a new generation of scientists

YSSP Young Scientists Summer Program

Proceedings of the YSSP Final Colloquium 2015

International Institute for Applied Systems Analysis
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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 2015.

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Proceedings editors: Benedict Singleton and Kathryn Platzer

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Day 1, Monday 24 August 2015

Advanced Systems Analysis

Fisheries-induced evolution of cannibalism

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Introduction. Natural populations react to harvesting by showing demographic, phenotypically plastic, and evolutionary responses. The understanding that evolutionary responses to fisheries can be rapid is supported by observational, experimental, and modeling studies. To date, however, research on fisheries-induced evolution has mainly focused on a limited number of life-history traits, including maturation schedules, growth rates, and reproductive investments. Consequently, selective changes in other traits, especially in those related to ecological interactions, have been largely ignored. Cannibalism is such an interaction that is especially frequent in fish populations: many fish species grow considerably in size during their life, which facilitates the predation of small fish by large conspecific fish. The aim of this project is to understand which ecological factors drive the evolution of cannibalism and how this is affected by fishing.

Methodology. I use a physiologically structured population model (PSPM) to study the ecology and evolution of Arctic char populations. This species is commercially harvested in some parts of its circumpolar distribution and has a highly variable life history and ecology. Several instances of cannibalism have been documented in Arctic char. The PSPM describes the ecological and bioenergetic processes an individual undergoes throughout its life as a function of its physiological state and the state of its environment. The latter, in turn, is influenced by the joint impact of all individuals in the population. This feedback shapes the selection pressures that drive evolutionary change.

Results. Char populations with a low cannibalistic tendency evolve to a rapid life history with a low size at maturation and without post-maturation growth. The evolution of cannibalism in such populations is hampered by the low maximum size of individuals. An alternative life-history strategy evolves to a high level of cannibalism, a large size at maturation, and substantial post-maturation growth allowing individuals to reach large maximum sizes. Introducing mortality costs for cannibalists stabilizes the selection for cannibalism. Harvesting of individuals from populations dominated by a cannibalistic life-history strategy is expected to increase their cannibalistic tendency. This leads to higher exploitation and stock collapse at lower fishing mortality rates than for non-cannibalistic populations, or to populations in which cannibalism does not evolve.

Conclusions. These results indicate that incorporating cannibalism in fisheries models does not change the predicted population response to harvesting in a qualitative manner. However, when cannibalism can evolve, populations become more vulnerable to harvesting and collapse at lower fishing mortality.

Fisheries-induced evolution of metamorphosis

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Introduction. Fishing is often size-selective, especially when larger individuals of a population are targeted. Because of this selective removal fishing will alter the genetic composition of the exploited population. Many fish species that are of commercial interest undergo metamorphosis, changing diet and habitat during their life. Metamorphosis decouples traits between life stages, allowing these traits to evolve independently from each other (Moran 1994). At the same time, metamorphosis is costly. The aim of this project is to understand the balance of these benefits and costs, to discern the ecological conditions favoring the evolution of metamorphosis, and thereby, to predict how size-selective fishing affects the evolution of metamorphosis.

Methodology. We extend the consumer-resource model by Persson et al. (1998). All individuals have access to a shared resource, while large individuals have furthermore access to an alternative resource. It is assumed that the two resources require different morphologies to be effectively utilized. On this basis, we use the framework of adaptive dynamics to investigate when metamorphosis can evolve.

Results. Metamorphosis can evolve when the alternative resource is in high supply. A population that has evolved metamorphosis will keep metamorphosing even when the alternative resource becomes scarce, resulting in an evolutionary hysteresis. When a population of fish with metamorphosis is being harvested, it will adapt by decreasing the extent of their metamorphosis and start their metamorphosis later in life. When the alternative resource is in high supply, this evolutionary response does not strongly affect yield or the maximum harvesting rate the population can tolerate before collapsing. However, when the alternative resource is scarce, the evolutionary response makes the population more robust against high exploitation levels, sustaining high yields even in populations that would have collapsed from overexploitation in the absence of evolution.

Conclusions. Size-selective harvesting of fish populations will lead to an evolutionary change in the extent and timing of metamorphosis. In particular, the morphology of individuals after metamorphosis becomes more similar to the morphology before metamorphosis. Furthermore, a smaller fraction of the population will undergo metamorphosis. This fisheries-induced evolutionary response can allow for a higher exploitation level of the harvested population.

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A forward-looking age based on longevity expectations

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Introduction. Many personal decisions are shaped by people's expectations of the future. However, such expectations are rarely included in the study of those personal decisions. Often, studies that analyze forward-looking decisions use chronological age, an inherently backward-looking measure, as a proxy for those expectations. Implicit in this approach is the notion that all groups move through life-course stages in a chronological lockstep. Quite to the contrary, however, we can actually observe that different groups behave differently even though they may all be members of the same birth cohort. There are many reasons for this heterogeneity, including the fact that perceptions of aging may not be the same for all individuals because they have different characteristics. Thus, depending on which particular stage individuals are in at a given point of time, their behaviors will be different from those of other members of the same cohort with different characteristics**.** However, **while** the perceptions of aging cannot be directly observed, an individual's perception of aging can be captured by linking it with subjective life expectancy, that is, how many years an individual thinks that she/he has to live. Subjective life expectancies are generally obtained in the form of survival beliefs, that is, the probability of surviving up to a specified target age. We propose a method to quantify people's longevity expectations using subjective survival probabilities and also the technique of Sanderson and Scherbov (2013) to transform it to an index measured in years. This will make it easier to use in any analysis where people's expectations matter and also make it comparable with the conventional age measure. We call this new approach of measuring age "forward-looking age." This alternative age measure can contribute to existing literature by providing new insights into the examination of individual decision making.

Methodology. We use a two-part methodology to compute a forward-looking age that is based on data of longevity expectations collected in the Health and Retirement Study (HRS). In the first part, we propose a method to translate those expectations into life tables. We tackle the focal points problem using a random effects ordered probit model to obtain refined probabilities that depend on the characteristics of each individual; we then use these refined probabilities to conduct an NLLS estimation of subjective survival functions and to construct life tables for groups with various characteristics. In the second part, the life tables are used to produce forward-looking ages that can be used in the study of forward-looking decisions.

Results and Conclusion. We find that there is substantial variation in the forward-looking ages of individuals with different characteristics (such as gender, cohort, education, place of birth, adverse health conditions, and smoking habits) and that this variation tends to increase with chronological age. In particular, we observe that education matters for both genders, but the magnitude of its effect is larger for women. Moreover, the presence of any particular health condition or smoking habits increases the forward-looking age. Therefore, the effect of smoking or having any adverse health condition is larger for lower-educated groups compared to higher-educated groups. Finally, the effect of education is higher for women of the younger cohorts. For men, there is no significant difference in terms of education among cohorts.

References

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Spatio-temporal assessment of HANPP based LCA indicators for sustainability assessment of agro-bioenergy related ecosystem services

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Introduction. Sustainability assessment of agro-bioenergy systems has often been done previously without being able to account for most of the associated sustainability challenges (e.g. food security, energy security, biodiversity conservation, fresh water depletion-consumption and pollution, greenhouse gas emission reduction and climate change mitigation etc.) within a single frame. In response to this, this study explored the possibility of applying a combination of the human appropriation of net primary production (HANPP) framework and life cycle assessment (LCA) based frameworks (namely the energy return on energy invested-EROEI, greenhouse gas balance-GHG and water footprint-WF frameworks) for sustainability assessment of agro-bioenergy systems across three broad agro-ecological zones (namely tropics-Latitude 0-23.5^{o} N and S, sub-tropics- Latitude 23.6-40^{o} N and S and temperate- Latitude 40.1 -60^{o} N and S), over three future time scales (namely 2030, 2050 and 2070), using maize ethanol and biogas production systems as case studies, and biomass, energy, carbon and water flows per hectare as reference units.

Methodology. While the HANPP framework accounts for the biophysical and socio-economic flows of biomass from nature to society, the LCA based EROEI, GHG and WF frameworks accounts for the energy, greenhouse gas and water flows involved in the energetic appropriation of the three different HANPP components relevant for agro-bioenergy production (namely the harvested grain-HG, the extracted residue-ER and the unextracted residue-UnE). The energetic use of harvested grain is a relevant sustainability subject because it competes directly with food supply chains, hence its connections to food security. The energetic use of extracted residue is important because it opens sustainability discussions on pathways for more efficient and cascade use (i.e. reuse) of biomass especially within the context of global transition to bio-economy. The energetic use of unextracted residues is also very essential because of the scramble for it. This relates to its purported availability for meeting emerging demands for animal feed (also a food security subject), as well as its uttermost importance for ecosystem maintenance and biodiversity conservation concerns (e.g. sustenance of food chain for primary consumers and decomposers, soil stabilization and erosion prevention etc.). The energetic use of unextracted residue is therefore expected to be trade-off between energy provision and food security or between energy provision and ecosystem maintenance. The method adopted involved the estimation of the different component of the HANPP using data outputs from the GAEZ model (1960-2000 for baseline setting) and the EPIC model (2000 to 2030, 2050 and 2070 respectively for the spatio-temporal assessment); as well as conversion factors from recent global HANPP assessments published in literature. This is followed by a three-prong (energy, greenhouse gas and water footprint) spatio-temporal LCA of the three relevant HANPP components (namely the HG, ER and UnE) for evaluation of the energy provision, greenhouse gas regulation and fresh water conservation potentials within global agro-bioenergy system context.

Results and conclusions. Final results of applying the coupled HANPP-LCA methodology suggests that the most efficient way of maximizing biomass for agro-bioenergy production with reduced environmental impacts (in terms of water usage and greenhouse gas emissions), higher energy gains and efficiencies (enough to meet World Energy Council's projected energy demands from biomass) and advantages for transitions to bio-economy, without conflicting with food security, ecosystem maintenance and biodiversity conservation concerns is through the energetic reuse or cascade use of extracted residues, even though the strategies for achieving this is not yet clear.

Evolution of cooperation in spatially heterogeneous environments

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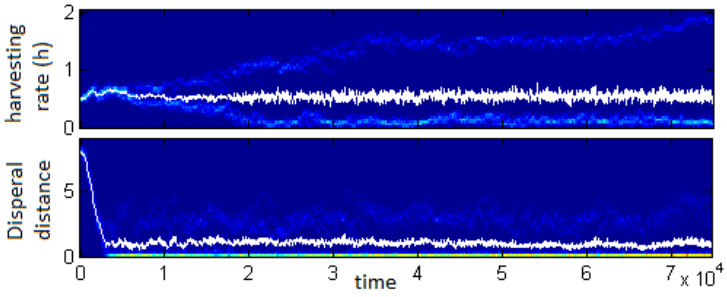
Introduction. Public goods that are freely accessible to everyone are at risk of over-exploitation by selfish consumers: a phenomenon called "the tragedy of commons" (Hardin 1968). Space plays a crucial role in the dynamics of ecological public goods, as consumers can harvest resource from their present locations and disperse to new locations when local resource levels drop. In such a situation, as the benefits of harvesting are offset by costs of dispersal, two strategies could potentially arise: the milker strategy, with low consumption and low dispersal, and the killer strategy, with high consumption and high dispersal. We explore the coevolution of harvesting rate and dispersal distance of consumers, using the milker-killer framework (Baalen and Sabelis 1992).

Methodology. We model consumer and resource populations on a continuous two-dimensional space. The resource grows logistically with a spatially varying growth rate (and/or carrying capacity). Consumers exploit the resource in their neighborhood at an individual specific consumption rate and disperse to other sites, when local conditions become adverse, at an individual specific dispersal rate. Both the resource exploitation rate and the dispersal distance can evolve over time through imitation of successful individuals.

Results. In a homogeneous environment, we find that when the benefits from harvesting (b) are low, the dispersal costs (c) prevent individuals from over-exploiting the local resource, giving rise to a stable milker strategy. As b is increased, evolutionary branching occurs, leading to co-existence of distinct milker and killer strategies. For moderate values of b, the milker strategy goes extinct after some time, leading to the tragedy of commons. But as b is increased further, both strategies remain stable. When b is very high, the killer branch goes extinct, as the resource is severely depleted. In a heterogeneous environment, where the resource growth rate varies across space, we find similar dynamics. However, if individuals are only able to imitate the nearest neighbours, rather than the globally fittest individuals, then the amount of heterogeneity determines whether or not branching occurs.



Conclusions. We show that space plays a crucial role in the dynamics of ecological public goods, leading to a variety of evolutionary outcomes, ranging from the pure milker strategies to ever changing mixed strategies.

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Organization of specially protected areas of local importance, Krasnoyarsk territory

Natalia Borisevich

Ecosystems Services and Management / Anatoly Shvidenko and Dmitry Shchepashchenko

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Introduction. Development of networks of specially protected natural areas (SPNAs) is an effective tool for protecting the biological diversity and maintaining the diverse ecosystem services of forest ecosystems. To take into account regional peculiarities and maximize the systems effect, the networks should include SPNAs of local importance. For the taiga conditions of Central Siberia, we consider the creation of two types of SPNA. The first SNPA, "Birch Grove," will be created in urban forests around the city of Krasnoyarsk; it aims to clean the urban-industrial environment and protect forests from natural and anthropogenic pressures. The second that we present here is the SPA of the northern rivers (Severnaja, Bahta, Fatjanikha, and Sukhaja Tunguska) which has been created far from populated areas and aims to preserve unique northern landscapes, rare and endangered plant and animals threatened by anthropogenic impacts, as well as poaching and "wild" tourism.

Methodology. Based on ground measurements, remote sensing data, and GIS information, we provided a biophysical assessment of major ecosystem services and a functional division of the planned SPNAs. These results were used for an economic assessment, based on methodological approaches developed for the forests of central Siberia, through assessment of the cadastral value of forests (Kuzmik and Sokolov 2007). The latter study takes into account the productivity of forests (amount and quality of wood), cost of wood, and systems of correction coefficients, which quantify 12 different ecological and social services of landscapes. To present more diverse information for creating the SPNAs, the soil protection service at "Birch Grove" was assessed using a model describing development and attenuation of soil erosion processes (Onuchin and Burenina 2010). For northern river catchments, the carbon sequestration service was assessed as Net Ecosystem Carbon Budget (NECB) based on the system methodology developed by the IIASA ESM Program (Shvidenko and Schepaschenko 2013).

Results and conclusions. Ecological and economic assessment of planned SPNAs presented evidence of the relevance of SPNA creation. For instance, the value of ecosystem services of urban forests "Birch Grove" was 75,000 rubles per hectare, which is about eight times greater than the value of the wood. The introduction of the relevant regime of forest management at this SPA would allow erosion processes to be stopped within 10-15 years (Figure 1), with a high economic benefit.

