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YSSP

40th Anniversary

Young Scientists Summer Program

Proceedings of the YSSP Final Colloquium 2017

IIASA's annual three-month Young Scientists Summer Program (YSSP) offers research opportunities to talented young researchers whose interests correspond with IIASA's ongoing research on issues of global environmental, economic, and social change. From June through August each year participants work within the Institute's research programs under the guidance of IIASA scientific staff.

The Proceedings of the Final Colloquium comprises summaries of the research results obtained during the YSSP that were presented at a workshop at the International Institute for Applied Systems Analysis, Laxenburg, Austria, 24–25 August 2017.

The Proceedings are the sole work of the authors with limited or no review by their IIASA supervisors or any other staff of the Institute. They are not for publication in the current form. Views or opinions expressed herein do not necessarily represent those of the Institute, its National Member Organizations, or other organizations supporting the work. This compilation contains all the summaries available at the time of finalization of the Proceedings.

Proceedings editors: Örjan Grönlund, Saige Wang, and Brian Fath

Contents

Arctic Futures Initiative 8

Air Quality and Greenhouse Gases 10

Advanced Systems Analysis 15

Evolution and Ecology 21

Energy 26

Ecosystems Services and Management 32

Exploratory Special Projects 46

World Population 48

Risk and Resilience 52

Transitions to New Technologies 60

Water 62

Thursday, 24 August 2017						
9:00 – 9:10	***Welcome and Introduction by YSSP Dean JoAnne Bayer (Wodak Room)***					
	WODAK Room			**GVISHIANI Room**		
Day 1 - Session 1	**Agent Based Models** Chair: Nikita Strelkovsky			**Renewable Energy Transitions** Chair: Luis Tudeschini		
09:10 – 09:35	Xiaogang He	WAT	Investigation of drought adaptation options using an integrated hydrological and agent-based model	Esperanza González	ENE	How residential nearly zero energy buildings (nzeb) can contribute to Brazil's role in achieving the global warming objective of 1.5°C
09:35 – 10:00	Leila Niamir	AIR	Assessing the macroeconomic impact of heterogeneous households' energy-saving behavior on air quality	Meng Jiang	ESP	Assessing energy and natural resource footprints under China's sustainable economic transformation
10:00 – 10:25	Liv Lundberg	RISK	Auctions for renewable energy – risks and opportunities	Kasparas Spokas	ESM	Incorporating geological constraints and risk in spatially explicit optimizations of carbon capture and sequestration projects
	10:25 – 10:45 BREAK					
Day 1 - Session 2	**Networks and I/O Analysis** Chair: Ed Byers			**Energy Systems Models** Chair: Piera Patrizio		
10:45 – 11:10	Saige Wang	ASA	Sectoral energy–water nexus in China under different energy generation mix scenarios	Karl-Kiên Cao	ENE	A novel method for incorporating power exchange limitations into energy system models and the impact of spatial aggregation
11:10 – 11:35	Nemi Vora	ASA	A systems perspective to understanding U.S. food-energy-water nexus through ecological network analysis	An Ha Truong	ESM	Co-firing biomass with coal for electricity in Vietnam: Where, when, and how much?
11:35 – 12:00	Gibran Vita	ENE	The dynamics of stocks or flows for environmental impact and human development	Mahban Arghavani	RISK	Seismic resilience of the electricity transmission grid of Qom in Iran: analysis of a prototype model
	12:00 – 13:30 BREAK					

Thursday, 24 August 2017						
	WODAK Room			**GVISHIANI Room**		
Day 1 - Session 3	**Wildlife Conservation** Chair: Åke Brännström			**Electric Power Grid** Chair: Clara Orthofer		
13:30 – 13:55	Ziyuan Zhu	RISK	A global analysis of wildlife damage risk financing	Ryan Hanna	ENE	The impact of microgrid adoption on greenhouse gas emissions from the electric power sector
13:55 – 14:20	Bernd Lenzner	ESM	Developing the first global scenarios for biological invasions in the 21st century	Dmitrii Iakubovskii	RISK	Risk of multiple failures in electrical grids due to natural hazards in the Eurasian Economic Union
14:20 – 14:45	Perla Catalina Chaparro Pedraza	EEP	Fisheries-induced life-history evolution in anadromous stocks	Yaru Zhang	TNT/ ENE	An analysis of energy transportation strategy for China's electricity system
	14:45 – 15:00 ***BREAK***					
Day 1 - Session 4	**Biodiversity and Ecological Change** Chair: Brian Fath			**Water Management** Chair: Simon Langan		
15:00 – 15:25	Vanessa Haller	ASA	Optimizing the functional grouping of species in ecosystem models	José Pablo Ortiz Partida	WAT	Robust management of multipurpose reservoirs under uncertainty
15:25 – 15:50	Takuji Oba	EEP	Towards enhanced realism in models of biodiversity evolution	Francine van Brandeler	WAT	Can a water crisis be averted in Mexico City? The effectiveness of water use rights in promoting sustainable water use and reducing groundwater over-exploitation
15:50 – 16:15	Maisa Nevalainen	AFI	Assessing the risk posed by oil spills to Arctic marine areas—Index-based approach for estimating vulnerability and sensitivity of Arctic biota	Tobias Sieg	RISK	Assessment of direct and indirect economic effects of flood damage – An application to German companies
	16:15 – 16:30 ***BREAK***					

Thursday, 24 August 2017						
	WODAK Room			**GVISHIANI Room**		
Day 1 - Session 5	**Iron and Steel** Chair: Sennai Mesfun			**Drought Risk and Impacts on Agriculture** Chair: Susanne Hanger		
16:30 – 16:55	Ming Ren	ASA	Robust solutions for the sustainable development of the iron and steel industry in the Beijing-Tianjin-Hebei, China	Claudia Canedo	RISK	Drought impacts and risks on agricultural production in the Bolivian Altiplano
16:55 – 17:20	Hana Mandová	ESM	Optimization of biomass resources for integrated steel plants to meet EU-28 emission reduction targets	Hanqing Xu	WAT	Drought risk, irrigation demand, and maize yield under climate change in the northeast farming region of China

Friday, 25 August 2017						
9:00 – 9:10	**Welcome and Introduction by YSSP Scientific Coordinator Brian Fath (Wodak Room)**					
	WODAK Room			**GVISHIANI Room**		
Day 2 - Session 1	**Grazing System Impacts** Chair: Myroslava Lesiv			**Resources Management** Chair: Karl Sigmund		
09:10 – 09:35	Radost Stanimirova	ESM	Modeling dynamics of South American rangelands to climate variability and human impact	Cornelius Hirsch	ESM	The rush for foreign land – agro-ecological drivers of FDI in land
09:35 – 10:00	Nannan Zhang	AIR	Reducing NH_3 emission from dairy production in China: Mitigation options, emission reduction potentials and costs	Daniel Cooney	EEP	Emergence of efficient extraction in social-ecological models for fisheries
10:00 – 10:25	Cécile Godde	ESM	Intensification of grazing systems: Challenges and opportunities	Lavinia Perumal	ASA	Assessing the impact of transport infrastructure on biodiversity
	10:25 – 10:45 ***BREAK***					
Day 2 - Session 2	**Health, Well-being, and Emerging Vulnerabilities.COM** Chair: Warren Sanderson			**Climate and Land Change Impacts** Chair: Fabian Wagner		
10:45 – 11:10	Jeofrey Abalos	POP	Adult children's education and parents' health status in the Philippines	Yaoping Wang	ENE	Investigation of the water use of power plants under changes in water temperature and availability
11:10 – 11:35	Jillian Student	RISK	Vulnerability is dynamic: Approaching the emerging challenges of coastal tourism	Karl Seltzer	AIR	Sectoral strategies for reducing ozone in China
11:35 – 12:00	Parul Tewari Caroline Wamaitha	COM	From shelves to the public: making science accessible	Milton A. Uba de Andrade Junior	ESM	Exploring future scenarios of ethanol demand in Brazil and their land-use implications
	12:00 – 13:30 ***BREAK***					

Friday, 25 August 2017						
	WODAK Room			**GVISHIANI Room**		
Day 2 - Session 3	**Labor and Education Dynamics** Chair: Wolfgang Lutz			**Forests!** Chair: Nicklas Forsell		
13:30 – 13:55	Sara Loo	EEP	Cultural evolution of low fertility at high socioeconomic status	Cholho Song	ESM	Assessing forest ecosystem under different management activities along climatic gradient in East Asia using BGC-MAN model
13:55 – 14:20	Karen Umansky	POP	The impact of education on attitudes toward immigration in Europe	Hadi	ESM	Three decades of forest cover changes in the humid tropical Indonesia: Detection and verification at high resolution
14:20 – 14:45	Malan Huang	ESM	Rural labor and evolution of cropping systems in China	Örjan Grönlund	ESM	Nature conservation management forests in Sweden; a spatially explicit analysis of current management potentials and societal trade-offs
	14:45 – 15:00 ***BREAK***					
Day 2 - Session 4	**Air Quality Measurements and Effects** Chair: Winfried Winiwarter			**Algae Blooms** Chair: Peter Burek		
15:00 – 15:25	Olugbemisola Samuel	POP	Dependency on use of solid fuel in the household and under-five mortality rate in Nigeria	Jing Li	WAT	How nutrients are interacting with Cyanobacteria growth? --Aquatic Ecosystem, Lake Vombsjön, Sweden
15:25 – 15:50	Andrew Fang	AIR	Assessing the effectiveness of urban emission control strategies in Hebei, China	Shaohui Tang	ESM	Effectively controlling phosphorus emission from agricultural fields under an uncertain climate: A dynamic stochastic agricultural phosphorus management model
	END OF COLLOQUIUM ***RECEPTION IN CONFERENCE AREA***					

Arctic Futures Initiative (AFI)

Assessing the risk posed by oil spills to Arctic marine areas — index-based approach for estimating biotas vulnerability and sensitivity

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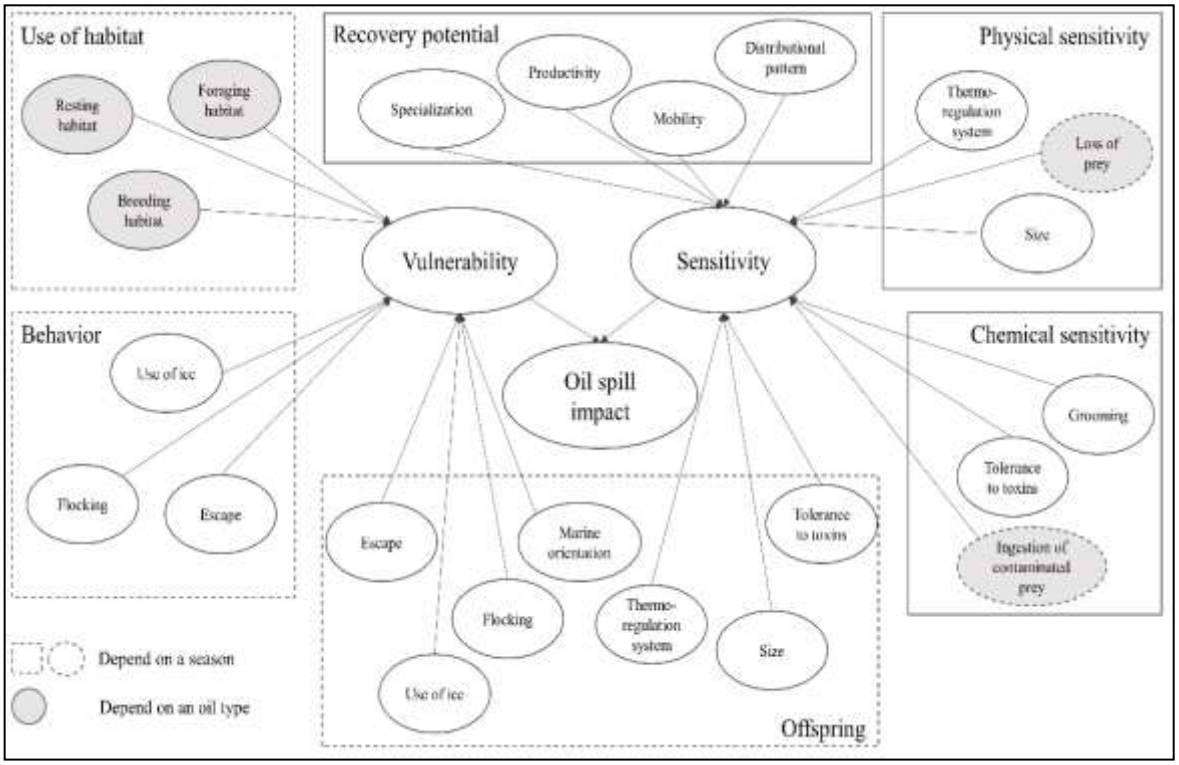
Introduction. Oil spill risk is a great matter of concern due to increasing maritime traffic in the Arctic. Assessing the risks related to such accidents is difficult due to lack of data, but improved understanding could help us to characterize risk and make informed decisions to reduce risk. The aim of the study is to develop an oil spill impact index of key Arctic ecological functional groups accounting for both their vulnerability and sensitivity.

Methodology. Based on an extensive literature review, we built a conceptual model (see figure) describing how the Arctic biota is affected by spilled oil. The conceptual model consists of (1) variables affecting the probability of contact if oil is spilled in an animal's habitat, (2) variables affecting the probability of death if the animal has been oiled, and (3) variables affecting populations' recovery potential. Using the conceptual model, we assessed the seasonal vulnerabilities and sensitivities of key Arctic functional groups as high, medium, or low (or none) to various oil types. Data gaps were acknowledged.

Results. Results suggest that generally functional groups most at risk are birds and certain invertebrates. There is variation among accident scenarios. For example, seal offspring are especially sensitive during spring and benthic fauna especially vulnerable to heavy oils that sink to the seafloor.

Conclusions. In the future studies, these results can be combined with oil spill models and species distribution models to conduct spatial risk analyses. The resultant spatiotemporal risk pattern can inform Arctic conservation, such as to plan shipping route with minimal ecological risk.



Air Quality and Greenhouse Gases (AIR)

Assessing the Effectiveness of Urban Emission Control Strategies in Hebei, China

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Introduction. Rapid urbanization and industrialization have created hazardous air pollution levels in Chinese cities, while domestic coal use has been shown to be an important, but overlooked contributor to local air pollution challenges (Liu et al. 2016).This work focuses on $PM_{2.5}$ reduction strategies because of its localized nature and its well-known health impacts. The study below explores the effectiveness of reducing urban domestic emissions in the Hebei province through the comparison of two models, which seek to quantify the impact of urban emission reduction on air quality in Chinese cities.

Methodology. Although both models estimate urban $PM_{2.5}$concentrations, the approach taken is different. The Carbon Footprinting and Air Pollution Dispersion (CFAD) model estimates the local air pollution and health benefits of reduced PM2.5 emissions through an air pollution dispersion model (Ramaswami et al 2017). The GAINS model estimates PM2.5 concentrations at the sub-provincial scale and uses a downscaling approach (Kiesewetter et al 2016) by urban areas to determine the effect of urban emissions on urban air pollution concentrations. Domestic emission reductions for the year 2010 are modelled across city, provincial, and regional scales to determine the response of each model. Model comparison is used to develop heuristics for the interaction of urban and regional emission effects on urban air quality.

Results. Initial comparison of the models for the Hebei province indicates similar energy use and $PM_{2.5}$ emissions from the domestic sector. Baoding is chosen as a case study city due to the similar area and population characteristics in both models. The GAINS model estimates approximately 28% of Baoding's $PM_{2.5}$ concentrations are attributable to primary $PM_{2.5}$ emissions from inside the city, while CFAD estimates that only 10% of the concentration is attributable to emissions from the city. Subsequently, the GAINS model shows more sensitivity to domestic emission reductions across all urban areas in the Hebei province; for the same level of domestic emission reduction, the concentration response is 1.7 times higher on average in GAINS than in CFAD.

Conclusions. Comparison of the two models indicates that although total provincial emissions are similar, the distribution of emissions across the province differs. In particular, because urban areas are defined differently, by population density and administrative boundary, the distribution of emission intensities across cities in the province differs. Therefore, while results point to the effectiveness of regional over local emission reduction strategies, they also point to the need for empirical data on spatial distribution of urban emissions within the province in determining the impact of emission reduction strategies.

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Sectoral Strategies for Reducing Ozone in China

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Introduction. While fine particulates ($PM_{2.5}$) are generally targeted for reducing global air quality induced premature deaths, ozone (O_3) alone causes hundreds of thousands of premature deaths, typically in Asian countries (Anenberg, et al 2016, Lelieveld, et al 2015, WHO 2016). In addition, O_3 also reduces crop productivity and is a greenhouse gas (Shindell, et al 2012, Myhre, et al 2013), providing several additional motivations for its reduction at the surface throughout the world. Since there are many precursors to the formation of O_3 in the atmosphere and its chemistry is non-linear, prescriptions for reducing O_3 in a given area can be complicated. This project seeks to evaluate strategies for reducing O_3 in China, where a majority of the premature mortalities due to ambient air pollution occurs (Lelieveld, et al 2015).

Methodology. The GAINS model, developed at IIASA, is used to simulate scenarios for reducing emissions from various sectors. Since sectors emit precursors to O_3 with varying proportions and quantities, this framework will evaluate each sector independently to determine the best sector to target for efficient reductions. The sectors included in this analysis are industry, residential, solvents, and transportation. GEOS-Chem, a chemical transport model (CTM), is then used to simulate the evolution of the atmosphere's chemistry from each set of strategies. Finally, to quantify impacts to human health, appropriate averaging values of O_3 from the CTM are used with concentration response functions developed from epidemiological studies (Jerrett, et al 2009, Turner, et al 2016).

