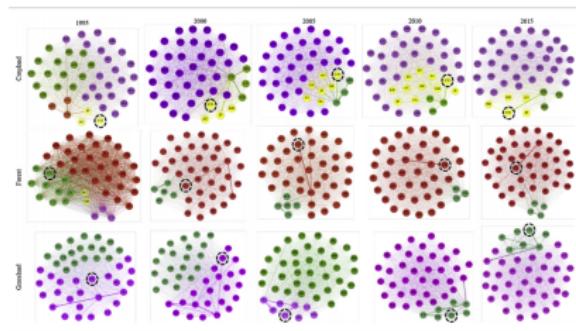
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# Global Landuse Trade and China



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# Background: Input-Output Models

## The Review of Economic Statistics

VOLUME XVIII

AUGUST, 1936

NUMBER 3

### QUANTITATIVE INPUT AND OUTPUT RELATIONS IN THE ECONOMIC SYSTEM OF THE UNITED STATES

#### INTRODUCTION

The statistical study presented in the following pages may be best defined as an attempt to construct, on the basis of available statistical material, a quantitative *Input-Output* of the United States for the year 1935.<sup>1</sup>

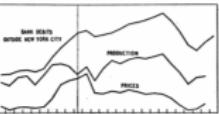
One hundred and fifty years ago, when Quesnay first published his famous schema, his contemporaries and disciples acclaimed it as the greatest "invention" since Newton's laws. The idea of general interdependence existing among the various parts of the economic system has become by now the very foundation of economic analysis. Yet when one considers the exacting application of this theoretical tool, modern economists must rely exactly as Quesnay did upon fictitious numerical examples. What would be the present state of the theory and policy of international trade if, instead of actual balances of foreign trade, the economist had to base his analysis upon assumed numerical set-ups supplemented by scattered items of actual statistical information? This is the situation in which the theory of economic organization at present stands when it comes to a problem of national production, consumption, and distribution. Despite the remarkable increase in the volume of primary statistical data, the proverbial boxes of theoretical assumptions are in this respect as empty as ever. Considerable progress has been achieved in the field of national income statistics. The economic balance of some of the most important branches of the national economy, particularly

The publication of this preliminary survey is prompted by the conviction that the inevitable path of any empirical research is that of trial and error.

Governmental publications constitute the main source of primary statistical information used in this study. Additional data were gathered from trade publications, and in some instances the results of special investigations have been utilized. In many cases, use was made of the work of the National Bureau of Economic Research on national income.

At the time that this study was initiated (1935) the publication of the detailed results of the 1930 Census was still far from complete. As a result, the Census of 1930 had to be used. It is because of this fact that the entire investigation is based on 1930 data.

CHART I.—SERIES INDICATIVE OF BUSINESS CONDITIONS



The general business conditions prevailing during that year are described in W. L. Thorp's *Business Annals* in the following terms:

## Background: Input-Output Models

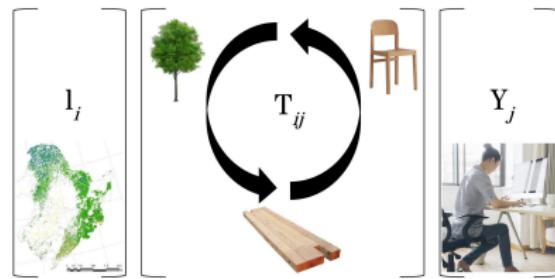
- How do we quantify and manage systems?
- Input-Output Analysis provides a modeling framework
- Direct consumption
- Trade occurs among sectors == Indirect consumption
- IO and MRIO models
- A new equation for a new era in science  $E = F(I-A)^{-1}$

# Background: Input-Output Models



# Background: Environmental Extension

- Allows for indirect/consumption based accounting



# Background: Environmental Extension

The diagram illustrates the environmental extension equation:

$$L_j = l_j + T_{ij} \cdot Y_j$$

The components of the equation are represented by icons:

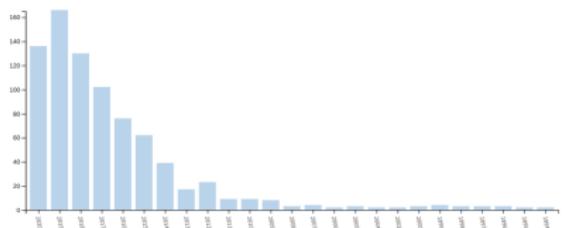
- $l_j$ : Land area used by region  $j$  (represented by a landscape image).
- $T_{ij}$ : Total area used for one monetary unit for a sector (represented by a tree icon).
- $Y_j$ : Final consumption (not used to create additional products) (represented by a person working at a desk icon).