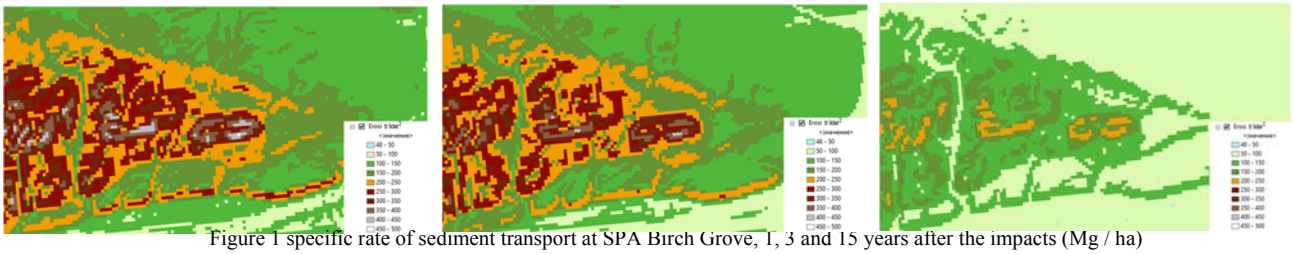

Figure 1 specific rate of sediment transport at SPA Birch Grove, 1, 3 and 15 years after the impacts (Mg / ha)

Table 1. NECB of northern rivers catchments

Watersheds	Area, 10^3 ha	NPP	HR	Decomp.	Fire	Biotic	NECB, g C/m^2/yr	NECB, 10^3 t C/yr
Severnaya	2,060	169	170	8	0	2	-10	-211
Bakhta	3,567	245	209	15	6	7	7	266
Sukhaya Tunguska	713	223	181	15	0	6	22	155
Fat'yanikha	597	279	214	14	0	7	44	260

Watersheds	Area, 10^3 ha	NPP	HR	Decomp.	Fire	Biotic	NECB, g C/m^2/yr	NECB, 10^3 t C/yr
Severnaya	468	206	201	15	0	7	-18	-83
Bakhta	3,264	253	210	15	6	7	14	470
Sukhaya Tunguska	526	252	187	17	0	7	41	216
Fat'yanikha	552	287	215	14	0	7	50	279

Assessment of the NECB showed that northern territories on permafrost mostly serve as a net carbon sink of around 11 to 50 g C m^{-2} yr^{-1}. However, the most northerly forest catchment of the River Severnaya serves as a carbon source to the atmosphere. This can be explained by intensification of the permafrost processes due to climate change: increase in the active layer and decomposition of organic matter. The results obtained will be used for the practical creation of the SPNA in Krasnoyarsk kray.

Future ethylene demand in the era of shale gas: An economic and environmental assessment of a sustainable technology

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Introduction. The research explores the future demand for ethylene, an important petrochemical, in the context of the American natural gas boom and how demand is associated with natural gas prices and societal approaches towards climate change. Sustainability transition approaches call for replacing non-renewable fossil fuel as the main feedstock for petrochemicals; however, there are few published studies. Also, the recent advent of unconventional shale gas from hydraulic fracturing and horizontal drilling in America has redefined the economics of ethylene manufacturing because gas is used as feedstock. This study focuses on three questions. What is the future demand for ethylene in the United States (US)? How is demand affected by gas feedstock price? What is the contribution of ethylene production to US energy demand for fossil-fuel feedstock and carbon dioxide (CO2)?

Methodology. To estimate future ethylene demand to 2050 and compare three natural gas feedstock price scenarios, this econometric analysis employed a multivariate vector autoregressive model as a key tool. Relationships amongst and between individual variables such as causality, response to sudden shocks and forecast variance were determined. The analyses were completed in the statistical program R. The historical dataset (1986-2014) and forecasted data (2015-2050) included monthly data from several US government agencies. To estimate ethylene's share of US energy demand and CO2 emissions, data was gleaned from private sector data, US government data and the International Energy Agency.

Results. The model estimates that future demand for ethylene in 2030 and 2050 will be 41 and 46 thousand barrels per year, respectively, using the EIA reference case gas price forecast in its Annual Energy Outlook 2015. This is a 43% increase from 2014 in 2050. A 50% less gas price scenario, results in a 95% rise in ethylene demand in 2050. A 50% gas price increase over EIA's reference case slows demand dramatically to only 7% in 2050 or 34 thousand barrels. The research generated an estimated range of CO2 emissions from ethylene crackers in the US in 2013. The high estimate associates 75% of all ethylene production capacity with 29 million metric tons or 0.6% of all US CO2, which is 18% of industrial CO2. A conservative estimate is that 45% of ethylene production capacity is associated with 17.4 million metric tons, 0.4% of all US CO2, which is 11% of industrial CO2.

Conclusions. According to the model forecasts, US ethylene demand will grow through 2005 under all gas feedstock price scenarios. Surprisingly, the price of natural gas feedstock was not an influential predictor of ethylene demand as crude oil price; however its impact is longer. Ethylene demand responded to a gas price hike by lowering as expected, returning to its mean in about 36 months. Ethylene demand was not driven by personal consumption in the long term, which implies that demand is inelastic. Although ethylene's share of overall CO2 emissions is less than 1 percent, it holds a significant share of industrial CO2 emissions, 11%-18%. Furthermore, the majority of sites are in two states (Louisiana and Texas), making ethylene a very concentrated source of significant emissions that can be targeted by climate change mitigation policies that would advantage biomass/ethanol feedstock.

Assess the costs and benefits of the Air Pollution Action Plan in Pearl River Delta region

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Introduction. There are compelling economic and social reasons for heightened focus throughout China and Guangdong on reducing pollution. Poor air quality is the most visible sign of China's and Guangdong's struggle to control pollution from sources that emit high levels of pollutants, such as the increasing number of vehicles on the road, the combustion of coal for electricity generation, and manufacturing. Poor air quality diminishes productivity, imposes a large burden of illness and premature deaths on the regional economy, and also affects the health of ecological systems. Ever since the announcement of the State Council's 2013 air pollution reduction and prevention action plan, many local level action plans have been proposed. According to the 2013 action plan, the concentration of PM2.5 in the Jing-Jin-Ji, Yangtze River Delta, and Pearl River Delta regions needs to be reduced by 25 percent, 20 percent, and 15 percent by 2017 from 2012 level, respectively (Ministry of Environmental Protection of China, National Development and Reform Committee, & Ministry of Finance of China, 2013). Coal-fired power plants, coal-fired boilers, and industrial furnaces in the three key regions need to install desulphurization, denitrification, and dust removal equipment by the end of 2015. Regions need to control several air pollutants simultaneously and comply with a cap on their total consumption of coal. The three regions have published air pollution prevention/control action plans and inventories of facilities within the four key sectors (power, steel, cement, and plate glass) that require installation of additional pollution control equipment. However, effectiveness and feasibilities of these action plans are largely unknown.

Methodology. This research utilizes the GAINS China model at the sub-national level to explore the implications of different air pollution reduction strategies at the Pearl River Delta region. The GAINS model can quantify the impacts of major air pollutants and greenhouse gases from technology based solutions (Amann, 2012). Focusing on the time period up to 2030 in 5-year intervals, a new set of control strategy is created based on policies proposed under the *Pearl River Delta Air Pollution Reduction and Management Action Plan*. Emissions reduction and ambient air pollution level were estimated and assessed against proposed targets. Using international market cost data of relevant air pollution control technologies, cost associated with SO2, NOx and PM 2.5 control strategies were calculated. Where Chinese local data is available, adjustment of costs for relevant technologies were implemented to obtain a more realistic picture of local costs.

Results. If we assume full compliance of proposed action plan, by 2020, the SO2, NOx, and PM2.5 emissions will be reduced by 584,300 t/year, 657, 900t/year and 208,600 t/year. Resulted average annual PM 2.5 concentration will meet the national class 2 standard, namely, 35 μg/m3. Using international market cost data, the total cost associated with pollution reduction of the three key pollutants is 6.2 billion 2005 Euro per year in 2015. Converting this to 2010 U.S. dollar, this cost is equivalent to 1.4% of Guangdong Provincial GDP in the year of 2010.

Conclusions. Comparing these results to those using control strategies proposed in the twelfth five year plan, it is evident that more stringent air pollution control strategies implemented in the near term not only enables rapid reduction of air pollution, but will also offset increase of future pollution resulted from energy demand growth.

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Socio-hydrological relationships and risks in the Lake Chad district in Chad

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Introduction. The Lake Chad basin in Central/Western Africa has gone through extensive hydrological changes since the 1960s. In this period the surface area of Lake Chad has shrunk from 25,000 km2 to 3,000 km2 and its volume has decreased by nearly 60%. The communities in the areas around the lake are rural and mostly based on agropastoral and fishing activities. They are thus directly dependent on hydrological factors such as rainfall, freshwater availability, floodplains and soil moisture. This study aims to increase the knowledge on the relationships between hydrological variations and agricultural production and identify risks to food security in the Lake Chad District in Chad, located just next to the lake.

Methodology. Observed agricultural data from 1988-2012 for 3 sub-districts was collected from a Chadian development organization, SODELAC, which has been working in the district for the past 30 years and weather data was collected from the Chadian weather services. For the analysis qualitative information sources are used together with bi- and multivariate regression analysis to establish and quantify the relationships between agricultural and weather variables. Results are compared across the 3 different sub-districts and are used to assess risks to food production due to weather conditions.

Results. Outputs from the bi- and multivariate models show highly significant relationships to several of the weather variables. Especially rain and lake variables have high correlations to the agricultural data. Lake level variables show higher correlations to maize crops than to millet crops, while rain variables are more correlated to millet crops. The multivariate models based on significant and verified variables generally have adjusted R^2 of 0.5 to 0.8 for the different agricultural variables, indicating a high level of weather sensitivity.

Conclusions. From the results it is possible to identify which weather variables that have been involved in food production failures over the studied time period. Furthermore critical thresholds of certain weather variables to food production can be specified. Under the assumption of continued socio-economic stability in the district these relationships can be used to assess risks to food security based on observed and forecasted weather variables. By verifying this assumption through field studies and continued local collaborations this body of knowledge could be useful for food security planning and rural development in the district.

Impact of OPEC's oil production strategies on the structure of US domestic transportation fuel supplies: A stochastic game-theoretic model

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Introduction. Since June 2014 the world oil price has dropped from $115/bbl to under $60/bbl. The low oil price brings benefits for the oil-importing countries in the short term because of savings on energy expenditure. But for the long term, low oil prices may cause concern for national energy security and renewable energy development because it discourages investment in domestic unconventional and alternative fuels. In the context of the current low oil price, this paper analyzes the potential effect of strategic interactions between the USA, China, and OPEC on the long-term US domestic transportation liquid fuels mix. The main contribution of this research is to provide a unified modeling framework to capture the strategic interactions and future uncertainties.

Methodology. A bi-level multileader multi-follower stochastic optimization framework is proposed for the purposes of this study. In this research, we make the following assumptions for upper-level agents: OPEC aims to balance short-term profits and long-term market share by choosing production levels; China tries to balance economic growth and environmental impact by controlling energy demands; the USA makes trade-offs between energy security and renewable fuel share by setting carbon prices. The upper-level agents make decisions expecting a response from lower-level fuel suppliers. Then, in the face of the decisions of the upper-level agents and the uncertain oil price and production technologies, the lower-level agents make investment decisions, aiming to maximize their own long-term profits.

Results. OPEC, by increasing the current production level rather than cutting output by 2 mbbl/day, can gain 7~8% of the US transportation market share from its competitors: biofuel and unconventional oil producers. For the USA, setting the carbon price is the dominant strategy, but the effect is relatively insignificant: a 27$/ton CO2 carbon price could increase biofuel share by only 1~2%. Sensitivity analysis shows that a 10% biofuel market share increase could be achieved by adding $100/t CO2; different market power assumptions on the part of OPEC can bias the market share estimation by as much as 15 percentage points. The subgame perfect equilibrium solution depends on how much OPEC emphasizes its market share. Results for China are not yet available, as the work is still in progress.

Conclusions. Based on the results, the USA will prefer to set a carbon price in order to balance its domestic fuels supplies and renewables share, but the expected effect will be limited unless the carbon price is relatively high. OPEC will make a decision depending on its preference for short-term (profits) or long-term (market share) benefits, which will determine the equilibrium outcome. This research could be extended in the following directions: i) Model more upper-level agents (Russia, different groups of OPEC members); ii) Consider the different risk attitudes of decision makers; iii) Incorporate the dynamic nature of decision making into modeling.

Disruption risks in an adaptive firm network

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Introduction. The interconnectedness of economic activities generates new types of risks, termed systemic risks. Localized interruptions of production or supply delivery of one firm can disrupt its customers, and cascade further down the supply chain. Such propagations can yield sizeable indirect economic loss. Firms can take several measures to mitigate these risks, e.g., diversifying suppliers or stockpiling inputs. Because of interconnectedness, risk-mitigating measures taken by one firm influence the risk exposure of other firms, as well as the overall level of risk in the economy. Thus, we are lead to ask three salient questions. Do individualistic strategies, aiming at profit maximization, lead to the highest economy-wide performance under risks? Within a supply chain, which firms can most effectively mitigate systemic risks? From a management perspective, which regulations and incentive schemes could be taken to mitigate systemic risks?

Methodology. We formulate and analyze numerically a stylized agent-based model, in which supplier–buyer interactions are represented by directed networks. Firms produce to meet the intermediary demand from other firms and the final demand from consumers. Firms can be affected by random perturbations, which temporarily disrupt production. To mitigate supply disruption, firms overorder from their suppliers. Through an evolutionary process, we contrast two scenarios in which firms either selfishly adjust their overordering rate to maximize profit or altruistically adjust their overordering rate to maximize the economy-wide gross domestic product (GDP).

Results. Altruistic strategies are found to lead to higher overordering rates than selfish strategies. The distribution of overordering rates is highly heterogeneous: downstream firms tend to overorder more than upstream firms. As expected, altruistic strategies always yield a higher GDP than selfish strategies. Upstream firms tend to benefit more from altruism than downstream firms. Our results are robust to changes in failure rate and productivity. For moderate failure rates, altruistic strategies reduce GDP fluctuation, but for larger failure rates, they lead to larger GDP fluctuations. Finally, the impact of each firm on systemic risk mitigation widely depends on its location on the network.