Results. China is making a concerted effort to reduce the impacts of air pollution in the coming years, and these efforts are captured in the baseline simulations. $PM_{2.5}$ concentrations drop precipitously (~50%) and O_3 features modest reductions (~10-15%) in the most populated regions by 2030. Since O_3 features a smaller reduction than $PM_{2.5}$, it inherits a larger proportion of the total premature deaths due to ambient air quality in the coming decades. The control measures related to the industry sector, which largely consists of the installation of selective catalytic reduction control technologies on solid fuel fired boilers and furnaces, generates the largest reductions in O_3, with preliminary results indicating that the strategies could lead to a reduction of up to 30,000 premature deaths in China, per year. The results also indicate that while portions of the country may be limited in volatile organic compounds (VOC) for the formation of O_3 for several seasons of the year, nitrogen oxides (NO_x) are limited throughout the country in the summer months when O_3 concentrations peak.

Conclusions. Reducing O_3 concentrations during summer months is key to reducing O_3 for averaging periods that are associated with concentration response functions for human-health. Throughout most of the country, NO_x is the limiting species during peak hours of summer months when O_3 is formed. Many strategies exist for reducing NO_x emissions during these key periods, but the industrial sector provides the opportunity for the largest reductions, and subsequently the largest benefits for future human health.

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Assessing the Macroeconomic Impact of Households' Energy-saving Behavior on Air Quality and Climate

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Introduction. Residential energy demand accounts for almost 24% of greenhouse gas (GHG) emissions in Europe. There are many ways to reduce households' GHG emissions, such as technological energy efficiency solutions, switching to low-carbon energy sources, and behavioral change. The impacts of the former two are readily traceable with the help of numerous macroeconomic, integrated assessment and technological models; however quantifying the macro impacts and drivers of energy-saving behavioral changes remains a challenge. Some rough assessments indicate that behavioral change alone can contribute from 4% (McKinsey 2009) to 5-8% (Faber, Schoroten et al. 2012) to the reduction of CO_2 emissions. Most of energy saving and air quality related studies has been focused on the national and global levels, and thus neglected the provincial and individual heterogeneity.

Methodology. To assess the impact of households' energy-saving behavior on air quality and climate, we design and implement a modeling framework that comprises several methods and tools within the same platform. To be able to go beyond a classical economics models and stylized representation of perfectly informed optimizer, the BENCH agent-based model has been developed further by adding a multi-stage behavioral process of decision-making among households who consider energy-saving decisions based on solid theoretical and empirical ground. The BENCH model was calibrated with the collected survey data in Navarre-Spain (800 households) and Overijssel-The Netherlands (1400 households). The BENCH calculates changes in electricity consumption and consequently avoided CO_2 emissions by households' energy-saving behavior annually.

Results. By running BENCH model, we track individual and cumulative impacts on CO_2 emissions of energy-saving behavioral changes among 3468 individual households in the Navarre region in Spain over 14 years (2016-2030). We design several socio-economic (bottom-up and top-down) scenarios, aiming to explore: (1) the impact of individuals' heterogeneities in terms of socio-economic factors e.g. income and electricity consumption; psychological factors e.g. attitudes and personal norms; and social factors e.g. social norms and learning; (2) the impact of climate-energy-economy policies e.g. carbon price pressure. The results show the impact of heterogeneous households' interactions (social dynamics) and carbon pricing strategy (10-50 € per ton by 2030) result in approximately 26% and 13% CO_2 emissions reduction by 2030 respectively. By combining both scenarios, about 31% of household electricity related CO_2 emissions can be avoided.

Conclusions. In this research, we aimed to shed light on the effects of individuals' decisions in the complex climate-energy-economy system and explore the impact of socio-economic heterogeneity on carbon emissions. By designing and running many socio-economic end-user scenarios and comparing with a business as usual scenario, we conclude that a combination of social dynamics (learning) and carbon price scenarios is the best strategy to reduce emissions.

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Reducing NH_3 emission from dairy production in China: mitigation options, emission reduction potentials and costs

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Introduction. Ammonia in the atmosphere contributes to several environmental problems. As an important precursor of inorganic aerosols, ammonia plays an important role in the formation of PM2.5 (Huang et al., 2014; Gu et al., 2015). Most of the NH_3 emissions are from livestock production, including the dairy sector. In this study, we aim to 1) assess the potential of abatement options on reducing ammonia emission from dairy production in China, 2) estimate the related economic costs and 3) explore the further pathways of emission abatement for dairy production in China.

Methodology. Ammonia emission abatement options considered in this study are based on the local experiments conducted in industrial dairy farms in China. This study explores the implementation of the control options and collects related economic parameters. We make use of the GAINS model that is a tool to estimate the environmental effects of air pollution and allows assessing options to reduce emissions and the costs of their implementation.

Results. We selected several ammonia emission abatement options and tested them for a Chinese dairy production system. Specifically, this included diet manipulation, acidification of manure under slatted floor in dairy housing, and different covers for slurry, solid and liquid manure, the latter separated from slurry. Ammonia emission reduction efficiencies for each option ranged from 7 to 94%. Compaction for solid manure separated from slurry can reduce ammonia emission, but the emission abatement efficiency was affected by ammonia emission from liquid waste released in the compaction process. The total costs for the implementation of the options ranged from -462.5 to 5070 $CNY \cdot cow^{-1} \cdot yr^{-1}$ (-60 – 655 $EUR\ cow^{-1} \cdot yr^{-1}$). Lower crude protein input for dairy diet is the only cost saving option, while the acidification in dairy housing (employing lactic acid) is the most expensive option.

Conclusions. Results from this study showed diet manipulation being an economically profitable way of reducing ammonia emissions. Covered storage is another cost effective way for ammonia emission abatement but comes at certain (low) costs. Ammonia emission from liquid waste released from solid manure during compaction reduced the emission abatement efficiency of compaction. Nitrogen retention in manure and use as a replacement of mineral N fertilizers in crop production can balance part of the cost for implementation.

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Advanced Systems Analysis (ASA)

Optimising the functional grouping of species in ecosystem models

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Introduction. Ecosystems around the world are faced with multiple and interacting threats. These interactions can only be detected with a full system analysis. For this end, a network analysis is often used. However, the first step in the network analysis is to assign the nodes that will be modelled. In ecosystems, the assignments of nodes could be on many levels ranging from species to broad functional groups. This could mean a network size from 700 to 20 nodes. This study aims to find the optimal number of nodes as well as the uncertainties that are introduced through exaggerated grouping.

Methodology. For this study used a network of a coral reef from the Great Barrier Reef. The EcoPath-based network utilized data from an honors thesis (Tudman, 2001) and the online database FishBase. The network incorporates 197 nodes at species level and eight nodes at a level of broad functional groups; mostly invertebrates, plankton and plants. System behavior was investigated by simulating the network over time after a threat had been introduced (reduction of biomass in one node). Then, two groups at a time were merged and the error between the reduced system and the full system was calculated.

Results. Analytical and simulation results show that the steady state of the full system can be reproduced by the reduced system without creating an error. This is not surprising since the equations are linear. However, the dynamics that are created when a system moves from the original steady state to the post-threat steady state differ between the full and the reduced system. Interestingly, a threat that changes a single population size is propagated through the whole system and affects the size of all other nodes. The error that is calculated for the mergers first slowly, then rapidly, increases with the number of species that are combined in one (Fig.1). Surprisingly, the increase in the error from combining six species to combining seven species is also substantial.

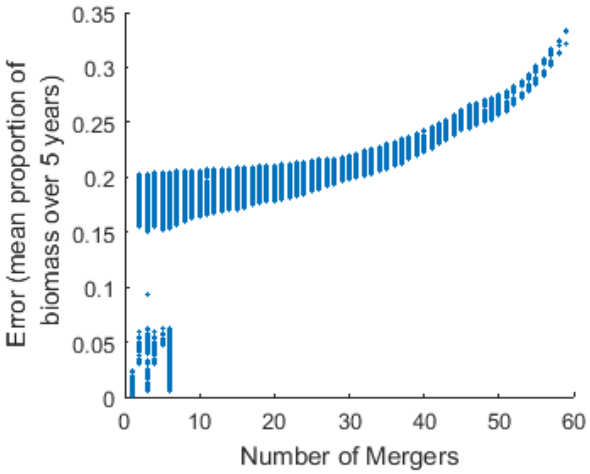

Figure 1: Error estimate for the mergers of the functional group, other demersals

Conclusions. As expected substantial error (the biomass of a species or functional group over five years could be on average up to 35% different from the estimate) can be introduced when species are grouped. However, the analysis also shows that if care is given to the species grouped that these errors can also be reduced. The results so far suggest that the grouping chosen for the network, could have a significant impact on any analysis conducted on the network. Further analysis, of all possible combination for the mergers, different threats and other parameter set (sensitivity) are going to be conducted to evaluate the robustness of the results presented here.

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Assessing the impact of transport infrastructure on biodiversity

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Introduction.

Globally, more than 25 million kilometres of new road development are expected by 2050 (Laurance et al 2014). The majority of construction will take place in developing countries and will include many areas that have high biodiversity and provide important ecosystem goods and services. Road development affects landscapes and biodiversity far beyond its immediate area and at multiple spatial scales. Despite this, long-term effects of roads on biodiversity over time are very rarely investigated. To determine the impacts of proposed road development in Africa we need to understand how roads have influenced the landscapes in the past. Therefore, my YSSP study involves exploring past interactions between roads and biodiversity. In this study, I use land cover as a proxy for biodiversity.

Methodology.

Using spatial analysis in ArcGIS and Land Cover Modeler in TerrSet, I analysed land cover transition in South Africa between 1990 and 2014 at both national and regional scales. The Cape Floristic Region (CFR), one of Earth's most biologically diverse terrestrial regions, was selected as a test case for exploring the effects of road on land cover change. The potential of land cover change and transition, at the pixel level was modelled using elevation, slope, distance to major roads and the density of major roads as explanatory variables. We focused on transitions from natural to non-natural and non-natural to natural land cover.

Results.

At the national scale, we found strong variation in land cover transitions across major regions and biomes, indicating high level of heterogeneity on the relationship between roads and biodiversity. Preliminary modelling results of the CFR show that, controlling on other biophysical and human variables, distance to the nearest major road and increasing road density both exhibited Influence on land cover transition, implying that roads might have negatively impact biodiversity.

Conclusion.

The preliminary findings confirmed our expectation of the impacts of roads on biodiversity in a globally important biome. We can build on these results to further explore the interrelationship between roads and biodiversity in other biomes and at larger spatial scales.

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Robust solutions for the sustainable development of the iron and steel industry in the Beijing-Tianjin-Hebei, China

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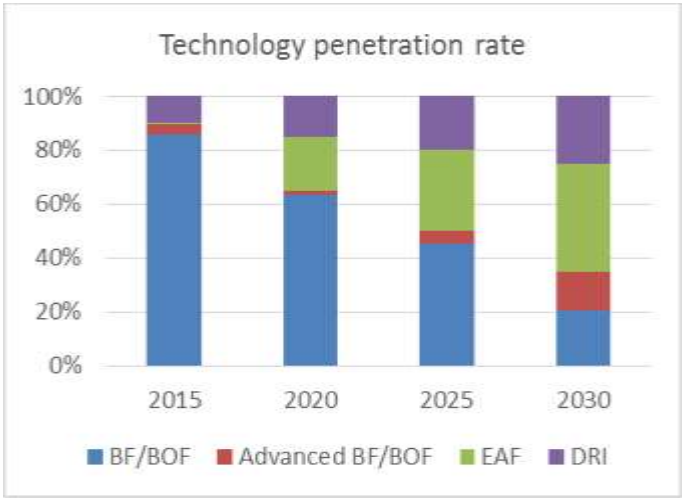
Introduction. Beijing-Tianjin-Hebei region accounts for nearly 1/3 of China's iron and steel production. However, iron and steel production consumes large quantities of energy and water and discharge a lot of CO_2 and air pollutants. The central government has made powerful policy to support introduction of advanced steel production technologies with lower energy and water consumption. This project developed a dynamic stochastic model, which includes current and future advanced iron and steel production technologies along with energy, water and environmental security constraints to explore the optimal and robust technological development path of iron and steel industry to 2030 in this region.

Methodology. The project develops a dynamic stochastic integrated model based on linear programing methodology, which includes current and future advanced iron and steel production technologies along with energy, water and environmental security and resource availability constraints. The model explored the optimal and robust technological development path of iron and steel industry to 2030 in Beijing-Tianjin-Hebei region, identifying the advantages of "with natural gas" and "without natural gas" technological options. Uncertainty about water availability was addressed with the two-stage (two types of decisions) stochastic optimization method (Ermoliev and Wets, 1988).

Results and Conclusions. A dynamic stochastic integrated model was established based on linear programing methodology. The model analyses various technological portfolios and identifies optimal and robust technological development paths of iron and steel industry in Beijing-Tianjin-Hebei region accounting for energy, water and environmental security targets. EAF technology and natural gas based DRI technology can decrease CO_2 and air pollutants substantially. Compared with traditional BF/BOF technology, EAF technology and DRI technology have clear advantages. However, EAF technology and DRI technology are limited by scrap availability and natural gas availability respectively. The research will offer a decision support system (DSS) for technology selection of iron and steel industry in Beijing-Tianjin-Hebei region and lay solid theoretical, methodological and practical foundation for establishing integrated long-term systems analysis based on (stochastic) optimization models.



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A systems perspective to understanding U.S. food-energy-water nexus through ecological network analysis

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Introduction. The interdependencies between food, energy, and water systems have been widely recognized with a call to adopt a systems perspective to understand synergies and trade-offs in their management(Hoff, 2011). Food trade provides pathways for vast quantities of embodied resource (energy, water, etc.) and emissions flows, providing a spatial understanding of food-energy-water teleconnections. This work utilizes ecological network analysis (ENA) to understand patterns and structure of domestic food trade in the United States (U.S.) and associated irrigation impacts. While our focus is on a single chain of interaction for food-water-energy through irrigation systems, the well-connected network stemming from free trade situation results in a complex system. ENA provides a useful tool of analysis by providing a holistic systems perspective through integrating direct and indirect impacts of interactions.

Methodology. The domestic food trade network focuses on cereal (barley, corn, rye, rice, sorghum, oats, and wheat) trade within the U.S. The data were obtained from publicly available government datasets and formed into weighted and directed multi-layer networks. There are 50 nodes in each network representing individual states (+ District of Columbia) and links include physical food trade, virtual irrigation water, irrigation associated embodied energy, and greenhouse gas emissions overlaid as distinct networks. This work applied three diverse levels of measures, each focusing on a different aspect of the network. We employed pointwise mutual information criteria (Fano & Hawkins, 1961) to analyse pairwise trade preferences and dependencies. Network relational analysis was used to quantify indirect effects of trade on given nodes and compared across virtual resource networks(Fath & Patten, 1998). Finally, we analyzed overall system robustness through calculating the network balance between efficiency and redundancy(Rutledge, Basore, & Mulholland, 1976).

Results and Conclusions. The prelim results on node dependencies demonstrate the significant reliance on within-state flows and transfers from neighbouring states. These results have important implications for water based food resiliency as a state may rely on singular irrigation source spanning multiple neighbouring states (e.g., Ogallala aquifer). We also find that indirect trade relations change from the direct ones ~60% of the time, resulting in more competitive compared to beneficial relations. Overall, the system demonstrates a fine balance between network efficiency and redundancy, producing a robust structure usually observed in highly evolved ecological systems. The results indicate the need to provide a systems-level perspective along with direct trade analysis to avoid misrepresentation of system level interactions.

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Sectoral energy–water nexus in China under different energy generation mix scenarios

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Introduction. Increasing demand for energy, an evolving generation mix, and water demand from competing sectors have important implications for water budgets and energy planning. The great diversity of water intensity among different energy types determines the water impacts of an energy system. To analyze water–related impacts in energy–related decisions, we extended the input–output analysis (IOA) and ecological network analysis (ENA) to future energy generation mix scenarios to assess the pressure energy development put on water resources.

Methodology. In this study, four energy generation scenarios for 2050, as planned in climate change mitigation roadmaps, and one baseline scenario were set up. The sectoral direct energy, water, water–related energy and energy–related water were inventoried. Then embodied water/energy consumption and sectoral energy/water flows were analyzed via IOA to build the nexus networks. The sectoral relationship and system properties of energy–water nexus networks were analyzed through tools, like control and dependence analysis, from ENA. A new indicator called *sectoral nexus impact* was defined to investigate the influence of the energy–water linkage on energy and water systems.

Results and Conclusions. The results showed that sectoral water–related energy corresponds highly to energy consumption, of which Metal smelting and pressing (Me), Transport, storage and post services (TS), Domestic services (Do), and Electricity, steam and hot water production and supply (El) are the largest sectors. The main export and import pairs are Chemical industry (Ch)–Agriculture (Ag), Manufacture sector (Ma)–Ag, Ag–Me, and Me–El, should be critical pathways for nexus management via adjusting the sectoral economic relationship. A higher nexus impact indicates stronger influence brought by the energy–water relationship, which can be used to identify energy generation scenarios that put less pressure on the water system. Comparing different scenarios, we concluded that the water pressure the energy development has put on for scenario 4 is the lowest, followed by scenario 3, 5, 2 and 1.

