Body of the proposal

Summary (Abstract)

Earth ecosystems are under threat from the impacts of anthropogenic effects on ecosystems. Quantifying, understanding and ultimately predicting and mitigating these dynamics requires an approach that recognizes the coupling of ecological and human systems and the importance of accounting for both direct and indirect effects. Ecosystems in China, particularly the heavily forested, high latitude north eastern region, are likely to undergo large responses to climate change, resulting in significant impacts to biodiversity and industries that rely on forest products. Work in the fields of evolutionary ecology and ecological genetics have demonstrated the importance of evolutionary dynamics in ecosystems; therefore, assessing the evolutionary potential of ecosystems to respond and/or influence human systems will provide useful insights. In this project, we will synthesize the recently advanced framework of landscape extended multi-region input output (LE-MRIO) economic modeling with forest landscape simulations of climate change impacts. We will then use systems based sensitivity analysis to examine how including trait variation in dominant tree species could influence the flow of forested landscapes embodied in trade. This work will not only introduce evolution into models of coupled human-natural systems, it will also produce potentially useful insights into the dynamics of an ecologically and economically important region of China.

Keywords: forests, dynamics, traits, networks, distribution modeling

1. Introduction

Planetary systems are being impacted by human actions. Because the magnitude of these impacts are comparable to planetary-level fluctuations observed on geological time-scales, many scientists have identified the current age in Earth's history as the Anthropocene (*sensu* Ellis et al. 2010). Perhaps the most threatening human impact is the increase in the mean global atmospheric temperature of the Earth, which is rising at a rate in-line with the worst-case scenarios (IPCC 2018). Even seemingly small changes in global temperatures are predicted to have large-scale impacts on marine and terrestrial ecosystems. Regardless of the cause, evidence of the impacts of the observed rise in temperature has already been documented: such as, sea level rise, desertification, increased drought, decreased crop productivity and higher rates of extinction. Combined with the increasing pressure on natural resources from an increasing global population and urban expansion, particularly potable water and arable land for agriculture, it is imperative that ecologists work to predict climate change's impact at the interface of natural systems and human society and the important socio-ecological relationships that they form (MEP Report 2009, FAO Report 2017, Liu et al. 201?, Winters *et al.* 2019).

The influence of indirect effects and emergent properties in the context of globalized human-natural systems necessitates an approach that can both quantify and provide a rigorous theoretical framework to study system structure and dynamics. Network theory (Wasserman and Faust 19??) with its basis in the mathematics of graphs and dynamical systems (Meadows et al. ????) provides this framework and has been applied across the sciences (Watts and Strogatz 199?, Sole' and Bascompte 200?, Borrett et al. 2018). The network approach has been applied successfully in ecology for decades, and over the last decade ecological network analysis has exploded in the literature (Borrett et al. 2014). In particular, the formalized nature of network theory has facilitated the development of specific hypotheses about the stability and resilience of systems in general that have applicability to ecosystem dynamics. For example, networks that are modular (i.e. that are comprised of interconnected sub-systems) have been demonstrated to be more resilient to perturbations; and this phenomenon has been observed in real ecological networks (Bascompte et al. 2005, Bastolla et al. 2009). This approach of linking network structure to function has been used to study a vast array of systems: including, disease transmission in societies (CITATION), the stability of food webs (Odum, Patten, Ulanowicz) and pollinator interactions (Bascompte and Jordano ????), the spread of invasive species (CITATION) and the habitat connectivity of threatened and endangered species (Dickson et al. 2018).

At least two significant challenges have limited the ability of scientists to study coupled human-natural systems (*sensu* Liu et al. 201?) from a network perspective: integrative analytical approaches to bridge research silos and reliable access to data quantifying system structure. Recently, advances in the field of multi-regional input-output modeling of economic systems (MRIO) (Leontief 195?) have developed tools that address both of these issues (EXIOBASE3-rx CITATION) and reviews and synthesis papers have begun to reconcile the overlapping theory previously isolated in separate disciplines (e.g. Lau et al. 2016, Liu et al. 2019, Weidgman et al. 2019, Borrett et al. 2019). The MRIO apporach, popularized by the Nobel Laureate Wassily Leontif (195?), was developed to analyze the interdependencies of industries within and among economies, which provided a means to quanitfy the effects of traded items from raw materials or "inputs" (e.g. wood, metals, oil, corn) to consumed products or "outputs" (e.g. chairs, knives, gasoline, chips). This inherently lead to the further development of methods to assess environmental extensions (EE) that quantified the impacts of industries that were related to production but were not considered products themselves, such as environmental pollutants (CITATION). More recently, these EE-MRIO have been used to quantify important ecological (CITATIONS), including landscape extensions (LE-MRIO) (Chen et al. 2019) (Fig. 1), and sociological (CITATIONS) factors related to climate change. Over eight decades an immense amount of MRIO models have been produced, but until the last decade models at the global scale with sufficient resolution were inconsistent and difficult to access and analyze. However, the recent release of the EXIOBASE3 that contains a global MRIO with regional details that can be used for the quantification of environmental and social extensions provides the means to conduct analyses involving landscape processes that were previously intractable within a coupled human-natural system context (EXIOBASE3rx CITATION).

