YSSP

Young Scientists Summer Program

Proceedings of the YSSP Final Colloquium 2018

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, 23–24 August 2018.

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Proceedings Editors: Merritt Harlan, Ansir Ilyas, Sara Turner, and Brian Fath

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	END OF COLLOQUIUM ***RECEPTION IN CONFERENCE AREA***					

Arctic Futures Initiative (AFI)

A comparative study on cooperation in the Arctic Ocean and the South China Sea

Ekaterina Antsygina, Queen's University (Canada), Russia
Email: ekaterina.antsygina@gmail.com
IIASA Supervisors: Lassi Heininen (AFI), Nadejda Komendantova-Amann (RISK)

Introduction.

Procedures of delineation of the extended continental shelves involving the Commission on the Limits of the Continental Shelf (CLCS) triggered an escalation of disputes between coastal states with overlapping claims. The CLCS shall not consider and qualify a submission involving land or maritime disputes unless it has the consent of all the parties involved.[1] The coastal states in the Arctic Ocean (AO) were able to reach non-objection agreements that allow the CLCS to proceed. The situation is different in the South China Sea (SCS) where the objections of the neighboring states stalemate the submissions. The hypothesis of the comparative study was that the pre-existing cooperation on environmental protection and security in the Arctic Ocean constituted a critical variable influencing the outcome of the delineation procedures.

Methodology.

The methods of comparative case study analysis and legal analysis were implemented. The following parameters were compared: relevant treaties and soft law instruments, membership in international and regional organizations, executive summaries of submissions to the CLCS and communications, types of disputes in the region, foreign interests, military presence and security issues, land reclamation, allocation of power in the regions, presence of natural resources in the zones of overlap, transport.

Results.

First, the comparative analysis showed that cooperation is not the only critical variable influencing different approaches in the compared cases, therefore the initial hypothesis was falsified. There are regional bodies to foster cooperation in the SCS and collaboration with a focus on confidence - building measures. Thus, strong sovereignty and legal certainty in the AO might have a greater impact to cooperation on delineation. Second, there are only overlaps of extended continental shelves in the AO. In the SCS such overlaps include claims based on both the distance and the natural prolongation criteria. Third, the possibility to find natural resources in the zones of overlap in the SCS is more significant. Fourth, the allocation of power in the AO and SCS differs, with equality of actors in the AO and one dominant actor (China) in the SCS.

Conclusions.

There is a gap in the legal doctrine on the correlation of the distance and the natural prolongation criteria. If the distance criterion prevails, the qualification of contested features as islands in the SCS gets even higher importance. The presence of natural resources in the zones of overlap in the SCS and high population density contribute to the significance of contested islands which, in its turn, might escalate the conflict. Legal certainty and compliance with the UNCLOS might facilitate the dispute management, delineation and delimitation in the SCS. The prognosis for the delimitation of extended shelves in the AO is optimistic for compromise solutions, taking into consideration existing cooperation, equality of states and the absence of such factors as contested islands and natural resources in the zone of overlap.

[1] CLCS/3/Rev.3, 6 February 2001. Annex I to the Rules of Procedure of the Commission on the Limits of the Continental Shelf, para. 5. (a). http://www.un.org/depts/los/clcs_new/commission_rules.htm; accessed August 15, 2018.

Air Quality and Greenhouse Gases (AIR)

Assessment of emission reduction strategies in the Gauteng city-region in South Africa

Luckson Muyemeki, North-West University, South Africa
Email: lucksonmuyemeki@gmail.com
IIASA Supervisors: Peter Rafaj (AIR), Gregor Kiesewetter (AIR)

Introduction. South Africa currently faces a serious problem of air pollution in urban areas as well as in industrial zones. Of concern are the high levels of Particulate Matter (PM), which are well above global health limits (Worobiec et al., 2011). This has serious health implications to the urban population as PM exposure especially $PM_{2.5}$ is linked to respiratory illnesses and premature mortality (Liu et al., 2016). Due to financial constraints and priority issues, policy makers in South Africa have failed to address the issue of air pollution and its health related impacts (Naiker et al., 2012, Scorgie, 2012). To deal with these policy challenges, suitable and cost-effective strategies need to be identified. In this study, potential mitigation options for the Gauteng City-Region – one of the most populated and industrialised regions in South Africa - are explored using an integrated assessment approach.

Methodology. IIASA's GAINS model is utilised to simulate baseline and alternative scenarios for reducing $PM_{2.5}$ and $PM_{2.5}$ precursor (sulphur dioxide (SO_2) and nitrogen oxides (NO_x)) emissions from key contributing sectors. The sectors targeted in this analysis include industries, residential, transport and waste. Costs for implementing control strategies in the baseline and alternative scenarios are calculated at a 4% interest rate. A local dispersion model (CALPUFF) is used to quantify the changes in $PM_{2.5}$ concentrations for each sector based on the different set of control strategies. These concentrations are then used as input in relative risk functions to determine the health impacts of $PM_{2.5}$ for each sector.

Results. The baseline scenario considers the impact of policies and measures on current and future emissions under the current legislation if fully implemented. The alternative scenario shows the extent at which emission levels can be further reduced through altering the activity mix and applying the best available technologies by 2030. In the baseline scenario, SO_2 emissions are reduced by 63% from 2010 to 2030, while reductions in emissions for NO_x (22%) and $PM_{2.5}$ (10%) are much smaller. The significant SO_2 emissions reduction result from the application of stringent controls (FGDs) in the power and industrial sector. Emissions in the alternative scenario are projected to decrease further for all pollutants (by 84% for $PM_{2.5}$, by 77% for SO_2 and by 75% for NO_x) as a result of targeted implementation of abatement measures. In the domestic sector, by the year 2030, $PM_{2.5}$ concentrations are expected to be reduced by 34% in the baseline scenario and by 98% in the alternative scenario. Differences are evident not only in terms of emissions and $PM_{2.5}$ concentrations but also in terms of costs. Control costs in the alternative scenario are higher by a factor of 2 than in the baseline scenario mainly due to the rapid implementation of strict emission standards in diesel vehicles.

Conclusions. Fine particulate air pollution is a major threat to human health in South Africa. Analysis with the GAINS model has demonstrated that by applying changes in the activity mix and introducing more stringent control measures $PM_{2.5}$ and $PM_{2.5}$ precursor emissions can be significantly reduced in the near / medium term. A fuel switch from coal to liquified petroleum gas in the domestic sector and the installation of high efficiency dedusters in the industrial sector produce the largest reductions in emissions and subsequently larger health benefits.

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Representation of short-term solar and wind variability in long-term energy models – a European case study

Hans-Kristian Ringkjøb, University of Bergen, Geophysical Institute, Norway
Email: hans-kristian.ringkjob@uib.no
IIASA Supervisors: Fabian Wagner (AIR), Sennai Mesfun (ESM)

Introduction. Long-term energy models are frequently used to aid policymaking, for strategic planning, and to understand the future of our energy system, and necessitates therefore robust modelling. As the European energy system is moving towards becoming more and more dependent upon variable renewable energy sources, particularly solar and wind, representing their variability in such models becomes increasingly important. In this work, we assess the representation of short-term solar and wind variability in a TIMES long-term energy model of the European power and district heat sector towards 2050, with the aim of exploring how various modelling approaches as well as different temporal resolutions influence the model performance.

Methodology. We have developed and applied the long-term energy model TIMES-EUROPE, a least-cost optimisation model of the European power and district heat sectors. In order to assess the importance of choosing an appropriate temporal resolution, we developed three model versions, all fundamentally identical but each with increasing temporal detail. Each of these versions were further modelled using three different modelling approaches: (i) a conventional deterministic approach; (ii) a deterministic approach with a peaking reserve constraint; and (iii) a stochastic approach that takes into account the uncertainty of short-term solar and wind variability. Finally, the various model versions and approaches were tested under two scenarios, a business-as-usual scenario, and one with a stringent climate constraint that leads to zero CO_2 emissions in 2050.

Results. Our preliminary results show that an adequate representation of short-term solar and wind variability is crucial for the robustness of the results. The simple low-resolution deterministic models are shown to overestimate the contribution of variable renewables to the system, even treating wind power as base-load rather than a variable energy source. An inadequate modelling of the variability can lead to suboptimal investments, and in a worst-case scenario to a system that could not be able to cover the demand in certain situations. Despite increased complexity and longer run times, a stochastic modelling approach gives a more realistic representation of the true wind and solar variability, leading to more reliable and robust results.
The results of the case study indicate that achieving a zero emission power and district heat system with large shares of variable renewables in Europe in 2050 could not only be technically feasible, but could also lead to a total system cost only ~4-6 % higher than the business-as-usual scenario depending on the model version and approach followed.

Conclusions. This work has shown that the choice of temporal resolution and modelling approach plays an important role in the performance of long-term energy models, and should be carefully evaluated when such models are used for decision-making. When modelling an energy system consisting of large shares of variable renewable energy sources, a stochastic modelling approach that takes into account the uncertainty of their short-term variability is recommended.