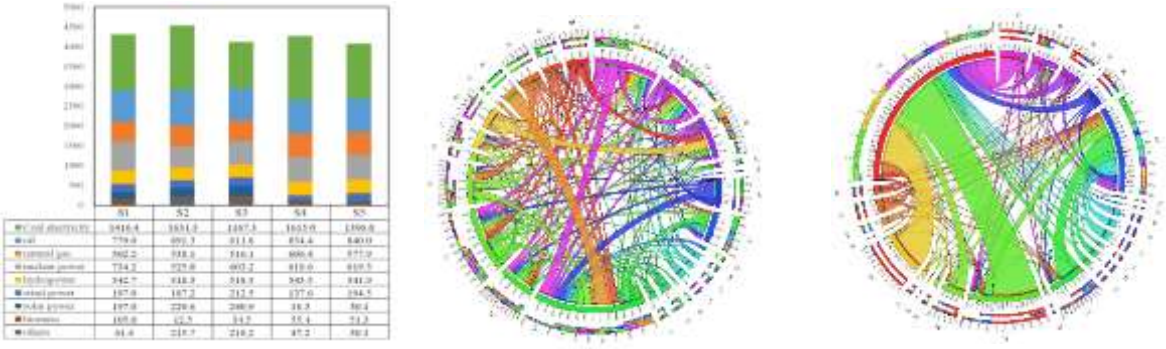

Fig. Energy generation mix scenarios, Embodied energy flows among sectors, Embodied water flows among sectors

Evolution and Ecology (EEP)

Fisheries-induced life-history evolution in migratory stocks

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Introduction. While salmon's share in world fishery trade is currently at 14% (FAO 2014), the exploitation of wild stocks has caused the decline of population abundances (Limburg & Waldman 2009). Salmon uses two habitats during their life cycle: the freshwater habitat in rivers and the ocean habitat. The timing of the switch between those habitats is critical for the survival and reproduction of individuals; therefore, it is subject to natural and anthropogenic selection pressures. Here we study how mortality caused by fishing affects the evolution of the timing of this habitat switch.

Methodology. We have developed a semi-discrete model with two habitats and a physiologically structured population. We use the bioenergetics approach by Martin et al. (2017) to model the energy allocation and demography of individuals. The two habitats differ in the strength of density dependence resulting from food competition. Survival in the freshwater habitat is constant, while survival in the ocean is assumed to depend on body size due to predation. In addition, individuals experience starvation, fishing, and background mortality. We use adaptive dynamics theory to study the outcomes of the evolutionary process with and without fishing mortality.

Results. Without fishing mortality, individuals switch from the freshwater habitat to the ocean habitat later if their length at maturation is small and earlier if it is large. In addition, evolutionary bistability in the habitat switch appears when increasing the length at maturation. Similarly, when the population is under fishing pressure, smaller lengths at switching to the ocean are evolutionarily selected when the length at maturation is large. However, bistability does not occur and the evolution of smaller lengths at switching to the ocean may even result in selection-driven extinction.

Conclusions. Mortality caused by fishing results in selection-driven extinction ('evolutionary suicide') when maturation occurs at large lengths. Therefore, overfishing can lead a population to extinction not only because of the depletion of individuals (ecological effects) but also because, after a few generations, smaller and smaller lengths of switching to the ocean are selected for, up to the point at which a very small length of switching drives the population to extinction. In migratory fish stocks, overfishing can thus cause extinctions due to both ecological and evolutionary causes.

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Emergence of efficient extraction in social-ecological models for fisheries

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Introduction. With around 30 percent of the world's fisheries classified as overexploited or depleted and another 58 percent considered fully exploited (FAO 2016), the social-ecological dynamics of fisheries provide an interesting and relevant example of the 'tragedy of the commons' and highlight the need for designing effective schemes for managing the utilization of common-pool resources. Previous work on fisheries management has described the effectiveness of punishing overfishers in promoting the stability of efficient extraction in two-strategy models of fisher extraction (Tilman et al. 2017), and it has been shown that hybridized schemes of rewarding cooperators and punishing defectors can promote and stabilize cooperation in public goods games (Chen et al. 2015). Integrating these approaches in this project, we examine how a social institution can best promote efficient extraction via rewards and penalties when fishers choose from a continuum of extraction levels.

Methodology. We model the dynamics of fisheries by coupling a bio-economic model of fish population dynamics and harvesting by fishers with a game-theoretic model for the payoffs that fishers gain from harvesting fish and from rewards or penalties meted out by a social institution. We describe the distribution of extraction levels in the fisher population by a probability density function and derive a differential equation for the change in this density as fishers use social learning to update their extraction levels. To extend the idea of rewarding cooperators and punishing defectors to a continuous-strategy setting, we introduce thresholds identifying the extraction levels eligible for rewards or penalties. We then choose these thresholds so as to maximize the rate of adjustment of the fisher population's average extraction level towards the socially optimal level of fish extraction.

Results. We show, for the continuous-strategy replicator dynamics, that the social institution should, at any given population state, either invest entirely in rewarding or entirely in punishing. Furthermore, given that the institution thus focuses on either rewarding or punishing, we show that it is optimal to concentrate the institutional incentives either on the efficient extractors or on the overfishers at the extremes of the fisher population's distribution of extraction levels. In addition, we derive conditions on the mean of this distribution that characterize when it is optimal to reward and when it is optimal to punish. Further, we define a more general social learning dynamics for the updating of extraction levels and describe optimal institutional designs in terms of a calculus-of-variations problem.

Conclusions. We have constructed a model of the social-ecological dynamics of fisheries incorporating continuous fisher extraction levels and have explored the role of institutional incentives in driving the average fisher extraction level towards its social optimum. We have identified directions for further research on optimal institutional design via functional analysis and the calculus of variations, and we have made contributions to understanding the evolution of cooperation and social optimality in continuous-strategy social dilemmas.

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Cultural evolution of low fertility at high socio-economic status

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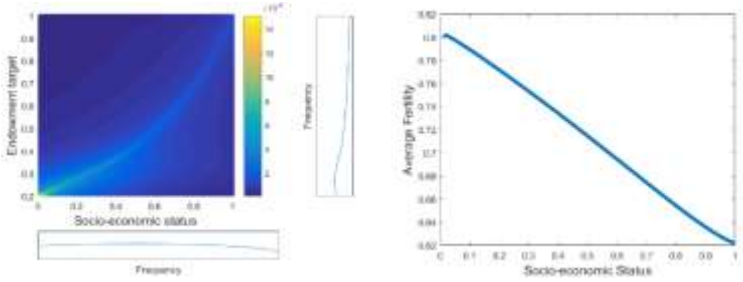
Introduction. As populations have developed and disparities between the rich and the poor have increased, there has been a distinct global transition of fertility from high to low, to the point where over half the global population live in countries with below-replacement fertility (Wilson 2004). Counterintuitively, socio-economic status is increasingly observed to be negatively correlated with fertility (Livi-Bacci 1986; Borgerhoff-Mulder 1998). This project explores the effect of cultural evolution on this correlation.

Methodology. Within the framework of cultural evolution, an integro-difference equation model is used to investigate the evolution of a large population that varies in socio-economic status and the endowment target according to which parents provide resources to each of their children. The number of children born to parents is proportional to their disposable wealth and inversely proportional to their endowment target. Children are assigned a socio-economic status according to their rank in parental endowment. Children learn their endowment target from their parents or socially, from a role model with similar socio-economic. We investigate how the evolution of endowment targets depends on social learning and a population's wealth distribution.

Results. Investigating the outcomes of cultural evolution in a population's bivariate distribution of socio-economic status and endowment target (left panel), we find that, for certain distributions of wealth, the correlation between socio-economic status and fertility is negative (right panel). This results from parents with higher socio-economic status adopting disproportionally higher endowment targets so as to ensure top rankings for their children in the competition for socio-economic status. For other wealth distributions, positive correlations between socio-economic status and fertility are found (not shown). Further, the higher the degree of social learning, the larger the population's average endowment target, and consequently, the lower its average fertility.



Conclusions. Since below-replacement fertility can lead to aging populations, understanding the socio-economic conditions that result in such fertility levels can help inform policies to combat problems that may arise from aging populations. More social learning can increase the average endowment target in a population, and thus result in lower fertility levels. However, even in populations with lower fertility, the within-population correlation between socio-economic status and fertility can be negative, and is sensitive to the population's wealth distribution.

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Towards enhanced realism in models of biodiversity evolution

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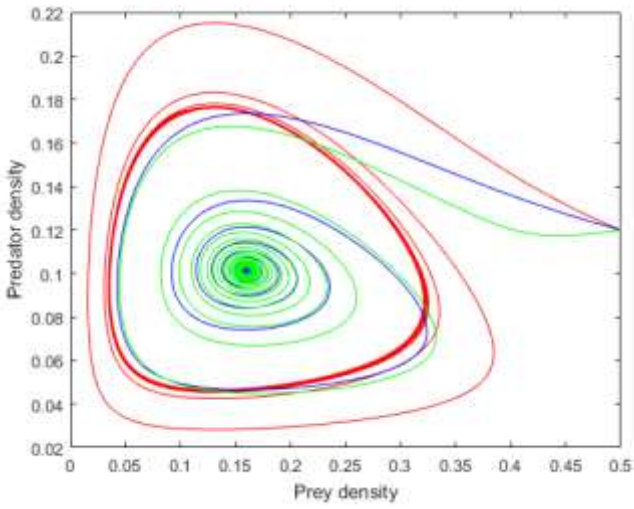
Introduction. Human societies depend on ecosystem services, which are maintained by biodiversity. Mathematical models of food-web evolution help to understand how biodiversity patterns and are increasingly used to inform ecosystem management and conservation. At the heart of these models are functional responses—the relationships between prey densities and predator intake rates—but the most commonly used functional responses are potentially problematic in that they have been developed under the assumption that prey densities are effectively constant on the timescale of predation (Holling 1959), an assumption which is generally not fulfilled in food-web model because multiple species consume each other.

Methodology. The aims of my project are to investigate the sensitivity of model predictions to the aforementioned timescale assumption and explore potential model improvements. Focusing on a classical nonlinear functional response, I (1) investigate the difference between a food-web model with a classical nonlinear functional response and a more realistic, but also more complex, counterpart and (2) propose a new functional response corresponding to the classical one that that can potentially yield more realistic dynamics in complex models of food-web evolution. I consider several model parameterizations from the literature.

Results. (1) Even for very simple food webs with only one predator species and one prey species, I find that for three parameterizations in the literature (de Roos et al. 1998; Tewa et al. 2013; Huo et al. 2016), there are significant differences. The model with the classical functional response predicts a stable limit cycle (red curve in the figure), whereas its more realistic counterpart predicts convergence to an equilibrium (green curve). (2) Without relying on the problematic assumption for the classical derivation of the nonlinear functional response, I have derived a new functional response, for which model predictions are in agreement with its realistic counterpart (blue curve) when the realistic counterpart predicts convergence to an equilibrium.



Conclusions. (1) Numerical results show that the classical functional response can result in misleading model prediction even for very simple food webs. (2) My new proposed functional response can occasionally also give misleading predictions, but it has a better overall performance than the classical one. Taken together, my study shows that care needs to be taken when constructing food-web models and that a new functional response can potentially improve predictions and enhance realism in models of biodiversity evolution.

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Energy
(ENE)

A novel method for incorporating power exchange limitations into energy system models and the impact of spatial aggregation

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Introduction. Optimizing energy system models (ESM) are frequently applied tools for the development of energy scenarios. A current challenge concerning their application is that they often need to be simplified [1]. One of these simplifications is the aggregation of spatial data. In the context of power systems, this translates into overlooking possible transmission grid congestion. These bottlenecks become crucial in systems that rely on high shares of variable renewable energy sources as electricity demand centers and resources hotspots are typically remote from one another and thus the expansion of electricity transmission grids needs to be considered. The objective of this research project is to derive ESM instances that maintain critical transmission links for energy scenario analysis while reducing spatial detail to a level that is computationally manageable.

Methodology. In order to identify critical transmission links, a highly spatially resolved model (benchmark model) is set up. For its creation a data scrap of the ENTSO-E power map is used [2]. As a case study for developing the algorithm we initially pick Germany for two reasons, (i) data availability for renewable power generation at high spatial resolution, and (ii) high wind and solar PV penetration which allows for model validation. As basic implementation the ESM REMix [3] is parameterized using empirical data of the year 2012. Spatially aggregated ESM instances are subsequently derived from the benchmark model by application of spectral clustering. Therefore, we use electricity prices as affinity attributes. The simplified ESM instances are finally evaluated against observables from the same year such as the frequency of congestion events.

Results. With a correlation factor greater than 0.64 the benchmark model is able to produce times series for electricity prices with a similar shape as recorded in 2012. The evaluation of aggregated ESM instances shows that critical transmission links are maintained. Compared to ESM instances that are derived differently (e.g. by clustering of neighboring regions) further advantages can be observed, (i) capacity factors of fossil fired power plants deviate less from the benchmark model's outputs, (ii) resulting congestion events are in the same order of magnitude as for a high spatial resolution. However, the latter applies for model setups which show a significant number of congestion events by default. Therefore, conservative assumptions regarding the maximal grid transfer capacities are preferable, though this can lead to supply situations with uncovered demand. These possible artifacts occur since, inter alia, the underlying 110 kV voltage level is neglected. Furthermore, the evaluation of model performance against model accuracy shows that computing times can be decreased from several hours to a few minutes while the deviation of the objective value is less than 2%.

Conclusions. With the presented methodology aggregated ESM instances can be derived from highly spatially resolved ESMs. This becomes attractive if solving the latter reaches computational limits. As transmission links that tend to represent bottlenecks in the future are maintained, the aggregated ESM instances are suitable for capacity expansion studies. Given the trend of increasing complexity of energy systems with high shares of variable renewable power generation, the presented approach can thus be used for scenario analysis which claims to capture both temporal and spatial balancing needs of electricity demand and generation.

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How residential nearly zero energy buildings (nZEB) can contribute to Brazil's role in achieving the global warming objective of 1.5°C

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Introduction. Buildings account for 14.6% of the final energy consumption and more than half of the electricity consumption in Brazil. The housing demand in Brazil is expected to substantially grow. Demand-side measures are relevant to achieve Brazil's nationally determined contribution (NDC) for climate mitigation, because of the limited remaining hydroelectric generation potential [1] and the expectation of high fossil fuel growth in the energy supply system in the coming years [2]. The objective of this research is to investigate the potential contribution of nearly Zero Energy Buildings (nZEB) in the Brazilian residential sector to meet Brazil's NDC and the global climate stabilization target of 1.5°C.

Methodology. The methodology consists of four steps. First, we define housing archetypes by region and income level, from which we derive hourly-basis demand by end-use, including space cooling (EnergyPlus dynamic model); hot water (based on Procel data) and other electric appliances (bottom-up demand model). Second, we use a mixed-integer linear programming (OPTbuild model) to select the optimal on-site renewable technology choices to meet energy demand at the lowest cost for the different archetypes, considering technology sizing and costs, operational schedules and fuel and electricity market prices. In the third step, we extrapolate the results to the country scale using future income distribution scenarios. Finally, we run the model MESSAGE Brazil to measure the emissions impact of implementing nZEBs.

Preliminary results. Findings show that, by implementing nZEBs for the new residential buildings, Brazil´s residential energy demand can be reduced by 20.6% in 2050, which would reduce 15 % of the accumulated CO_2 emissions between 2015-2050. If the entire stock of residential buildings in Brazil were to be replaced by nZEBs, the corresponding CO_2 emissions reduction would be 55.8% in 2050. The least-cost technology choice by 2020 would include solar PV, thermal solar collector and electricity purchases from the grid. By 2050, the battery would be in the mix of technologies.

Conclusions. nZEBs offer a CO_2 mitigation potential from buildings by including energy efficiency measures, envelope improvement and integration of renewable energy supply technologies into new building construction. By 2050, it is technically possible to substantially reduce residential building energy consumption in Brazil through nZEBs. However, the implementation of on-site renewable technologies requires changes to the net metering policy and financial support to make these changes affordable. Moreover, policies oriented towards reducing barriers to retrofitting existing buildings would be necessary. Finally, Brazil should consider establishing a comprehensive building code and enforce a Brazilian Labelling Program.

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The impact of microgrid adoption on greenhouse gas emissions from the electric power sector

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Introduction. Technology, policy, and market forces are interacting in ways that make insular power networks an attractive option for electric utility customers. Such "microgrids", which can use renewables and fossil fuels, can increase reliability relative to the bulk grid and may reduce energy costs. As industry forecasts point to increasing adoption rates, it is important to understand how greenhouse gas (GHG) emissions from these systems compare with marginal emissions from standard utility service. This study is the first to assess these impacts—and does so for likely first adopters who have a need for reliable service. It further analyzes the effect of a carbon tax.

Methodology. The methodological basis for the work is a new model that determines least-cost investment and operation of distributed energy resources (DERs; e.g. natural gas generators, solar photovoltaics (PV), battery and thermal energy storage) in a microgrid for utility customers like hospitals and office campuses. The model includes the key costs that affect economics— investment cost, energy provision, emissions & expected reliability losses (i.e., costs due to power outages)—and computes costs, supply and demand of energy services (i.e. electricity, heating, cooling, natural gas) and carbon dioxide emissions relative to provision by a central utility.