As ecosystems are comprised of biological organisms that can respond not only ecologically but also evolutionarily, it is important to understand the roles that processes such as adaptation and natural selection might play. The interplay between ecological processes (e.g. birth, death, migration) evolutionary dynamics (e.g. adaptation, speciation, radiation) has been studied intensively within the field of ecological genetics (*sensu* Conner and Hartl 2004). Ecological properties, such as ecosystem functioning (Tilman 2001, Hooper et al. 2002, Violle et al. 2007), stability and productivity (Díaz and Cabido 2001, Tobner et al. 2013), and resilience against disturbances and environmental gradients (Laliberte et al. 2010, Sakschewski et al. 2016), are typically approached with the assumption that intraspecific trait variability (ITV) is negligible compared to interspecific trait variability, which leads to species is generally characterized by mean trait values (Albert et al. 2011). However, numerous studies have challenged this assumption by showing that ITV significantly affects various ecological processes (Laurans et al. 2012, Schoeb et al. 2013), and it is likely that such variability is an overlooked but important part of ecosystems worldwide impacting whole communities and ecosystems (Whitham et al. 2008) (Figure 2). Some studies have observed geographical trends in functional traits from a geographic or ecological perspective (Swenson and Enquist 2007), and numerous studies have documented significant correlations between ITV and climatic variables (i.e., temperature, precipitation, soil) and environmental gradients (i.e., latitude and elevation) (Hulshof et al. 2013, Meng et al. 2017, Salazar et al. 2018). Evolutionary impacts of climate change in plant species have already been observed (Parmesan 2006), and further studies have indicated that climate change will also be acting on processes and properties that only occur at the level of whole systems and ecological networks observed for associated communities of forested ecosystems (Solance et al. 2015, Lau et al. 2016, Keith et al. 2017).

The overarching goal of this project is to quantify how climate induced changes to forests will impact the structure of couple human-natural systems, focusing on the ecologically and economically important forests of China. Although previous work has presented the risk of climate change and its influence on forest ecosystems (Shi et al. 2018) and the important influence of the indirect effects of humans on natural ecosystems via landscapes embodied in LE-MRIO (Chen et al. 2019), a recent academic literature search using Academic Search Premier (CITATION) yielded no studies of either theoretical nor empirical investigations into the potential impacts of intraspecific variation on landscapes and their emobided trade in human systems via LE-MRIO. Taking advantage of the recent developments in global LE-MRIO databases (EXIOBASE3rx CITATION), trait-based models of plant responses to climate change (ADGVM CITATION) and ecological network analyses (Lau et al. 2016, Borrett et al. 2017, Hines et al. 2018, Huang and Ulanowicz 201?), this study will assess the evolutionary potential of the dynamics of these systems using a trait-based approach that incorporates empirical studies of tree species ITV in the forests of NE China. Although substantial work has been done examining the links between ecological and human systems through the lense of economic trade models and the impacts of climate change on trait variation in forest tree species and their associated communities, we are not aware of any studies that have yet examined the ecological network structure of coupled human-natural systems and their evolutionary potential within a single study, and, therefore, this work will be a significant advancement in our understanding of and ability to predict the complex dynamics of ecosystems in the Anthropocene.