Conclusions. Under stochastic perturbations, the economy-level optimal performance cannot be reached by profit-maximizing firms. Supply chain linkages impose coordination of overordering efforts. The contribution of firms to systemic risks is heterogeneous, and the strategies of downstream firms can significantly reduce systemic risks. This highlights the potential for implementing of targeted regulations or incentive schemes. The model will be used to test the validity of such policies. Finally, the findings will be tested against more realistic economic hypothesis regarding production and prices.

Trait-based community dynamics of a North-Sea ecosystem

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Introduction. Ecological experiments and theoretical considerations indicate that ecosystem functioning depends on biodiversity only in terms of the "functional characteristics" of organisms present in the ecosystem, which are expressed through their traits (Díaz and Cabido, 2001). This leads to the question: are some traits more important than others for community dynamics and structure, and which traits are the important ones? We set up an ecological model for trait-specific biomass dynamics in North Sea macrofauna. We believe that the identification of dynamically-dominant traits (DDT) would provide some evidences to understand the benthic community structure. Additionally, prediction of benthic functioning and its performance in interaction with environmental variability are expected to be more accurate. This model will assist in identifying significant interactions among traits, and thus those traits that determine benthic community development.

Methods. We used a database from a long-term macro-zoobenthos time series at four sites in the North Sea (AWI time series data). Data include benthos samples collected each spring from 1969 to 2011. Additionally, an autecological database was generated from different traits covering life history, behavioral characteristics, morphological attributes and environmental preferences of benthic species. 'Multivariate Autoregressive State-space Model' was used to implement different scenarios in our analysis. The core functionality of MARSS is based on likelihood maximization using the Kalman filter, combined with an EM algorithm.

Results and discussion. Model showed all possible interactions among traits, and between traits and environmental factors in each sampling sites. The largest interactions between traits and environmental variables were seen in the case of sea surface temperature and salinity.

Conclusion. Trait-level description provides more abstract and generic representation of benthic communities. At the same time, dynamically-dominant traits are preferable as they capture great fraction of variability and likely to be highly significant to exhibit greater developmental stability.

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Drivers of Global Transformations

Estimating carbon stock changes considering vegetation shift and land use changes: Case study of the Korean Peninsula

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Introduction. Net primary productivity (NPP) is considered to be an important indicator for forest ecosystems, given that the role of the forest is highlighted as a key sector for mitigating climate change. As much as 64% of South Korean territory is covered by forest, making the development of the forest sector a primary concern for the government. Discussions regarding how to maximize carbon sequestration in the forest sector have been under way since the Korean government announced the 1st comprehensive plan for improvement of the forest carbon sink. The objective of this research is thus to estimate the change in South Korean forest carbon stocks under differing climate change scenarios.

Methodology. The G4M model was used in this project to estimate NPP changes under different climate scenarios. As input data we used detailed (1km x 1km) downscaled monthly precipitation and average temperature data from the Korea Meteorological Administration (KMA) for the four RCP scenarios (2.6/4.5/6.0/8.5). To validate the results of the model against historical development, MODIS NPP data from 2001 to 2010 was used. Spatial statistics tool in ArcGIS 10.1 was used for analyzing different trends among the scenarios, as well as NPP changes from 2011 to 2100.

Results. In this study, MODIS and G4M showed similar NPP values from 2001 to 2010. In the future, average NPP per ha would increase in all RCP scenarios. The total NPP of forest increased in most of the RCP scenarios except RCP 8.5. The average temperature increased 5℃ in the RCP 8.5 scenario and by 1℃ in the RCP 2.6 scenario. In addition, the standard deviation of annual precipitation was the highest in the RCP 8.5 scenario. Precipitation change in the wider range could cause water stress on vegetation that would cause a decrease in forest productivity.

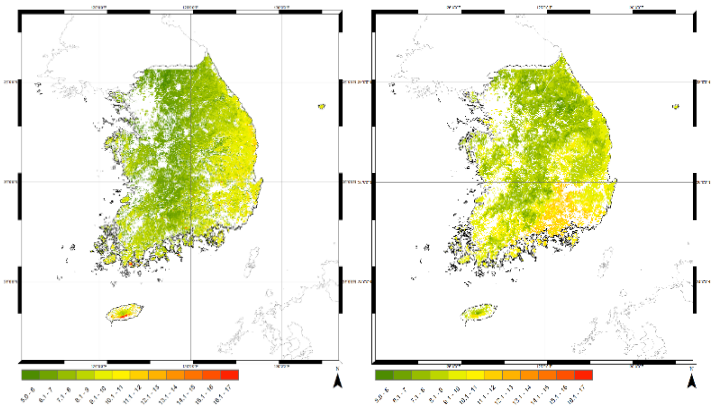

Figure . Average NPP from 2001 to 2010 (Left: MODIS, Right: G4M)

Conclusions. In this study, we calculated NPP change under different climate change scenarios to estimate carbon sequestration in the forest ecosystem. However, we assumed that the forest biome will change as a maximizing increment of NPP. Further study is thus required for considering species changes under the climate change.

Assessing the abatement potential of ammonia emissions from agricultural management practices in China

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Introduction. Ammonia (NH_3) is a key precursor to atmospheric fine particulate matter ($PM_{2.5}$) and an important component of the reactive nitrogen cycle, with strong implications for both regional air quality and ecosystems (Huang et al. 2012). Due to limited information about fertilizer usage, two of the most important ammonia emission sources—i) farm-size structure for livestock production and farm practices, and ii) ammonia emission estimates for agricultural fertilization and livestock farming across China—are usually based on time-averaged emission factors and temporal profiles, leading to uncertainties in the evaluation of controls on ammonia in emission levels and control technologies. In this study, we update activity data and emission factors in the GAINS model (Amann et al. 2011) to improve spatial and temporal distribution of baseline ammonia inventory in China. We also develop applications for NH_3 control measures in order to estimate maximum mitigation potential. The results should allow for discussion of a realistic agricultural ammonia mitigation policy in the future that would consider impact on cost-effective benefits and concentrations of particulate matter in China.

Methodology. First, we update activity data and emission factors for ammonia emissions from agriculture in 2010 at the province level based on FAO, IFA, and yearbook database to improve spatial and temporal distribution of the baseline ammonia emission inventory in China. Second, we establish a reasonable set of assumptions supported by statistical data to develop a more realistic potential for ammonia mitigation measures in China. For mineral fertilization application mitigation measures, we take three main control steps—i) reduce excessive fertilization based on modification of activity data, ii) replace urea with lower volatility fertilizers and alternative urea fertilizer formulations, and iii) improve application methods based on modification of control strategy (SUB_U). For livestock production, we first understand the farm-size structure in China and then develop applications to estimate maximum mitigation potential using European GAINS technologies. The integrated assessment model GAINS will be used for scenario projection and emission estimates in response to different strategies.

Results and Conclusions. There has been a significant change in livestock production structure in the last decades. From 1998 to 2010 the ratio of pigs' total livestock density (LSU) on small farms (0-15 LSU farm size), for example, decreases from 83 to 46%, while the ratio on large farms (>500 LSU farm size) increased from 2 to 10%. We expect the trend to continue and the majority of production on industrial farms to lead to increased potential for controlling ammonia emissions. The consideration of the livestock production structure allows for a more realistic assessment of mitigation potential.

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Modeling the biogeochemical process of phosphorus cycle and assessing the phosphorus fertilization in China

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Introduction. Phosphorus is a major limiting nutrient for plant growth. Modern agriculture heavily on phosphorus fertilizer, which is mainly derived from phosphate rock. It is a nonrenewable resource and current global reserves may be depleted in 50-100 years. The locations of phosphate reserves concentrate in few countries. The locations are highly sensitive and the price changes according to the political and corporate agenda, which may lead to social unrest and political conflicts. Aquatic eutrophication, caused by emissions of nitrogen and phosphorus from farmland, is a common and serious problem. It is essential to find a more integrated and effective approach to reducing phosphorus in the Argo-ecosystem while maintain crop yield and minimizing environmental risk.

Methodology. Firstly, we modeled the phosphorus cycle in the soil-plant system based on the long-term field experiments of China. We conducted a sensitivity analysis to identify the suitable model parameters for which calibration was needed. The sites-based work supplied information for Chinese simulation. Secondly, we built the gridded China EPIC model based on IIASA's global EPIC, with updated Chinese local data. Then, running the model for 31 years to simulate the rain-fed and irrigated maize yields, nitrogen stress, phosphorus stress, temperature stress and water stress. Finally, based on the gridded China EPIC model, we run the model from 1918 to 2010 to get the soil available phosphorus in Chinese top soil and analyze the soil P dynamics in China.

Results and Conclusion. We first used long-term monitoring data to do sensitivity analysis, calibrate and validate the mechanistic model EPIC. The sensitivity analysis results indicate that EPIC model is able to simulate long-term crop production, soil organic carbon changes and soil P dynamics in China. PSP, PARM(20) and PARM(77) are among the most important parameters and the suitable numbers are 0.1-0.5,0.1-0.8, and 0.6, respectively. Second, we built the gridded China EPIC model to simulate the long-term maize yields, soil available P, N stress, P stress, water stress and temperature stress. The results show that EPIC with detailed information is robust for long-term production and P simulation and can be used for further analysis and predictions.

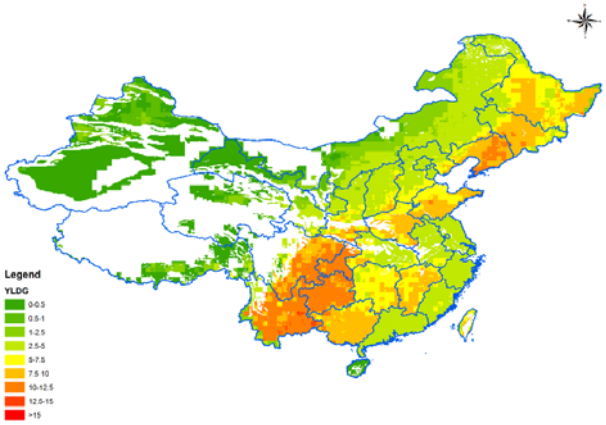

Fig.1. The simulated yield (in t/ha) of rain-fed maize in China

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Poverty & Equity

Risks of correlated wheat yield losses in the world's breadbaskets

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Introduction. As the 2008 food price crisis or the 2010 drought in Russia and other cereal producing areas have shown, it is mainly the confluence of weather extremes in different parts of the world that cause immense price shocks and risks to food security which can lead to famine and political instability. However, to date, little is known about the drought and yield loss dependence structures of the global "breadbaskets".

Methodology. In order to model the interdependencies between wheat yield deviations in 5 "breadbaskets" - USA, Argentina, India, China and Australia – the copula methodology is used. The copula methodology goes back to Sklar's theorem[1] which allows to build multivariate distributions using a copula and univariate marginal distributions. This study uses and compares two different ways of constructing multivariate copulas: vine copulas[2] and ordered coupling using the mini-max approach[3]. Wheat yield data is taken from historical observations in the major food producing countries on a state/ province level.

Results. Investigating the correlation structures of wheat yield deviations, both within and between "breadbaskets", we find high correlations within and not very significant correlations between the regions. Comparing overall wheat production losses in the "breadbaskets", it is shown that ignoring the correlation structure between the different states/ provinces leads to significant underestimation of risks of production losses. On a global scale, the difference is not as significant. Furthermore, the comparison between different copula structures and copula families shows that the choice of structure is not relevant in most "breadbaskets".

Conclusions. The results of this study show clearly how important it is to consider a correlation structure of wheat yield losses. This is especially interesting for crop insurance schemes or crop price forecasting. Further research could investigate the effects of increased variability in wheat yields and of future wheat production projections and how they will change likelihoods of production losses.

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Analyzing patient register data – A key to improve primary health care process of T2D patients?

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Introduction. Diabetes mellitus has become one of main burdens on public health in most countries. A tendency toward less physical activity has led to increased obesity and thus greater prevalence of type 2 diabetes (T2D), cardiovascular disease, and complications related to these (Shaw et al. 2010). Studies and statistics show that even though general health has improved in Finland, differences between socioeconomic groups have actually increased (Tarkiainen et al. 2012). Even though the quality of care in Finland is considered generally good, better cost-efficiency and control of risk factors are needed to improve the equity of health care and to prepare for the future costs and needs of aging populations (OECD 2012).

Data from the patient register of type 2 diabetics were analyzed to discover possible explanations for spatial differences in treatment outcomes and to be able to assess different health care practices between health care units in region of North Karelia, Finland. The role of primary health care (PHC) in chronic disease treatment is significant, and finding ways to improve the efficiency of the health care system in the future is considered essential.

Methodology. A literature review and preliminary data analysis were used to evaluate the possible reasons behind spatial differences of T2D treatment outcomes. Patient register data cover multiple attributes of all T2D patients living in region of North Karelia. Register data were analyzed to find relations between patients' treatment outcomes, spatial accessibility to a primary health care unit, and other patient characteristics. GIS software was used for geocoding address data and to calculate the road distances to the health care units.

Results. Preliminary results showed that spatial accessibility does not have a statistically significant influence on treatment outcomes. Further data analysis with patient visit data did not indicate spatial accessibility as having a strong influence on patients' utilization of health care services. The literature review showed the versatility of approaches associated with the study of spatial differences of chronic diseases but did not provide readily applicable methods for the research question.

Conclusions. Previously, it was known that spatial differences in treatment outcomes and preventive care exist in the area of interest. Although understanding of the influence of patient characteristics, health care resources, treatment practices, and spatial accessibility was increased with this study, no unambiguous explanatory factors for the spatial differences in treatment outcomes were discovered. New approaches for further study, need for more advanced analysis methods, and the need for additional data sources were noted.

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Nutrition transition and the future of food demand in India

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Introduction. A puzzling feature of Indian economic development over the past two decades is the movement of per capita income and average per-capita calorie intake in opposite directions. The per-capita incomes have increased, and average per-capita calorie intake has declined over time. The decline is not limited to the rich, but the poor have also reduced their calorie intake. As Indian population is rising, it is important to examine the drivers of change to understand the future demand and its potential impacts on the environment. In this work, we develop different scenarios of future food demand, taking into account change in population age-sex composition, education and future economic growth and analyse the implications for dietary patterns by 2050.

Methodology. The study uses household-level data from the Consumption Expenditure Survey (1993-94, 2004-05 and 2011-12) of the National Sample Survey Organization (NSSO) to examine the changes in food consumption pattern in India. We first analyse the effect of place of residence, education, religion, and monthly per-capita expenditure (MPCE) on per-capita calorie consumption using log-log regression models. We also look at the effect of these drivers on diet composition using more than 120 food items classified into 17 food groups. On the basis of the econometric results, we perform some projections of future calorie intake in India at detailed level. For this purpose, we rely on projections produced at IIASA for the Shared Socio-economic Pathways (SSP) that provide detailed population projection by state in India, along the various dimensions above.