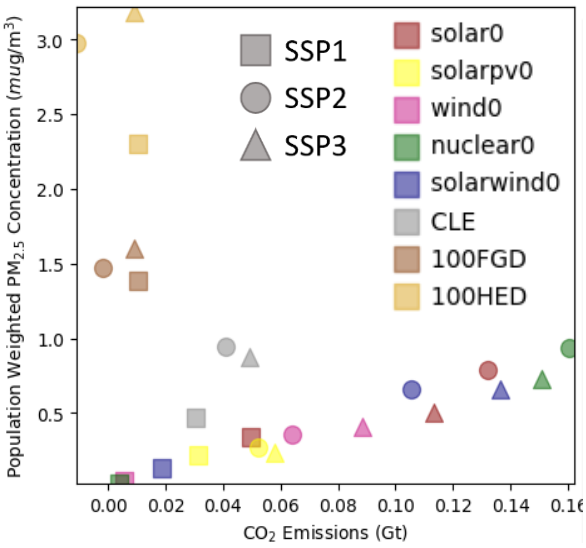
Air pollution and climate co-management in South Africa's energy future: When the "best available control technology" may not be the best policy

David Abel, University of Wisconsin – Madison, Nelson Institute for Environmental Studies, USA
Email: dwabel@wisc.edu
IIASA Supervisors: Fabian Wagner (AIR), Matthew Gidden (ENE)

Introduction. The Republic of South Africa is facing an uncertain energy future defined by multiple, often competing, objectives. The current energy system in South Africa is dominated by coal and is characterized by high CO_2 and pollutant emissions, expected to further increase given projected growth. In general, previous work finds that energy, air pollution, and climate policies are often addressed separately in South Africa, and the nation could benefit from a framework that accounts for interacting environmental, economic, social and political factors [1,2].

Methodology. We use an integrated assessment approach to analyze the impacts of future energy scenarios on South African air pollution and climate goals. We develop and perform an energy systems analysis for South Africa using the MESSAGE ix model and link results from MESSAGE to the Greenhouse Gas – Air Pollution Interactions and Synergies (GAINS) model to calculate emissions, fine particulate matter concentrations, and attributable mortality. We run a range of simulations for South Africa to show the comparative greenhouse gas emission and air pollution impacts of potential energy and air policies or interventions (including the energy systems cost feedback of air policy implementation) across three shared socioeconomic pathways (SSP1, SSP2, and SSP3) representing low, baseline, and high challenges to climate change mitigation and adaptation. The energy interventions include 100% investment subsides (for solar PV, solar PV & CSP, wind, nuclear, and solar PV & wind), and three control strategies (current power-sector legislation, 100% flue-gas desulfurization, or 100% high efficiency dedusters).

Results. In comparing power sector interventions, we consider cost, final $PM_{2.5}$ concentrations (and related mortality) and CO_2 emissions. In the figure, we show the reduction in average CO_2 emissions vs. the reduction in average $PM_{2.5}$ concentrations from 2020 to 2050 across scenarios. We see that most control strategies target $PM_{2.5}$ concentrations, but have little impact on CO_2 emissions, while investment incentives target CO_2 emissions, but have less of an impact on $PM_{2.5}$. The CLE scenario uniquely shows benefits to both CO_2 and $PM_{2.5}$ because the costs of these controls reach a price threshold that causes rapid decline of coal-fired power in addition to direct pollutant control. Therefore, current legislation may drive a transition away from coal power regardless of socioeconomic pathway. In general, control strategies are only cheaper than 100% subsidies by between $2-$14 billion total from 2020 to 2050 in 2010 U.S. dollars.



Conclusions. The Republic of South Africa should design energy policies around multiple objectives. Here we show the climate and air quality benefits of air controls and power-sector subsidies and the benefit to balancing both strategies. This behavior is important given current and pending policies such as the Integrated Energy Plan, National Development Plan, and Renewable Energy Independent Power Producers Procurement Plan. Other factors to consider in future work might include economic development, energy access and water conservation.

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Towards phase-out overcapacity policy solutions for air quality and public health improvement in the Jing-Jin-Ji region of China

Boshu Li, Peking University, College of Environmental Science and Engineering, China
Email: liboshu@gmail.com
IIASA Supervisors: Shaohui Zhang (AIR), Janusz Cofala (AIR)

Introduction. The phase-out overcapacity policy (PoP) in iron and steel (IS) sector has been widely launched as the key policy of current "Supply-Side Structural Reforms" in China since 2016. Jing-Jin-Ji (JJJ) region, as the top largest steel producer, aims to cut IS capacity by over 58.1 Mt before 2020. However, previous relevant studies mainly focused on qualitative discussions on the reason and risk of overcapacity while ignoring the relevant indirect effects, such as air quality, public health, and economic consequences.

Methodology. To conduct the integrated PoP assessment, the intensity use (IU) curve was firstly developed to project steel production on a provincial level from 2015-2030 that uncovers the core influencing factors to the future IS capacity. All historical output data were obtained from the actual IS plants in JJJ region, enabling realistic policy simulation to identify the changes in energy use before and after the implementation of PoP. Then we soft-linked IIASA's GAINS model, Peking University's IMED|CGE and IMED|HEL models to assess the comprehensive effects on energy use, CO_2 and air pollutant emissions, health endpoints and monetize health impacts, labor supply, and overall economic growth under two different scenarios.

Preliminary Results. Two scenarios were constructed: PoP scenario and baseline (BL) scenario that assumes no PoP policy adoptions. Initial comparison of two scenarios in the JJJ region indicated 764.2 PJ primary energy saving in 2030 due to PoP. The air pollutants emissions in all three regions will keep decreasing from 2015 to 2030, while Hebei reduce the most pollutant emissions in absolute term, by 75 kt SO_2 (equivalent to an 8.0% reduction of emissions in BL scenario), 125.3 kt NO_X (12.5%), 145 kt $PM_{2.5}$ (3.0%). The $PM_{2.5}$ concentration in a region is not only determined by local emissions and diffusive air conditions, but also by regional transmissions. Despite Beijing hasn't anymore IS plants since 2015, there is a significant reduction of $PM_{2.5}$ concentration, which is 8.0 ug/m³ (15.1%) in 2020, by the massive co-benefits of PoP in Beijing. Meanwhile, Tianjin and Hebei have to bear the cost of $5.6bn as a result of steel plants mandatory shutdown by governments.

Conclusions. Comparing the measurable benefits and costs of PoP in the aspect of energy saving, air quality, human health and GDP variation, the preliminary findings proved our expectation of the integrated impacts of PoP which is cost-effective. However, the policymakers should not ignore the big differences in net benefits in different provinces, especially the less developed province Hebei has a much biggest GDP loss. This calls for necessary financial aid to promote closer cooperation among provinces. The insights and methodology framework from this study could become a reference to deal with similar overcapacity challenges in other sectors (e.g., coal, cement, and construction) and regions in China.

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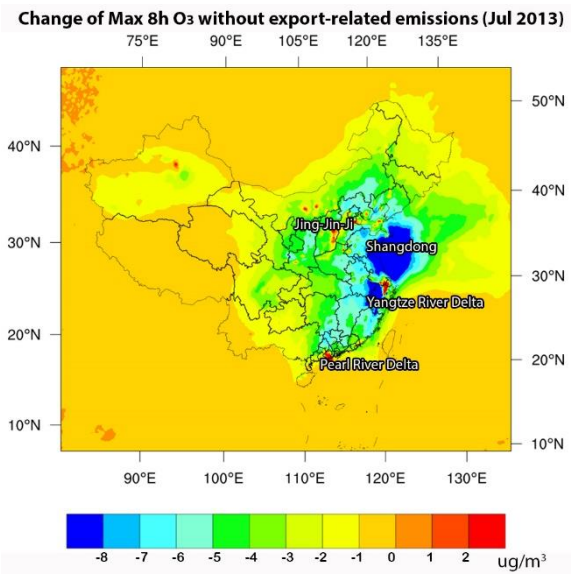
China's export industries and their contributions to O_3 pollution

Jiamin Ou, University of East Anglia, Norwich, United Kingdom
Email: jiamin.ou@uea.ac.uk
IIASA Supervisors: Zbigniew Klimont (AIR), Shaohui Zhang (AIR)

Introduction. China's ground-level ozone (O_3) shows a worrying trend exceeding national limit values consistently since 2013. As a secondary air pollutant, O_3 is closely related to emissions of Volatile Organic Compounds (VOC), Nitrogen Oxides (NOx) and Carbon Monoxide (CO). China is one of the world's largest exporters of coke, electronic appliances, synthetic leather, and other products. Export industries, therefore, make up significant share of emissions. This is especially true for VOC, of which emissions are largely from evaporative sources in producing those products. Nevertheless, the contribution of export industries to O_3 and the potentials to reduce such emissions have been less studied.

Methodology. We combined the input-output (IO) analysis with air quality model (CMAQ) to study the contribution of China's export industries to its ground-level O_3 pollution. Production-based emission inventories for three O_3 precursors (VOC, NOx and CO) in 2013 were developed. Consumption-based emissions were estimated by IO analysis and contributions of export to O_3 precursors' emissions were quantified. With the help of air quality model, export's contributions to ambient O_3 level were studied. Finally, a mitigation scenario was developed assuming that by 2030, emission footprint of key industries in China will be comparable with the EU average.

Results. China's export industries made up 13%, 15% and 10% of the nation's anthropogenic VOC, NOx and CO emissions, respectively. For export-dominant provinces in the east and central coast, export emissions accounted for as much as 30% of total emission budget, i.e., Shandong, Guangdong, Zhejiang and Jiangsu. We estimate that in July 2013, export-related emissions were responsible for a nationwide increase of 2.2 ug/m^3 of maximum 8h average O_3. For highly populated coastal areas, its contributions were even higher: 7.5, 6.7, 5.8, 3.2 ug/m^3 for Zhejiang, Jiangsu, Shandong and Guangdong, respectively. Export-related emissions also led to significant increases of O_3 in Jing-Jin-Ji[2] (3.6 ug/m^3). By adopting cleaner production practices in line with the EU by 2030, VOCs embodied in export products can be reduced by 38% (1.4 million tons). Total VOC emissions from industries (excluding combustion) can be reduced by 50% (5.7 million tons, 21% of total anthropogenic VOC).