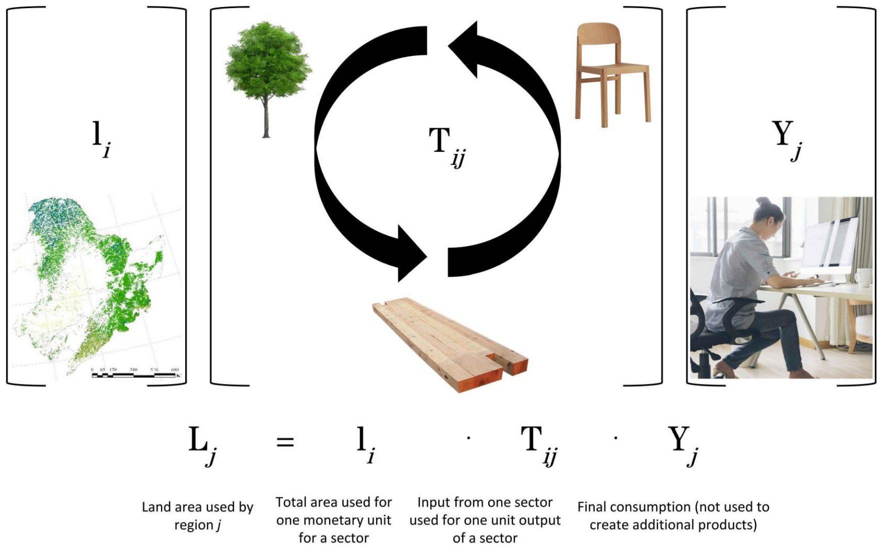

Figure 1. The generalized environmetnally extended MRIO model applied to quantifying embodied landscapes, such as forests. A vector of landscape usage values (**l**$_i$) for all industries across regions within different nations is multiplied by the matrix of inter-regional trade of goods produced by each region (**T**) and finally consumed in a given region (**Y**). This quantifies the percent of each producing region's forest landscape that is used to produce each unit of goods that are traded with other regions (**L**$_i$). More details on the underlying structure of multi-regional input-output (MRIO) models can be found in the original work of Leontief (19??) and more recently applied to landscapes in China (Chen et al. 2019).

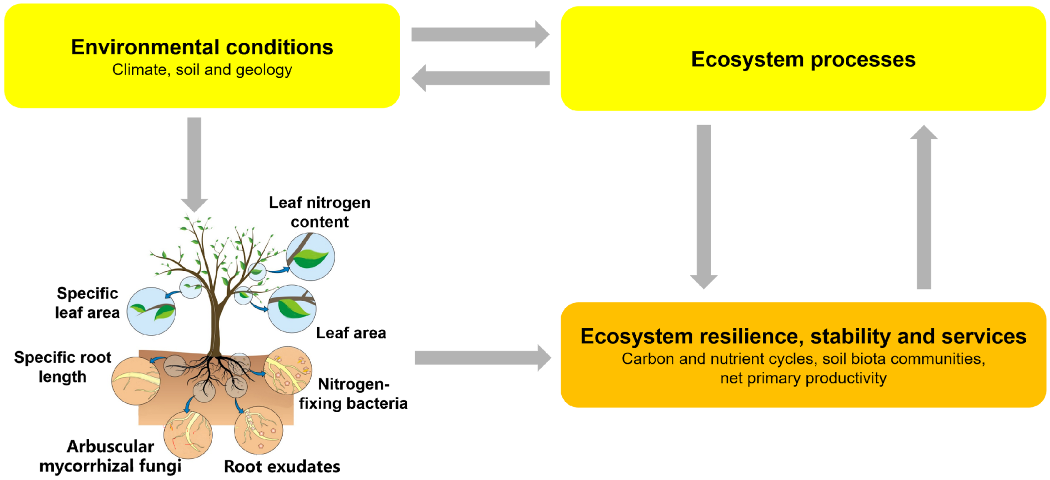

Figure 2. Accumulating evidence from recent studies support the relationship among traits associated with the response of organisms to environmental conditions, such as climate, soil and geology, and traits that determine effects of organisms on ecosystem resilience, stability and ecosystem services, which is a key point of coupling humans and natural systems.

2. Research contents

2.2 Specific research contents

Compile potential ranges of intraspecific trait variation from the literature for use in simulations of the geographic distribution of forest tree species in NE China.

Study the intraspecific trait variation (ITV) patterns of dominant tree species along latitude gradient in NE China. We will conduct field survey to measure functional traits of the four dominant tree species and then test intraspecific trait variability across latitude gradient.

We will model and predict the responses of forest tree species to climate change with the compiled trait data and surveyed functional traits from this region.

Species distribution predictions using a range of climate scenarios will used to parameterize landscape extended multi-region input-output (LE-MRIO) for NE China and its global economic trade network.

LE-MRIO will be analyzed using a network theoretic approach as developed in the field of ecosystem network analysis (ENA).

This project uses a global analysis framework and focuses on NE China forests for an empirical investigation of the models, mainly adopting the methods of remote sensing, field investigation, laboratory analysis and model simulation (Figure 3).