Results and conclusions. The results confirm an overall decline in per consumer unit (CU) per-day calorie intake in India during 1993-201 by 53 kcal (2%). However, urban areas show an increase in per CU per-day calorie intake by 46 kcal (2%) for the most recent time. Increase in education and monthly per-capita expenditure increases total calorie intake, but the consumption of cereals, red meat, vegetables, and alcohol declined with increase in education. The results further indicate that, religion becomes less influential factor of consumption for certain products over time. The evolution of the different drivers of change do not act in the same direction for the future projections. In our central projection scenario, change in age-sex composition lower the demand by 4% in 2050, compared to 2010, mainly due to aging. Educational attainment and rural-urban migration also lower the demand by 37 kcal and 10 kcal per-consumer unit per day, respectively. On the other hand, interstate migration increases demand by 12 kcal per-consumer unit per day. These results illustrate the sensitivity of the future projections to the change in population structure in India. Taking into account the different possible path of population development in India at a detailed level appears crucial to provide reliable projections of food demand.

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Role of social cohesion and informal care givers in life satisfaction among elderly in urban areas

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Introduction: In contexts where elderly care is mainly shouldered by family members, the health outcomes of givers and receivers of elder care may be affected by family relationships, type of care activity, and perception of care. This study focuses on the associations of these aspects with self-perceived health and difficulties in the daily activities of both care-givers and care-receivers, accounting for possible discrepancies in reporting care activities between the two groups. This approach is unique, as most existing studies focus on the health of either care-givers or care-receivers.

Methodology: The present study is based on primary data collected between November 2014 and January 2015 from care-receivers aged 65 and above and their (co-resident) care-giver aged 18-60 years in West Delhi, a district of New Delhi (India). Dependent variables are self-reported health and difficulty in doing daily household activities of both care-givers and care-receivers. Individual demographic and social network-related characteristics, as well as household-related characteristics, are the independent variables. The type of care activity includes household care, personal care, social and emotional care, and financial care. Descriptive statistics and logistic regressions have been used to examine the association between demographic, household, and social network characteristics on the one hand and self-reported health and difficulties in household activity on the other.

Results: Findings show that the discrepancy in reporting about care-giving and -receiving activity is significantly positively associated with older people's health outcomes; for the care-giver it is mostly positive except for personal care. Among male care-receivers, education, working status, wealth, and conversation on private matters with relatives and close friends are found to be important predictors of self-reported health for the male elderly. Wealth and relationship with care-giver turn out to be the main predictors for female care-receivers' self-reported health. Age and wealth are the two most important predictors of difficulties in daily activities for both male and female care-receivers.

Among care-givers, wealth and the relationship with the elder care-receiver are found to be the most important predictors of bad health (both self-reported and difficulties in daily activities). Middle-aged care-givers aged 36-50 years are found to have five times more difficulty in carrying out daily activities than young care-givers if they are caring for a man rather than for a woman, while care-givers above the age of 50 are also reported as having difficulty in daily activity, but it is statistically not significant.

Conclusions: Undoubtedly in a setting where universal health care is not available, wealth is a key predictor of health outcomes of both care-receivers and care-givers. This study adds to the literature by showing that who the older persons receive care from, and who the care-givers give care to, also matter for health. There are substantial gender differences: health outcomes of female care-receivers depend on who they receive care from. Likewise, caring for a man seems to exacerbate the health of care-givers to a greater extent than caring for a woman. Traditional gender role and gender inequality may explain such discrepancies between male and female care-receivers and -givers.

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Household income distribution, basic needs and total energy consumption: a case study of Brazil

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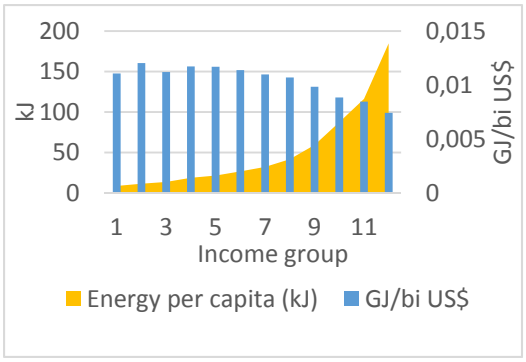
Introduction. In recent years, despite almost 2 billion people ascending to the middle class[1], over 2.2 billion people remain vulnerable to multidimensional poverty[2]. Erasing these vulnerabilities and rising consumption class will affect the nature and the extent of energy demand and GHG emissions. Using Brazil as case study, this project aims at analyzing i) differences in expenditures across income groups ii) the energy intensities across different income groups, iii) the energy intensity to provide basic needs and iv) the energy growth implications of income growth and distribution.

Methodology. The notion of "basic needs", as defined in this project, includes seven factor criteria related with education, nutrition, shelter and transportation. Using available data from the Brazilian Consumer Expenditure Survey (POF), we analyze for 12 income groups the following topics: 1. access to electricity, 2. education level of the head of household, 3. access to piped municipal water, 4. access to improved sanitation facilities, 5. access to motorized transport, 6. recommended intake calories and 7. house constructed with permanent materials. Intensity and content of household-level energy consumption were estimated using the hybrid input-output energy model, which combines monetary and energy flows for each sector and type of final demand[3]. The hybrid matrix was built using the Brazilian Energy Balance and Input-Output Matrix (year 2009), and incorporating a price adjustment for income classes, an innovative methodological approach.

Results. We observe that most important vulnerabilities lie in water and sanitation access, and level of education. As shown in the graphic, the total (direct and indirect) energy consumption per capita increases with income; however, the energy intensity decreases as the income level rises. The price adjustment leads a difference of up to 77% in energy intensity, when compared with non-adjusted method.



Conclusions. Overall, while energy consumption and human development are positively correlated with income, energy intensity follows the opposite pattern; confirming empirically previous conjectures. Subsequent steps will isolate the energy consumption related with basic needs to that related with discretionary expenditure.

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Should I stay or should I go? A plural rationality approach for sustainable disaster risk reduction in Mozambique

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Introduction. Mozambique is extremely prone to natural hazards. Following major floods in 2000, one of the main measures to reduce disaster risk has been extensive relocation of people living on flood plains. The results of the resettlement scheme are, however, debatable. This paper utilises the theory of plural rationality (Beck & Thompson 2015) aiming to capture the different worldviews stakeholders have on the nature of the problem (disaster risk) and its solutions (risk reduction). The paper also examines how harnessing these different worldviews can improve DRR measures.

Methodology. This study is designed as qualitative case study. Data have been collected during four field work trips in 2008, 2012, 2013 and 2015. Material consists of interviews with keys stakeholders involved in DRR activities in Mozambique (n=63); interviews (n=22) and focus group discussions (n=4) with people who have been relocated along the lower Zambezi river valley; and observation. In addition policy and project documents as well as secondary data have been utilised.

Results. This analysis identifies three distinctly different approaches to deal with flood risk mitigations. 1) *Relocation:* mainly advocated by the government. People should not live on high risk areas and must thus be resettled to safer areas identified by experts. 2) *Living with floods – as usual*: many relocated people (or those under threat of relocation) prefer to stay by the river because of their livelihoods and sense of belonging. They feel that decisions on risk taking and where to live are theirs only. 3) *Living with floods – improved:* approach is advocated by international and non-governmental organisations. It highlights the different needs of different communities and advocates training and the creation of different infrastructures such as elevated platforms that would make long-term dislocation unnecessary.

Conclusions. Although international frameworks emphasise the importance of multistakeholder approach, DRR measures remain highly normative in which problems and their solutions are given from above. Yet such top-down procedures rarely work when it comes to adaptation or rebuilding people's lives and livelihoods after a disaster event. The government of Mozambique is implementing a resettlement scheme that has given local people or other stakeholders few chances to voice their concerns or influence the measures. As a result this 'one view' solution has failed in many areas. Following the theory of plural rationality, more sustainable solutions could be reached by including all voices in decision-making process and finding compromises. To come up with such clumsy solutions by design would require true accessibility for and responsiveness from all stakeholders.

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What's missing from Ostrom? Design principles, cultural theory, and Faroese *grindadráp*

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Introduction. Many societies face challenges in managing natural resources; one response is to manage them collectively as a common pool resource (CPR). Elinor Ostrom's *design principle*s for successful CPR institutions have been influential and applied in a wide variety of settings: challenging orthodox economic predictions that CPRs can only be managed through systems of privatization or state control. The principles are not without criticism: Ostrom's adherence to a rational choice-based approach, it has been argued, led her to underappreciate the possibilities/importance of macro-level factors; to hold an over simplistic picture of human behavior; and to be quiet on issues of power and inequity. This presentation explores the possibility that *cultural theory* (CT), a theory of plural rationality related to context, could be used to ameliorate these criticisms. This involves comparison of design principle- and CT-based analyses of a CPR institution: Faroese pilot whaling, *grindadráp*.

Methodology. This research is based on three months' fieldwork in the Faroe Islands in 2014. These data were used to carry out a CT analysis of Faroese whaling. The findings were then compared to an assessment based on Ostrom's design principles (Kerins 2010).

Results and conclusions. Faroese pilot whaling embodies all eight of Ostrom's design principles, suggesting that it is likely a successful institution and will prove to be a long-standing one. By contrast, the CT analysis suggests that *grindadráp* is based around the principles of egalitarianism and hierarchy. This is the mark of a true CPR institution (Thompson 1998) and is what has ensured that *grindadráp* has maintained its place in modern Faroese society. The particular principles that predominate vary at different social scales, becoming more hierarchical at the national and international scales. The institution itself has changed repeatedly, but the egalitarian base of the practice has usually been reinforced. Despite this, when faced with particular challenges (such as how to ensure equitable distribution of meat and blubber), it has proved possible for solutions rooted in alternative logics to be voiced and accepted. Thus Faroese whaling, in CT terms, is *clumsy*: effective and appropriate in responding to diverse challenges.

CT and Ostrom's design principles are largely complementary; the design principles may be interpreted as guidance for creation of an egalitarian-hierarchical institution. By using both approaches, practitioners and stakeholders are presented with a more nuanced picture of a CPR institution and can better assess the possibilities of enduring management. Future work will explore the creation of composite design principles and whether CT also augments Ostrom's later work on socioeconomic systems.

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Do weak institutions drive deforestation? Identifying relevant governance indicators for global forest modelling

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Introduction. Deforestation accounts for around 3.0±1.1 Gt CO2 of global greenhouse gas emissions (Harris et al. 2012), and is a major cause of biodiversity loss, soil erosion, and many other environmental problems. Its primary cause is the conversion of forests for more profitable purposes, mainly agriculture. This idea is captured in IIASAs global forest model (G4M). G4M is a spatially explicit model, combining a biophysical and a socioeconomic component. It is used to compare the agricultural and forestry net present values of land and model deforestation trends. More recently, the importance of differences in the quality of institutions has been recognized (Buitenzorgy and Mol 2011; Galinato and Galinato 2012). Most authors find that a country is more likely to limit its deforestation if its institutions allow forest protection to be properly enforced.

In this research project, the importance of differences in institutional quality in the context of the G4M was examined. The model predicts land use change based on a purely economic rationale. To match observed deforestation and afforestation patterns, a residual factor is calibrated for each country. We showed that taking differences in institutional quality into account allows a substantial part of this residual to be explained.

Methodology. We conducted OLS regressions with 139 indicators on institutional quality and built a composed index from the most significant indicators. Integrating the indicator into the model allowed the model's residual to be reduced.

Results. Adding an institutional quality index to G4M reduces the model's residual factor and hence improves the model with respect to its NPV-based routines.

Conclusion. The results allow a better understanding of possible impacts of differences in institutional quality on forest cover change.

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Labor market dynamics and projections using the Characteristics Approach of Sanderson and Scherbov

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Introduction. In the last decades there have been significant discussions about the future of labor markets, especially as the life expectancy of individuals is continuously increasing over time. This is crucial for pensions systems, as most of the schemes depend on the amount of time that individuals stay in the labor market. Standard models assume that individuals work between ages 15-64 and then retire. However, especially in developed countries, individuals now rarely start working at age 15 and, increasingly, do not retire at the age of 65. We develop a model in which individuals decide their optimal retirement age according to changes in demographic and economic variables.

Methodology. We develop a theoretical life cycle model where individuals take decisions based on their income, health status, and life expectancy. Lifetime is divided in two broad periods: a period when individuals work and a period where they are retired. The length of these periods is endogenous: individuals decide when to optimally retire in order to maximize lifetime utility. We then use life tables from the United Nations "World Population Prospects: The 2015 Revision" to forecast how retirement ages would evolve under different scenarios.

Results. We test different assumptions on economic variables and pension schemes and we see that in all of them individuals should naturally be delaying their retirement age by around 8 years by the end of the century. The nature of the pension scheme, however, has a big impact on the decision, as defined benefit schemes tend to give enough incentives to people to retire before the optimal time on an equitable pension system.

Conclusions. The forecasted postponements in retirement immediately imply that the ratio between people in the labor market and retirees should not be as bad as expected with the standard models. Should countries take extreme measures designed to deal with this "support ratio" problem? The answer, of course, depends on many factors, but most importantly on the configuration of the pension system. In the end, if the system is not designed in such a way that individuals receive something that is commensurate with what they are contributing, then problems will definitely arise.

Stakeholder analysis for better policymaking: A case of electric cars in the UK

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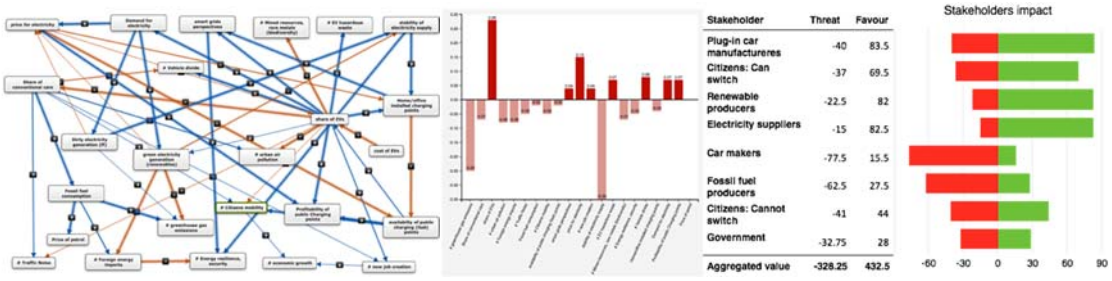
Introduction. Public policymakers often have to balance the interests of many different stakeholders, that is, groups of people who can affect or are affected by the achievement of policy goals. The recent promote uptake of plug-in cars in the UK is no exception. This research aims to perform stakeholder analysis of recent British government policies to transition to plug-in cars in the UK. It seeks a format to identify and profile stakeholder groups and to quantitatively evaluate policy impact on different stakeholder groups.