Conclusions. China's O_3 has been increasing amid the growing industrial output for export. Such increase was most notable for the densely populated areas along the coastline. By comparing the current practices in China and the achievable emission levels in the EU, we found significant emission reduction potential from several manufacturing industries. Potential of cleaner production in terms of O_3 abatement is large and calls for focused and concrete action.

[2] Beijing-Tianjin-Hebei region

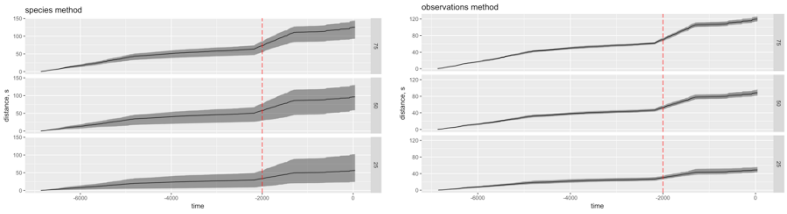
Advanced Systems Analysis (ASA)

Comparing composite metrics for detecting abrupt changes in ecosystems

Jessica Burnett, University of Nebraska-Lincoln, USA
Email: jessicaleighburnett@gmail.com
IIASA Supervisors: Brian Fath (ASA), Elena Rovenskaya (ASA)

Introduction. A growing concern with anthropogenic impacts on the environment has increased the demand for mathematical and statistical techniques for detecting ecological regime shifts, or changes in a system's structure or functioning. Some model-free methods which yield composite metrics (i.e. one measurement for the entire dataset at each time step) were introduced in the ecological regime shift literature as potential approaches for tackling the data limitation barriers, and for reducing the subjectivity inherent in ecological data analysis. We use a multi-species time series to (i) determine the influence of data quality and prior knowledge have on composite metrics from model-free methods and (ii) identify discrepancies in regime shift detection among these methods.

Methodology. We use a multivariate time series of paleodiatom community structure (relative abundances of 117 species at 763 points over ~7k years) from a sediment core (data avail.: Spanbauer et al. 2014) to achieve our aims. We randomly subset the entire time series (100 iterations) based on one of species dominance, species identity (random selection of species), and time (random % of observations) to achieve our aims. We compared results from the following methods: Fisher Information (for equations see: Cabezas and Fath 2002), variance index (max. eigenvalue of the covariance matrix; Brock and Carpenter 2006), averaged-higher-order statistics, and cumulative distance (Burnett et al. *in prep*). We (i) varied the parameter controlling the percentage of dominance, random species, and random time points, and (ii) compared the years at which each metric positively identified a shift



Figures. Cumulative distances, s, may serve as an early warning indicator of abrupt changes in multispecies data. Location of shift identified by Spanbauer et al. (2014) using Fisher Information (red vertical line). Average s ± 95% confidence intervals (shaded) are presented for the species (left) and observations (right) subsetting methods.

Conclusions. We randomly sampled a multispecies time series to determine the influence of potential subjectivities that may occur in the analysis of ecological systems data: during data collection and during data analysis. The distance metrics identified signals of the abrupt shift sooner than that identified by Spanbauer et al. (2014) and were robust to the subsetting parameters.

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A networks-based approach to the energy-water nexus

Aman Majid, University of Oxford
Email: aman.majid@new.ox.ac.uk
IIASA Supervisor: Tatania Ermolieva (ESM), Yurii Ermoliev (ASA)

Introduction. The inherent interdependencies between the water and energy sectors presents vulnerabilities to planning and operational resilience given that both industries are conventionally managed in silos across the world. The need to decarbonise critical national infrastructure to meet ambitious climate targets presents a compelling question: could co-management of the water and energy sectors yield significant monetary and environmental savings? However, a lack of transparent models and tools currently make it difficult to address this question. In this work, we develop a mathematical framework to model multi-sector infrastructure systems using a networks-based approach. Further, we develop an open-source model that executes this framework to optimise infrastructure operation and planning. We then apply this methodology through a case-study based on the water and energy systems of the United Kingdom.

Methodology. Infrastructure systems are modelled as a spatially defined directed graph, where nodes represent the physical assets (e.g. power stations, water reservoirs, treatment plants etc.), as well as region of demands. Arcs connecting nodes within the network are representative of commodity flows between points with associated features such as distance and cost. Resources are allocated to regions of demands using a multi-commodity network flow (MCNF) linear programming (LP) algorithm. Requirements for new technological investments are also determined within the LP formulation.

Results. The MCNF methodology was applied in a case-study based on the water and energy infrastructure systems of the United Kingdom (Fig. 1.). National level transmission networks for both water and energy systems were defined using multiple datasets acquired from open-data portals. Firstly, model validation was through a simulation from the baseline year (2014), which revealed ~34 GL d^{-1} of water and ~25 GWh d^{-1} of electricity were consumed in the energy and water sectors respectively. Whilst these values were computed to be within the same order of magnitude as real reported data (Fig.1.), further work is required to better calibrate the model to reduce this discrepancy. When compared with individually optimising the operations within each sector, coupled-systems optimisation resulted in an overall lower operational expenditure (~15%).

Conclusions. Preliminary results from the coupled-systems optimisation suggest both monetary and environmental benefits could be realised through the co-management of the water and energy sectors. However, further work is required to better calibrate the model to real-world data. In this work, availability of resources (e.g. water) and demands are assumed to be deterministic. Future work will introduce stochasticity to these data to better understand the influence of uncertainties within the optimisation of technological investments.

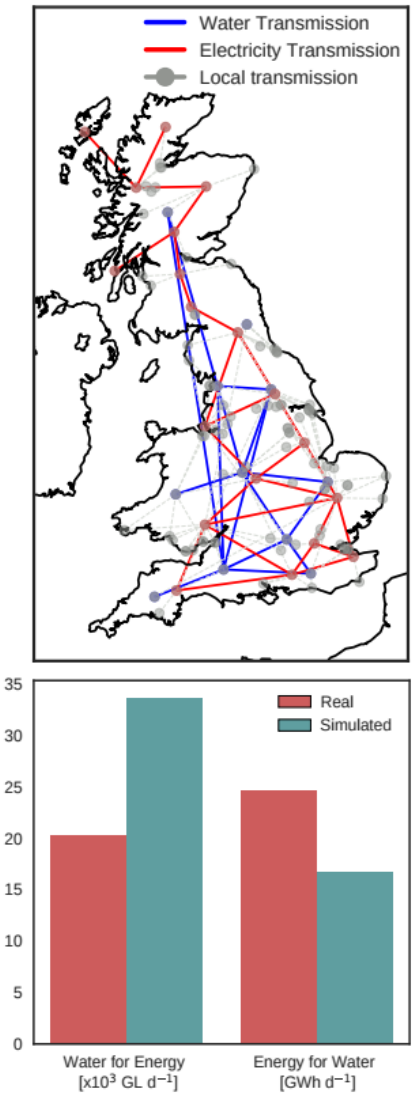


Fig. 1. Illustration of the MCNF model (inset top) and preliminary results from the system simulation as compared real data (inset bottom)

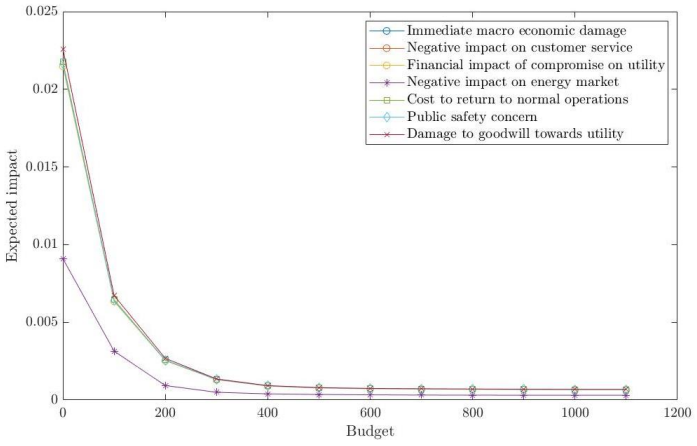
Portfolio optimization of security measures for protecting electric power grids from cyber threats

Alessandro Mancuso, Aalto University, Finland
Email: alessandro.mancuso@aalto.fi
IIASA Supervisor: Piotr Żebrowski (ASA)

Introduction. Electric power grids extensively rely on IT systems, making them vulnerable to physical and cyber threats with frequent and costly impacts worldwide. For instance, a recent cyber-attack to an electric grid caused a power outage in Ukraine, showing the need for an efficient allocation of security measures to reduce the risks of cyber threats. Standard approaches guide the selection of security measures by prioritizing the cyber threat scenarios through a qualitative assessment. These approaches consider cyber threat scenarios separately, thus they possibly result in sub-optimal resource allocations for the system. For this reason, we propose a systemic analysis based on Bayesian Networks to quantify the risks of cyber threats to electric power grids.

Methodology. Bayesian Networks provide a sound framework for Probabilistic Risk Assessment by representing combinations of events possibly leading to severe outcomes. Specifically, nodes represent the random events in cyber threat scenarios and arcs show the causal dependencies among these random events. Security measures reduce the likelihood of potentially threatening events thus mitigate the risks of cyber threats, evaluated as the expected impacts on different criteria, such as safety, economy and customer service. A combination (portfolio) of security measures is Pareto optimal if no other feasible portfolio further reduces the risks of cyber threats for any impact criterion without increasing the risk for other criteria. The selection of Pareto optimal portfolios is based on an implicit enumeration algorithm that considers budget and technical constraints.