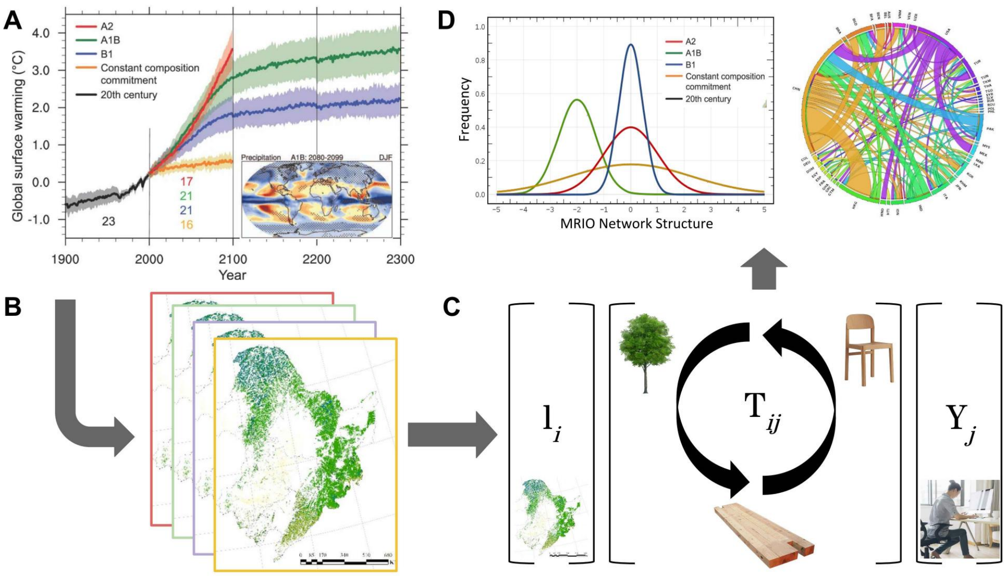

Figure 3. Flow diagram of the overarching modeling workflow linking trait variation (ITV) in forest species to the network structure of forest landscapes embodied in LEMRIO. First, (A) climate change models will be used to generate (B) species disitributions for forests in NE China both without and with intraspecific trait variation (ITV), which will be both simulated, using published trait ranges for species within this range, and emprical, employing trait observations from field sites in NE China. The predicted ranges of forest species will be used to parameterize (C) landscape extended multi-region input-output models (LE-MRIO) as projected into the future by market-based transition models. Last, the forest landscape networks embedded the resulting LE-MRIO will be analyzed using ecosystem network analysis (ENA) to study the potential impact inluding trait variation could have on our predictions of the structure and function of coupled human-natural systems in forested landscapes.

3. Research design & methodology

3. Overarching framework

3.1 LEMRIO Modeling

3.2 Trait Based Modeling of Forest Responses to Climate Change
3.2.1 Trait simulations for ranges of forest distribution

3.3 Trait empirical work in NEC
3.3.1 Study Area
3.3.2 Sampling

3.4 Ecological Network Analysis of LEMRIO

3.5 Data and Analytical Software Management

3.1 Coupled Human-Natural System Modeling Using LE-MRIO

LEMRIO and coupled human natural systems brief overview

Although ecologists have been employing sytems and network apporaches for over 75 years, the sioling of theory and empirical work into various subdisciplines has slowed its development. The MRIO framework was imported from Leontif's early work into ecology by Hannon (19??). This lead specifically to the field of ecosystem network analysis (ENA) and contributed to the development ecological network theory (Lenzen 2007, Fath et al. 20??, Huang and Ulanowicz 201?).
NETWORK STRUCTURE INFLUNCES NETWORK FUNCTION

- When did the analysis of the properties of graphs begin (Euler)? In ecology?
- diversity-stability (MacArthur 1955, May 197?)
- ecosystem flows and indirect effects (Odums)
- complex systems (Meadows)
- small world (Watts and Strogatz)
- network evolution (Ulanowicz)

Models will be obtained from EXIOBASE3, which has recently released global MRIO along with associated data to calculate environmental extensions, such as embodied forest landscape.

- EXIOBASE3
- EXIOBASE3-rx
- EXIOBASE-futures? -> FUTURE WORK

3.? LEMRIO Analysis with ecological network metrics

- Extending software from previously developed community genetics modeling and network analysis packages in R (Lau and Borrett 2014, Borrett et al. 2014).
- Ascendency and the Window of Vitality
- Control Analysis
- Cycle Analysis
- Stability = Robustness = Size of the Largest Component?

3.1.1 Study area

NE China is one of the most important forest regions in the country. The forests here account for approximately 35% of the total forest area, 50% of the national timber production and 40% of total forest biomass for all of China (Zhou 1997, Fang et al. 2001, Wang et al. 2006). Given the importance of this region to the nation, the muti-decade trend of warming at higher latitudes (Peng et al. 2009, Piao et al. 2010) has major consequences for these ecosystems, such as shifting biomass and biodiversity and reducing productivity and stability (Piao et al. 2006, Peng et al. 2011, Fang et al. 2014).