A large black arrow points from the  $T_{ij}$  term to the  $Y_j$  term, indicating the flow of land area used from production to final consumption.

Below the equation, definitions are provided:

- Land area used by region  $j$
- Total area used for one monetary unit for a sector
- Input from one sector used for one unit output of a sector
- Final consumption (not used to create additional products)

# wos\_mrío\_time.jpg



# wos\_mrío\_auth.jpg



# wos\_mrio\_funding.jp





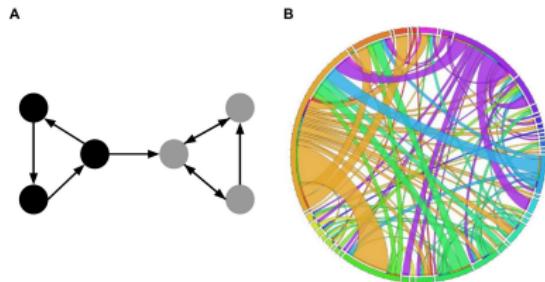
# wos\_mrio\_region.jpg



# Background: Networks are Everywhere



# Background: Networks are Everywhere



## Background: Ecological Network Analysis

- Ecological network theory provides predictions and metrics (Lau 2017)
- Systems theory provides strategies for interventions
- ENA <- Odums, MacArthur, Ulanowicz, Patten,
- SNA -> ecological networks (Watts and Strogatz, etc.)
- Structure linked to function (Donella Meadows)

# Which metric?

# Why information metrics?

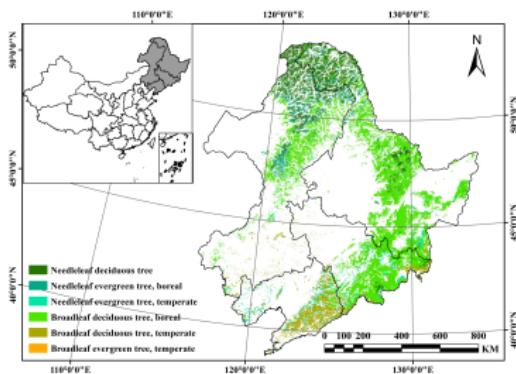
## Research: Why Chinese Forests?

- Work = Forest Land Embodied in Trade

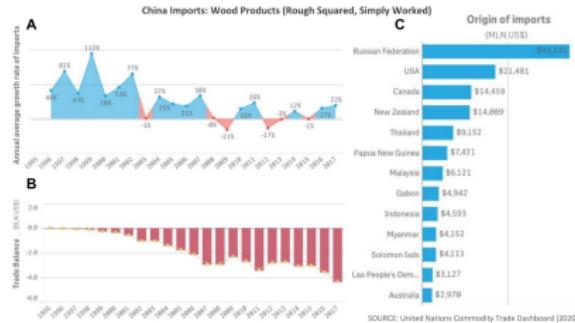
# A Brief History of Forest Time in China

- China is big and diverse
- Long history of human habitation in China
- Historically, two primary regions of forestry
- Forest conservation impacts harvest
- Flows within China and among countries globally important

# Research: Why Chinese Forests?



# Research: Why Chinese Forests?



# Methods: Model MRIO<sub>China</sub>

**Table 1**  
The structure of the ecological MRIO account.

		Intermediate use		Final demand				
		Region 1	... ...	Region m	...	Region 1	... ...	Region m
Input	Output	Sector 1	...	Sector n	...	Sector 1	...	Sector n
		Region 1 Sector 1 ... Sector n	...	Region m Sector 1 ... Sector n	...	Region 1 Household consumption Non-market consumption Government consumption Business investment ...	...	Region m Household consumption Non-market consumption Government consumption Business investment ...
Intermediate inputs in regions		$x_{ij}^{ex}$		$f_i^T$				
Primary inputs		$p_j^S$						
Exogenous environmental inputs		$u_j^S$						

# Methods: Model MRIO<sub>China</sub>

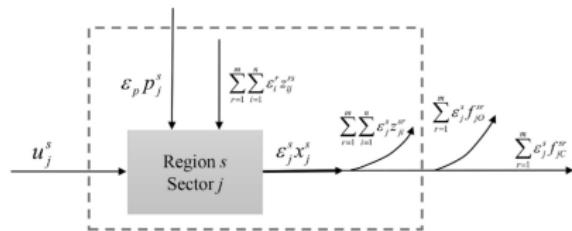
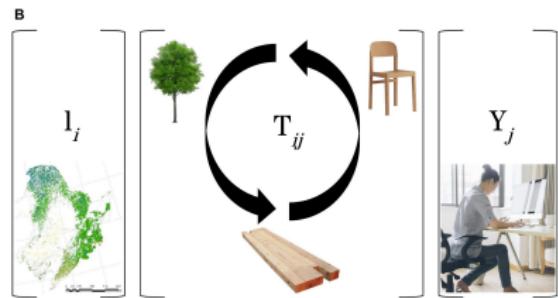


Fig. 2. Resource use flows for Sector  $j$  in Region  $s$  within the world economy.