Results. We illustrate the methodology by analysing the cyber threat scenarios concerning the advanced metering infrastructure of an electric power grid. The model provides additional insights on risk management when performed for different budget levels. In particular, this figure shows the risk profile of each impact criterion for different budget levels. Increasing the budget level leads to implementing security measures that are increasingly effective, thus reduce the risks of cyber threats. In case of multiple Pareto optimal portfolios, further analysis supports the selection of cost-efficient solutions from the set of Pareto optimal portfolios.



Conclusions. The results show that a systemic analysis of multiple cyber threat scenarios leads to an optimal selection of security measures. Unlike standard approaches, the optimization model integrates budget and technical constraints that limit the set of feasible portfolios. Therefore, we propose this methodology as a new practice for assessing the risks of cyber threats and for supporting risk-based decisions on resource allocation to cyber-physical systems.

Cooperation in common-pool resources and public goods between individuals and communities

Tum Nhim, Wageningen University & Research, The Netherlands
Email: tum.nhim@wur.nl
IIASA Supervisor: Nikita Strelkovskii (ASA), Matthias Wildemeersch (ASA)

Introduction. Managing a shared resource remains a challenge, especially when it is a common-pool resource (CPR) or a public good (PG). Restraining CPR extraction or investing to a PG is good for collective interest, but is costly for individuals, giving rise to social dilemma that may lead to inefficient use or depletion of the resource. Most studies in commons literature mainly focus on cooperation either in CPR or in PG, but rarely both combined. Both problems, however, are strongly coupled in natural settings. An example is resource users need to collectively invest for the production of resource so that enough amount of the resource can be generated and shared among all users. Cooperation in CPR is thus conditional upon the cooperation in PG.

Methodology. This study employs a stylized agent-based simulation to analyse under what conditions cooperation in CPR and PG emerges across two communities having different access to the resource. The upstream community gets the first claim of resource, while the downstream gets what remains. The upstream, however, depends on investment from the downstream for the production of the CPR. Agents make decision on levels of extraction and investment over time, starting from randomness. Resource extraction by an agent is observable to others, but investment is not, leaving agents uncertain on how much to invest in PG. While taking more resource or investing less to its production makes an agent economically better off in the short-term, doing so erodes his self-image which can potentially inflict loss on his economic performance in the long-term. Agents thus make decision balancing between doing well economically and doing good morally by learning from their nearest neighbours and other agents in a different community, copying the strategies that yield the best outcome.

Results. Fig. 1 shows evolution of extraction and investment strategies of each agent. Starting with random extraction and investment, the two strategies evolve to rather different equilibria. The extraction converges to a moderate level for both the upstream (Fig. 1(a)) and the downstream (Fig. 1(c)), even if the upstream gets more access to the resource. The investment strategy, however, has richer dynamics, exhibiting branching. In the upstream (Fig. 1(b)), the branch investment evolves towards 1 (full investment) and 0.2 (very low investment). In the downstream community, the branch investment evolves to 1 (full investment), 0.5 (moderate investment) and 0.0 (no investment). The richer dynamics in investment comes from the fact that agents face uncertainties, about how much would other agents invest.

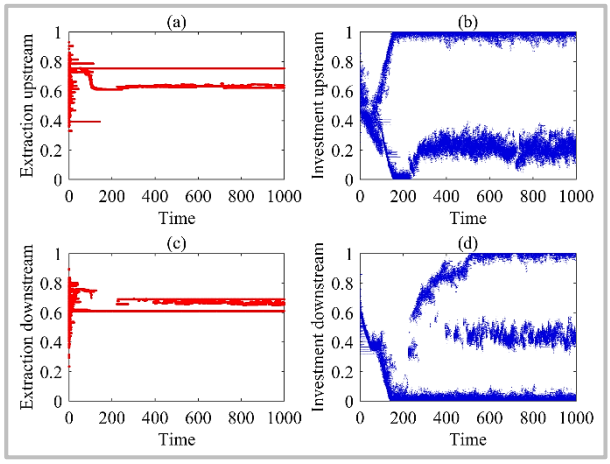


Fig. 1. Temporal evolution of extraction and investment strategies for upstream and downstream villages

Conclusions. In short, uncertainties could potentially give rise to social diversity, leaving some defecting, fully cooperating, or doing what the average does. The final objective of this work is to understand how strength of ties within and between communities can generate more cooperative behaviour.

Economic impacts of carbon taxes – An agent-based modelling approach

Anton Pichler, University of Oxford / Institute for New Economic Thinking, Smith School for Enterprise and the Environment, UK
Email: anton.pichler@wolfson.ox.ac.uk
IIASA Supervisors: Sebastian Poledna (ASA), Stefan Thurner (ASA)

Introduction. To limit global warming to no more than 2°C (1.5°C), a large-scale transformation of the economic system toward low-carbon technologies will be necessary. Due to a limited time window, this change will need to be unprecedently fast (Pearson and Foxon, 2012). Policy makers usually have to trade off their climate policy ambitions with other policy goals, such as sustaining and promoting economic welfare. This project analyses the impact of a specific climate policy – a carbon tax – on various essential economic indicators like growth, capital formation etc.

Methodology. This research focuses on the economy of a single country, Austria. We use a data-driven agent-based model (ABM) which depicts the Austrian economy in great detail (Poledna et al. 2018). Firms can replace parts of their existing capital stock with new – less CO2 intensive and more productive – capital stock. Yet renewal investments come with a cost and the actual investment decision will depend on the price of carbon. The policy maker exogenously aims to decarbonize the economy by taxing emissions originating from the economic activity of the firms. We run Monte Carlo simulations of the economy ten years ahead and quantify the effectiveness of the climate policy and its impact on the economic performance.

Results. Capital replacement is costly and thus, potential gains from productivity increases and lower emission intensity need to be substantial to stimulate additional investments in high-tech low carbon technologies. Similarly, the magnitude of decarbonization depends largely on the available state of technology, even in cases of strong policy interventions. The analysis also showed that costs on carbon do not necessarily affect the economic performance adversely. In general, the impact on economic growth are minor and if emission tax revenues are appropriately rebated, negative impacts are absent. In absence of carbon taxes greenhouse gases continue to rise, even in case of positive technical change and improvements in the carbon intensity of technology.

Conclusions. Carbon taxes do not necessarily impede economic growth and other key economic indicators. This suggests that active climate policy does not need to conflict with other policy goals of promoting economic welfare. Overall, greenhouse gas emissions do not fall in the baseline scenario but rise even in case of decreasing carbon intensity. This underlines the necessity of strong policy support to facilitate the low-carbon transition. Since the effectiveness of carbon taxes is constrained by the technological frontier, R&D in the low-carbon technology sector will play a central role in this context.

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Foresight into economic development futures of Kyrgyzstan

Elham Sedighi, Gorgan University of Agricultural Sciences and Natural Resources, Iran
Email: elm.sedighi@gmail.com
IIASA Supervisors: Elena Rovenskaya (ASA), Nadejda Komendantova (ASA)

Introduction. Kyrgyzstan, located in Central Asia, is a lower-middle income country. Currently, its economy is based on mining and remittances, but the country has a potential to develop other economic sectors, for instance, hydropower electricity, agriculture, textile, tourism, etc. (World Bank, 2017). In order to realize this potential, Kyrgyzstan needs to have a comprehensive strategy. The policy-making process at all stages from strategic planning to implementation is subject to deep uncertainty. This research aims at a) revealing key drivers and plausible futures of Kyrgyzstan's economic development and b) generate top-priority robust policies to be implemented to improve national well-being.

Methodology. This research applies scenario planning and multi-criteria analysis. In the scenario planning part, first, key factors were identified and, using the morphological analysis, a number of plausible futures have been formulated. In the multi-criteria analysis part, 40 actions and nine policies extracted from official documents (GoK, 2017) were analyzed using a pairwise comparison against 11 selected criteria based on experts opinions. The criteria, adapted from the OECD Framework for measuring well-being including health status, work-life balance, education and skills, social connections, civic engagement and governance, environmental equality, personal security, subjective well-being, income and wealth, jobs and earnings and, housing are used as criteria.

Results. Six plausible futures of Kyrgyzstan were derived ranging from a scenario, in which the economic base is modernized and the country is embedded in the global supply chain to the scenario in which it deteriorates and the state collapses. The preliminary analysis revealed that among nine considered policies "development of the country's industrial potential" and "favorable business environment to attract investment and develop export" are the most effective ones. Among 40 considered actions, the priority actions are: (1) Attract foreign direct investment in strategic industries; (2) Develop small and medium-sized enterprise; (3) Implement public-private partnership projects; (4) Introduce ratings of regions and cities; (5) Improve the investment climate and protect the rights of the investor. Fig. 1 shows five most important actions related to each policy.

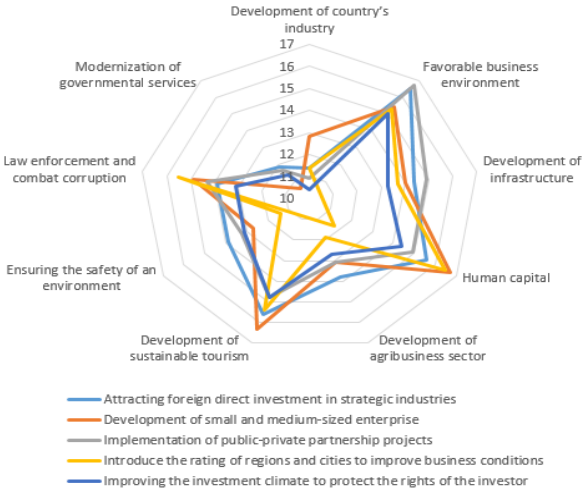

Fig1: Five top prior actions related to policies

Conclusions. Rapid and environmentally sustainable economic growth is the foremost priority for Kyrgyzstan. In developing countries, manufacturing usually acts as the engine of growth. Existing evidence from countries that embarked on a steep and sustained growth trajectory suggests that their growth has been primarily based on an expanding and internationally competitive manufacturing sector. In this respect, development of international relations and improvement of business environment can have positive impacts on economic growth.