In the past few decades, studies have demonstrated that forested ecosystems in the middle and high latitudes of the Northern Hemisphere are especially vulnerable to climate change (Chapin et al. 2005, Lloyd and Bunn 2007, IPCC 2018). The potential impacts and interactions of climate change on northern forest ecosystems have aroused considerable attention in the global carbon cycling and climate change impacts research (Bonan 2008, Keenan et al. 2013). The forest region of Northeast China distributes from middle to high latitude, acting as an important ecological green barrier and carbon sink (Wang et al. 2008, Fang et al. 2014). Past climate research shows that Northeast China is very sensitive to global warming and is one of the most significant warming areas in both China and the world (Wang et al. 2003, Shi et al. 2018, Su et al. 2018).

The primary research focus will be comprised of Heilongjiang, Jilin, Liaoning provinces, and eastern part of Inner Mongolia Autonomous Region (Figure 3). The latitude and longitude range from 38°43′-53°34′ N and 115°37′-135°5′ E, respectively. Geographically, this region is characterized by plains separated by three mountain areas: Changbai-Zhangguangcai Mountains, Xiaoxing'an Mountains and

Daxing'an Mountains, and the majority of forests in NE China are distributed in these mountain regions (Wang et al. 2006). The climate in NE China is controlled by the high latitude East Asia monsoon, changing from warm temperate to cool temperate zones latitudinally and from humid to semiarid zones from east to west (Wang et al. 2006). The NE China has all major forest types of northeast Asia, including temperate broadleaf deciduous, broadleaf evergreen, and needle leaf evergreen, and boreal broadleaf deciduous, broadleaf evergreen, and needle leaf evergreen forests. Considering the distribution areas and ecological functions, we attempted to select two to three dominant tree species for each forest type to measure intraspecific trait variation along with latitude gradient in NE China.

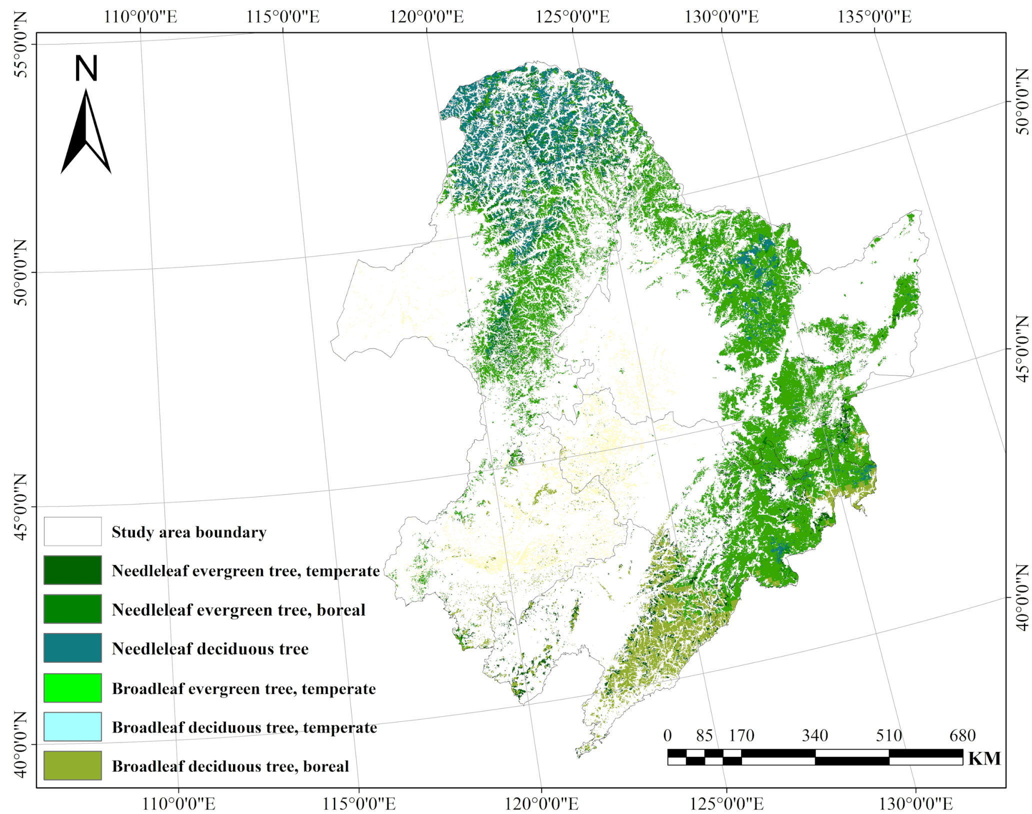

Figure 3. The distribution area of dominant forest types in NE China

3.3 Sampling design and field survey

Considering the objectives of this project, we will measure intraspecific changes in forest tree functional traits across latitude in NE China study area. In this region, we will select 15 sites along the latitudinal gradient (Figure 3). We will conduct vegetation measurements during the growing season from July to August. At each site, we will conduct field surveys to sample all individuals at similar phenological stages for all species. To determine the spatial structure of the intraspecific functional trait variability, we select three to five sites (depending on site availability) along the latitudinal gradient (Table 1). In each site, we will randomly allocate three to five 20 × 20 m plots to conduct all measurements, including the diameters at breast height (1.3 m above the root collar) of all trees within the plot.