Methodology & Results. The multi-criteria and multi-stakeholder nature of the focal policy issue has defined two task groups of data collection and analysis. The first focus is on building a system model, which defines the policy context, key variables, and the cause-effect relations between them. The other is a focus on stakeholder identification and elicitation of their preferences. First, I conducted background research, collecting over 30 documents and performing qualitative content analysis. From the content analysis I built a qualitative system model, represented as a fuzzy cognitive map. Further, the policy of subsidy for purchases of plug-in cars in the UK was simulated in the model, thus outputting the policy performance values. The background research also revealed an initial set of stakeholders as important actors. The set was further cross-validated and significantly extended by applying a soft-system methodology and the value network analysis. To elicit preferences I employed either of two strategies: i) deriving preferences from the document content analysis and value network analysis; ii) deriving appropriate representatives for stakeholder groups, who were asked to use the cardinal ranking method to rank variables of interest (criteria). Finally, the policy impact was aggregated as a weighted sum of the performance values and (criteria) importance weights for variables unique to each stakeholder group, the aggregation being performed for negative and positive impact separately, as well as both for each stakeholder group and for each variable (criterion).

Conclusions. This research is built upon mixed methods to couple system modeling of a policy issue with stakeholder preferences regarding the outcomes of the modeled scenarios. This provides a comprehensive and balanced view of the stakeholders being positively/negatively affected by a focal policy.



Consumers' willingness to pay to improve water supply services in rural Kazakhstan

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Introduction. If rural water projects are to be both sustainable and replicable, an improved planning methodology is required whereas the participation of water users plays an important role and that includes a procedure for eliciting information on the value placed on different levels of service. Therefore, the importance of the concept of willingness to pay (WTP) for water in rural areas has been understood for some time. In the view of recently launched Water Program in Kazakhstan aiming to cover 80% of rural people with piped water, the current research investigates the water users' view to the water supply interventions and assesses the factors influencing consumers' willingness to pay for piped water supply.

Methodology. 2500 household questionnaires on access to water and sanitation, perceived characteristics of water source (quality, reliability, time spent, water treatment) and socio-economic background were collected from 25 villages in Northern Kazakhstan. Initially the analysis included the comparison of official statistics and the gathered data in terms of the access to water and sanitation, and the overall willingness to connect to piped water system as it is seen from the consumers' point of view. The binary logistic regression has been used to identify the main drivers of willingness to connect and to pay for piped water services. Further on, the ordered regression has been used to identify the drivers of WTP among different water users.

Results. The most common water sources are private boreholes, wells and standpipe, which is significantly different from official statistics. A quarter of the respondents is not willing to connect to piped water and up to 70 % of them use a private borehole supply. There is a small proportion of those who would connect but think that access to water should be without charge. Although one third of the sample is willing to pay still the payment offered is quite law. Nevertheless, three third of the respondents believe that water supply is the responsibility of the government, while 13% believe that it is a local water consumer's responsibility. The main influencing factor on peoples' willingness to pay is the access to the existing water source and its perceived characteristics, such as water quality, reliability of the source, time spent to collect water, and water supply responsibility. Although the perceived financial situation of the household did not show to be a significant factor still within different water users it was a significant factor.

Conclusion. The results can be used to better identify the water supply scenario reflected in proper technological choice and the level of service to be provided; thus, making rural water projects feasible at a larger scale. Furthermore, integration of local people into the decision-making process is a quite unique approach for the Central Asian countries that should facilitate the mechanisms to manage water supply and improve the efficiency of water policy.

System approach to integration of labels from crowdsourcing campaigns.

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Introduction. Crowdsourcing is a new approach to performing tasks, where a group of distributed worldwide volunteers are substituted for an expert. Recent results show that crowdsourcing is an efficient tool for annotating large datasets. One of the most successful citizen science projects is Geo-Wiki, the main goal of which is to improve a global land cover map using crowdsourcing techniques. Note that labels collected from the crowd can be of a low quality, as volunteers are often non-experts and may be unreliable. That is why advanced methods for integrating annotations are necessary for increasing the reliability of estimates.

Methodology. Analysis of data received from non-experts is a challenging task that requires a systems approach. The research thus included analysis of all main steps of any crowdsourcing campaigns: preparation of images for validation, task assignment, and aggregation of collected votes. During the research we used methods of computer vision and machine learning. All numerical experiments and hypotheses testing were based on an actual dataset from the Geo-Wiki project.

Results. i) We proposed strategies for the preparation of a dataset of images for effective crowdsourcing campaigns in the future. The strategies were applied to existing datasets and were shown to be effective; ii) Methods were proposed for solving problems of inconsistency in volunteers' votes. Analysis of methods was based on numerical experiments; iii) The original Geo-Wiki algorithm of image distribution among volunteers was studied. Drawbacks were analyzed in detail. We suggested and tested possible improvements to the algorithm; iv) New ways were found of constructing a dataset for experts to obtain information on the reality on the ground. Different approaches were proposed and compared; v) A machine learning algorithm for aggregation of volunteers' votes was used. The algorithm showed a higher accuracy than a majority-voting heuristic algorithm.

Conclusions. Crowdsourcing is a new and powerful tool. Unfortunately, it is inadequately studied**.** We thus used and elaborated systems analysis methodology in this developing field. The research allowed empirical knowledge to be obtained for development of new policies for organizing crowdsourcing campaigns and other citizen science projects. In contrast to other researches we performed numerical assessment using real-life data (not a synthetic dataset) containing results from the Geo-Wiki crowdsourcing project. We provided new tools for an emerging field: global land cover maps.

Food & Water

The early identification of the human drivers affecting groundwater system of Yucatan, Mexico, using material flow analysis

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Introduction. Groundwater systems are the predominant accessible reservoir of freshwater storage on Earth. When the interconnections between groundwater and society are studied, problems arise Successful groundwater resource management relies on models that effectively capture these interactions. In Yucatan, Mexico, a meteor impact 65 million years ago dominates the geomorphology, forming a complex groundwater system that is the only source of freshwater for the population. Novel experimental and modeling approaches are needed to understand how groundwater common pool resources, as complex systems, interact with the social system. Substance Flow Analysis (SFA) is an analytical method that allows assessment of the flows and impacts of chemical substances within the environment. It has been used to investigate hazardous materials for environmental risk assessment in water bodies, and it has become a useful tool for resource management, especially in developing countries where there is poor availability of reliable data.

Methodology. The objectives were:) to develop a water balance of the geohydrological zone in Yucatan by quantifying groundwater flows associated with present-day economic sectors (industry, agriculture, livestock, and household consumption); ii) to construct an SFA to map flows throughout the relevant processes of the system (extraction, uses, treatment, final disposal, and recycling), including quantification of inputs and outputs; and iii) to identify key points at which the substances appear to be lost or to accumulate. As effective SFA is able to determine the pathways through which pollutants are generated and emitted, an SFA was constructed using applied systems analysis. I adapted the SFA framework, bringing together local and scientific knowledge. Combining this with mass balance and based on current data and estimation, I accounted for the flows. I depicted water Sankey flows within each sector using STAN. Directed outputs to the aquifer show how human activities influence the aquifer (Figure 1).

Results and conclusions. Results show that the total input, movement, and transformation of water fluxes by society cannot compensate for the final disposal of wastewater. SFA can be developed despite the lack of reliable data. As our results do not only depend on literature, as we found results through stakeholder workshops, statistical data, and expert opinion, SFA can be an instrument to address complex problems in a transdisciplinary process.

The method will serve as a basis for long-term groundwater strategic planning and can be applied in regions with similar characteristics.

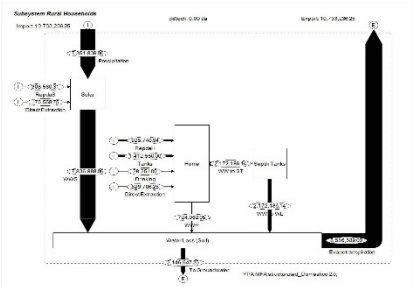

Figure 1. SFA of the subsystem Rural Household showing Sankey flows

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The impact of non-renewable groundwater use on global food security toward 2050

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Introduction. Non-renewable groundwater use, defined as groundwater removal that is greater than recharge, has drastically increased over the last decades due to rapidly growing food demand. Crops produced in irrigated areas now account for 40% of global food production (Molden et al. 2007). However, the strain on the environment is becoming increasingly clear, and recent studies show that current practice is not sustainable (Wada et al. 2012).

Methodology. This study associates specific crops with non-renewable water use by estimating a spatially detailed water balance for 26 major crops considering crop-specific cultivation dates, water requirements, natural recharge, recharge from irrigation, and groundwater abstraction in production areas. Embodied non-renewable groundwater in products is then tracked in the global trade network to the end user. The global model runs on a 0.5° grid from 2010 to 2054 on a monthly time step under SSP2 for 5 GCMs.

Results. Preliminary results show an increase in global non-renewable groundwater use in the future (See Figure 1). Intensive production areas in the Indus Basin, Northeast China, and the United States show substantial non-renewable groundwater use. Rice, wheat, and maize are most important crops grown.

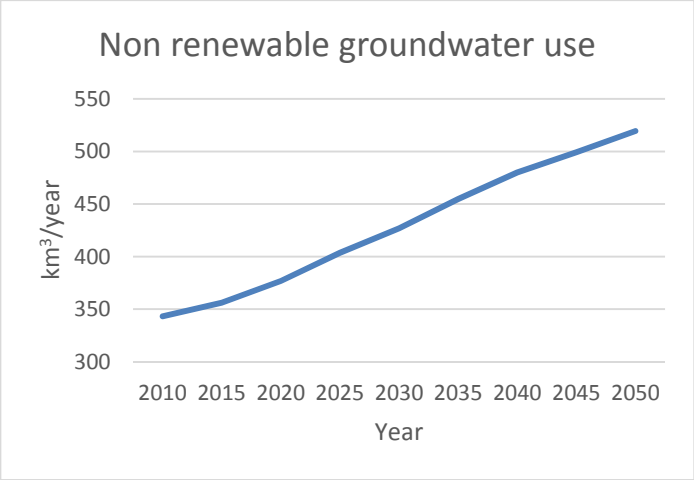

Figure 1: Global non-renewable groundwater use increases towards 2050

Conclusions. This study adds further proof to the expectation that non-renewable groundwater use will increase in the future and that important agricultural areas are at risk if no mitigation measures are taken. It is shown that certain water-intensive crops are grown in heavily irrigated areas where water availability is limited. Decision makers could benefit from this research by careful consideration of future crop allocation, using caution in extension of irrigated areas, and improving irrigation systems.

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Day 2, Tuesday, 25 August 2015

Energy & Climate Change

HFC emission and mitigation strategies for China using the GAINS model

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Introduction. Hydrofluorocarbons (HFCs) are potent greenhouse gases with a global warming potential (GWP) thousands of times greater than that of carbon dioxide. Given the high growth rate in China's HFC production and consumption market, past and future HFC emissions in China are of great interest. China faces great mitigation challenges, especially under the 2015 North American proposed amendment to the Montreal Protocol to phase out HFCs. In this research, activity data and emission factors of HFC were updated and validated in the GAINS model. HFC consumption and emissions from 12 sectors in China through 2050 were explored. Spatial distribution of HFC emissions across China at provincial level were obtained; these could be used to make provincial control regulations and reduction targets. The business-as-usual (BAU) scenario and maximum technically feasible reduction (MTFR) scenario to 2050 were developed for understanding the magnitude of HFC emissions across sectors and analyzing HFC mitigation potentials.

Methodology. The GAINS model was used for emission estimation and scenario projection. Following the GAINS methodology for non-CO_2 greenhouse gases, emissions from source s in region i and year t are calculated as the activity data A_{its} times an emission factor ef_{ism}. If emissions are controlled through implementation of technology m, the fraction of the activity controlled is specified by $Appl_{itsm}$ (Höglund-Isaksson et al.2013). The driving factors for HFC consumption estimation in different sectors vary greatly, for example, GDP per capita in purchasing power parity or econometric parameters derived from the PAMS model. Control strategies were adjusted to allow the emission gap between the BAU and MTFR scenario to be explored. The CO_2-equivalent values were obtained using emissions of HFCs, multiplied by their weighted GWP (100-year).

Results. The GWP-weighted HFC consumption in China will increase from 112 Mt CO_2-eq in 2010 to 2,269 Mt CO_2-eq in 2050 under the BAU scenario. Total HFC emissions are projected to increase from 104.8 Mt CO_2-eq in 2010 to 462 Mt CO_2-eq in 2050. Among the 12 sectors, the stationary air conditioning (56%) and foam (18%) sectors are the top two contributors. The main emissions areas are the eastern provinces (Shanghai, Zhejiang, Jiangsu), where the majority of manufacturers are located. Compared with the BAU scenario, HFC emissions will decrease to 0.91 Mt CO_2-eq in 2050 under the MTFR scenario, showing great mitigation potential.

Conclusions. There is substantial potential for minimizing China's HFC emissions. Hydrocarbon, ammonia, and low GWP alternatives (i.e., HFO) are feasible technologies that can be chosen as alternatives to HFC. When control strategies are drawn up, the share of sectors and regional differences should be taken into account.

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Ecological network analysis of virtual total suspended matter (TSPM) within China

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Introduction. Human activities such as coal combustion, industrial processes, and road transportation are disturbing the natural atmospheric balance. Over the past decade, Beijing has suffered from severe air pollution, notably from particulate matter, which has serious human health consequences as it can enter the lungs and the circulatory system. Much attention has been paid to the direct PM emissions; however, the hidden driving forces of the economic activities are rarely mentioned. Thus, policy attention is needed to control of indirect air pollutants (i.e., embodied emissions). In this study, indirect emission of particulate matter 2.5 ($PM_{2.5}$) from 42 sectors in Beijing is separated from the total emissions to see how much embodied $PM_{2.5}$ from each sector has been overlooked.

Methodology. Input-output analysis (IOA) is used to distinguish direct and indirect emissions from each sector and trace those embodied emissions back to the source sectors (Leontief 1970). Ecological Network Analysis (ENA) as a systems-oriented methodology used to analyze the structure of ecosystems and identify flow of materials within the system (Fath and Patten 1999; Fath 2004) is adopted in this study to reveal the control relationship of each sector over the others in terms of both direct and indirect emissions and to determine which economic sectors drive the embodied $PM_{2.5}$ emissions. The two approaches are therefore applied in tandem to investigate the embodied emissions that result from the current monetary flows and economic structure. The analysis is conducted using 2010 input-output data from the Beijing Statistical Yearbook and emission data from the IIASA GAINS model.