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Evolution and Ecology (EEP)

Fruit harvesting: A potential threat to plant-frugivore systems and frugivore-driven evolution of fruit size

Mozzamil Mohammed, Al Neelain University, Sudan
Email: mohammed@iiasa.ac.at
IIASA Supervisors: Åke Brännström (EEP), Ulf Dieckmann (EEP)

Introduction. Frugivorous species, i.e., animals that feed on fruits, play a central role for plant communities by providing seed-dispersal services (1). Frugivores gain nutritious food from fruit consumption while dispersing the seeds encapsulated in the fruit pulps. The plant-frugivore interactions benefit both partners and strongly affect plant persistence and plant spatial distributions (2). However, such mutualistic interactions between plants and their frugivores are now increasingly being threatened by anthropogenic activities. An important example of an anthropogenic disturbance that can potentially expose plant-frugivore systems to risk is fruit harvesting. Fruit harvesting imposes extra mortality on plants and hence affects the global plant density and consequently the density of frugivores as well as the evolution of fruit traits.

Methodology. We develop a spatially explicit individual-based model to investigate the effect of fruit harvesting on plant-frugivore systems and on frugivore-driven evolution of fruit size. We then use a pair-approximation method to facilitate the analysis of the model.

Results. Our theoretical findings agree with previous theoretical and empirical studies of seed dispersal (1, 2), confirming the importance of plant-frugivore interactions for plant persistence and plant spatial distributions. In particular, frugivore species gradually shift the spatial distribution of plants from clustered through random to segregated. Our results show that the benefits plants receive from their frugivores largely depend on the fruit-production rate of plants. Frugivores increase the global plant density through the global dispersal of seeds; thus, fruit harvesting decreases the global plant density, leading to a higher level of plant aggregation, and potentially, extinction. Frugivores allow plants to persist where they otherwise would not when harvesting is intensive. Results show that fruit harvesting imposes negative selective pressures on fruit size, resulting in evolution towards smaller fruit size.

Conclusions. By developing and analyzing a spatially explicit model of plant-frugivore-human interactions, we elucidate the effects of frugivores and fruit harvesting on plant demography, plant spatial distributions, and the evolution of fruit size. We find that frugivore species are important for plant communities that experience harvesting. In particular, fruit harvesting can drive plants to extinction in the absence of frugivores even if plant fecundity is high. In the presence of frugivores, fruit harvesting also changes the spatial distribution of plants from segregated to more aggregated.

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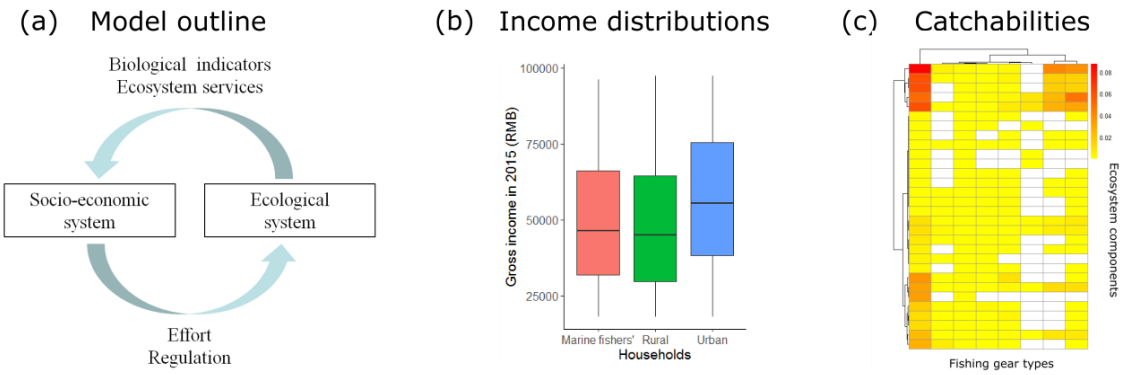
Reform of China's Marine Fisheries Management using Output Control

Yi Huang, Xiamen University, China
Email: yi.huang@iiasa.ac.at; huangyi@stu.xmu.edu.cn
IIASA Supervisors: Mikko Heino (EEP), Ulf Dieckmann (EEP)

Introduction. Many marine fisheries are facing the challenge of having to move toward more sustainable management regimes. Fisheries management measures for this purpose range from catch limits to effort limits, representing so-called output control and input control, respectively. China ranks as the world's leading fishing nation and has traditionally relied on input control only, which has resulted in poor sustainability. China is now trying to implement output control in some fisheries. To understand the socio-economic and biological impacts of changing the management measures, the advantages and disadvantages of input-control and output-control systems should be compared.

Methodology. To describe the past and current fisher population, social survey data have been used to analyze the characteristics of and changes in the fishers' population in terms of demography, mobility, and income. To predict the impacts of changing the management system, we have developed a coupled biological-socio-economic model (a). First, an Ecopath with Ecosim (EwE) model has been devised to simulate the northern South China Sea (NSCS) ecosystem. Catchability, describing efficiency of fishing gears in capturing different ecosystem components, has been estimated using the EwE-predicted biomass together with effort and catch data. Next, different management scenarios (i.e., input and output control) will be applied to predict their impacts on the ecosystem and the fishers' life.



Results. The social survey data show that the total fisher population has decreased from 1989 to 2015. The fisher households' income is similar to that of rural households, but less than that of urban households (b). Catchabilities show great variation with respect to fishing gears and ecosystem components (c), suggesting large differences in the efficiency of different fishery segments as well as in the vulnerability of different parts of the ecosystem to exploitation. Some commercial species such as croakers are facing extreme overfishing.

Conclusions. The population of Chinese marine fishers is shrinking because of the net outflow to other occupations. Some of the species in the NSCS are unsustainably harvested. Using output control, it is necessary to change the management by limiting the total landings of some of the key species in the NSCS.

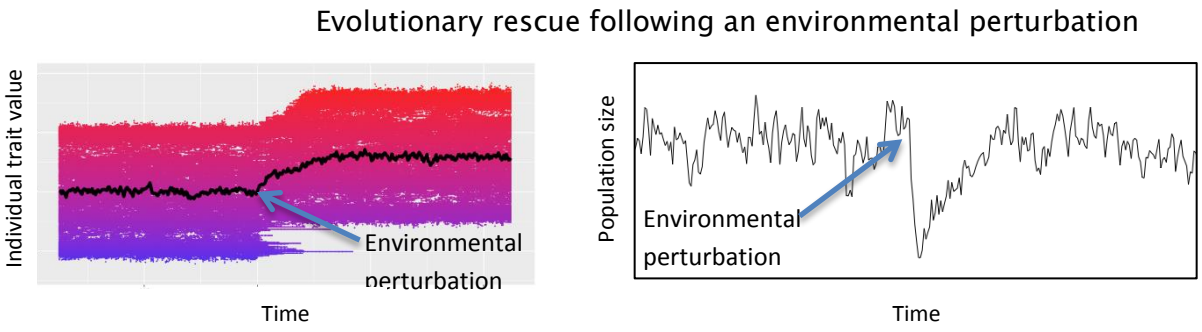
Evolutionary rescue in changing environments

Anna Vinton, Yale University, New Haven, USA
Email: anna.vinton@yale.edu
IIASA Supervisors: Ulf Dieckmann (EEP), Åke Brännström (EEP)

Introduction. Evolution can rescue species facing population decline and extinction due to natural or anthropogenic environmental change (Gonzalez et al. 2013, Carlson et al. 2014). The potential for evolutionary rescue to prevent species extinction is of both pure and applied interest, as it could provide additional tools for managing ecological systems. Evolutionary rescue occurs when a genetic adaptation allows a population to recover from population decline that would otherwise lead to its extinction (Gonzalez et al. 2013). Theory suggests that evolutionary rescue cannot help all populations amidst rapid environmental change, so identifying the limits of evolutionary rescue is a priority for conservation biology. Theory surrounding evolutionary rescue has emphasized the importance of factors including temporal and spatial environmental heterogeneity, gene flow, and ecological interactions on their own, but unlike in simple models that treat these variables exclusively, in a natural system these factors all play a role in concert.

Methodology. Based on the relevant processes described in the literature mostly in isolation, we have developed an integrative strategic model to investigate the rate and propensity of evolutionary rescue in heterogeneous environments. We investigate (1) the role of environmental gradients, (2) density-dependent interactions, and (3) the magnitude of environmental perturbation. We will use this to assess the varying propensity of a population for evolutionary rescue.

Results. We show that without evolution, a shift in the environment such as an increase in temperature will lead the population to go extinct. With evolution, a population has the ability to adapt to the new environment, and rebound after an initial decline via evolutionary rescue. As the magnitude of the environmental shift grows, even evolving populations may lack the ability to adapt sufficiently fast to avoid extinction. Prior local adaptation along an environmental gradient allows populations to adapt to larger environmental perturbations.