To determine the intraspecific trait variation along the climatic gradient, we will use the mean annual temperature (MAT) and mean annual precipitation (MAP) from weather stations that are as close as possible to the sampled sites. In each plot, we will randomly sample three soil cores and collected about 250 g of mineral soil at a depth from 0 to 15 cm in each soil core. Fresh soil samples will be placed in sealed plastic bags, marked with plot information, and transported to the laboratory following collection. We will measure gravimetric soil moisture with fresh soil samples dried at 105 °C for 48 h. Other fresh soil samples will be air-dried and ground in order to pass through a 2 mm sieve. We will then measure soil pH using an Accumet AB15 pH meter (Fisher Scientific, Pittsburgh, PA, USA) with a 1:2.5 air-dried soil to water ratio. Soil nitrogen will be measured using a wet Kjeldahl digestion method. Soil phosphorus is determined by a $HClO_4$-H_2SO_4 microwave digestion Mo-Sb colorimetric method. All physical and chemical analyses will be conducted according to the Standard Methods for Observation and Analysis in Chinese Ecosystem Research Network (Liu 1996). We will average the values of three samples at the same plot as representatives of soil nitrogen and soil phosphorus of the plot.

3.4 Functional trait measurements

There are a large number of potentially related traits that reflect species ecological strategies, determine how plants respond to environmental factors and influence ecosystem properties (Kattge et al. 2011, Pérez-Harguindeguy et al. 2013). The functional traits we selected for all recorded tree species are closely related to light capture, resources utility, growth, and productivity (Meers et al. 2010, Sabatini et al. 2014, Refsland and Fraterrigo 2017). The selected functional traits and related physiological-ecological functions are listed Table 1. Functional trait were selected using criteria from the handbook for worldwide functional traits measurement (Pérez-Harguindeguy et al. 2013). According to the handbook, we sample at least 10 individuals for each observed species in each sampled plot. All sampled individuals will be reproductively mature and visually healthy.

Table 1. Functional traits measured in this project.

Functional traits	Physiological-ecological functions	Type	Unit
Leaf area	Light capture, leaf transpiration	Continuous	mm^2
Leaf carbon concentration	Leaf structure	Continuous	mg/g
Leaf dry matter content	Resistance to physical hazards	Continuous	mg/g
Leaf nitrogen concentration	Photosynthesis	Continuous	mg/g
Leaf phosphorus concentration	Photosynthesis	Continuous	mg/g
Life history	Environmental stress regimes	Categorical	mg/g
Plant height	Competitive vigor	Continuous	m
Specific leaf area	Photosynthesis, growth rate	Continuous	cm^2/g
Specific root length	Water and nutrient absorption	Continuous	cm/g
Stem specific density	Stability, defense, architecture, hydraulics, C gain and growth potential of plants	Continuous	g/cm^3
Tree band	Growth rate	Continuous	cm

3.5 Simulations with Trait Value Ranges to Estimate the Impacts of Intraspecific Variation

The Adaptive DGVM will be used to with variable trait inputs over a range possible trait values for each species. A similar approach has been employed to conduct sensitivity analyses in ecosystem networks (Hines et al. 2017).

3.6 Trait-Based Modeling and Statistical analysis

We will first compare the mean values, standard deviation, and coefficients of variation (CV) of the continuous traits for the studied tree species. Then we will fit a general model across three nested scales (individual, plot and site) with the method of restricted maximum likelihood (REML) in R 3.4.1 (R Development Core Team 2017) using the *lme4* package (Bates et al. 2014). Based on the result of the general model, we will quantify the intraspecific variation of the traits through variance partitioning across the three nested spatial scales for the full model with the *nlme* package in R software (Pinheiro et al. 2015). To quantify the effects of the climate and soil variables on the functional traits, we will fit linear mixed effect models (LMEMs). In these models, the environment variables are treated as fixed factors, and the plot nest site is treated as a random factor, accounting for the non-independence of the traits within sites and plots. We will build full models with all environmental variables and then select the best models according to Akaike Information Criterion (AIC).