Preliminary Results. This study analysed three customer types—an office building, school and hospital—at 43 locations across the state of California (Fig. 1) before and after investment. At all locations analysed thus far, and for all adopters, microgrids reduce both GHG emissions and the total cost of energy relative to the "utility customer" that does not invest (Fig. 2). A high demand for reliability provides incentive for investment, while high electricity rates and low natural gas prices in California increase cost effectiveness. Together, these factors favour technologies that are renewable (solar PV) and that increase energy efficiency (gas generators with heat capture, thermal energy storage)—and hence that reduce marginal emissions of a grid with 40% fossil fuel generation. Thermal DERs are crucial to reductions (Fig. 2) and results hold under a 12 $/tCO$_2$ carbon tax.

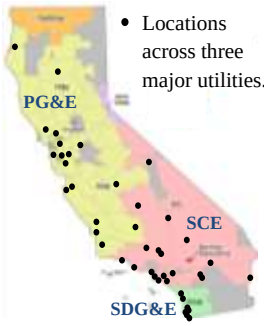

Figure 1. Locations in California.

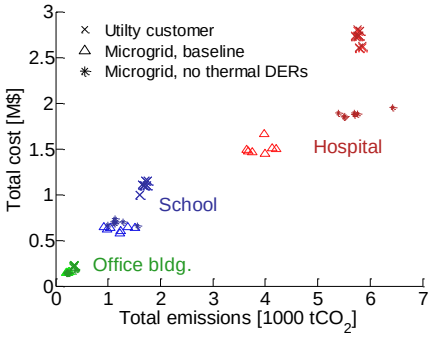

Figure 2. Total cost and emissions.

Conclusions and Policy Implications. Under current conditions, microgrids in select locations are cost effective with renewable and combined heat and power systems. The resulting systems are flexible and could operate to reduce emissions. Today, measures supporting the increased use of microgrids may then be an effective option for those seeking GHG emission reductions. The long-term potential for reductions is more questionable, however, as microgrids that use natural gas are incompatible with goals for deep decarbonization (i.e., >80% reductions in GHG emissions by 2050 relative to current levels). Long-term thinking may require greater exploration of policy intervention, e.g. via the carbon tax that has little effect on results under conditions today.

The evolution of embodied energy in household durables, consumables and services from 1995 to 2011 across nations

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Introduction. Household consumption is a main driver of global environmental impact [1]. Sustainability agendas encourage lifestyles changes and production strategies to extend the lifetime of goods. However, a decent modern life implies material prerequisites, including a bundle of household durables and consumables [2]. Durables (vehicle) require consumables (fuel) and services (mechanics, insurances). How much energy resources are captive directly and indirectly to household durables?

Methodology. We calculate the life cycle energy footprints (EF) of 200 different goods of 44 nations and 5 continents from 1995 to 2011 using EXIOBASE 3, an Environmentally Extended Multiregional Input-Output (EE-MRIO). We employ consumption-based accounting, where the consumer of a good is accountable for all upstream resources. Thus, the EF of a household equals to the energy consumed directly plus the embodied energy in all purchased goods.

Results. Durables are only responsible for 9% of global EFs. However, the services and consumables complementary to durables demand half of total energy.

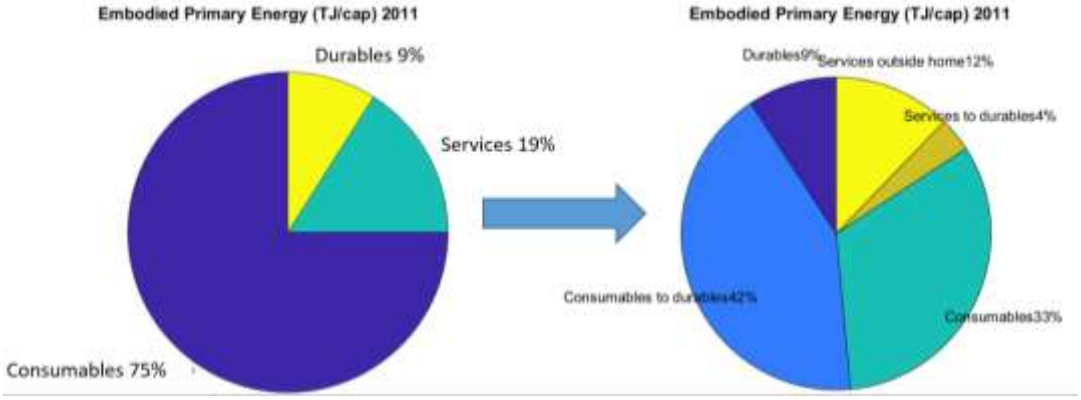

Figure 1 Global share of embodied energy under the common scope (left). Considering goods complementary to durables, 55% of the total embodied energy is directly (9%) and indirectly related to durables (46%) (Right).

Conclusions. We find that the rise in durable goods largely drives energy needs due to the amount of services and consumables that are complementary to durables. We present a novel perspective on the structural role of durables for achieving sustainability.

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Investigation of the water use of power plants under changes in water temperature and availability

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Introduction. Thermoelectric power generation requires cooling, normally provided by wet cooling systems. The withdrawal and discharge of cooling water are subject to regulation. As a result, operation of power plants may be vulnerable to changes in streamflow availability and rises in air and water temperatures. In Asia, about 489 GW of coal-fired power plants (~37% of existing coal-generation capacity), are currently under construction, permitted, or announced for operation before 2028. These power plants may add to existing water stress in the thermoelectric sector, and may face water limitation themselves.

Methodology. We combined high-resolution (0.08^{o}x0.08^{o}) outputs from a global hydrological model, PCRGLOBWB, with cooling water use models (Bartos and Chester, 2015) to calculate the potential available capacity for each existing and planned coal power plant in Asia at a daily time step. The location and design of the existing and planned coal power plants are from the Global Coal Plant Tracker dataset and a previously geo-referenced dataset (CoalSwarm, 2017; Raptis and Pfister, 2016). Three climate change scenarios (1.5^{o}C, 2^{o}C, and 3^{o}C warming in global mean temperatures) from the GFDL-ESM2M global climate model were compared.

Results. The total potential available capacity for the coal power plants in the study region increases by ~4%, due to an overall increase in streamflow, from historical to the different warming scenarios. Under the same warming scenario, if all the planned coal power plants were added to existing power plants, the total potential available capacity increases, but the average capacity factor decreases from ~0.72 to ~0.7, suggesting an increase in water limitation. Spatially, many planned and existing power plants in Pakistan and northwestern India, northern China, and northwestern China have near-zero potential available capacity (assuming use of cooling tower with freshwater). Water-limited power plants also occur throughout India and in central China. At watershed level, two of the six watersheds that have the highest installed generating capacities expect decrease in potential available capacity (Yangtze River Basin: -2.9%; Huai River Basin: -1.7%) for existing power plants and the others expect increase (Yellow River Basin: 10.5%; eastern India: 7.3%; Hai River Basin: +6.3%; Pearl River Basin: +0.1%).

Conclusions. Climate change may bring some positive influence to the thermoelectric generation sector in Asia by increasing the available streamflow for cooling water, but the historically water-scare regions remain under high water stress, and the coal power plants there cannot operate with wet cooling systems without over-extracting the available streamflow. The projected decrease in potential available capacity in the Yangtze River in central China also suggest more attention be paid to the water resources constraint on the development of power supply in this traditionally water-abundant region.

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Ecosystems Services and Management (ESM)

Exploring future scenarios of ethanol demand in Brazil and their land-use implications

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Introduction. Brazil is the world's largest sugar producer and exporter, and the second largest ethanol producer (FAO, 2016; RFA, 2016), using 9.13 million hectares of sugarcane cropland area in 2014/2015 (CONAB, 2016). The ethanol share of this production is essentially directed to meet the high domestic demand in Brazil. This demand is mainly influenced by different factors, such as: ethanol-gasoline blend mandates (which may change under policy interventions); size and structure of the fleet (considering the rampant increase of flex-fuel vehicles), and relative prices between ethanol and ethanol-gasoline blend (which lead consumers' choice between the fuel-blend and ethanol). Because the increased demand for sugarcane ethanol in Brazil has the potential to cause significant land use and environmental impacts, we first design in this study different possible scenarios of future ethanol demand to better understand these impacts, and then analyse their implications in an economic model of agricultural and land use in Brazil.

Methodology. We based our demand projections using historical data on fleet numbers and structure, found in the National Emissions Inventory for Road Vehicles (2013) and SINDIPEÇAS & ABIPEÇAS (2017). We designed three scenarios based on the Shared-Socioeconomic Pathways (SSPs) narratives, using different projections of gross domestic product (GDP) and population growth adapted to the national context. The scenarios called Renewable fuels oriented (RF), Business as usual (BAU), and Fossil fuels oriented (FF) were also set with different fuel-blend mandates and relative prices variation between ethanol and the fuel-blend. Land-use was assessed by projecting Brazil's land-use change and agricultural outputs through 2030, taking into account future ethanol demand, as well as external trade and exogenous drivers. Our approach is based on the GLOBIOM-Brazil, a bottom-up global economic partial equilibrium model of agriculture, forestry and bioenergy sectors, especially refined for Brazil.

Results. Our projections indicate that ethanol demand is highly sensitive to variation in relative prices between ethanol and the fuel-blend, and to the increasing share of flex-fuel vehicles in the fleet. Depending on the SSPs, future number of flex fuel vehicles, including motorcycles, could vary from 56.5 million to 70.8 million, leading to corresponding ethanol demand of 48.8 billion litres in the BAU scenario, 31.9 billion litres in the FF and 63.6 billion litres in the RF scenario. Respectively, these numbers are 64%, 7% and 114% higher than the production observed in 2015. Preliminary results show that sugarcane expansion is sensitive to the future demand of ethanol.

Conclusions. We expect to suggest possible mitigation strategies in terms of deforestation and carbon emissions. Our scenarios also show the extent to which potential government interventions (i.e., fuel-blend mandates and influences on fuels prices) could influence the Brazilian ethanol demand and related land-use change.

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Grazing systems intensification: Challenges and opportunities

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Introduction. Global demand for livestock products and competition for land are growing rapidly. In this context, grazing systems intensification, by increasing food production per unit area, has been suggested as an important way of increasing livestock product outputs while sparing land for other uses (e.g. afforestation, bioenergy and crop production), and limiting environmental impacts. In this study, we aim to better understand the global potential for grazing systems intensification in a context of climate change, its role for food production, land sparing and climate change mitigation, in order to identify policy interventions for more sustainable livestock production pathways.

Methodology. The intensification strategies tested are nitrogen fertilisation, legume sowing and ruminant stocking rate optimisation. Pasturelands, for which the three intensification strategies are considered, are represented by the EPIC model [1]. Rangelands, which are in remote areas and for which only stocking rate optimisation is considered, are represented by the G-range model [2]. Stocking rate optimisation is represented by a global stocking rate optimiser developed based on Wirsenius et al. (in prep.)'s work for the Brazilian beef sector. Livestock greenhouse gas (GHG) emissions and food production are estimated by the digestion and metabolism model RUMINANT [3]. The climate change scenarios are sampled from the ISI-MIP scenarios [4], in order to account for uncertainties in the radiative forcing and in the response from the climate system. Uncertainties concerning CO_2 effects on grasslands are also considered. The outputs analysed are soil carbon, GHG emissions from grasslands and ruminants as well as ruminant food production at a 0.5-degree spatial resolution on a global scale for years 2000 and 2050.

Preliminary results. EPIC and G-range models were harmonised in their main biophysical processes. Their outputs were consistent with evaluation datasets. Legumes sowing seems to have the highest potential for grasslands GHG emissions reduction globally, while stocking rate optimisation could bring around substantial benefits, especially in parts of Sub-Saharan Africa and Latin America.

Conclusions. Although grasslands represent about a third of the earth land surface, they are poorly understood. Our results suggest that grasslands are not only one of the largest land use types but also great resources which, if properly managed, can provide in a sustainable way large amounts of the additional food humanity will need in the coming decades. Production-side mitigation options considered here add to the sometimes rather simplistic literature seeing the only opportunity for emissions reduction in agriculture through substantially reducing beef consumption.

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Nature conservation management forests in Sweden; a spatially explicit analysis of current management potentials and societal trade-offs

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Introduction. The dominant use of the Swedish forestland is highly efficient forestry based on clearcutting and replanting of a few tree species. However, a significant share of the Swedish forestland is dedicated to voluntary set aside natural conservation. From a forest management perspective, there are two main types of conservation approaches: forest stands left to free development, and stands in need of active Nature Conservation Management (NCM) to maintain their conservation values. The latter alone is reported to amount to more than three percent of the Swedish forestland. However, there is no comprehensive national data on these areas, neither on actual areas and it's management nor the potential values. On the contrary, there is only a consensus among foresters that NCM is not carried out to the extent needed, presumably caused by expectations of low profitability of NCM.

The aim of this project is twofold; 1) to describe forests in Sweden currently chosen for NCM 2) to quantify the profitability of the management of these stands.

Methodology. First, a set of categories were defined in order to describe the management objectives on the NCM stands. These categories were based on descriptions of habitats in need of special consideration during forest operations formulated by the Swedish Forestry Agency. Second, a spatially explicit analysis was made over a dataset of 27 000 NCM stands (130 000 ha) to analyse the occurrence of the different categories in Sweden.. Third, management profitability, the difference between revenues and costs, was calculated for each stand in the dataset. Revenues were simulated for different thinning strategies and intensities, removal of between 20 to 40% of standing volume, in "type stands" which were representative stands selected in each geographical region, age class, and tree species distribution. Costs were estimated using cost functions adapted to the dataset features by means of specific factors derived for each descriptive category.

Results. Six descriptive categories were formulated, covering 80% of the analysed NCM-area in the dataset. The most frequent category was *old coniferous forests*. Even though all categories could be found in all regions of the country, NCM-stands categorized as *close to human activities* and *close to water* were more common in the southern part of the country and even more frequent in densely populated southern regions. Depending on the intensity of the thinning removal, NCM was found to be possible on 40-60% of the area in the dataset without exceeding the legal requirements on minimum forest stocks. The preliminary results indicate large variations in profitability and that the more categories the stand fits into, the lower the profitability of management.

Conclusions. A major challenge in forestry is to carry out an initial sorting among all stands in order to point out areas of interest for NCM. The method applied in this study used basic forest characteristics and publicly available data to categorize forests identified for NCM. The used method could be potentially applied to all forests in the country and it could be complemented by a multi-criteria analysis able of weighing the descriptive categories In this study it is shown that the management of NCM forests where fewer criteria are met can be profitable, while an increasing amount of conservation values reduces profitability. Therefore, subsidies aimed at promoting this kind of management should be especially directed toward forests with high values where the current management is mostly unprofitable.

Three decades of forest cover changes in the humid tropical Indonesia: detection and verification at high resolution

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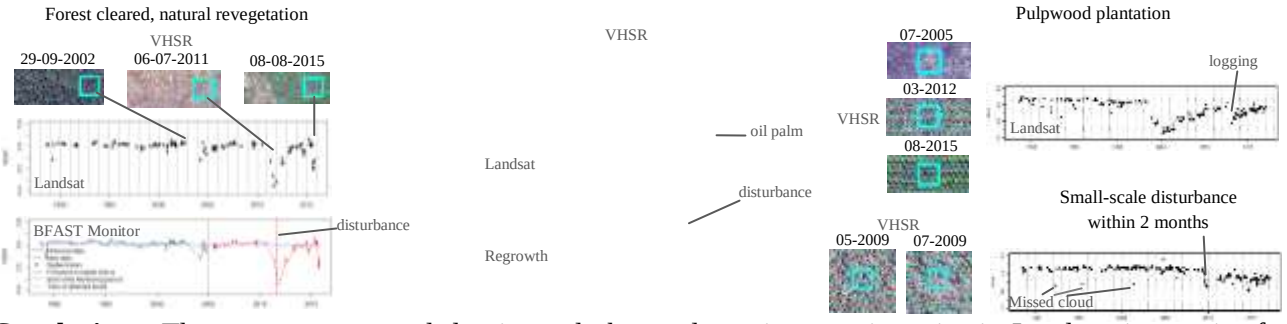
Introduction. Forest conservation and restoration could provide half of the target net CO_2 emission reduction set in Paris climate agreement. Satellite remote sensing is presently the most feasible means to map and monitor tropical forests. Previous change mapping approaches typically assessed changes based on annual or epochal composites of single-best available pixels. These approaches are not able to detect transient changes (sub-annual) between the composite periods, and gradual changes such as forest degradation and regrowth. The aim of this research is to detect continuous changes in rainforests of Indonesia in the past three decades.

Methodology. We used the Google Earth Engine platform to retrieve cloud-free per-pixel time series (16-day nominal interval) of spectral vegetation indices from high resolution (30 m) Landsat satellites image archive spanning 1987-2015. We applied the BFAST Monitor algorithm to detect disturbance, and the regrowth algorithm to detect post-disturbance regrowth. Regrowth is defined as return to previously defined stable spectral state (i.e., pre-disturbance state). The detected changes were verified using very high spatial resolution (VHSR) images.

Results. Spectral indices that use near infrared (NIR) and shortwave infrared bands (NDMI, NBR) show more clearly the disturbance signal than the indices using NIR and red bands (NDVI, EVI). Forests cleared and converted to oil palm plantation attain stable spectral signal which is consistently lower than pre-disturbance level. Thus, the regrowth algorithm can potentially be used to detect forest-to-oil palm conversion as non-regrowth. Forests re-growing after small-scale clear cut recover to the spectral signal before clearing. Thus, they are inseparable spectrally, but can be differentiated based on the occurence of disturbance. Pulpwood plantation (e.g., acacia) shows distinct short term (~7 years) harvesting/logging signal.