Conclusions. We have developed an integrative model that allows us to simulate the eco-evolutionary consequences of an environmental perturbation along an environmental gradient and to investigate the potential for a population to rebound via evolutionary rescue. Using this tool, we can now compare the extinction propensities resulting from an environmental perturbation in homogeneous environments and along environmental gradients. On this basis, we can also study the role of dispersal. Our initial results underscore the importance of incorporating the potential for evolutionary rescue in predictions of species extinctions due to climate change and habitat loss.

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Energy
(ENE)

Developing an integrated modeling framework for assessing interactions between smart irrigation technologies and energy transformations in the Indus river basin

Ansir Ilyas, Lahore University of Management Sciences, Lahore, Pakistan
Email: 17060062@lums.edu.pk
IIASA Supervisors: Simon Parkinson (ENE), Edward Byers (ENE)

Introduction. Irrigation is the primary consumer of water for human activities and implementation of modern so-called smart technologies, such as digital metering and control devices, demonstrate tremendous potential for solving the dual problems of water scarcity and access inequality. The Indus River Basin in South Asia is a critical region for smart irrigation technology expansion because it is one of the most water-scarce river basins in the world and is home to the world's largest contiguous irrigation system. Despite potential benefits for local water availability, it is unclear how implementation of smart irrigation technologies in the Indus will interact with the basin's tightly coupled water and energy supply systems, which feature prominently distributed groundwater wells and large-scale hydropower schemes.

Methodology. This research enhances an integrated modeling framework for assessing current and future development scenarios in the Indus River Basin to enable quantification of interactions between implementation of modern irrigation technologies and long-term energy system transformations. The tool links an engineering-economic model, representing investment and allocation decisions across water, energy and land-use sectors, to a water resource/hydrological model, representing the detailed biophysical processes at high spatial and temporal resolutions.

Results. A portfolio of smart irrigation technologies and approaches were incorporated into the Indus modeling framework using data collected through engagement activities with local irrigation planning authorities and a literature review. A direct linkage between water availability, climate and crop yields was further incorporated into the modeling tool. An integrated scenario analysis was designed to explore long-term tradeoffs, synergies and uncertainties associated with multi-sectoral policies aimed at simultaneously increasing clean water and energy access in line with the Sustainable Development Goals.

Conclusion. The study demonstrates a new methodology for quantifying interactions between smart irrigation technologies and long-term energy transformations, and lays foundation for an integrated policy analysis providing new insights to regional decision-makers. The approach and tools in this research can readily be transferred to other regions.

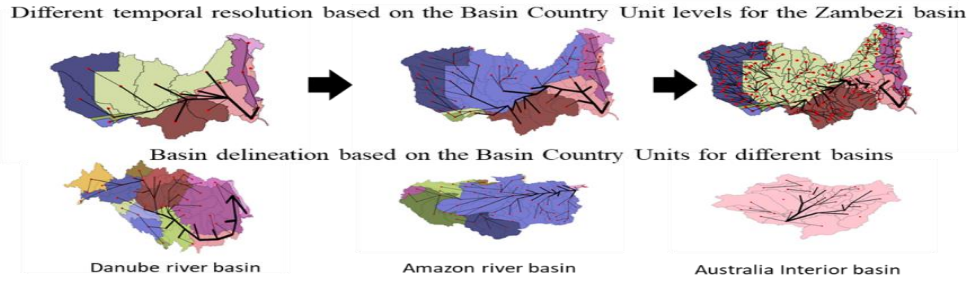
Development of flexible basin-scale nexus assessment tool

Fabio Amendola Diuana, COPPE/UFRJ, Brazil
Email: fadiuana@gmail.com
IIASA Supervisors: Edward Byers (ENE), Simon Parkinson (ENE)

Introduction. Recently, increasingly integrated assessment of the water-energy-land (WEL) nexus at the basin scale has been pursued [1][2]. The MESSAGE-Basin framework links an engineering-economic model representing investment and allocation decisions across WEL sectors to water resource and land use models, as is currently being deployed for the Indus Basin in southwest Asia. Using global datasets, this project has tested and improved the flexibility of the framework at different spatial resolutions, for different locations, in R and Python programming languages.

Methodology. Nodes within the basin are defined by the intersection of sub-catchments and countries, 'basin-country units' (BCUs). BCU nodes are linked by a reduced river network (RRN) that transmits water resources. With the spatial delineation defined, all other model data and input parameters are processed (both upscaling and downscaling) to the corresponding nodes. The flexibility the RRN was evaluated for different global basins, for different levels of detail and compared between R and Python. Data processing and aggregation was also tested for the Zambezi basin.

Results. So far, the results from processing and manipulation of the input data are very promising and demonstrate the desired model flexibility, both in spatial and temporal dimensions. The basin delineation methodology implemented to develop the RRN produced consistent results for all analysed basins; and at different spatial resolution levels (Figure).



This flexibility facilitates the processing of other data inputs. For example, renewable energy for wind and solar capacity factors (Renewables Ninja hourly data, 0.04° grid) and water resource availability (Community Water Model daily data, 0.08°) were calculated and aggregated for each BCU node at monthly timestep. Additionally, to harmonize from potential resource availability to actual availability, exclusion zones were developed using criteria such as population density, protected areas and distance from existent hydro powerplants.

Conclusions. Considering the initial objectives of this project, this project has made concrete steps towards developing and testing the flexibility of the MESSAGE-Basin model framework, with the aim of application to different basins across the world. The development of a solid and reliable RRN methodology facilitate the use of the global datasets at various spatial scales, depending on the application. In the long term, the main objective is to apply the MESSAGE-Basin model to Brazil using multiple river basins interconnected by the energy system.

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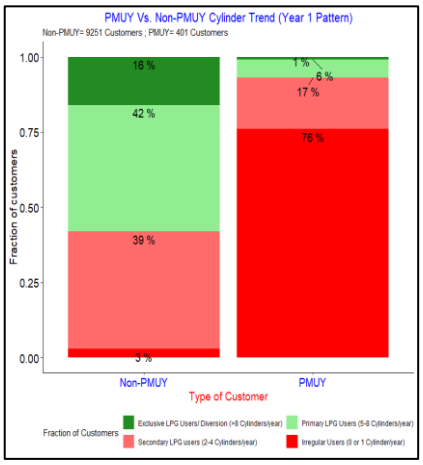
A novel approach to study adoption of liquified petroleum gas (LPG) by rural poor: Insights and policy implications for India's *Ujjwala* program

Abhishek Kar, The University of British Columbia (*UBC*), Canada
Email: abhishek.kar@alumni.ubc.ca
IIASA Supervisor: Shonali Pachauri (ENE)

Introduction. Daily collection & burning of solid fuels for cooking in 500 million households across the Global South and the resultant household air pollution pose severe health, ecological and development risks. In response, India has recently provided financial incentives to 50 million poor women to purchase liquefied petroleum gas (LPG) stoves (& cylinders of 14.2 kg of LPG) under the *Pradhan Mantri Ujjwala Yojana* (PMUY) program (Dabadge, Sreenivas, & Josey, 2018). This study assesses whether LPG consumption trends among rural poor PMUY beneficiaries are comparable with rural non-PMUY consumers, and the underlying factors affecting LPG use.

Methodology. The current scholarly approach of self-report-based surveys/ case-studies entails risk of response biases linked to social desirability, acquiescence, and transient mood state. We use a novel approach of analyzing >150,000 LPG cylinder purchase transactions for 20,000 domestic LPG customers (~50% are PMUY beneficiaries) from three sales outlets in rural Karnataka. Descriptive statistics and linear regressions have been applied to study the role of seasonal variability, price fluctuations, and time (years of experience as LPG user) in influencing purchase decision choice. We assume that purchase equals usage for cooking food at home, but it may not always hold true.

Results. PMUY has resulted in a doubling of the rural LPG customer base within 13 months. However, 75% of PMUY customers who have been enrolled for a year have not purchased even a single refill. Exclusive LPG use for cooking would require eight LPG cylinders for a family of five annually. In general, both climatic (e.g. lack of access to dry fuel in monsoon) and agricultural (e.g. higher cash surplus post-harvest for discretionary spending) season linked variability influences monthly LPG purchase trends. Time (experience/ familiarity with LPG) is strongly correlated to increase in consumption. Volatile (international market linked) distributor price (paid at outlet) and moderate net price (=distributor price – subsidy received after purchase) rise does not significantly affect sales.



Conclusions. Participation in PMUY while desired by the rural poor has not translated into regular use. Whether PMUY beneficiaries increase consumption over time like their non-PMUY peers (who are likely more affluent and more motivated as they had to pay upfront ~80 USD as capital cost) is unknown. A mid-course correction to PMUY by providing additional financial incentives is recommended to encourage usage, e.g. a cash advance to better manage distributor price volatility that is currently provided to non-PMUY customers should be extended to the less affluent PMUY. Analysis of similar datasets for other regions is necessary for an objective assessment of the program.

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Ecosystems Services and Management (ESM)

Predicting mammal abundance trends under climate and land-cover change

Judith Ament, Zoological Society of London & University College London, UK
Email: judith.ament@ioz.ac.uk
IIASA Supervisors: David Leclère (ESM), Tamás Krisztin (ESM)

Introduction. To mitigate further ecosystem breakdown and its consequences for human health and wellbeing, understanding the biodiversity consequences of future climate and land-use scenarios is crucial. To this end, models are needed that can accurately predict species diversity and abundance trends over large areas. One approach to this challenge has been to use species distribution models to infer the extent of suitable habitat for different species and reconstruct past abundance trends (*Visconti et al. 2011*), but this approach ignored population density dynamics over space and time within the extent of suitable habitat. To better capture the influence of variations in population density on abundance trends, we extend this approach with a recent model predicting population density from life history traits and environmental covariates directly (*Santini et al. 2018*). We evaluate the predictive capacity of both original and extended models against observed records of population abundance from the Living Planet Database.