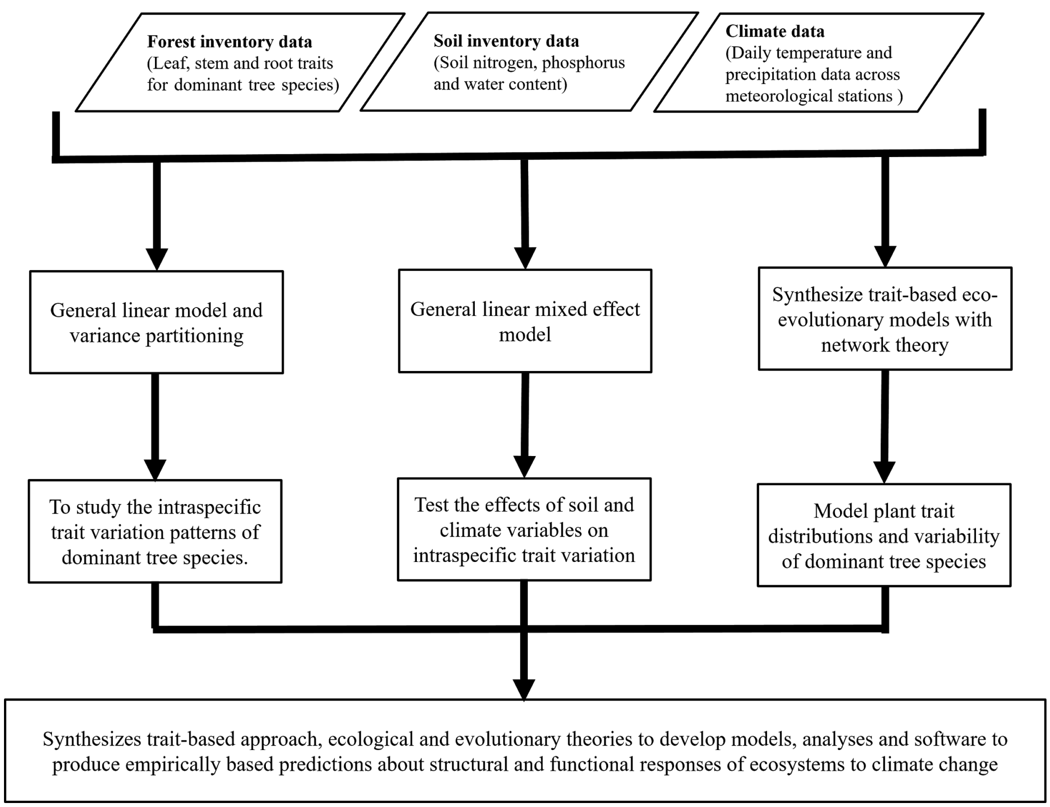

Figure 4. Roadmap of trait-based modeling.

3.? Sensitivity Analysis of Trait-Based Models on LE-MRIO Metrics

Following the general architecture developed by Urban et al. (2016).

The trait-based transfer function predictions will then be coupled to a network modeling framework developed by Lau and collaborators (2016) to predict network level responses to genetically based trait variation in foundation tree species,

We will integrate the surveyed data into the synthesized modeling and analysis workflow (Fig 4) and sensitivity analyses will be performed to explore the potential state-space of ecosystem responses using methods developed previously for MRIO and ecosystem network models (Lenzen 2010, Hines et al. 2016).

4. Features and innovations of the proposal

Model synthesis will produce a more comprehensive framework for examining and predicting the responses of natural systems to environmental change. The formal algebraic unification of the formulae used in these fields, which have been developed separately with distinct variable and parameter conventions, will yield new insights.

The trait modeling alone will produce predictions of forest responses to climate change in China. Given the importance of the natural resources and the unique biodiversity contained in the study area, these findings will provide essential information for making management and policy decisions for these ecosystems and the human systems with which they are connected.

The output from the synthetic workflow will expand our perspective of the potential mechanistic underpinnings of ecosystem resilience and stability. Generally, diversity-stability predictions have lacked defined mechanistic pathways and, therefore, development of causal hypotheses has been challenging. The coupling of trait-based and climate models with network architecture will produce a generalizable causally rooted set of tools for insights into not only the study region in China but also other systems as well.