Conclusions. The apparent temporal density and observed consistent trajectories in Landsat time series for the different cases (verified with VHSR images) shown above indicate a promising potential to characterize the continuous forest change in Indonesia's rainforests. The next step is to assess the continuous change detection accuracy with sizable and class-representative reference samples. Challenges remain in calibrating the algorithms to handle spurious outliers and consecutive missing observations. The present approach allows for automated (vs. visual interpretation) mapping of disturbed vs. intact forest, disturbance date, regrowth date, and natural re-vegetation vs. plantation, also for near real-time monitoring as new satellite observations are ingested.

The Rush for Foreign Land – Agro-ecological drivers of FDI in land

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Introduction. Given the increasing demand for agricultural products for human consumption, fuelled by a growing world population and increasing per capita income, one strategy within the global agricultural sector has become the long term leasing or purchasing of vast acres of land in other countries to expand production. These foreign direct investments (FDI) in land are termed foreign land acquisitions (FLA) in the literature and have simultaneously gained widespread media attention, becoming known in the public debate as "land grabbing". Lay and Nolte (2017) established significant differences between FLA and traditional FDI regarding the impact of institutional quality in the host country, while Arezki et al. (2013) were puzzled by the insignificance of the "yield gap" in the host country as a driving factor for increased land investments. We return to this question with a significantly improved dataset for FLA-deals and agro-ecological data from biophysical models.

Methodology. Agro-ecological pull factors in the host countries of FLA deals are identified by means of a regression analysis within a gravity-model. Analysing flows of FDI in land between country-pairs poses estimation challenges, mainly due to the very high number of zero-flows, i.e. the absence of an investor-host-country relation between most of the possible country-pairs. In the econometric literature, using a Pseudo-Poisson maximum likelihood estimation has emerged as a best-practice approach for tackling this challenge. In the first step, we constructed new variables for potential output from rainfed crop production, net-rainfall in rainfed crop-production areas, soil and climate conditions from EPIC data and –following Arezki et al. (2013), but using data from Mueller et al. (2012) – constructed a yield gap variable. We then regressed the sum of FLA-hectares of country pairs on these explanatory variables. Simultaneously, we control for a set of relevant bilateral and unilateral characteristics, to analyse which determinants have a significant impact on the sum of hectares of FLA-investments between a country pair.

Results. Besides distance and cultural proximity, the results suggest that land abundance and net rainfall in rainfed crop-production areas in the host countries have a strong positive and significant effect on the amount of FLA. The coefficient for institutional instability is also positive, which together with the negative host-GDP coefficient, underline the concentration of FLA deals in weaker economies, less stable countries of the global south. As in previous studies, the yield gap variable leads to ambiguous results, suggesting that investors do not appear to look for potential investment gaps to close but rather for areas where production can be expanded with potentially lower costs for irrigation. The FLA-areas also tend to be significantly larger in countries with soil characterized by moisture and clay content.

Conclusions. Our results support the established hypotheses about smaller economies and weaker governmental institutions in host countries and contribute to the debate about the role of the yield gap as a pull factor for these FLA-deals. The main outcome is the clear positive impact of potential rainfed crop production in the host countries on their attractiveness for FLA. Overall, our results suggest that agricultural FLA location decisions are primarily driven by agro-ecological factors and water availability for crop production, rather than a stable business and investment environment.

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Rural labor price and evolution of crop planting structure in China

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Introduction. Crop planting structure in China have changed greatly since 1980, e.g. grain area decreased but cash crops area increased sharply in recent years, mainly due to demographic evolution, agricultural technology innovation, and market reform. With the rapid economic growth of the 1990's, nonagricultural sectors have increased their demand for rural labor, the higher urban wages stimulated a large transfer of rural labor toward off-farm employment in urban areas, which has brought about a rapid increase in rural wages and opportunity costs of farm labor. This project selected eight different crops aims to determine the impact of rural labor change on crop structure in China.

Methodology. Exploratory Spatial Data Analysis (ESDA) was employed to analyze the spatial heterogeneity and spatial autocorrelation of China's main crops area in the province level, comprehensive consideration of driving factors between various crops, Linear Mixed Model then was employed to analyze the relationship between crops structure and potential drivers.

Results. Our results show that the impact of both rural labor price and agricultural labor migration level on crop planting structure vary across provinces and crops. In general, both were positively related to cash crops area but had a negative significant effect on traditional grain crops. Higher per capita GDP significantly increased the cash crops area but decreased traditional grain crops and cotton area. However, the impact of agricultural subsidies on crop planting structure was just the opposite against the per capita GDP. An increase in agricultural mechanization was possible given the higher proportion of area to easily mechanized crops than a relatively less to hardly mechanized crops. We found a positive impact of agrometeorological disaster on vegetable area but a negative significance on wheat and corn area.

Conclusions. The study reveals there was significant spatial heterogeneity and spatial autocorrelation of China's main crop area in the province level, which showed significant agglomeration characteristics and formed a typical center-periphery structure in space. It has significant spatial heterogeneity in various factors influencing crop-planting structure, which showed that the same driving factors had an obvious regional difference across provinces. The important factors influencing the crop planting structure are rural labor price, agricultural labor migration level, agricultural mechanization and agricultural support subsidies.

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Developing the first global scenarios for biological invasions in the 21st century

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Introduction. Human action has fundamentally altered the biotic and abiotic properties of the Earth resulting in the emergence of a human-dominated era, the Anthropocene (Crutzen 2006). Anthropogenic behaviour has affected any feature of the biophysical environment with the main threats on global biodiversity being overexploitation, habitat destruction, alien species invasion and climate change (Maxwell et al. 2016). While most of these are already assessed by existing scenario frameworks, long-term trajectories of alien species invasions have not been addressed quantitatively yet. In an expert-based assessment, the first global alien species scenario narratives (ASSN) have been developed. This project aims to i) relate these scenarios to the Shared Socioeconomic Pathways (SSP) and ii) comprehensively assess existing datasets to establish first statistical models of the drivers of future alien species richness projections.

Methodology. To match the alien species scenarios to the SSPs we constructed a matrix including the assumptions for each scenario related to individual social, environmental and economic aspects captured in the narratives that was then analysed in a Multi Correspondence Analysis (MCA). To assess dataset availability, a literature search was conducted and already existing scenario initiatives and databases were consolidated. The statistical models to investigate alien first records – driver relationships were constructed in a Generalized Additive Mixed Effects Model (GAMM) framework.

Results. The MCA analysis clusters narratives based on their assumptions (e.g. demographic trends, global and regional trade patterns). Our analysis shows that the ASSNs line up well with the SSPs suggesting that assumptions derived under the ASSNs can be interpreted in a SSP context. The database assessment lead to the collection of comprehensive datasets for Land Use and Land Cover (Land Use Harmonization dataset, Hurtt et al. 2011), Demography (Wittgenstein Centre, HYDE Klein Goldewijk 2011) and Biodiversity (following de Baan et al. 2013). Other drivers without sufficiently long historic datasets for statistical model construction are discussed qualitatively. The aforementioned drivers show significant relationships with the number of first records of established alien species and thus provide a solid basis for further model development.

Conclusions. The study successfully links the ASSNs to the SSPs. This way analysis conducted and conclusions drawn within the framework of the ASSN can utilize SSP-based datasets and can be interpreted in a wider context which strengthens the relevance for other international scenario frameworks. Additionally, for the first time we provide a comprehensive overview on variables capturing the relevant drivers for biological invasions. Most drivers provide sufficiently long historic records to assess statistic relationships across a large temporal scale. Others (lacking sufficient data) are discussed in a comprehensive way providing insights into relevant indicators which high potential as input variables for models investigating future alien species richness projections.

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Optimization of biomass resources for integrated steel plants to meet EU-28 emission reduction targets

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Introduction. Iron and steel production process is fully dependant on fossil fuels, mainly coal, which makes this sector one of the biggest contributors to the European emissions. This industry hence has a strong motivation to introduce renewables – such as biomass – into the process to reduce the inevitable CO_2 emissions. The fuel switching, however, does not face only technical restriction but also concerns related to the biomass availability, economical feasibility of the solution and the relevant environmental benefit that could be achieved. This work hence addresses lack of literature focusing on this topic and studies the biomass potential for the iron and steel industry in EU-28 from the whole system perspective.

Methodology. The existing BeWhere model has been modified for this work to study the impact of the new demand for the biomass resources from the iron and steel industry on its supply for already existing biomass dependant industries. This existing demand included combined heat and power plants, pulp and paper mills and sawmills, and was focusing on ten different types of woody biomass. At the same time, four different types of biomass pre-processing technologies for iron and steel making purposes have been considered, to provide detailed analysis on economic feasibility of the solution. The on-site versus whole-system emission savings, as shown in Figure below, were compared to understand the environmental benefits across different boundaries.

Results. The preliminary results demonstrate that even though there is sufficient amount of biomass resources within the EU-28 countries to partially substitute fossil fuels used for iron and steel making purposes, the biomass utilisation with commercialised technologies is currently not economically feasible. On the other hand, the non-commercialised technologies show potential to produce bio-based fuels for such purpose with competitive prices. However, a significant emission reduction would require governmental support. Additionally, the results indicate that only certain iron and steel making plants have suitable location to successfully integrate the bio-based fuels, and hence biomass should be treated as emission reduction strategy for specific plants rather than a full European incentive.

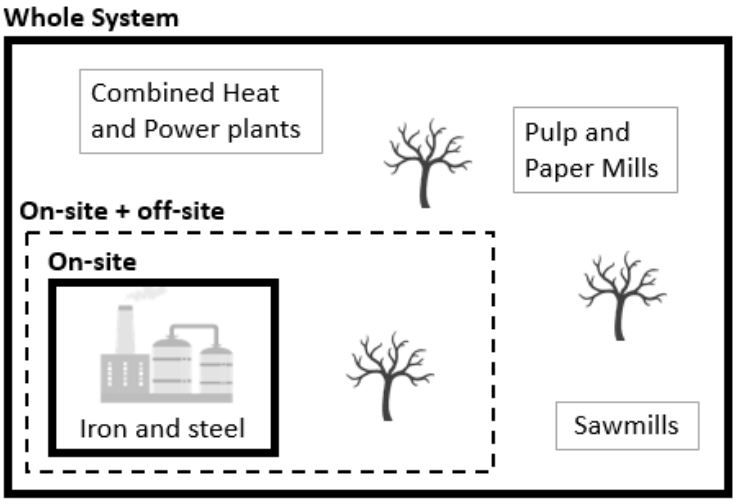

Figure: Comparison of emission savings across different boundaries.

Conclusions. Introduction of biomass into European iron and steel industry is an effective strategy to reduce significant amount of emissions. However, the current fossil fuel prices make this substitution economically unappealing. Additionally, this solution should be considered only for specific iron and steel plants rather than industry as a whole, to enhance the use of local resources and minimise emissions due to biomass transportation.

Assessing forest ecosystems under different management activities along climatic gradient in East Asia using BGC-MAN model

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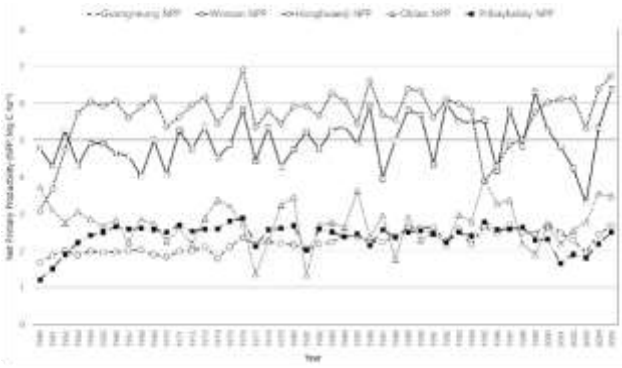
Introduction. Forests of the Mid-Latitude Ecotone (MLE), a transition zone between the forest biome and drylands in Northeast Asia around 30°-60° latitudes, provide different forest ecosystem services and have related different management regimes. Temperate forest in South Korea and Japan is well managed and protected, but forest in North Korea has been substantially degraded. In China and Mongolia, temperate forests have gradually been connected to boreal ones that are distributed from Northern Mongolia to Russia near the Baikal Lake. This study aims to identify forest growing stock volume (GSV) and Net Primary Productivity (NPP) changes in the MLE under different climate and ecological conditions while considering the impacts of various management activities on state and productivity of forests.

Methodology. Different forest ecosystems and management activities were analysed by using BGC-MAN model (Pietsch, 2014). To cover the MLE in East Asia, we selected five pilot sites by each species dominated by pine (*Pinus sylvestries* and *P. densiflora*), oak (*Quercus spp.*) and larch (*Larix mongolica* and *L. sibirica*) which are distributed along a climatic gradient of maritime climate to dry continental climate. We first used site-specific data such as species, soil characteristics, and management description which are selected through a review of previous studies. (White *et al.*, 2000). We supplemented on bio-physical data by including GIS data, such as STRM and HWSD. We used global climate data at 0.5-degree spatial resolution and modified them by considering temperature lapse and horizontal angle of solar radiations. A set of forest management activities were characterized: natural preserved forest, forest degradation, sandy and cold forest stands, and forest fires. We simulated forest GSV (m^3) and Net Primary Production (NPP; Mg C ha^{-1}) during 1951-2005 and analysed the received results.

Results. The BGC-MAN model was performed well in estimation of the forest GSV and NPP. For instance, in case of the Gwangneung coniferous forest, GSV and NPP were estimated 391.6 m^3 ha^{-1} and 6.4 Mg C ha^{-1} in 2005 by the model. This and other results were in the acceptable ranges with measured and derived from literature characteristics of forests on sample plots. Although there were some deviations, overall results for selected pine, oak, and larch sites were satisfactory. However, the dynamics of GSV and NPP were substantially different by latitudes, site conditions, management regimes, and climatic variations.



Conclusions. Different environmental conditions and different forest management activities were estimated. We figured out changes of forest ecosystem, and these results can explain some ecological transition in East Asian part of the MLE. It allows optimizing the appropriate forest management and social efforts along the gradient.

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Assessment of Policy Impacts on Carbon Capture Sequestration and Bioenergy for U.S. Coal and Natural Gas Power Plants

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Introduction. Reducing electricity-sector emissions relies heavily on countries' ability to either transition away from carbon-intensive energy generation or to sequester its resultant emissions with carbon capture and storage (CCS) technologies. The use of biomass energy technologies in conjunction with carbon capture and sequestration (BECCS) presents the opportunity for net reductions in atmospheric carbon dioxide (Fuss et al., 2014). The use of BECCS technologies is required in almost all scenarios that have a greater than 66% probability of limiting global average temperatures below 2^{o}C (IPCC, 2014). In this study, we investigate the limitations of several common policy mechanisms to incentivize the deployment of BECCS using the techno-economic spatial optimization model BeWhere.

Methodology. We consider a set of coal and natural gas electricity power plants in the United States (U.S.) selected using a screening process that considers capacity, boiler age and capacity factor from the EPA 2014 eGRID database. The set makes up 470 GW of generation, and produces 8,400 PJ and 2.07 $GTCO_2$ annually. We consider co-firing up to 15% for coal power plants and CCS for all plants. Co-firing is restricted to woody-biomass residues sourced from certified and managed U.S. forests obtained from the G4M (www.iiasa.ac.at/g4m) and GeoWiki (www.geo-wiki.org) databases. We consider the development of carbon dioxide pipelines along the existing natural gas pipelines infrastructure. Lastly, geologic storage is considered with injectivity, geomechanical pressure, and storage capacity limitations to ensure safe and adequate storage. Total system costs are then minimized under several policy mechanisms or emission targets.

Results. Costs are minimized under two policy mechanisms: a carbon tax and geologic sequestration credits, such as the Q45 credits. Results show that the carbon tax scenario incentivizes co-firing at low to medium carbon taxes, but is replaced by CCS at higher tax values. Carbon taxes do not strongly incentivize BECCS, as negative emissions associated with sequestering biomass carbon content are not accounted as revenue. On the other hand, carbon credit scenarios result in significant CCS deployment, but lack any incentive for co-firing. These results are compared to emission target optimizations where the deployment of BECCS is doubled to match similar emissions reductions compared to the carbon tax and geologic sequestration credit scenarios.

Conclusions. Current proposed policies to decarbonized the U.S. fossil fuel electricity fleet, such as the Q45 geologic sequestration credits, do not incentivize the deployment of co-firing and BECCS technologies. Although carbon taxes do incentivize co-firing technology for coal power plants, U.S. policies will also need to compensate for negative emissions caused by the sequestration of biomass carbon that would have been emitted without interference to incentivize the development of BECCS.

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Modeling dynamics of South American rangelands to climate variability and human impact

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Introduction. The combined pressures of climate change and shifting dietary preferences are creating an urgent need to improve understanding of how climate and land management are jointly affecting the sustainability of rangelands (Steinfeld & Gerber, 2010). In particular, our ability to effectively manage rangelands in a manner that satisfies increasing demand for meat and dairy while reducing environmental impact depends on the sensitivity of rangelands to perturbations from both climate (e.g., drought, fire) and land use (e.g., grazing) (Archer et al., 2004).