Methodology. First, we approximated trends in mammal species distribution, by using ESA-CCI land cover data in conjunction with IUCN species habitat preferences and species range data to calculate changes in the extent of suitable habitat for North American mammal species between 1992-2013. Subsequently, we calculated spatially and temporally explicit bioclimatic variables (i.e., precipitation of the warmest quarter and temperature variability) from the CHELSA climate time series. We then applied regression models for population density within the suitable habitat for each species using these spatially and temporally explicit environmental variables, to generate estimates of mammal abundance trends. Finally, we compared modelled trends of suitable habitat and mammal abundance to observations of 176 populations of 57 mammals in Northern America, between 1992-2013.

Results. Across 176 observed populations of 57 North American mammal species, abundance decreased by 1.14% between 1992-2013. During the same period, range-wide suitable habitat increased by 1.51% for these species. Range-wide temperature seasonality and precipitation of the warmest quarter increased by 10.0 and 6.71%, respectively. The combined suitable habitat and density models predict a 14.1% decrease in range-wide mammal abundance for these 57 species. Although the magnitude of change of the observed abundance trends is matched much more closely by change in suitable habitat, the temporal dynamics of observed mammal abundance are much better reflected in the modelled abundance trends from the combined habitat and density models.

Conclusions. Despite a range-wide habitat increase for the evaluated species, range-wide abundance was predicted to decline heavily, in contrast to only minor declines in the observed population data. Potential causes for this discrepancy may be a poor reflection of species range-wide abundance dynamics in the location-specific observed population records; lack of temporal dependency in the density model; species-specific density responses not well captured by the density model; use of land-cover instead of land-use data; small validation sample size; and other species threats causing additional declines across species ranges, such as overexploitation, disease, invasive species, habitat disturbance, or loss of connectivity.

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Bioeconomic transition: Fossil fuels and biomass consumption under the SSP

Raphael Asada, University of Graz, SIS, Austria
Email: raphael.asada@uni-graz.at
IIASA Supervisors: Tamás Krisztin (ESM), Fulvio di Fulvio (ESM), Florian Kraxner (ESM)

Introduction. Bioeconomy (BE) strategies aim at reducing fossil fuels dependency, which closely relates to fossil resources consumption. In this project, we analyze the current drivers of fossil and biomass raw material consumption (RMC) to investigate how future RMC under perpetuation of the current drivers configuration will develop and what the implications for a possible BE transition are.

Methodology. We estimate biomass and fossil RMC in an environmentally extended multi-regional input-output analysis [1] using the World Input-Output Database (WIOD) [2]. Data from the EORA Footprint Summary [3] is included to check the results' robustness against differences in sectoral aggregation and in construction principles of the underlying input-output (IO) databases. We set up panel fixed-effects (FE) models, which explain RMC with GDP, economically active population, urban population, area of pastures, as well as forest/cropland, energy supply, and material supply (normalized by population). Using the models, we project RMC under the five Shared Socioeconomic Pathway (SSP) scenarios [4] up to the year 2050. The sample includes most of the OECD/BRIC countries (37).

Results. The FE models concordantly identify GDP as the major driver of RMC, followed by material supply. The amount of economically active population has a mitigating effect, since individual income theoretically tends to decrease with increased share of economically active population. Higher urban population mitigates RMC as well which may be explained by a higher efficiency of urban infrastructures. The projected RMC paths increase throughout most countries and SSP scenarios with considerable differences in levels and raw material composition. Only 2.8% of all 740 RMC pathways show an absolute decline for 2010–2050 with the highest number in SSP1 (2.2% for fossil RMC). Comparing EORA and WIOD projections (Fig. 1), the initial degree of convergence does not directly translate to subsequent time steps. WIOD projections tend to diverge fossil and biomass paths more strongly.

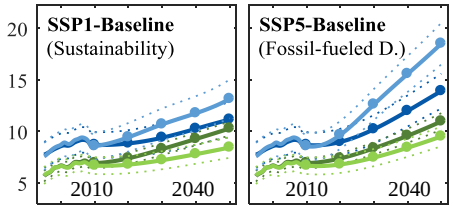

Fig. 1: Estimated biomass (green) and fossil (blue) RMC of the USA (t/cap; past 1995–2010, projected 2010–2050). Darker lines are EORA-based, lighter ones on WIOD. Dotted lines show PIs at $\alpha = 0.05$.

Conclusions. Notwithstanding that EORA- and WIOD-based projections differ, their key message is the same: Upcoming conditions are likely to counteract a potential BE transition and increase – instead of decrease – fossil RMC, if current RMC drivers are perpetuated. This finding is reflected by both underlying IO databases but more pronounced by WIOD. Fostering a BE transition as a vision for green growth would thus imply to decouple GDP and fossil RMC while recouple GDP with biomass RMC. National BE strategies should therefore not only promote bio-based innovations but also critically address their direct and indirect potential for de- and recoupling, taking systemic responses into account.

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Introducing advanced transport biofuel production – the market effects on the traditional bioenergy sector and forest industry production

Elina Bryngemark, Lulea University of Technology, Sweden
Email: Elina.bryngemark@ltu.se
IIASA supervisors: Nicklas Forsell (ESM), Pekka Lauri (ESM), Anu Korosuo (ESM)

Introduction. One of today's major climate mitigation challenges is to replace fossil fuels with renewable energy in the transport sector. Second generation biofuels produced from forest industry's by-products (e.g. sawdust, bark and wood chips) are considered to be sustainable although not yet economically competitive. Promoting the production via a policy demand target would accelerate the deployment of such biofuels. However, by-products are currently used for other purposes and increased demand is expected to lead to increased competition. This study investigates the forest biomass markets effects, and the effects on the traditional bioenergy sector and the forest industry production, of introducing an advanced transport biofuel target to the market.

Methodology. The Swedish Forest Sector Trade Model (SFTSM) II, originally developed by Lestander (2011) and Carlsson (2011), is used and extended further in this study. SFTSM II is a partial equilibrium model including supply of forest raw material, demand for products and energy, and endogenous production and energy conversion. The modeling extension developed within this study includes a new module of advanced transport biofuel demand and production which is used to analyze scenarios of 0-25 TWh bio- Synthetic Natural Gas (SNG) produced from wood chips, sawdust, pellets and harvesting residues.

Results. Using the extended SFTSM II, an advanced transport biofuel demand target is shown to affect the whole forest biomass market including both the traditional bioenergy sector and the forest industries. A 25 TWh bio-SNG production leads to increased by-product prices (wood chips by 23%, sawdust by 25% and bark by 24%), which leads to higher revenues in the sawmilling production and increases the production of sawnwood which is satisfied with additional forest harvest (0.820 million m^3f roundwood which is approximately a 2% increase). Increased forest harvesting produces also more harvest residues in the forest. The additional supply of harvest residues is used in the traditional bioenergy sector. Increased by-product prices lead the traditional bioenergy sector to use more fossil fuels and less biomass. For 25 TWh of bio-SNG production, the substitution equals 1 TWh of energy output. Furthermore, it is found that paper and wood board production decreases substantially as a consequence of the higher by-product prices.

Conclusions. This study shows the importance of considering the market dynamics when evaluating a policy target; an advanced biofuel demand target of 5-25 TWh affects feedstock allocation and production in both the traditional bioenergy sector and the forest industries. This in turn leads to increased use of fossil fuels and industrial transformation. Overall product prices increase with the policy target, but the impact is mitigated by the synergy effects between sawnwood production (for which the price decreases) and demand for sawmilling by-products.

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Generating WUDAPT Level 0 and Level 1 data for China

Meng Cai, The Chinese University of Hong Kong, Hong Kong
Email: caimeng@link.cuhk.edu.hk
IIASA Supervisors: Linda See (ESM), Olha Danylo (ESM)

Introduction. Rapid urbanization has occurred since the late 1970s in China, and this urbanization trend may still continue for another 20-30 years. Urban residents are especially vulnerable to current and future climate hazards caused by urbanization, where these impacts can be assessed using weather and climate models. The model settings require detailed urban canopy parameters (UCPs), which are often not available. To address this data gap, the World Urban Database and Access Portal Tools (WUDAPT) initiative is building a global database of urban form and function, which will provide UCPs for models using freely available data sets (Bechtel et al., 2015). The WUDAPT level 0 data characterizes cities into local climate zones (LCZs) with standardized UCPs (Steward and Oke, 2012). The WUDAPT level 1 data provide more detailed and localized UCPs. This study aims to create WUDAPT level 0 data for all of China and to develop a method to generate level 1 data from openly available data.

Methodology. In order to acquire the LCZ map of China, Landsat 8 imagery and the normalized difference vegetation index covering the whole country were compiled in the Google Earth Engine (GEE) platform. Training samples of 17 LCZs from over 50 cities in China, previously digitized in Google Earth, were added to GEE. A random forest classifier was then applied to these input data to produce an LCZ map for China. To acquire the level 1 product, building footprints were acquired from the Google Static Maps Application Programming Interface. The building heights were extracted from an open digital surface model, i.e. the ALOS World 3D at 30m. Thereafter, UCPs including the sky view factor, building coverage ratio, building volume density, frontal area density and roughness length were calculated based on the retrieved building footprints and building heights. The Kowloon Peninsula in Hong Kong was selected as a test area due to the presence of high-density urban form.