# Methods: Environmentally Extended Model

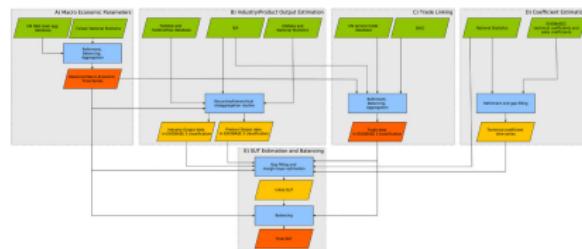
## MRIOD<sub>China</sub>



# Methods: Model Source

NEED TO ADD FIGURE WITH DATA FLOWS

*Maybe check the Mi 2018 supp mat*



## Main Focus of Research

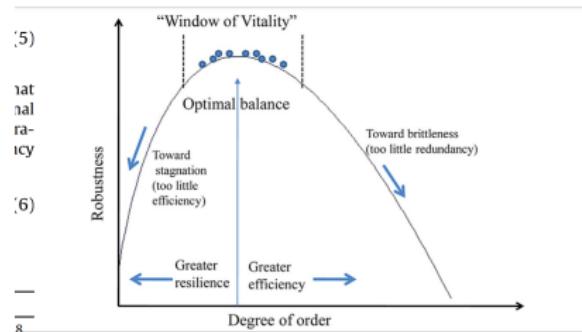
- ① What research has been done on forest or forest landscape embodied networks?
- ② What is the network structure? How can we characterize it?
- ③ What can we say about the potential system dynamics based on network structure?

# Research: Network Analysis

- LEMRIO global (Tian 2019)
- LEMRIO local (Chen 2019)
- Your LE-MRIO China
- Your ENA analysis
  - Small world
  - Modularity
  - Centrality
  - Control
  - Resilience

# Research: Structural Analysis

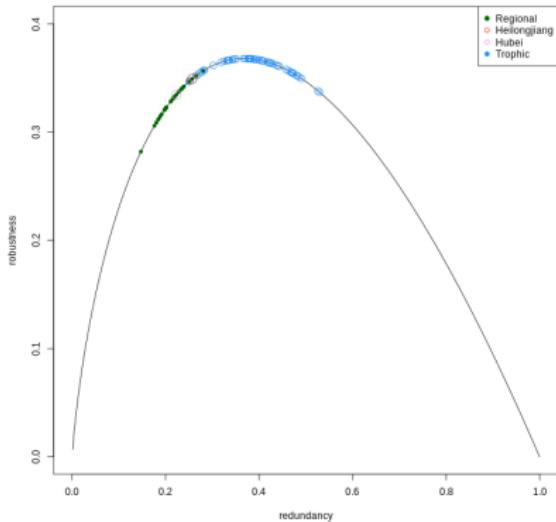
- Analysis = Structure = Robustness



## Research: Structural Analysis

- Overly efficient = Brittle
- Overly redundant = Stagnant
- Both can lead to niche openings
- Niches can then be filled by natural selection, adaptation or invasion

# Forest Landscape Networks are More Efficient but Less Robust

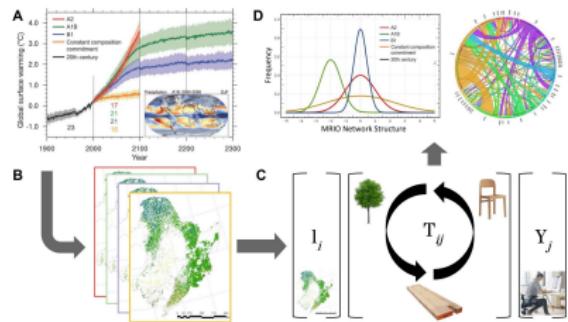


## Caveats

- Limitations of MRIO
- Potential impacts of storage lags and buffers

# Future: Next up, climate change variability

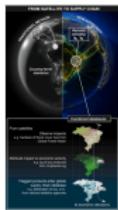
- Next up = Climate change impacts and global scale



# Future: Next up, climate change variability



# Future Work: Remote Sensing Trade Models



## Q & A