Methodology. To characterize the sensitivity of rangeland vegetation to variation in climate, we analyzed gridded time series of satellite and climate data at 0.05-degree spatial resolution from 2003 to 2016 for rangeland ecosystems in South America. We used panel regression and per-pixel OLS to analyze the relationship between time series of enhanced vegetation index (EVI) derived from NASA's Moderate Spatial Resolution Imaging Spectroradiometer (MODIS) and gridded precipitation data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS). To quantify the degree to which livestock management explains geographic variation of EVI, we used global livestock distribution (FAO) and feed requirements data from the Global Biosphere Management Model (GLOBIOM). Because rangeland ecosystems are sensitive to changes in meteorological variables at different time scales, we evaluated the strength of coupling between anomalies in EVI and anomalies in temperature and precipitation at 1-6 month lags.

Results and conclusions. Results reveal geographically extensive patterns of EVI variability suggesting a joint variation in ecosystem and climate across a range of time scales. Pixel-wise OLS regressions only show a few geographic clusters of coefficients that are statistically different from zero for precipitation, temperature and their squared terms. However, the coefficients estimated from the panel regression for the precipitation term and the lagged precipitation term are statistically different from zero, suggesting that between group variation is a crucial component to explain the variability of EVI to these climate variables. Our results show statistically significant relationships between EVI and precipitation during summer, fall, and winter in both rangeland-based and mixed rainfed livestock production systems in South America. Further, lagged precipitation effects, which reflect memory in the system, explain significant variance in winter EVI anomalies. While precipitation emerges as the dominant driver of variability in rangeland greenness, we find evidence of a management-induced signal as well. Further research is on-going.

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Effectively controlling phosphorus emission from agricultural fields under an uncertain climate: a dynamic stochastic agricultural phosphorus management model

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Introduction. A fundamental drawback of many studies on integrated ecological and economic modeling of eutrophication is the implicit assumption that the ecosystem is deterministic and the social planner/farmer face no uncertainties (Goetz and Zilberman 2000). While convenient, these assumptions may lead to overly simplistic representations of reality, given that ecosystems are inherently stochastic (Warmink, et al. 2010). Uncertainty may be particularly important to capture in coupled human-natural systems. There is some concern that deterministic models calibrated with average/median parameter values may lead to suboptimal policy recommendations (Crost and Traeger 2013). To address this issue, this study examines how weather uncertainties affect optimal choices of best management practices (BMPs) over adaptation by building on the soil-lake model of optimal phosphorus (P) management (Tang and Sohngen 2016) and combine it with methods in robust decision making under uncertainty.

Methodology. This study develops a dynamic stochastic optimization agricultural P management model by building on Tang and Sohngen (2016) and combining it with methods of nonsmooth stochastic optimization (Ermoliev and Norkin 1997) for robust decision making. The environmental security constraints are introduced in the form of quantile-based probabilistic constraints, which define a nonconvex and possibly highly discontinuous optimization model. The probabilistic constraints are then introduced into the objective function via nonsmooth risk functions, which are ultimately converted to linear ones via auxiliary variables. The general model is then applied to the Western Lake Erie basin, with the bioeconomic components of the model specifically calibrated for this region.

Results. The robust solutions, compared with its scenario-based deterministic counterpart, indicate that more stringent P abatement measures should be taken to meet the target loading. Specifically, about 16% reduction in P fertilizer application and earlier and longer periods of cover crops adoption are warranted under the stochastic model compared to its deterministic counterpart. The widely promoted BMP—conservation tillage, has shown to be short-term practice which should be reduced eventually. Even more stringent control strategies should be put into practice if climate change is taken into account.

Conclusions. This article develops an integrated dynamic stochastic model to show how different BMPs should be used for controlling agricultural P emissions, in the face of stochastic weather events. Though specially calibrated for a particular study area in the numerical analysis, the model developed in this paper is of generic interest, which can be readily modified to provide location-specific policy prescriptions. A simple comparison with its deterministic counterpart shows that incorporating stochasticity into the model can have qualitatively different policy recommendations for the optimal BMPs adoption path.

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Co-firing biomass with coal for power generation in Vietnam: Where, when and how much

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Introduction. Vietnam is committed to cut down the greenhouse gas emissions of the nation by 8% compared to the Business As Usual (BAU) scenario by 2030 as in its Intended Nationally Determined Contributions (INDC). The country, however, approved the latest Power Development Plan, which will extend the share of coal from 25% to 53% in total electricity generation to satisfy the growing electricity demand. According to the plan, an additional of 43 GW of coal power will be added to the existing 15 GW and thus increase the greenhouse gas emission from coal power plants from 90 $MtCO_2eq$/year to 350 $MtCO_2eq$/year. The question is how Vietnam will achieve these two conflicting goals. In this study, we explore co-firing, a technology that allows partial substitution of coal by biomass, as a potential pathway to reduce the carbon emissions from the fast growing Vietnamese coal sector.

Methodology. We adapted the existing BeWhere model (www.iiasa.ac.at/bewhere) for the case of co-firing in Vietnam by making it recursive dynamic until from 2015 to 2030 with a yearly time step. Four co-firing technologies are considered, two types of biomass and the spatial location of the planned coal power capacity. We use GAMS to identify the optimal choice of the co-firing technology for each coal plant using domestic biomass resource from rice residue. The objective function minimizes electricity production cost, which also includes the emission cost in term of carbon price. Two scenarios for co-firing to be used are with carbon credit and with emission target. In each scenario, we try to find out when the coal power plant will do co-firing, how much biomass will be needed, how much emission reduction can be achieved and what the associated cost will be.

Results. When the carbon price is set below 6 $\$/tCO_2eq$ the co-firing technology is not economically feasible. Started from this carbon price, one third of the 96 coal plants is selected for co-firing with direct and separate injection technology at 15% mixing ratio, which helps reduce emission by 9.5 $MtCO_2eq$ by 2030 (account for 2.6% of BAU scenario). When the carbon price reaches 30 $\$/tCO_2eq$, almost all coal power plants will retrofit for co-firing, which results in 17 $MtCO_2eq$ emission reduction (4.7% of BAU scenario). In case emission target is set up for each year, co-firing could not help the coal power plant to achieve the target even with 8% emission cut. This is because in the first year the existing power plants will install cheaper co-firing technology with lower co-firing rate, which end up in lower emission reduction while ensuring the emission target is met. Then from the previous year, the new plants will face stricter emission reduction target that could not be achieved by co-firing even with the highest mixing rate technology.

Conclusions. Incentive such as carbon price is very important to adopt co-firing technology. This will help to compensate for the investment cost and operation cost of retrofitting existing plants for co-firing. Implementing co-firing could result in emissions reduction of about 5% compare to the BAU scenario when all planned coal power plants retrofitted for co-firing. It is not feasible to achieve 8% or 25% emission cut compared to BAU with co-firing alone when using emission target for coal power plants for each year. To achieve these target one option is to consider negative emission technologies such as carbon capture and sequestration.

Exploratory Special Projects (ESP)

Assessing energy and natural resource footprints under China's sustainable economic transformation

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Introduction. China is a large energy and resource consumer in the world. The energy consumption of China accounted for 23% in 2016 (BP, 2017) globally and almost one-third of world natural resource were utilized in China in 2008 (UNEP, 2013). The global economy nowadays is increasingly interlinked among counties and economic sectors. Through the whole production chain, the natural resources including energy are transferred directly and indirectly worldwide and across different economic sectors. In the context of reaching Sustainable Developing Goals (SDGs), it is important to have the knowledge of not only the direct energy and resource flow but also combined with embedded flows (i.e. material footprint) for the better evaluation of the resource efficiency in the perspective of consumption ends. Thus, this research focuses on the footprints of key energy and natural resources in the key economic sectors in China.

Methodology. In my research, Material footprints are calculated by the top-down method Environmentally Extended Multiregional Input-Output Analysis (EE-MRIO). In this model, three matrices are required to construct: the material intensity matrix (i.e. satellite accounts), global input-output table and final demand matrix. By applying the Leontief quantity model, the footprints are calculated. The data required are obtained from USGS, SERI, EXIOBASE and Tsinghua University. The forward and backward linkage analysis is also adopted.

Results and discussion. The iron footprint of China reached 0.84 billion tons (41.0% of global extraction) which exceeded its domestic extraction (0.71 billion tons) in 2007. The total iron ores equivalent (direct and embedded) imports of China was 0.39 billion tons comparing to 0.40 billion tons of direct imports flows. The total iron ores equivalent exports from China reached 0.25 billion, whose major consumers were North American and Europe. In the perspective of industries, over 45.1% and 39.7% of iron in China were utilized by construction and manufacture industries. As for the coal, China was a net coal exports country from the perspective of footprint. The footprint of coal of China reached 1.88 billion tons with 0.75 billion tons exports and 0.11 billion tons imports. United States, Japan and Germany were the main importers of Chinese coal footprint. The utilization of the construction materials was more concentrated. The construction materials footprint of China reached 8.17 billion tons. Including the embedded transfer via trade, 96.4% of construction materials consumed were extracted within the border. The construction industry took up 74.0% of the construction materials. Additionally, even though the absolute amounts of resource and energy consumption of China were large, China only ranked 20, 35 and 34 among 48 counties and regions in terms of per capita footprint of iron, construction materials and coal respectively, with the amount nearly a quarter of developing countries in Europe and North America.

Figure 1 Global iron footprint flow

Figure 2 Export flow (direct and embedded) of Coal of China

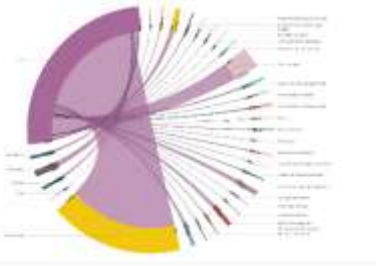

Figure 3 Construction materials footprint structure in China

World Population (POP)

Adult children's education and their parents' health status in the Philippines

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Introduction. This research examines the association between children's education and the health status of their parents. It also investigates whether this association (or lack thereof) is consistent across a series of health indicators, representing different health dimensions. There are various mechanisms by which children's education could influence parental health, including provision of better instrumental support, and transfer of both material and non-material resources (Torssander, 2013). For example, well-educated children are more likely to give better care to their parents because they have more resources and have more flexible jobs that enable them to provide assistance to their parents. They are also more knowledgeable about health-related information and are more comfortable in navigating the health care system, which comes to play when children give health-related advice to their parents or when they decide how to address the health problems of their parents (Friedman and Mare, 2014; Torssander, 2013; 2014). Highly educated children also tend to adopt healthier behavior and lifestyle, which in turn, can influence the health behaviors of their parents.

Methodology. Data are drawn from the 2007 Philippine Study on Aging (PSA), a nationally representative survey of older Filipinos aged 60 years and over. We examine the characteristics of the most highly educated child in relation to the older person's health status, thus only respondents with at least one living child are included in the analysis. Four health indicators are the main outcome variables in this study, including difficulty in activities of daily living (ADL), instrumental activities of daily living (IADL), mobility limitations and grip strength. Logistic regression and quantile regression models are used in the multivariate analyses.

Results. Children's education is significantly associated with the health status of their parents. Specifically, older Filipinos whose children have a tertiary education have lower odds of reporting unfavorable health status compared to their counterparts whose children have less than a tertiary education, controlling for the confounding effects of other established factors. However, contrary to most findings, the influence of parental education is not always significantly associated with their own health status. Other significant factors associated with health status of older Filipinos include age, place of residence, perceived income adequacy and religiosity.

Conclusions. Results of the study support the contention that education is not only an individual resource, but could be a household or family resource that could benefit other family members (Torssander, 2012; Yang et al, 2016; Zimmer et al, 2007). Although the exact mechanisms of how children's education influence the health status of their parents remain to be explored, the current study demonstrates that investments in human capital of younger generations also confers benefits to older generations (De Neve and Harling, 2017; Friedman and Mare, 2014; Yahirun et al, 2016).

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Dependency on use of solid fuel in the household and under-five mortality rate in Nigeria

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Introduction. Children exposed to smoke from solid fuel are likely to suffer from Lower Respiratory Infections (Samuel *et.al*, 2016). Despite the U-5 mortality rate of 128 deaths per 1000 live births in Nigeria, 70 percent of households in the country still use solid fuel for cooking; hence, children in such homes are exposed to emissions of harmful biomass smoke (Olisaekee, 2014). Therefore, this study identify types of cooking fuel used within the households, factors influencing it and the extent to which the use of such fuel had contributed to under-five mortality rate in Nigeria. Lastly, socioeconomic differences in the use of solid fuel as it implied on under-five mortality was examined.

Methodology. The 2013 Nigeria Demographic and Health Survey dataset was used for analyses in this study. The analyses were using done using Cross tabulation method and Binary Logistic Regression technique on STATA version 13.

Results. From the result, 70 percent of households in Nigeria used firewood for cooking. The bivariate relationship shows that, the proportion of deaths was higher for children living in homes where solid fuel was used for cooking than children living in homes where non-solid fuel was used. Hence, there is a significant bivariate association between use of solid fuel and under-five mortality (P<0.01). Findings from the study established that level of education, wealth status, place of residence and region are factors influencing the use of solid fuel in the household. Finally, the odds of dying increases for children whose mothers have primary or no education when compared with their counterparts whose mothers have higher education (OR= 1.69; P = 0.007). Similarly, the odds of dying declined among children living in rich homes compared to those living in poor homes (OR= 1.28; P =0.029).

Matrix showing Odds of dying				
Wealth Status	Level of Education			
	E_1	E_2	E_3	E_4
W_1	0.134	0.119	0.096	0.077
W_2	0.097	0.086	0.069	0.056
W_3	0.087	0.078	0.063	0.053

Conclusions. Wealth status and educational attainment of mothers remained highly significant determinants of under-five mortality in Nigeria. The standard of living in the household and the level of education of the mother determines the type of cooking fuel used in the household and eventually the chances of deaths among under-five children.

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The impact of education and age on attitude toward immigration in contemporary Europe

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Introduction. Migration is an inherent part of contemporary Western societies, particularly in the EU. A vast block of literature examines public views toward immigrants focusing on an ethno-racial component; however, the research on attitudes to immigration as a phenomenon is quite scarce (Meuleman et al. 2009). Moreover, the scholarship could be enriched by investigating formation of attitudes toward immigration utilizing panel data (Ceobanu and Escandell 2010). This paper aims to shed light on the current state of affairs and understand the heterogeneity in the population by evaluating the effects of education, age and cohort on attitudes toward immigration in European countries over the span of twelve years.

Methodology. This micro-level, panel, cross-sectional research examines the change in general, cultural and economic aspects of attitude toward immigration in 16 European countries between 2002 and 2014. Data from the European Social Survey (ESS) was obtained to measure individual-level parameters, while data from the Eurostat was used to account for macro-level parameters, such as migration rate. The empirical framework here tests the hypotheses that level of educational attainment will have a positive effect on the above-mentioned aspects of attitude toward immigration, while the effect of age and cohort will be negative. Furthermore, respondents with a higher level of education are expected to retain a positive attitude toward immigration even at an older age.

Results. The results at the country level coincide with the general trend of the full sample and show that respondents tend to have a more positive attitude toward immigration in its cultural than in general and economic aspects. While older age groups showed a consistent decline in positive attitude toward immigration in all three aspects being in line with findings for older cohorts regardless of the year of survey, the effect of level of education was positive, significant, and almost linear. Respondents with tertiary education were found roughly three times more likely to favor immigration in cultural and economic aspects than respondents with lower than secondary education, while being twice more likely to have a pro-immigration sentiment in general aspect. Moreover, respondents with higher level of educational attainment retained a more positive attitude toward immigration within most age groups, except for the 75-year-old age group, within which it declined in all three aspects.

Conclusions. Examining heterogeneity in the population is key to understanding attitudes to immigration. This research attempted to assess the effect of level of educational attainment on general, cultural and economic attitudes to immigration, while disentangling the age and cohort effects. The effect of the level of educational attainment on positive attitude toward immigration was found significant and consistent on both aggregated and individual-country levels.

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Risk and Resilience
(RISK)

Seismic resilience of the electricity transmission grid of Qom in Iran: analysis of a prototype model

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Introduction. Increasing number of power supply interruptions due to earthquakes leads to heavy direct and indirect economic losses and indicates importance of resilience of electric power networks. Iran as one of the most seismic prone countries in the world and high vulnerability of its electric power grid requires risk and resilience assessments. The main focus of this study is on transmission grid because of high economic value of its components, high potential of widespread cascading effects and complicated and longer recovery time.

Methodology. This research is based on the network performance analysis and the graph theory. We are using a prototype model of the electricity transmission grid of Qom to calculate the average performance of the system over considered time. Vulnerability curves were developed for such components as towers and lines. The performance of each component was considered by the weight factors, which were developed based on the connectivity criteria. The recovery time was calculated by using the gamma cumulative distribution function. The recovery process was modelled by the use of three simplified recovery functions. Finally, in several different modes of removing transmission lines and under different distribution of peak ground accelerations (PGAs), grid resilience was calculated.

Results. As shown on the Figure 1, grid resilience was calculated in different scenarios of removal of transmission lines, which had different weight coefficients and were related to different vulnerability curves. The numerical results indicate that: 1- Increase of resilience by increasing redundancy (to an optimum amount). 2- Increase of resilience by improving recovery. 3- Less sensitivity of resilience to redundancy changes by using the linear recovery function than the others. 4- Stronger impact of higher voltage transmission line of 400 kV than lower voltage of 230 kV on resilience. 5- Reduction of resilience by increasing PGAs. By identifying the effective factors on different parts of the resilience curve and changing these factors, resilience can be increased.