Results. In 2010 production of "Petroleum, Coking and Chemicals" was the main source of direct $PM_{2.5}$ emission, 41.6 kt/y, followed by "Construction," 19.2 kt/y. The indirect $PM_{2.5}$ emissions from "Wholesale & Retail" and "Manufacturing Products" were 21.1 kt/y and 17.7 kt/y, respectively. Overall, for all sectors, indirect emissions account for 30.75% of the total. The sectors with the most and least proportion of indirect emissions are "Textiles and Wearing Apparels" and "Construction," respectively. From a systemic perspective, production of machinery and equipment is largely controlled by the other sectors, while sectors involving daily necessities are driving the $PM_{2.5}$ emissions in the whole system.

Conclusions. According to the results, indirect $PM_{2.5}$ represents a large proportion of total emissions. Production and supply of daily necessities are the dominant sectors of $PM_{2.5}$, which reveals that individuals should take some responsibility for reducing $PM_{2.5}$ emissions. Thus, personal purchasing power can be directed toward the production and supply of products with lower emissions and thereby alleviate air pollution and promote a more conservation-minded lifestyle.

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Urban versus rural emission contributions to air pollution in India

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Introduction. Rapid economic development combined with weak air quality regulations has led to significant increases in emissions in India, and several Indian cities rank among the most polluted cities in the world. Due to its direct association with health impacts, fine particulate matter ($PM_{2.5}$) is the main pollutant of concern, including both primary particulates like dust and soot, and secondary PM, which forms from chemical reactions of nitrogen oxides (NOx), sulfur dioxide (SO_2), ammonia (NH_3), and volatile organic compounds (VOCs). Different anthropogenic emissions sectors contribute to $PM_{2.5}$, including transportation, a typical urban emission source, and traditional biomass cookstoves, a typical rural emission source. This study seeks to understand and evaluate the impacts these two spatially distinct emission sectors have on $PM_{2.5}$ air quality in Northern India, and their respective potentials for improving the situation.

Methodology. To evaluate contributions to $PM_{2.5}$ air quality from traditional urban and traditional rural sources and to quantify their mitigation potentials, we develop several emissions scenarios around maximum reduction strategies for transportation (typical urban emission source) and domestic sector (typical rural emission source) to drive air quality conditions using the Community Multi-Scale Air Quality (CMAQ) model from the U.S. Environmental Protection Agency. Emissions are generated from the Greenhouse Gas – Air Pollution Interaction and Synergies (GAINS) Model and consist of a baseline scenario and projection used for present (2010) and future (2030) conditions assuming current legislation (CLE), a scenario assuming maximum feasible emission reductions in the domestic sector, and one scenario exploring leapfrog technology application to transportation scenario. These scenarios drive CMAQ sensitivity simulations, which are used to compare and contrast emission sector reduction techniques. To analyze distinct contributions from changes in emissions sectors, updated urban and rural activity and population information is applied to the baseline and sensitivity emissions scenarios.

Results. This study applies best available information on population distributions and domestic and transportation sector activity information to GAINS emissions in Indian sub-regions. Incorporating this information provides a basis for assessing changes in traditional urban (e.g. transportation) and traditional rural (e.g. domestic cookstoves) emissions and how they impact regional $PM_{2.5}$ air quality. CMAQ output for a representative pre-monsoon month in 2010 has been validated; sensitivity simulations for 2030 have been initialized and once complete will provide a comparative assessment of $PM_{2.5}$ concentrations determined by future reductions in transportation, traditional urban emissions, and domestic cooking, traditional rural emissions. Greatest changes in ambient $PM_{2.5}$ concentrations suggest which sector will provide the greatest benefit to regional air quality improvements.

Building neural networks to analyze uncertainty in global warming models

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Introduction. Current prediction methods strive to minimize the difference or the error between the prediction result and the actual value. Extrapolating historical data records into the future always results in increasing error, and the prediction can only be applied into a short time outreach. This is because data contain uncertainty, and no current methods take into account the uncertainty wedge which always increases with time. Projection is therefore needed to capture possible values in the future. Furthermore, we wish to maintain a balance between the historical dynamics, the opening, and the extension of uncertainty wedge in the prognostic outreach.

Methodology. We define a method of constructing the uncertainty wedge. The historical data is divided into three parts as following: i) the L1 part to capture historical dynamics; ii) the L2 part to capture dynamics change and construct the uncertainty wedge; iii) the testing part to apply the wedge with the historical data. We use Radial Basis Function (RBF) Neural Networks which has reported good performance in short-term prediction. Changing the capture of dynamics affects a different uncertainty wedge and length of extension. We then manipulate the complexity of capturing the dynamics by changing the number of nodes in the network to see the effect on the uncertainty wedge and the extension.

Results and conclusions. We apply the method of constructing an uncertainty wedge for climate-related data (time series and non-time series), and investigate how complexity affects the prognostic outreach of the model. To conclude, both too simple or too complex models have poor projective performance, and it is possible to optimize complexity to reach the optimal projection.

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The influence of spatial and temporal intermittency of renewable energy on storage deployment in the Alpine region

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Introduction. The Alps have great potential for the use of renewable energy, which is an important aspect of climate change mitigation. Yet, the renewable energy potential of the region is limited by physical resource constraints, necessitating the use of decision-making tools to understand deployment. This project aims to quantify the spatial and temporal variation of renewable energy sources in the Alpine region, as well as to determine the potential contribution of each energy source to different sectors, including electricity, heating, and transportation. This is accomplished using the BeWhere tool, a techno-economic engineering model for renewable energy systems optimization. BeWhere identifies the location, size, and technologies appropriate for a renewable energy system in a specific region, including the Alps.

This project has made several contributions to understanding intermittency and methods for renewable energy integration. First, it has developed spatial and temporal profiles for wind power, solar power, and demand in the Alpine region. Second, it has enhanced the representation of the electricity sector in the BeWhere tool, by requiring supply to exceed demand in all sampled timepoints throughout the planning period. Finally, it has included several novel techniques for compensating for intermittency, including power-to-gas (P2G) and power-to-liquid (P2L) technologies. P2G/P2L can convert excess electricity, or over-generation, into gaseous or liquid fuels for use in heating or transportation.

Methodology. *Representation of spatial and temporal heterogeneity*. Using global climate reanalysis and historical electricity system data, we derived solar resource, wind resource, and demand estimates at high spatial and temporal resolution.

Technology enhancement in BeWhere. We included representation of P2G/P2L technologies in BeWhere, as well as enhanced representation of the electricity sector. We are able to study technology deployment using scenario analysis of different technology prices, CO_2 prices, and resource constraints.

Applications. We anticipate applying this model to understand several important energy system configurations that can contribute to climate change mitigation. First, we hope to quantify the contribution of P2G and P2L technologies in compensating for intermittency and providing a source of low-carbon gaseous and liquid fuels to the Alpine region. While several studies have identified a potential role for P2G/P2L in energy systems, none have studied deployment at high temporal or spatial resolution. Second, we hope to study carbon-neutral energy systems that do not rely on geologic carbon storage or high amounts of electrification of heating and transportation. These systems can use P2G, P2L, and carbon captured from biomass (a source of biogenic carbon) to satisfy energy demands.

Reference: BeWhere. www.iiasa.ac.at/bewhere

Gas/liquid fuels as storage for intermittent renewable electricity: Systems performance and localization in the Alpine Region

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Introduction: Decarbonisation of the energy sector by increasing the share of renewable resources, such as biomass, wind and solar technologies, is an essential step towards the deployment of low-carbon and sustainable energy systems. According to IEA [1] , the share of share of renewables in the global electricity mix is projected to increase over the coming years (from 20% today to 65% by 2050, of which about 2/3 is intermittent in nature). Due to the spatial and temporal mismatch between the availability of intermittent resources and electricity demand, significant power over-generation potential is to be expected from economy-wide or global deployment of solar and wind power systems. In order to balance the mismatch (both in time and location) between power generation and demand, reliable storage systems are crucial. In this regard, the power-to-gas/liquid (P2G/L) technology can offer benefits that would make it an interesting alternative to conventional storage technologies (such as batteries). In this process, the power over-generated from the power dispatch system can be stored in gas/liquid fuels via electrochemical reduction of steam and CO_2. The reduced gas, similar to syngas, can then be used for the synthesis of higher-grade transportation/gas fuels. Here, we study the potential of P2G/L systems as storage for intermittent renewable electricity in the Alpine region.

Methodology: We use the BeWhere model [2], a geographically explicit techno-economic optimization model, to estimate the potential for electricity over-generation in the Alpine region by considering energy production potential from biomass, hydro, solar and wind resources within the region. The model minimizes the cost of the entire supply chain (including the capital, O+M, transmission and emission cost) of the different technologies selected to meet the energy demand of the region.

Results: We have made several advances in the BeWhere model, and in understanding P2G/L deployment. First, we enhance the temporal resolution of the existing Alps-BeWhere model in order to quantify potential excess power generation over the course of one year. We then evaluate the power over-generation potential and subsequently the production of liquid and/or gas fuels. We are currently evaluating different scenarios in order to assess the impact of the most influential parameters, such as carbon emission and fossil fuel prices. The liquid and gas fuel (produced in the P2G/L plants) is utilized to satisfy or partially displace fossil fuel demand in the transportation and heating sectors within the Alpine region, respectively.

Conclusions: Preliminary results indicate that the P2G/L can provide a competitive power storage alternative as compared to conventional storage devices (such as battery storages). More importantly, it adds flexibility to the energy sector by creating a link between power and liquid or gaseous fuels.

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Renewable energy production from municipal solid waste to mitigate climate change: A spatially explicit assessment for Malaysia

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Introduction. The utilization of municipal solid waste (MSW) as a renewable resource could overcome waste disposal issues, generate power for fossil fuel displacement, and mitigate CO_2 emissions from landfill. However, the availability of waste feedstock varies with the effectiveness of waste management while the profitability and the environmental impact are mostly dependent on the conversion technology, plant location, and plant capacity. The study thus aims to evaluate the complexity of waste-to-energy (WTE) supply chain networks for energy production and the CO_2 mitigation potential through a spatially explicit approach. The Malaysian peninsular is selected as a case study area.

Methodology. This study adapted the IIASA techno-economic engineering model for optimizing renewable energy systems (BeWhere) [1] and developed a WTE optimization component. BeWhere is based on mixed integer linear programming (MILP) and is written in the GAMS, using CPLEX as a solver. The model minimizes the full supply chain cost of WTE (Figure 1). The model optimizes the capacity and location of WTE production plants and assesses the energy and by-product potentials, given the feedstock locations and the power demand under different cost and environmental indicators. Several scenarios were designed to analyze the impact of energy and carbon mitigation potential of WTE with various fossil fuel prices or carbon tax in the supply chain.

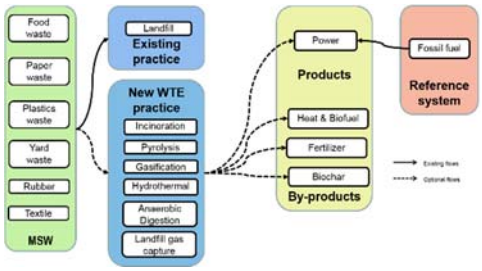

Figure 1 Supply chain network of WTE

Results. The preliminary runs show that pyrolysis and incineration for power production are the preferred options, primarily because of the low economic investment and the high energy conversion efficiency. Apart from the power as the main product, the system produces biofuel as by-product. It is found that most of the plants are installed in more highly populated cities with large potential for waste biomass, hence reducing logistical costs and emissions from transportation. The preliminary results show that WTE could be substituted for about 15% of the Malaysian power production following a business-as-usual scenario.

Conclusions. WTE is a promising form of renewable energy for Malaysia and a proper solution for the high dependency of landfill. BeWhere for MSW provides a robust spatial explicit solution for WTE with assessment of the energy production and CO_2 mitigation potential.

References

[1] BeWhere Model: http://www.iiasa.ac.at/bewhere

Innovation and technological capabilities of the Chinese wind turbine industry: An international comparative study

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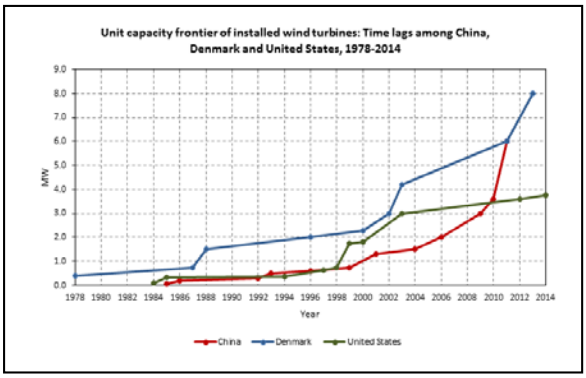
Introduction. Technological innovations are vital if we are to move to a sustainable energy system. Driven by the concerns of climate change and energy security, energy RD&D investment by the world's major economies has increased again after decades of stagnation and decline, and incentives to stimulate clean energy technology investments have also triggered significant increases in private sector investments into renewable energy. Given this growth in spending on energy technology innovations, the present research attempted to develop a set of quantitative innovation metrics derived from the Energy Technology Innovation System (ETIS) approach in order to evaluate how effectively a nation's ETIS has operated over time. The wind turbine industries in China, Denmark, and the United States were used as an example of a supply-side energy technology to understand the status and growth dynamics of wind energy knowledge and technology through cross-country comparisons.

Methodology. Drawing upon the innovation systems (IS) approach as well as existing work on innovation metrics, approximately 35 quantitative indicators grouped as inputs, outputs, and outcomes were identified as being the most important for a well-functioning ETIS. The associated data were collected from multiple official statistical agencies (e.g., OECD, IEA, UN) to quantify the values of indicators by means of descriptive statistics. For some of these indicators, scaling analysis and scenarios projections at unit level were performed using the LSM II model developed at IIASA.



Results. At the present stage, Denmark leads in almost all value chains of developing, manufacturing, and exporting large wind turbines. China lags behind the United States and Denmark in wind energy knowledge and technology accumulation. However, the production capability of Chinese wind turbine manufacturers has grown rapidly and enormously. China has already surpassed the United States in manufacturing larger wind turbines, and the time lag between China and Denmark in installing (manufacturing) wind turbines, measured by the unit capacity frontier, is increasingly shortening.