5. Annual research plan and expected results

5.1 Annual research plan

Timeline	Work content
2020.01-06	Compile relevant studies and write a review from publicly available sources. Formulate field survey plan through analyzing TM satellite remote sensing data, forest facies maps and forest survey data. Conduct model synthesis and write necessary simulation and analytical software.
2020.07-10	Perform field survey according to the plan across all sampled sites. At each site, record environmental variables such as latitude, longitude, elevation, topography, slope position, aspect; measure DBH, height and density for canopy tress species; sample leaves and roots to measure functional traits for all canopy tree species. Perform elemental analysis for root, stem and leaf samples; measure other root, stem and leaf functional traits.
2020.11-12	Compile data and perform statistical analysis; write annual summary report and make next year’s work plan.
2021.01-06	Complete two articles for publication.
2021.07	According to the work plan, perform field survey to supplement field data and related laboratory analysis. Conduct simulations using the empirical trait data and synthesized model.
2021.08	Prepare presentations and attend an annual symposium to present research work
2021.09-2021.12	Compile data and perform statistical analysis; write the third article draft for publication; write the project completion report.

5.2 Expected achievement

Reveal the intraspecific trait variability for dominant tree species along a latitude gradient in NE China.

Predict how forest dominant tree species of NE China respond to climate change according to the trait-based and climate models with network architecture.

Pulished 2-3 SCI articles and assist host institution to support one graduate student

6. Research foundation and working conditions

6.1 Applicant research foundation

The applicant's research interest is using mathematical and computational, data-driven methods to study the forces that impact interactions among species in complex communities. This work has primarily involved using network theory and data synthesis to investigate the potential ecological and evolutionary responses of fungal, insect and food-web interactions, focusing on foundation species. The applicant also conducts research and does educational outreach for promoting an open approach to scientific analyses. The applicant has published 24 SCI articles, 7 articles as the leader author.

The applicant was employed as a postdoctoral research fellow from May 2014 until April of 2018 at Harvard Forest, Harvard University. During this time, he served as a research scientist for several projects funded by the U.S. National Science Foundation (NSF). For all projects, he attended international meetings and presented findings, and was the lead author on multiple publications originating from these projects. The applicant also supervised undergraduates and lab technicians involved in various aspects of the projects. From May 2015 until April of 2016, the applicant served as a researcher on a project investigating the non-linear dynamics of inquiline food webs. For this project, the applicant conducted mathematical modeling and computational simulations of ecosystem dynamics using the Harvard Odyssey Compute Cluster. The applicant used observations from an experiment that manipulated key ecosystem variables to analyze the results of the simulations from the mathematical models. Then, the applicant joined an inter-disciplinary team of researchers that were working on developing computational tools for increasing scientific reproducibility. For this project, the applicant participated in the research (as a domain scientist) and development (as a software engineer) of software tools.

The applicant has been awarded a Postdoctoral Fellow under the Chinese Academy of Sciences President's International Fellowship Initiative (PIFI). The wage provided by the PIFI can cover the subsistence cost during the funding period. The co-supervisor is Dr. Yu Liang, who is the PI of Landscape Progress Group and associate researcher at Institute of Applied Ecology, Chinese Academy of Sciences. Dr. Liang and her research group focus on main forest types of NE China, including Korean pine forest and boreal larch forest. They have conducted a series of field work on forest species composition and ecosystem functions, which will provide the data foundations for this project. They have integrated field survey, spatial modeling and geographical information systems to study the response of forest ecosystems to various natural and social factors over large spatial and temporal domains, which will provide research basis and preliminary conclusion for this study. The members of Landscape Progress Group can help the applicant to conduct field work.

6.2 Working and supporting conditions

This project relies on CAS Key Laboratory of Forest Ecology and Management, Chinese Academy of Sciences, which can provide data foundation for this project. The laboratory focuses on forest ecology and conducts systematic and comprehensive studies on the forest ecosystems of NE China. In Changbai Mountain National Nature Reserve, the host institution have founded the Changbai Mountain Forest Ecosystem Research Station, which has established multiple standard plots for typical forest types (such as 25ha broad-leaved Korean pine forest plots, 5ha poplar forest plots, 4ha spruce forest plot, 4ha larch forest plot, 1ha maple birch pine forest plot, etc.). The research stations have performed long-term comprehensive observation and experimental studies on the structure, function and dynamics of forest ecosystem, accumulated many years of climate and forest inventory data. In Huzhong National Nature Reserve of Great Xing'an Mountains, the laboratories have established long-term observation plots to monitor forest ecosystems structure, function and succession dynamics, providing an ideal platform for field data collection and operation.

The laboratory currently has a series of analytical instruments such as mass-spectrometers, gas phase, liquid chromatographs, and elemental analyzers, which can fully meet the need for sample testing in this project. The Landscape Progress Group has Dell Precision Fixed Workstations with high performance and professional applications. The group also has access to the compute cluster at Tsinghua University, which can be used to run models and simulations. The workstations and compute cluster can meet the needs of spatial data processing and modeling work in this project. The host institution will provide all necessary facilities and environment for working and living to guarantee the project implementation.

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