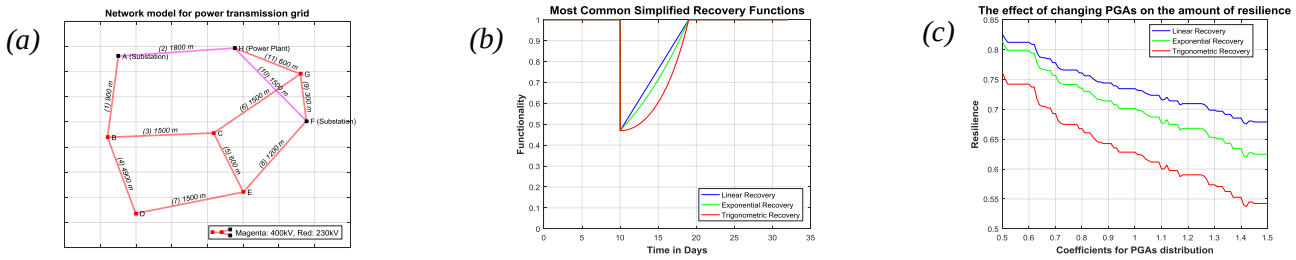

Figure 1: (a): Network model for power transmission grid, (b): Use of three recovery functions to make resilience curves, (c): Reduction of resilience by increasing PGAs

Conclusions. The present study is the first attempt to calculate the resilience of the Iran's electricity transmission grid on the example of a prototype model. The study developed a basic framework for calculating power grid performance and resilience in order to investigate how effective parameters act. Unlike the existing methods for network performance analysis, i.e. connectivity and power flow analysis, this research distinguishes between the recovery of facilities in the network by classifying damage levels to different degrees between zero and one and assigning performance values to each level. In other words, this study attempts to combine the advantages of the most important methods in power network analysis, i.e. the rapidity and simplicity of connectivity analysis with the accuracy of power flow analysis, without using any of these two methods.

Drought impacts and risks on agricultural production in the Bolivian altiplano

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Introduction. The South American Altiplano is besides Tibet the largest high plateau in the world. Climate variability in the Altiplano is associated to the El Niño Southern Oscillation (ENSO), and droughts have being mainly driven byEl Niño phases (Thompson et al., 1984; Francou, 1985; Tapley and Waylen, 1990; Garreaud and Aceituno, 2001). One constrain to study drought occurrence in the Altiplano is the uneven and scarce distribution of weather and crop related ground data. To this aim, a new framework for timely warning of droughts at an inter-annual time scale was developed for the Bolivian Altiplano, using a combination of ground and satellite imagery data.

Methodology. Precipitation, temperature, vegetation and ENSO monthly time series from July 1981 to June 2016 were statistically analysed to detect trend changes and interrelationships. Additionally, two crops, namely quinoa and potato crop yields for the same period were looked at. In a first step, data quality analysis was applied to diminish the observational errors and cloud/snow noise of the satellite data. In a second step, the validation of satellite rainfall products was applied and contrasted to the ground data weather stations. Furthermore, a linear regression of vegetation with temperature and precipitation data was applied to better understand their relationship. Additionally, precipitation variation during the ENSO events as well as crop production was evaluated. Finally, crop production was related with vegetation variability under drought events based on normal and ENSO years. Differences in risk as well as climate signals of ENSO years were afterwards determined.

Results. From the 68 weather stations only a third could be used for statistical investigations. Major data gaps were filled using mean monthly values. At first, the relationship between rain satellite and ground data showed significant correlation along the 23 data sets. Additionally, the Normalized Difference Vegetation Index (NDVI) indicated significant relationships with precipitation and temperature variables, showing that vegetation is very much affected by climate variables. Also precipitation varied during the ENSO years, and as a consequence we confirmed that precipitation significantly decreases in El Niño phases. Finally a relationship between NDVI and crop yield was shown. To summarize, ENSO warm phase (El Niño) has a negative effect on precipitation that impacts the vegetation, and in consequence also affects crop production. The differences in risk can be used for estimating possible management strategies and costs, such as government funding for assistance during drought periods.

Conclusions. The impact of droughts on crop production could be in principle mitigated by early warning mechanisms. Consequently, a better understanding of potato and quinoa yield variation was developed based on its relationship with precipitation and temperature. Therefore, considering that El Nino phase generally drives a drought event, it is possible to evaluate the crop production impact, based on the relations with the vegetation and climate indicators. Satellite data is an important source of information particularly in regions where observed data is limited. The suggested framework can be used as a blueprint how early warning based financing could be established for drought events in the Altiplano.

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Risk of multiple failures in electrical grids due to natural hazards in the Eurasian Economic Union

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Introduction. Electricity transmission grid is a complex system that is sensitive to power outages, which, inter alia, can be caused by different natural hazards such as earthquakes. Power outages can spark cascade accidents leading to huge damages and costs. Therefore, it is important to investigate the reliability of energy power systems (EPS). This study focuses on three countries of the Eurasian Economic Union, the Russian Federation with six united power systems (UPS), the Republic of Kazakhstan, which is divided into three energy regions and the Kyrgyz Republic, which has a single EPS.

Methodology. The methodology of this research is based on six steps. The first step is the overlapping of maps of seismic zones and EPS schemes for Russia, Kazakhstan and Kyrgyzstan. The second step is the identification of the information about each power plant in the three above mentioned countries and each interconnection between them. These power plants and interconnections could be dislocated in seismic area with defined earthquake intensity score according to seismic resistance parameter of each element by information about which intensive score of seismic could impact to different types of power plants or lines and could provoke the degradation or devastation of this element. The main goal of this step is to define the probability of failure for each element. The probability of earthquake with a high intensity score, which must be higher or equal to resistance parameters of the components of the grid, was applied. The third step is to apply the power optimization model in order to identify potential power shortage. The programing efforts are based on C++ 11. With the help of programming we generate states for this model with dependence only for elements with the probability higher than 0 by the criteria (n-1 is without one working element etc.; n-2; n-3). Then each of this state is optimized by the gradient method. The results of this optimization show deficits in EPS. During the final step we make two distributions for each working and not working lines (deficit and probability of accident). The results show importance of different lines in terms of interconnectivity.

Results & conclusions.

During this program we are investigated the methodology and got results. The probability of failure on current interconnections was determined from six investigated approaches. Current methodology was explored and defined from three different ways. The special seismic zone maps were found for each country and the data were unified regarding to consultation with research institutes of these countries. Also information about each elements included to UPS were found on the schemes maps and checked by official public information of energy corporations reports for last year. The information and maps were combined to database and each investigated element (206 stations and 98 lines) got its probability of failure caused by earthquake. Based on this data we already found six high-capacity lines between Kyrgyzstan and Kazakhstan that could be damaged by frequency earthquakes in this area. In addition, we have found two lines between south and north regions of Kazakhstan, one line between north Kazakhstan and UPS of Siberia (Russia) and three lines between west Kazakhstan and UPS of middle Volga (Russia) which placed in seismic regions with high intensive score. As well as the program for calculating results was developed and tested. We got 695681 states by different criteria and deficits for each state. In conclusion, we will check each of suspect line by distributions and T-test for take the more clarify results.

Auctions for renewable energy – risks and opportunities

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Introduction. At the end of 2016, 176 countries had targets for renewable energy (REN21, 2016). In reaching these goals, policies for renewable energy plays a crucial role. The last years, there has been a trend to transition, from feed-in policies towards auctions for renewable energy. Between 2005 and 2016 the number of countries that had employed auctions grew from 5 to 67 (IRENA, 2017). Auctions allow the government to control the amount of new installed capacity and competitive auctions can help decrease the cost of producing electricity from renewable energy. There are however concerns about the efficiency and fairness of auctions. This work aims to study risks and opportunities with an auction design that promotes small scale actors, which is currently used in Germany.

Methodology. Two methods are utilised in this project: a serious game and agent-based modelling. In the serious game, developed in this project, players take on the role of power companies and citizens. Both power companies and citizens can choose between investing in a "safe" option and submitting a bid to the renewable energy auction. Citizens have higher costs for preparing bids, and can only submit one bid to the auction while companies can submit two. To compensate for these disadvantages, citizens that win in the auction will not be paid their bid, but the highest accepted bid (also known as a uniform auction). Companies that win will, on the other hand, be paid according to their submitted bid (also known as a discriminatory auction). The game was played on two occasions, with seven players the first time and nine players the second time, for four, respectively five rounds. The agent-based model is structured similarly to the game. There are two types of agents: citizens and power companies. The power company agents can choose between investing in a gas or coal power plant or to take part in the auction. At this point, the power company agents are using profit maximising to decided what to invest in. Citizens agents take part in the auction and bid their break-even cost (a dominant strategy for uniform auctions). In future work, the agent-based model will be modified with behaviours observed in the game.

Results. The preliminary results from the game show that players initially are sceptical towards the auction. This lead to high bids being accepted in the first round, which gave players who took part in the auction this round highly lucrative contracts. When the remaining players realised this, the auction participation rose significantly in the following rounds. The increased number of bids drove down the highest accepted bid, which decreased the revenues for the auction participants. Both times the game was played, the highest accepted bid in the auction in the last round was just above the level that was enough to recover investment costs. With the design of the auction, citizens were incentivised to place very low bids (some were below the level of recovering costs), which also led citizens to dominate the auction. To compete with this, companies started to bid increasingly aggressive.

Conclusions. These findings suggest that with an auction design combining uniform and discriminatory payments, small-scale actors may not be at a disadvantage (this was also seen in the latest auction for wind power in Germany, (Wehrmann & Wettengel, 2017)), but that the design in itself may increase the risk of overly aggressive bidding.

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Assessment of direct and indirect economic effects of flood damage – An application to German companies

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Introduction. Floods have multiple effects on affected regions. Direct effects only occur inside flooded areas, while indirect effects typically occur outside the flooded area [Merz, 2010]. Comprehensive impact assessments, including direct and indirect effects are increasingly demanded by stakeholders [Meyer, 2013]. As a gap, coupled direct and indirect economic flood effects on a subnational level are rarely assessed [Koks, 2015]. Therefore, a model chain is developed, which incorporates direct flood damage estimates to companies' assets within a regional Input-Output-Model to estimate indirect economic effects. The model chain is applied to a flood event in the year 2013 in Saxony, Germany.

Methodology. Random Forests (RFs) are used to estimate direct flood damage to assets for each company individually (micro-scale) [Sieg, 2017]. Since the RF outputs are at the micro-scale, a new approach is used to aggregate direct economic effects to regional scale (meso-scale). This approach replicates company characteristics and flood impacts, which are used as inputs for the RFs, based on empirical data and official statistics. Meso-scale outputs of the RFs are taken to shock the economic system using a Supply-side/Ghosh-price Input-Output Model (SIO) [Dietzenbacher, 1997].

Results & Conclusions. Results are computed for 100 sets of replicated input variables. Figure 1 shows distributions of direct and indirect effects per sector. Direct effects are shown as the absolute damage of a respective sector in relation to the sector's capital stock. Indirect effects can be interpreted as the increase in output prices of the sector's production as a consequence of the flood. Absolute direct damage to companies is estimated around 1.2 billion EUR, the reported damage is numbered around 0.6 billion EUR. Distributions of both results show different variances for different sectors. A comparison of the two outputs illustrates that high direct damage to sectors does not necessarily correspond with high indirect effects. In conclusion, the model chain set up enables a coupled estimation of direct and indirect economic effects on different company sectors. Meso-scale estimates of direct damage are reasonable compared to reported damage numbers for an early stage model and likely to be improved in near-future.

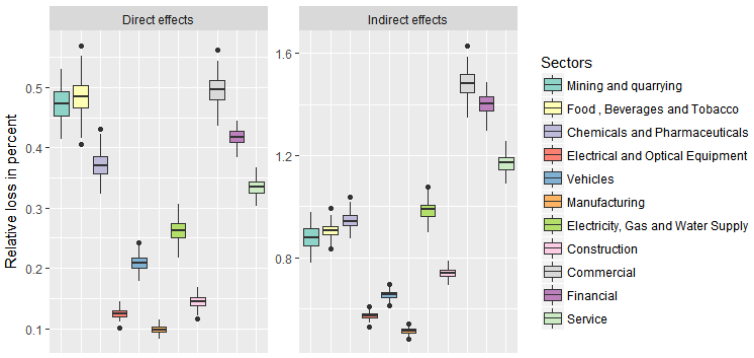

Figure 1 Boxplots of direct damage related to the capital stock (direct effect) and the increase in output prices (indirect effect) per sector in percent

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Vulnerability is dynamic: Approaching the emerging challenges of coastal tourism

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Introduction. Tourism is one of the largest sectors in the world, contributing to 10% of global GDP. While an important contributor to economic prosperity, tourism is both a driver of and at risk to global (environmental) changes. Coastal tourism is especially dependent on local environmental resources and occurs in vulnerability hot spot areas for environmental changes. Vulnerability is dynamic and we need a new lens for understanding how vulnerability emerges in coastal tourism systems. My research operationalizes a dynamic approach to analyzing coastal (tourism) vulnerabilities, exposure to new hazards, and the emergence of vulnerabilities through exploring socio-ecological interactions and feedbacks. The main objectives of my YSSP study are to demonstrate an innovative transdisciplinary approach to study coastal tourism systems and to develop an agent-based model (ABM) for exploring dynamics and emergence of vulnerability under various scenarios.

Methodology. Empirical data was collected on two Caribbean islands: Barbados and Curaçao. The dynamic approach involves mixed methods and stakeholder participation. The mixed methods include: semi-structured interviews, focus groups, simulation-aided interviews, simulation sessions, and agent-based modeling. Semi-structured interview questions employ the ARDI framework to better conceptualize the actors, resources, dynamics and impacts in the coastal system (Étienne et al. 2011). The development of the simulation and ABM was informed by the Companion Modelling approach (Étienne (Ed.) 2013).

Preliminary Results. Using simulations and agent-based modeling, my approach operationalizes the concept that vulnerability is dynamic and emerges from complex interactions between humans and the environment. The approach itself is dynamic, iterative and involves stakeholders in problem definition, design, and evaluation of emerging vulnerabilities in the coastal system. This approach thereby offers a number of advantages over more conventional methodologies that are often conducted in a top-down and static manner. A coastal tourism system ABM is being developed using data from both interviews and simulation observations. In its current form, the ABM includes the major actors: nearshore operators, boat operators, hoteliers, beach vendors, dive operators, and tourists; and the environmental resources: beach, sea, sand, coral reefs, sea turtles, fish, and mangroves. The tourism demand side's creation of waste and revenue are in preliminary stages while the supply side's decision mechanism for operational inputs are under development. Further interactions among stakeholders and environmental feedbacks will be added. Multiple environmental and tourism scenarios can be included and tested once the endogenous mechanisms are in place. Overall, this general approach with mixed methods can be adjusted and applied for understanding emerging vulnerabilities in coastal tourism and beyond.

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A Global Analysis of Wildlife Damage Risk Financing

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Introduction. While large mammals play a pivotal role in maintaining ecosystem functioning and provision of ecosystem services, their conflicts with humans are becoming common and intensive problems worldwide and cause billions of dollars of economic losses annually (Nyhus, 2016). Wildlife damage financing is a major tool of human-wildlife conflict (HWC) mitigation strategies, usually in the form of direct compensation, which often fails. Damage insurance recently emerged as a new financial instrument, but the key factors and necessary enabling environment for an effective wildlife damage insurance scheme are unclear. In my YSSP research I try to investigate the role of wildlife damage risk financing in HWC mitigation and to identify the key characteristics and enablers of effective wildlife risk financing schemes.

Methodology. I conducted systematic review and critical comparative analyses of 13 wildlife damage risk financing cases, covering a range of global geographic regions, wildlife taxa, and countries at different development stages. The Social-Ecological Systems Framework (McGinnis et al, 2014), originally proposed by Elinor Ostrom, was employed as the analytical framework to diagnose and compare the cases in a structured manner and to identify key factors of successful HWC risk financing schemes. Institutional analysis was applied to the cases to further explore their similarities and difference in terms of risk financing administration procedures and the roles of different actors.

Results and Conclusions. The results show that wildlife damage financing, both compensation and insurance, in developed countries generally work well, although insurance premium in these countries is often heavily subsidized by governments. Risk financing is likely most useful when wildlife damage occurs with high intensity and low frequency and damage risk mitigation is often too costly. Viable insurance and compensation programs, especially those in developing countries, often involves some levels of decentralization with hybrid rule-making organization. The overall program often exhibits some polycentric governance structures, in which some public, private, civil society and community groups simultaneously work together and sometimes end up with novel institution setting and rules. In such these polycentric governance setting, both transaction costs and moral hazards are substantially reduced.

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Transitions to New Technologies (TNT)

An analysis of energy transportation strategy for China's electricity system

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Introduction. In China, nearly 75% of electricity production is from coal. However, the distribution of coal resources and the demand of electricity are geographically unbalance. Coal or electricity needs to be transported or transmitted among regions. In addition, with the implementation of China's air pollution control policies, more clean energy resources would be used to generate electricity such as hydro and photovoltaic. This means that the power generation structure is changing, which would lead to a new challenge to energy transportation between regions. Furthermore, China is adopting new energy transportation technology as well as new power generation technology, and these technologies provide a chance to reconfigure the electricity system both technologically and spatially. Thus, the objective of my YSSP project is to study multi-regional energy transportation strategies for China's electricity system and analyse the power generation structure in each region.