Conclusion. Adequate innovation metrics are crucial to characterize the functioning of ETISs. The multi-dimensional indicator framework developed enables the evolution of national innovation and technological capabilities to be analyzed, and these were tested with a case study on wind turbines. The results suggest a rapidly growing technological capability and the closing of innovation gaps on the part of leading countries with respect to China's wind turbine industry.

Impact of EU energy policy on ground level ozone pollution

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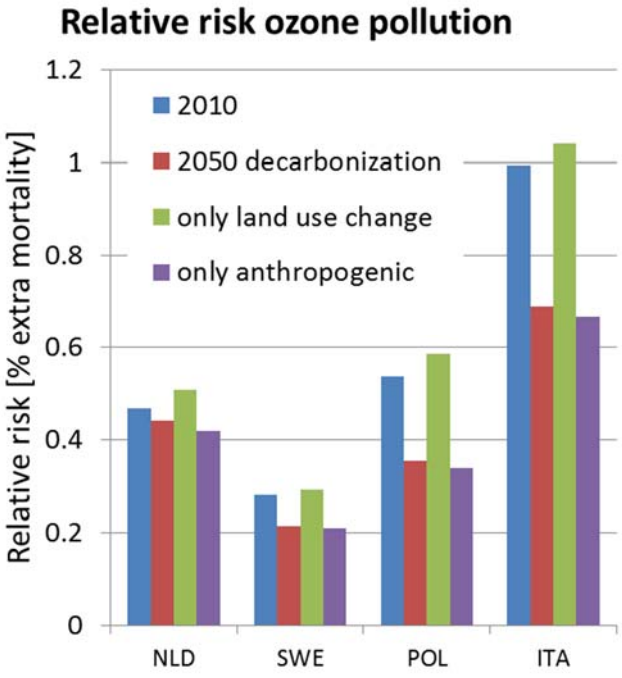
Introduction. Anthropogenic activities and associated air pollutant emissions have caused ambient ozone concentrations to rise to levels harmful to humans and vegetation, especially during summer smog episodes. Ozone production in the atmosphere is driven by emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) from natural and anthropogenic sources. EU energy policies aimed at reducing greenhouse gas (GHG) emissions can influence both anthropogenic emissions of air pollutants and biogenic VOC emissions, the latter because of land use change. This study assesses the impact of changing anthropogenic emissions and land use because of EU energy policy on ground level ozone pollution, also including climate change.

Methodology. The impact of two energy scenarios on European ozone levels was calculated. Anthropogenic emissions were taken from Integrated Assessment Model GAINS and land use change from the Global Biosphere Management Model GLOBIOM, which both used energy scenarios developed by PRIMES: a current legislation (CLE) case and a decarbonization scenario with 40% reduction of GHGs plus extra energy efficiency measures. Using these datasets, ozone levels and damage indicators for the two scenarios were calculated with LOTOS-EUROS for 2030 and 2050.

Results and conclusions. Land use change causes an increase in isoprene emissions for the EU28 of 20-51% for 2030-2050 compared to 2010 depending on scenario. Anthropogenic emissions of NO_x and VOC are projected to strongly decrease for both the CLE and decarbonization scenario leading to an increase of 3-4% in ozone concentrations for high-NO_x regions such as the Benelux but a decrease of 2%-8% over the rest of the domain in 2050. Ozone-induced relative risk (RR) of death decreases across Europe from 0.3 – 1.3% in 2010 to 0.22 – 1.0% for 2050 (see figure). The change in anthropogenic emissions is the dominant driver for the observed change in ozone health damage. We found that climate change could increase relative risk for ozone by a factor 1.09-1.78 compared to current climate conditions, which means that climate change will, depending on region in Europe, partly or completely cancel out the reduction achieved by lower emissions or even increase ozone health damage compared to 2010.



Implications of electricity transmission for integrating variable renewable energies

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Introduction. Long-term energy planning models used to analyze the integration of variable renewable energy (VRE) often incorporate limited temporal and spatial resolution resulting from the difficulty to access high-quality data. It is therefore crucial to develop a method for indirectly representing the costs and benefits of the various options to maintain a reliable grid while integrating VRE. Little research has been conducted on how transmission can enable better matching of VRE generation with electricity demand on a spatial basis. Hence, the copper-plate assumption[1] found in most energy modeling tools. Using China's power sector as a case study, we create an optimization tool to explore the impact of transmission system expansion on electricity production costs and wind generation siting.

Methodology. We develop a high-resolution linear programming capacity expansion model using hourly load and wind capacity factors data at the province level. Demand is located in Guangdong, while the other 31 provinces can only be electricity producers from wind. Generation and transmission capacity expansion is optimized through a cost minimization approach for nine scenarios constrained by a renewable portfolio standard (RPS) – 10, 30 or 50% – and by a restriction on transmission line siting (see Fig. 1) – **No transmission** (production within Guangdong only), **Adjacent** transmission (production in any of Guangdong's adjacent provinces), or **Full** transmission (production in any provinces).

Fig. 2 Transmission restriction scenarios

Results. In all scenarios, the cost-minimized mix locates wind turbines in one province only. Wind + transmission costs can be reduced by up to 38% and 68%, if building transmission lines is allowed from adjacent provinces and all provinces, respectively. The resulting reduction in installed wind capacity ranges from 51% to 73%. Electricity overproduction can be up to 45 times lower when moving from **No** to **Full** transmission configurations. Lowest residual peak load occurs in **Adjacent** configurations. We calculate that the cost error in copper-plate assumption models – corresponding to transmission costs – is at least 17% of the total cost in our **Full** transmission scenario.

Conclusions. While transmission expansion significantly decreases costs and overproduction, a cost-minimizing approach does not systematically favor configurations with highest wind capacity values, as the capacity value is derived from the highest residual peak load hour while costs are minimized over the year. Next steps will consist in applying the same methodology to other consuming provinces to derive an average error in cost calculation between high- and low-resolution models. The SWITCH model will be used to compare transmission expansion with other options for integrating VRE.

[1] A transmission system where power can flow unconstrained from any generation site to any demand site.

Displacement of fuelwood due to use of improved cooking fuels in India

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Introduction. About 3 billion people worldwide depend on traditional biomass (wood, crop residue, dung) as their main source of household cooking energy. The use of biomass, and other solid fuels, has attracted international attention due to their negative impacts on health, environment and society. WHO (2013) estimates that indoor air pollution from inefficient use of these fuels contributes to almost 4.3 million deaths annually around the world. These impacts have prompted multiple efforts at the local, national and global scale to transition people to the use of improved fuels. Recent trends indicate that only a partial transition to cleaner cooking fuels is taking place in many countries, and fuels are often stacked (i.e. used along with) rather than completely substituted. However, research has not explored the extent to which households stack fuels even though it has major implications for household greenhouse gas emissions accounting. We contribute to this literature by analyzing recent trends over a decade (2001-2011) in India to estimate the amount of fuelwood that is displaced due to the growing use of liquefied petroleum gas (LPG) for cooking.

Methodology. We use LPG as the improved fuel for our analysis as most Indians aspire to use it given its ease of use, efficiency, and reduced emissions. We use the Indian national census data and the Indian National Sample Survey Organization Socio-Economic surveys from 2001 and 2011 to estimate per capita fuelwood displacement on account of LPG access and use. This displacement is identified by estimating fixed effects models to identify the drivers of fuelwood consumption by rural and urban populations. We include controls for state (and region), income, social class (caste), employment, fuel prices, gender of household head, education level of household head, size of the household, and the amount of other fuels used for cooking.

Results. We observe that the number of households using fuelwood for cooking over the decade has decreased in percent but not in total numbers. However, both the share and number of supplementary users (those who use fuelwood in addition to LPG) has increased. The average use of fuelwood per month also increased from 149.34 kg/capita in 2001 to 169.93 kg/capita in 2011. We find that LPG access displaces between 11.97 to 12.41 kg/capita/month on average, while every additional GJ of LPG consumed displaces between 88.41 and 91.69 kg/capita/month. On aggregate this suggests that 45.65 MT (22% of FW in 2011) of fuelwood was displaced due to the use of LPG for cooking in 2011.

Conclusions. A transition to improved fuels is observed over the decade in India. However, this transition is not total and people continue to use multiple fuels (stack) to meet daily cooking needs. Our results can improve the calculation of fuelwood saving used in carbon credits for improved cook stoves. The results can also inform the impacts on forest resources from the use of improved fuels.

Food & Water

Integrated systems analysis approach to robust energy, food, and water provision in coal-rich areas of China: Shanxi case study

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Introduction.

This project will develop a harmonized strategic approach for integrated modeling to achieve a secure sustainable supply of energy, food, and water under natural and human-related intentional and unintentional threats.

Methodology.

Two-stage stochastic optimization

Results.

A two-stage stochastic model was built. Interdependent strategic long-term (anticipative, ex ante) decisions and short-term (adaptive, ex post) decisions (adjustments) were incorporated into integrated stochastic optimization models, and a robust strategic solution to achieve a secure sustainable supply of energy, food, and water under natural and human-related intentional and unintentional threats was achieved.

Conclusions.

- Systemic risks induced by interdependencies between energy (coal) and food production and resource (water and land) availability are treated in the developed two-stage STO model.
- With the developed two-stage STO model, energy (coal) and food security can be analyzed under water availability and land constraints.
- For further coal development, the water storages should be built to avoid water shortage. Otherwise, the energy demand and crop demand could not be met.
- It seems that food production in Shanxi cannot be of high level. The policy maker should arrange a long-term food purchase agreement with other food producer.

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Integrating water and energy models for optimal long-term resource management

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Introduction. Availability of and access to water and energy are key ingredients of economic and social development. Unfortunately, half the world's population still lack access to both freshwater and basic energy services. Future predictions show that the situation may become worse with about a 40% increase in energy demand and 30% increase in water demand by 2040. In addition, water and energy are highly interdependent, with water needed in all phases of the energy lifecycle and energy needed in all phases of the water lifecycle. While recent years have seen an increasing number of studies on the water-energy nexus, the research is focused on scattered individual areas of the nexus, each important in their own right. With increasing evidence of the different interdependencies of the water and energy systems there is a need to develop applicable holistic water-energy nexus methodologies to maximize the possible co-benefits from integrated planning.

Methodology. After a literature review several key elements were identified as important factors to consider in future water and energy integrated models in order to capture critical feedbacks and interdependencies. This includes consideration of different power plant cooling technologies, climate change impacts, a representation of the water infrastructure system and its corresponding energy consumption, physical water resource limitations, and adequately synchronizing the water and energy systems both spatially and temporally. A partial-equilibrium linear programming energy model had already been developed prior to the YSSP program. During the program a spatially and temporally compatible water resource and infrastructure model was developed in the General Algebraic Modeling System (GAMS). The two models were linked based on shared multi-use reservoirs, water consumption by the energy system, energy consumption by the water system, and a global objective function which is capable of optimizing multiple objectives depending on the needs of the users. The models were developed for the region of mainland Spain.

Results. Preliminary results show that the interdependencies of water and energy systems can have considerable impacts on future resource management strategies and technology choices. For example, certain policies which may favor water-intensive energy technologies like biofuels will result in increasing competition for limited surface water resources in agriculture basins, leading to increases in alternative energy-consumptive water-processing technologies such as desalinization and water transfers.

Conclusions. While the integrated model is still being calibrated and checked, even preliminary results show that the water-energy nexus will be a crucial part of future resource management strategies and it is clear that integrated, holistic management approaches will be the key to sustain the kinds of lifestyle patterns and population increases that are predicted in the face of diminishing natural resources and climate change.

Spatio-temporal analysis of droughts: Statistical characterization

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Introduction. Droughts are one of the most costly natural disasters, causing impacts on water availability for agriculture, human consumption, energy generation, and the healthy maintenance of ecosystems. It is thus important to understand the behavior of droughts and the mechanisms behind them in order to forecast them better, and also to have more accurate projections on how they may be affected by climate change. However, most studies on the subject do not address the simultaneous evolution of droughts in time and space. They focus on time series analysis of area-averaged quantities or on the spatial heterogeneity of a drought of a given duration. Therefore, this research consists of characterizing the spatio-temporal dynamics of drought around the world during the past 30 years, identifying patterns of motion and behavior.

Methods. Soil moisture data from the Climate Forecast System Reanalysis (CFSR) at a monthly time scale was analyzed to identify anomalously dry regions at each time step. Data values were replaced by their respective percentiles and drought was defined when a percentile value was below a given fixed threshold. Regions under drought were aggregated into clusters at each time step by a proximity criterion, and their continuity through time was tracked. Different cluster characteristics were studied, including the distributions of their duration, total distance traveled by the centroids and distance between their start and end locations, and rates of change in area and intensity.

Results. Studying the drought cluster tracks showed that there are "hotspots" where more clusters pass through. These match with the semi-arid regions of the world. Some regions also exhibit consistent patterns of displacement for droughts that pass through them. Both the hotspots and the displacement patterns were found to be seasonally dependent. The rates of change in area and intensity were found to be non-linear functions of the clusters' area and intensity in a given time step. Finally, different parameterized distributions were fitted to the distributions of the clusters' properties. The parameters varied more with the threshold of drought chosen than with the continent where the droughts were studied.

Conclusions. Drought clusters are dynamic and can travel long distances, sometimes across continents, evolving along the way. The size and intensity of a drought impacts its future evolution, with smaller droughts experiencing larger relative area changes than larger ones. The cluster characteristics follow common distributions, allowing us to do comparisons between regions and study the sensitivity of the threshold definition.

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Towards sustainable livestock production systems: Analyzing ecological constraints to grazing intensity

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Introduction. Increasing food production from cropland and grassland is essential to meet the future food demand of a growing world population without further land-use expansion. Food production is estimated to increase strongly to meet future food demands. On pasture lands, this would require a growth rate 40% larger than the production increase between 1962 and 2005 to close the food gap. Grasslands cover a large part of the global land-surface and hence it is of outstanding importance to increasing food production in a sustainable way, e.g. by not degrading essential ecosystem services. This project aims at contributing to a better understanding of the major determinants and ecological constraint of the global livestock production system and the analysis of further production potentials.

Methodology. We assess grazing intensity (e.g. the share of Net Primary Production consumed by grazing animals) at the global scale in a spatially explicit manner. To do this, we use a number of global datasets on animal feed-demand, monthly availability of NPP and socio-economic frame conditions to analyse seasonal shortage and surplus periods of biomass supply and provide an estimate of how much additional biomass would be available if management were optimal (e.g. storage facilities were available).