Methodology. The electricity system model in my research is derived from the IIASA's MESSAGE modelling framework. China's electricity system is structured into nine levels, including resources, northwest, southwest, northeast, north, central, south, east, and demand level. Linking of these energy levels are realized by using conversion technologies (generation, transportation, transmission, distribution, etc.). The energy types are considered based on the regional energy characteristics, for example, the northwest region is rich in coal, wind, and hydro. Investment cost, operating and maintenance cost form the total electricity system costs. The constraints of the model include demand, regional power plant carrying capacity, regional water resource availability and regional air pollution control. By default, MESSAGE minimizes the cumulative total system costs as a criterion for optimization.

Results and Discussions. Figure 1 shows the results of the energy transportation between regions from 2015 to 2050. Coal would mainly be transported from north and northwest China to central, south and east China, while the electricity would be transmitted to southwest and east where the strict air pollution control policies are applied. Figure 2 shows the electricity generation structure from 2015 to 2050. In 2050, about 48% of total China's power generation would be from clean energy sources, especially, the ratio is higher in the air pollution control areas. The ordinary power plants with low efficiency and high pollution would be replaced by those with higher efficiency and lower pollution emissions. The ways of energy transportation between regions and the structures of power generation in each region would be greatly influenced by local water resource availability and applied air pollution control policies.

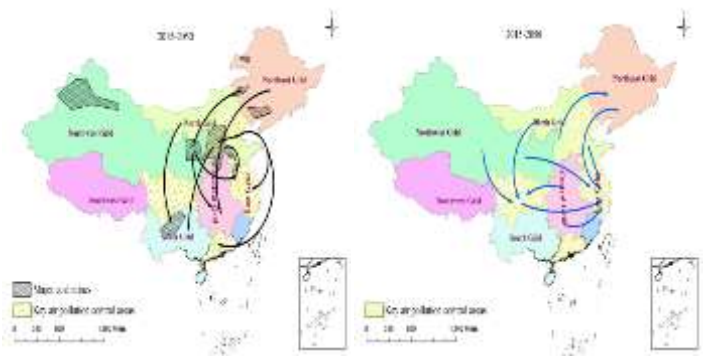

Fig.1. The flows of coal transportation (left) and electricity transmission (right) between regions from 2015 to 2050

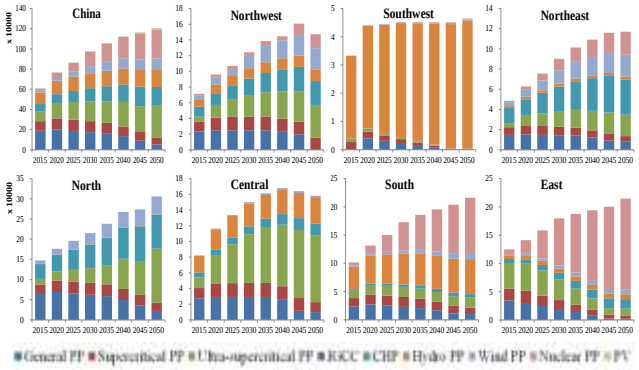

Fig.2. The electricity generation structures for overall China and each region from 2015 to 2050

Water
(WAT)

Investigation of drought adaptation options using an integrated hydrological and agent-based model

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Introduction. California has endured a record-breaking drought since the winter 2011 and will likely experience more severe and persistent droughts in the coming decades under changing climate. At the same time, human water management practices can also affect the drought characteristics including frequency and intensity (He et al., 2017), which underscores the importance of human behaviour in effective drought adaptation and mitigation. Currently, although a few large-scale hydrological and water resources models (e.g., PCR-GLOBWB) consider human water use and management practices (e.g., irrigation, reservoir operation, groundwater pumping), none of them includes the dynamic feedbacks between local human behaviours/decisions and the natural hydrological system. It is, therefore, vital to integrate social and human behavioural dimensions into current hydrological modelling framework in order to better understand the mechanisms of human-water interface.

Methodology. This study uses the agent-based modelling (ABM) approach and couples it with a large scale hydrological model (i.e., Community Water Model, CWatM) (Burek et al., 2016) in order to have a realistic representation of social, environmental and economic factors and a more dynamic representation of the bi-directional interactions and feedbacks in the coupled human and natural water system. For a case study, we focus on drought management in California and consider two types of agents, which are (group of) farmers and government agencies. We assume that their corresponding objectives are to maximize the net crop profit and to minimize water scarcity, respectively. Farmers' behaviours are linked with local agricultural practices such as cropping patterns and deficit irrigation. More precisely, farmers' decisions are incorporated into the ABM-CWatM framework across different time scales in terms of daily irrigation amount, seasonal/annual decisions on crop types and irrigated areas.

Results and Conclusions. As the first step, we apply an evolutionary algorithm and use observed daily discharge data during the period 1991-2010 to calibrate CWatM. After the calibration, Kling-Gupta efficiency (KGE) values reach to 0.83 and 0.91 at daily and monthly timescale respectively, indicating that CWatM produces a reliable representation of the terrestrial hydrological cycle in California. We then incorporate a key parameter α into this calibrated model, which characterizes farmers' management practice to soil water deficit towards crop water stress. Model simulations with and without considerations of α parameter show significant differences of streamflow and groundwater depletion. Additional simulations with regionally heterogeneous α highlight the crucial role of spatial heterogeneity on the system-level dynamics. Scenario analysis with different water management practices and associated drought adaptation options shows the necessity of including individual's (or group's) behaviours as an additional source of uncertainty when modelling the large-scale human-natural systems.

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Aquatic ecosystem status of Lake Vombsjön, Sweden

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Introduction. As cyanobacterial blooms, which are also called Harmful Algae Blooms (HAB), have become one of the most critical concerns for drinking water supply when using surface water as resources, their growth mechanisms, especially interaction with nutrients such as nitrogen (N) and phosphorus (P), need to be well understood to develop sound control measures. This study aimed to investigate ecosystem status of Lake Vombsjön in southern Sweden for its HAB control.

Methodology. Data from 1990 to 2016 was used to investigate potential historical changes in concentrations of N, P, and N:P ratio. N:P ratio is an important factor as when the ratio of N:P is low, N availability is limiting other species to grow except some cyanobacteria (blue green algae) that are able to fix atmospheric nitrogen (N_2), giving them a competitive advantage. Previous N:P ratio models were used to evaluate changes in the risk of cyanobacterial blooms (Smith et al. 1995, Horne and Commins, 1987). The temporal trend of cyanobacterial biomass was evaluated based on field data in 1989-2002, 2005, 2009, 2010 and 2016. Although not all bloom-forming cyanobacteria are toxic. As precaution, cyanobacterial blooms should be considered toxic, as evidence shows that up to 75% of blooms are toxic (WHO, 2015).

Results. Lake Vombsjön is still at eutrophic to hypertrophic status, which means rich nutrient condition for algae growth. One possible reason of high nutrient level in the lake might be due to cyanobacteria as potential drivers of N and P cycling through assimilating N from air and P from the lake bottom (Cottingham, et.al, 2015). The temporal changes of N:P ratios have large amplitudes in the past decades from less than 5 to above 200. N:P empirical models showed that N:P ratio below 22 favours cyanobacteria growth and particularly N_2-fixing species. Observations confirmed this as more than 80% of samples were dominated by cyanobacteria ($\geq$ 50%). Wind speed and gust have strong correlation with cyanobacterial biomass (r^2=0.86 and 0.85), likely indicating that wind and improved mass transfer in the surface water might speed nitrogen assimilation process. There was no clear temporal trend of cyanobacteria biomass, except for increased number of toxic species.

Conclusions. Firstly, Lake Vombsjön has evolved towards a more unstable ecosystem with enlarged N:P ratios. Secondly, cyanobacteria might behave as biological drivers maintaining eutrophication status, increasing the number of toxic species. Lastly, only P control is not sufficient to turn lake to a good status, external factors such as N:P ratio, wind speed, gust, internal phosphorus load in the lake sediment and cyanobacteria as biological drivers should also be considered.

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Robust management of multipurpose reservoirs under uncertainty

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Introduction. The future of water resources system analysis will continue engaging with problems that deal with competing objectives, multidisciplinary processes, non-monetary values, and uncertain climatic and socio-economic conditions. This is especially true for multipurpose reservoir operations, which have complementary purposes, but also conflicting water management goals. For instance, a water supply objective would require having the water elevation close to its maximum storage to increase the reliability of water supply. On the contrary, flood management would advocate for an empty reservoir with capacity for high flows. Different stakeholder groups pursue one objective or the other and problems arises on how to balance trade-offs and maximize profits among competing water management objectives.

Methodology. We formulate the reservoir management problem as a two-stage stochastic optimization model to maximize the expected net-benefits of water users. We can then express the goal function $f(R)$ as maximizing expected net benefits from fulfilling water demand and minimizing occurrences of water shortages:

$$F(R) = \sum_{i}\sum_{m} B_{im} RR_{im} - \sum_{s=1}^{S}\sum_{m} C_m^s p_m^s y_m^s$$

Subject to water mass balance constraint, and other technical and resource constraints. B_{im} denotes net benefits by unit of water supply to user i in month m. RR_{im} is the released water to each user. C_m^s is the cost associated with potential shortages y_m^s, and p_m^s is the probability of the shortage equal to 1/S where S is the number of scenarios (years with inflow records). We apply the formulation to the case of the Big Bend Reach of the Rio Grande/Bravo, a transboundary river basin of high significance for United States and Mexico.

Results. Preliminary results suggest that we can improve the operation policy of the reservoir in such a way that higher regional economic benefits can be achieved, while increasing environmental flow allocation. The robust operation policy derived from the stochastic approach, in the long term outperforms the traditional deterministic reservoir operations policies (Figure 1).

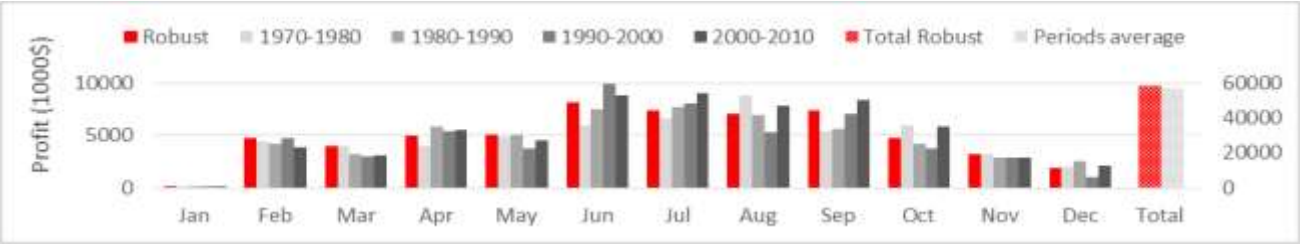

Figure 1 Seasonal distribution of profits under robust and traditional reservoir operation for different periods

Conclusions. This research demonstrates the usefulness of using two stages dynamic stochastic optimization to build robust reservoir operation rules with conflicting objectives to maximize regional economic benefits under uncertain reservoir inflows while meeting human and environmental water demands. In the long term, it is feasible to obtain higher regional economic benefits by considering the stochastic nature of inflows into water systems.

Can a water crisis be averted in Mexico City? The effectiveness of water use permits in promoting sustainable water use

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Introduction. Megacities such as Mexico City increasingly struggle to meet the demand for water. Over-exploitation of local water resources and the import of water from other basins has contributed to land subsidence, unequal access to water, ecosystem degradation and conflicts between users and basins (Oswald Spring 2015). Furthermore, projections for 2030 show decreasing rates of water availability per capita for Mexico City and its surrounding basin. This research aims to assess whether water use permits, the main policy instrument for restoring the water balance, can contribute to more sustainable water use behavior.

Methodology. We use data on water availability and use published by the National Water Commission to analyze the state of local river basins and aquifers, and the characteristics and evolution of water uses across the region. Semi-structured interviews were conducted with 60 key actors in Mexico to examine their perception on the effectiveness of water use permits for fostering sustainable water use. To compare the institutional goals to the (perceived) outcomes of the water use reforms, we developed a performance analysis based on Oran Young's framework of institutional analysis for environmental change (Young 2008).

Results. Although water users face many restrictions, these are not adequately enforced. Water resources are over-allocated, meters are absent and there are widespread irregular uses of water. In addition, there are issues of reliability regarding data on water availability and use, and the methodologies employed are not always transparent. The regional water resources management office has insufficient capacity to monitor all water users. Sanctions and fees for water abstractions are inconsistently applied, and users have few incentives to comply with regulations. While the structure of decentralized and participatory river basin and aquifer organizations exists, these lack autonomy and mandates to hold users accountable and enforce water use permits.

Conclusions. Water use remains unsustainable as users resort to informal practices and water imports rather than to curbing overall use. Enhancing participatory water resources management at lower scales may increase water user accountability and environmental and social considerations. Because of limited results of the currently employed water use regulations, alternative measures for addressing water demand and supply need more emphasis: Increasing water use efficiency, reducing leaks, harvesting rainwater and reusing wastewater are practices that have already been developed but remain small scale and piece-meal. Shifting from a linear (take-use-discharge) model of water use to a sustainable, circular model will require a paradigm shift among water users and managers.

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Drought risk, water demand and maize yields under climate change in the Northeast Farming Region of China

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Introduction. Maize is the number one cereal crop in China and together with wheat and rice has played a leading role in guaranteeing national food and feed security. Because of the increasing temperature and uncertain rainfall in recent years, drought risk has been the main limiting factor for maize production in the Northeast Farming Region of China (NFR). Given the importance of the NFR in China's maize production, we performed crop model simulations to investigate how drought risk potentially affects irrigation water demand during different maize growth stages. We estimated across the NFR the spatial and temporal variation of soil moisture conditions and irrigation water demand during the main crop development stages for historical observed weather and under different future climate projections.

Methodology. In order to improve the overall performance of crop simulations, we coupled two well-known models that capture different key agricultural processes. These models are the process-based and site-specific Decision Support System for Agro-Technology Transfer (DSSAT) model, and the cropping zone centered Agro-Ecological Zone (AEZ) model. We first simulate by the DSSAT model the performance of the maize for selected agricultural observation stations according to the available observation data of crop growth, development data and crop management. We then transfer these verified site results into the AEZ model. Finally, we apply the updated AEZ model to the geo-spatial database of the NFR to provide a robust and reliable probabilistic assessment of climate change impacts on irrigation water demand and yield of maize.

Results. The AEZ simulation results show that drought risk in different growth stages reduces maize yield and estimated crop water deficit was better than other indicators of drought stress for explaining maize yield variability. During 1981-2010, average soil moisture deficit and irrigation water demand was higher in the western NFR in all growth stages due to an observed decrease in annual precipitation occurring from east to west. The drought risk for maize was particularly high in the crop development and mid-season stages. Average irrigation water demand was highest in the vegetative period (crop development stage), especially in the western parts of Jilin province. The lowest irrigation water demand was found in the late stage from maturity until after harvest. For future climate change, the simulations using a range of 20 climate change scenarios from five different climate models and for four RCPs (for average thirty year periods of the 2050s and 2080s) provide an uncertainty assessment of future water demand in each growth stage. Results compiled for the observation sites show: (i) an overall increase in irrigation water demand by 2050s compared to the baseline (1981-2010), and (ii) the irrigation water demand will likely decline during the stage of crop development but increase in the yield-sensitive mid-season stage.

Conclusions. Drought risk will continue to be a critical factor for maize production in the NFR. Due to climatic gradients, soil moisture deficits and hence irrigation water demand is higher in the western NFR in all maize growth stages. Drought risk mitigation measures should focus especially on the crop development and mid-season stages. Climate change will affects soil moisture conditions and irrigation water demand in all crop growth stages. The ensemble of future climate projections indicates an increasing frequency and rising amount of irrigation water requirements in the mid-season stage when the maize plant is most sensitive to water deficits and which should be given priority for soil moisture monitoring and irrigation.

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Index

An Ha Truong....45
Andrew Fang....11
Bernd Lenzner....39
Catalina Chaparro Pedraza....22
Cécile Godde....34
Cholho Song....41
Claudia Canedo Rosso....54
Cornelius Hirsch....37
Daniel Cooney....23
Dmitrii Iakubovskii....55
Esperanza González....28
Francine van den Brandeler....66
Gibran Vita....30
Hadi....36
Hana Mandová....40
Hanqing Xu....67
Jeofrey B. Abalos....49
Jillian Student....58
Jing Li....64
Jose Pablo Ortiz Partida....65
Karen Umansky....51
Karl Seltzer....12
Karl-Kiên Cao....27
Kasparas Spokas....42
Lavinia Perumal....17
Leila Niamir....13
Liv Lundberg....56
Mahban Arghavani....53
Maisa Nevalainen....9
Malan Huang....38
Meng Jiang....47
Milton Aurelio Uba de Andrade Junior....33
Ming Ren....18
Nannan Zhang....14
Nemi Vora....19
Örjan Grönlund....35
Radost Stanimirova....43
Ryan Hanna....29
Saige Wang....20
Samuel Olugbemisola Wuraola....50
Sara L. Loo....24
Shaohui Tang....44
Takuji Oba....25
Tobias Sieg....57
Vanessa Haller....16
Xiaogang He....63
Yaoping Wang....31
Yaru Zhang....61
Ziyun Zhu....59