Results. Seasonality of biomass provision creates in many parts of the world shortage and surplus periods of NPP which can be seen as ecological constraints to grazing intensity. In cold climates, grazing intensity is limited by a short growing period and the fact that biomass supply is severely constrained in winter. The same is true for many arid areas where biomass growth is severely limited during dry periods. This period of short biomass supply reduces the annual average grazing intensity by constraining the number of animals that can be fed by the amount of biomass available over the year. At the same time, in periods with biomass surplus not the entire utilizable fraction can be eaten by the animals. The limitations posed by seasonal patterns can be overcome by management such as storage options. We find that largest potentials for storage of biomass is located in Sub-Saharan Africa and Latin America, followed by Central and Eastern Asia.

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Global nitrogen and phosphorus pollution for major crop production

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Introduction. In the last several decades, global food production growth has been triggered by a large increase in the amount of fertilizer application; for example, global nitrogen (N) fertilizer application increased nine-fold and global phosphorus (P) fertilizer tripled from 1960 to 2010 (Sutton et al. 2013). Consequently, significant environmental issues have been caused at different scales (e.g., air and groundwater pollution, eutrophication, soil degradation, ecosystems diversity reduction, and coastal water pollution) (Sutton et al., 2013). It is important to identify the hotspots of crop-specific nitrogen and phosphorus pollution on a global scale.

Methodology. PEPIC, a grid-based EPIC model under the Python environment, was used to investigate the nitrogen and phosphorus pollution for four major crops: maize, rice, soybean, and, wheat. Here, total annual losses of N (including the annual losses of N to air and water) and P (the annual losses P to water) to environment were considered as the N and P pollution. To identify the hotspots of N and P pollution, a global food production unit map obtained from Elliott et al. (2014) was used to aggregate the grid-based outputs.

Results. Total annual losses of N to environment (aggregated from four crops based on crop harvested areas) ranged mainly between 15 and 90 kg N ha^{-1} (Fig. 1a). However, southeastern parts of China, Republic of Korea, and Chile presented the higher amount (larger than 150 kg N ha^{-1}). Generally, total annual losses of P to the environment (also aggregated from four crops based on crop harvested areas) were less than 10 Kg P ha^{-1} in most of the world, especially in Africa, west parts of Asia, and western parts of USA (Fig. 1b). On the other hand, hotspots were located in southeastern parts of China, Republic of Korea, Japan, Chile, and New Zealand, where total losses of P were larger than 30 kg P ha^{-1}.

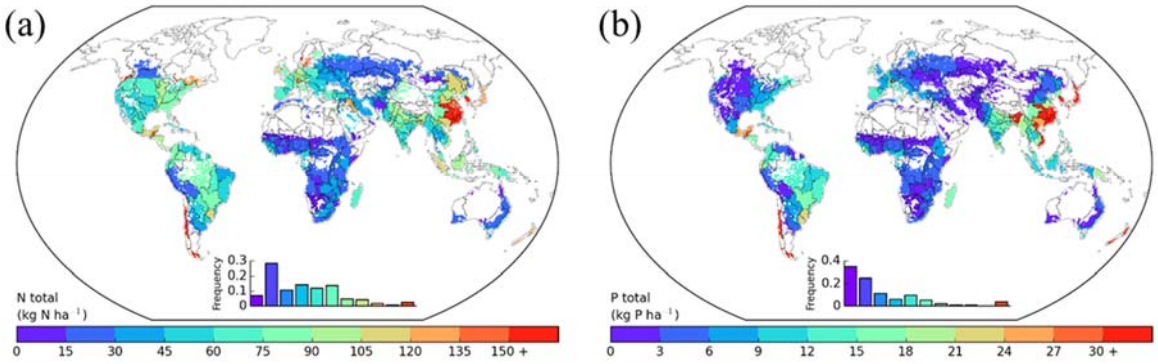

Fig. 1 Global distribution of total annual losses of N and P to environment around 2000

Conclusions. Using this biophysical crop model, it is possible to spatially explicitly simulate the crop-specific nitrogen and phosphorus pollution. In this study, the hotspots of global N and P pollution at the level of food production unit were identified. To reduce the N and P pollution in these high pollution areas, smart agriculture management practices should be introduced.

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Hydro-climatology: What is needed in the Hindukush-Karakoram-Himalaya?

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Introduction. Millions of people rely on river water originating from snow and ice melt in the Hindukush-Karakoram-Himalayan (HKH) region. One such basin is the Upper Indus Basin (UIB), where the contribution of snow and glacier melt is more than 80% and therefore highly susceptible to global warming and climate change. The area of the UIB at Tarbela Dam is 172,173 km^2, and meets millions of people's agro-electric needs. Accurate results of hydro-climatic studies are vital for future precise policymaking and sustainable water resource development. This research thus evaluates the accuracy of various hydro-climatic studies for six sub-basins of the UIB.

Methodology. This research evaluates the accuracy of five bias-corrected general circulation model (GCM) precipitation data sets, based on basin-wise mass balance assessment and Turc-Budyko non-dimensional analysis. The data sets are based on five GCMs: i) GFDL-ESM2M, ii) Had GEM2-ES, iii) IPSL-CM5A-LR, iv) MIROC-ESM-CHEM, 5) NorESM1-M, all for the period 1985-1998. These precipitation data sets have been utilized in six different hydrological models used in the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP). Modeled flows results of these six models have been evaluated by comparing them with measured flows for all sub-basins. GEAZ/FAO water scarcity and other relevant hydro-climatic studies were also assessed during 1961-1990, using the above-mentioned approaches.

Results. The basin-wise mass balance assessment and Turc-Budyko analysis show that all precipitation data sets used in ISI-MIP significantly underestimate precipitation in the UIB, particularly in the Karakoram sub-basins. ISI-MIP's WBM and MPI models are not suitable for the UIB because they significantly underestimate modeled flow compared with the measured flows (and the other four models). The remaining four models provide consistent but significantly low modeled flows (<50%) compared with the records measured in all sub-basins, except for the Kharmong Basin. GAEZ/FAO shows severe water scarce conditions in the UIB and other nearby Asian basins. In GAEZ/FAO, significantly underestimated precipitation data have been adopted to estimate available surface renewable water resources; thus their modeled flows are also far lower than the actual available renewable water resources.

Conclusions. All ISI-MIP hydrological models have used underestimated precipitation data, which is the main cause of underestimation of the modeled flows. Similarly, the GAEZ/FAO water scarcity does not give a true representation for the UIB, mainly because of underestimated precipitation. For future precise and accurate policymaking and sustainable water resource development, there is an intense need to improve hydro-climatic studies in the UIB. It is highly recommended and needed that ISI-MIP and other such projects/models' results be checked at the regional scale. An important message from this study is that extreme caution should be exercised in selection of precipitation data sets and hydrological models, particularly in mountain regions such as the HKH.

Coastal disasters in China: Impacts, risk and resilience

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Introduction. China is one of several countries severely affected by coastal disasters. In the context of global climate change and fast urbanization, coastal disaster risks are expected to rise significantly in China. To date, coastal disaster risk research in China has been fragmented. This research aims to systematically illustrate the current situation of coastal disaster impacts, assessing coastal resilience, then to explore the ability of coastal adaptation options to reduce vulnerabilities and improve coastal resilience.

Methodology. First, the annual variation and geographic distribution of direct economic losses and casualties caused by marine disasters at provincial level in China were analyzed based on collected multi-source data of marine disaster damage of China from 1989-2014. Second, an indicator system for coastal resilience in China was built from six capitals: human, natural, physical, financial, social, and institutional capital, adapted from resilience framework in the IIASA flood resilience project (Keating, et al. 2014). Thirty-two indicators and 47 sub-indicators were calculated by using entropy weight to evaluate coastal resilience in 2000 and 2010. Finally, changes in coastal resilience and coastal disaster changes were diagnosed and measured.

Results. i) In the temporal dimension, the direct economic loss induced by coastal disasters showed no obvious trend, but casualties showed an obvious decreased trend from 1989 to 2014 although population has increased rapidly in coastal China; ii) In the marine disaster category, storm surge caused the most economic losses, up to 92.49 %, making disastrous waves the main contribution to casualties since 1998; iii) In the space dimension, Guangzhou, Fujian, and Zhejiang suffered the highest direct economic loss induced by marine disasters, and Zhejiang, Fujian, and Guangdong suffered the highest casualties from 1989 to 2014; iv) Overall, the coastal resilience index increased from 2000 to 2010; the largest increase was in institutional capital, while natural capital decreased.

Conclusions. The results suggest that marine disaster reduction measures by the Chinese government have had a significant effect on marine disaster prevention over the past 25 years. However, coastal China still faces high risks from ecological and slow onset hazards mainly caused by climate change, as well as a great challenge to balancing coastal risks and socioeconomic development. Other ecological and slow onset marine disasters cannot be ignored.

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Impacts of spectral nudging on the simulation of present-day rainfall patterns over southern Africa

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Introduction. Regional climate models (RCMs) are expected to provide finer-scale simulations than those provided by global climate models, whilst maintaining the large scale circulation patterns provided by the host models. In this study, we examine the influence of spectral nudging on the simulation rainfall patterns in South Africa.

Methodology. We use the Conformal-Cubic Atmospheric Model (CCAM) as RCM to downscale ERA-interim reanalysis data with a resolution of 50km in the horizontal over the globe. The simulations are performed for the period 1979-2011. A scale-selective filter (spectral nudging technique) is used for nudging the CCAM simulations. The filer is applied at length scales of 4000 km, 1000 km and 200 km and 0 km (no nudging). Simulations are also performed without using any atmospheric nudging (only sea-surface temperatures and sea-ice are provided in this case). The filter is applied at six-hourly intervals and from 900 hPa upwards. The model simulations of rainfall are compared against CRUTS3.2 observed monthly rainfall data sets, and the merits of the different length scales of nudging are discussed.

Results and conclusions. Use of the spectral-nudging technique ensures that observed synoptic-scale circulation patterns are represented with increasing realism as the length-scale at which the filter is applied decreases. The model was able to simulate the rainfall pattern and seasonality realistically.

The influence of property size on sustainable agricultural intensification in Mato Grosso, Brazil

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Introduction. Size matters. Farmers' decisions, such as whether to clear vegetation, whether to keep livestock or plant crops, and which technologies to use, are all influenced by property size, that is, how much land a farmer has. Across the tropics, the dynamics of land use change differ greatly, for example, between areas dominated by smallholder farming or export-oriented industrial agriculture. However, the models of land use and land use change which are commonly used to evaluate alternative policy or development scenarios often do not include the distribution and ownership of land. Nowhere is the consideration of the distribution of land more relevant than in Brazil. Smallholders make up 81% of owners of farm properties in the Brazilian Legal Amazon, and are not only more credit-constrained but also less educated than the owners of larger properties; smallholders are also responsible for an increasing share of deforestation. Between 2005 and 2011 the contribution of deforestation by large landholders (>2,500ha) fell by 63%, whereas that of smallholders (<100ha) rose 69% [1]. Future efforts to promote equitable, sustainable development in Brazil must consider the size distribution of landholdings.
I developed a high-resolution map of landholdings for the central Brazilian state of Mato Grosso, an epicenter for land use change and deforestation. This dataset was used to test the hypothesis that property size is a determinant of which farming practices farmers adopt; it was used to evaluate the effect of environmental and agricultural policies on rural property owners, and how their responses vary with farm size.

Methodology. I classified land use in Mato Grosso into four property size classes, ranging from <100ha to > 2,500ha, and six land uses: forest, single-cropped soy or cotton, double-cropped soy-maize or soy-cotton, and pasture. This classification used multiple data sources, including data on the distribution of properties and their sizes for 1,839 census-tracts (covering 81.2% of Mato Grosso), rural cadastral data of 34,687 properties (covering 34.5% of Mato Grosso), and satellite remote sensing data on land use classifications [2].
I differentiated the production costs that farmers with differently sized properties face, and then integrated these data into a land use optimization model which operates at municipality scale and covers the whole of Mato Grosso. This recursive dynamic model solves for each five-year time step starting in 2006 and captures the behavior of different farm size classes through their differentiated costs of production. We used this model to test different scenarios for the transition to sustainable agriculture in Mato Grosso.

Results and conclusions. I mapped the distribution of farms, their sizes, and their agricultural practices across 6,119 census-tracts in Mato Grosso. This novel dataset describes the proportion of land per census tract that is occupied by, say, small ranchers (<100ha) or large soy-maize producers (>2,500ha). I confirmed that agricultural practices in Mato Grosso are strongly influenced by property size; smallholders (<100ha) are more likely to raise cattle than the owners of larger properties (>100ha), who in turn are more likely to plant crops such as soy, soy-maize, or cotton. This spatially explicit dataset can be used in further analyses to, for example, investigate the impact of government policies on deforestation and reforestation, or investigate the role of investment and subsidies in promoting sustainable agricultural practices, .

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Quantifying GHG emission from paddy field in China under climate change based on the coupling of DNDC, DSSAT, and AEZ models.

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Introduction. Rice is one of the most important food crops in China, and rice planting is a major contributor to the high level of CH_4 and N_2O emissions because of excessive application of nitrogenous fertilizers and basin irrigation. An important scientific and policy issue is how to balance the trade-off between food security concern and GHG emission reduction. In this research, the DNDC model (Li et al 2003) is employed to simulate the CH_4 and N_2O emissions from paddy fields in China. However, the default crop cultivar varieties in DNDC cannot represent the richness and regional diversity of cultivar varieties in China. A good approach to solving this problem is updating DNDC crop cultivar parameters by communicating with DSSAT and AEZ for parameter calibration and validation, in a way similar to the DSSAT-AEZ coupling in Tian et al (2014). We then use the updated DNDC to evaluate plausible emission reduction choices under the condition of maintaining the prevailing attainable yield.

Methodology. i) Coupling DNDC with DSSAT and AEZ for enriching and updating cultivar parameters in DNDC; ii) Up-scaling DNDC model with the assistance of the cropping zone classification method in AEZ.

Results. Some key parameters, such as maximum potential yield and C/N ratio, that are calibrated and validated by DSSAT and AEZ based on observation data from nine agro-meteorological stations in China, were translated into the DNDC model. The DNDC simulation results show that the attainable yield without water stress and nitrogenous stress is more or less equal to the maximum observed yield, and the recorded nitrogenous fertilizer application is higher than the crop growth requirement by a scale of 5-35%, which leads to excessive N_2O emission. A comparison between the recorded real fertilizer application and the optimum fertilizer scenario suggests a N_2O emission reduction rate in the range of 9.1% - 68.3%.

Conclusions. i) The application of nitrogenous fertilizers is excessive in all nine case-study stations. ii) Reducing the application level of nitrogenous fertilizers to the optimum level will mitigate N_2O emission without negative consequences for yield. iii) The relationship between CH_4 emission and nitrogenous fertilizers is complex and obscure.

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