Results. WUDAPT level 0 data for all of China and WUDAPT level 1 data for the test area have been generated. Our experimental results show that the overall accuracy of the national level LCZ map is between 60-70%, except for some high-density cities as well as some western cities in China that have relatively lower overall accuracy of about 50-60%. The accuracy of the building information and the UCPs is about 70% to 90%. The accuracy increases with coarser spatial resolution after aggregating the UCPs into 100m, 250m and 500m resolution, indicating that a coarser resolution can be used to provide better prediction accuracy, which is relevant for mesoscale urban climate modelling.

Conclusions. This study generated WUDAPT level 0 data for China at the country level using the GEE platform, and developed a method to acquire level 1 data from existing sources of open data. The WUDAPT level 0 & 1 products for China can provide researchers, scientists and practitioners with a useful data set on urban morphology. These results can be used as inputs to urban climate modelling, which can be used to further analyze the impacts of urbanization on cities in China.

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The impact of water erosion on global crop yields

Tony Carr, University College London, United Kingdom
Email: tony.carr.16@ucl.ac.uk
"IIASA Supervisor:" Juraj Balkovič (ESM), Christian Folberth (ESM), Rastislav Skalsky (ESM)

Introduction. Water erosion leads to the loss of fertile topsoil and lower agricultural productivity. Several studies already estimated the amount of global soil lost due to water erosion but not much attention has been given to the impact of water erosion on global crop yields (Myers 1993, Borrelli et al. 2017). This study will generate new estimates of soil loss in global cropland due to water erosion and assess the impacts of this loss on agricultural productivity.

Methodology. The global-gridded crop model IIASA-EPIC was used to simulate maize yields under the influence of water erosion. To consider the heterogeneity of global field management practices and their impact on water erosion amounts, scenarios for different soil disturbance, residue management and cover crops were developed. Evaluated crop yields and water erosion values were used to compare crop yields with and without the influence of water erosion. In addition, the magnitudes of crop yields and water erosion under the different field management scenarios were used to determine the best strategies for reducing water erosion while maintaining high yields.

Results. On a global scale, water erosion has only a minor impact on maize yields. However, in regions with strong rainfall and low fertilizer input, the effect can be severe. The results also show an increased loss of soil organic carbon in the soil with water erosion. In regions with low fertilizer input, this can lead to lower yields. In addition, the negative impact of water erosion on crop yields increases with less soil cover from residues or fallow crops (Fig. 1). Nitrogen fixing cover crops and no tillage management (i.e. leaving crop residues on the field after harvest) show the greatest potential to protect against erosion and simultaneously stabilize crop yields.

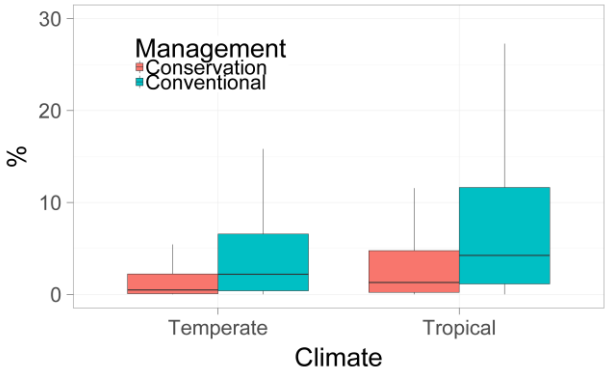

Figure 1: rel. difference between maize yields w/ and w/o water erosion 2001-2010. Under conventional management the soil is less protected than under conservation management.

Conclusions. This study demonstrates that water erosion is an important factor in global agriculture often neglected in crop simulations. Due to the large share of high fertilizer-input agriculture worldwide, water erosion does not seem to have a big impact on maize yields on first sight. However, high fertilizer input can mask the impact of water erosion on the loss of organic matter in the topsoil, which reduces available nutrients for crops. This becomes visible in developing regions where the decline of soil organic carbon due to water erosion leads to a decline in crop yields. Plant residues and nitrogen fixing cover crops in between seasons can be used to protect the soil against water erosion and stabilise crop yields.

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Improving spatial distribution of forest carbon stock estimation using Convolutional Neural Network (CNN) classification

Sungeun Cha, Korea University, South Korea
Email: tgy2005@korea.ac.kr
IIASA Supervisor: Dmitry Schepaschenko (ESM), Anatoly Shvidenko (ESM)

Introduction. In South Korea, where more than 63% of the country covered by forest (KFS, 2017), an accurate estimation of carbon stock is essential to understand the carbon cycle. However, current estimates of Korean forest carbon stock are mostly derived from expensive field data (KFRI, 2011). Any techniques, which allows reducing amount of ground data with reliable accuracy, would save cost and time. The goal of this research is to test the Convolutional Neural Network (CNN) algorithm fed with a portion of the national forest inventory (NFI) data in order to predict the carbon stock for entire country using satellite imagery and auxiliary information.

Methodology. Spatial distribution of growing stock volume (GSV) of South Korean forests was predicted by CNN algorithm, which is a sort of deep machine learning. 20% and 30% portions of NFI data were used as a training datasets. We estimated the rest of the area using various satellite images and topographic factors. As the CNN architecture consists of 107 layers, the number of channels / filters increased from the initially 128 size to 256, 512, and gradually decreased. The CNN model was simulated with 480 epoch before the model get overfitting (LeCun *et. al.*, 2015).

Results. Figure 1 (a) shows the GSV estimates based on full set of NFI data, with an average of 128 m^3ha^{-1} and a total GSV of 727.42 M m^3 in the Korean Peninsula. Figure 1 (b) and (c) show results where 30% or 20% of the total NFI data is used for training CNN model ($R^2 = 0.53$ and 0.45) , and prediction of GSV for remaining forest area. The average of GSV in the Korean Peninsula was 130 and 137 m^3ha^{-1}, and a total GSV of 741.90 and 780.94 M m^3 respectively. The accuracy of the average and the total carbon stock was reached 98.05% using the CNN model with 30% input data (Figure 1 (b)), and 93.15% using the CNN model with 20% of input data (Figure 1 (c)).

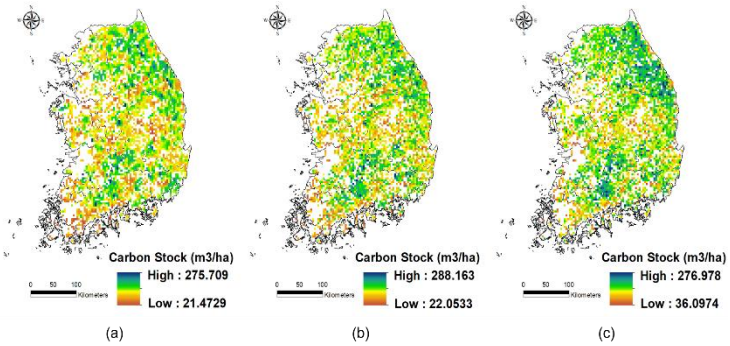

Figure 1 Carbon stock maps of South Korea: (a) The "true" carbon stock map based on the NFI data, (b) The carbon stock map based on 30% of NFI data and machine learning, and (c) The carbon stock map based on 20% of NFI data and machine learning

Conclusions. In this study, spatial distribution of carbon stock of forests in Korea was predicted by CNN model based on remote sensing data and portions (20% or 30%) of NFI data. It is meaningful to estimate carbon stocks in regions with high accuracy using satellite images, and topographic factors. However, further research is needed to understand the weight of input data to minimize the cost for collecting uninfluential data.

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Global child nutrition vulnerability to climate shocks: An empirical approach

Matthew Cooper, University of Maryland, College Park, USA
Email: mattcoop@terpmail.umd.edu
IIASA Supervisors: Steffen Fritz (ESM), Stefan Hochrainer-Stigler (RISK), Georg Pflug (RISK)

Introduction. The WHO and the IPCC have named malnutrition as a major expected impact of climate change due to the anticipated effects of droughts, floods and heatwaves on agricultural yields and food system infrastructure. However, identifying the most vulnerable populations is challenging because the impacts of these climate shocks are mitigated or amplified by many environmental, agricultural, governmental and infrastructural factors. Efforts to date have consisted of indices that weigh such factors using *a priori* assumptions. To improve such predictions, this paper combined historical observations of child nutrition and local climate conditions on the global scale to estimate how various factors moderate climate impacts and to map which populations are most at risk.

Methodology. Our dataset consisted of 600,000 geolocated child nutrition observations from 51 countries combined with a variety of geographic and meteorological data. For each child, we calculated a metric of how water availability over the previous 24 months differed from the long-term norm, considering both precipitation and evapotranspiration. Unusually dry and unusually wet periods were both associated with worse nutrition outcomes, and we modelled how this association was moderated by a variety of national, environmental, and agricultural factors. This model highlighted which factors are most critical for nutrition during climate shocks, and, when applied to global datasets, can map where nutrition will be most affected by future anticipated shocks.

Results. We found that a variety of factors can mitigate the impacts of climate shocks, including urban land cover, high GDP and grain productivity per capita, nutritionally diverse agricultural systems, and environmental health. Irrigated agriculture was found to mitigate the effects of drought and topographic roughness was found to increase vulnerability to excessive rainfall. We used the estimated coefficients for each of these factors to map climate vulnerability for all countries with a GDP per capita of less than $9,855. These maps show that drought is most likely to lead to malnutrition throughout the Sahel and Sahara, the Horn of Africa and Yemen, as well as parts of south Asia. Conversely, areas where excessive rainfall is most likely to lead to malnutrition are mountainous parts of central Asia, Papua New Guinea, and some coastal areas in Latin America.

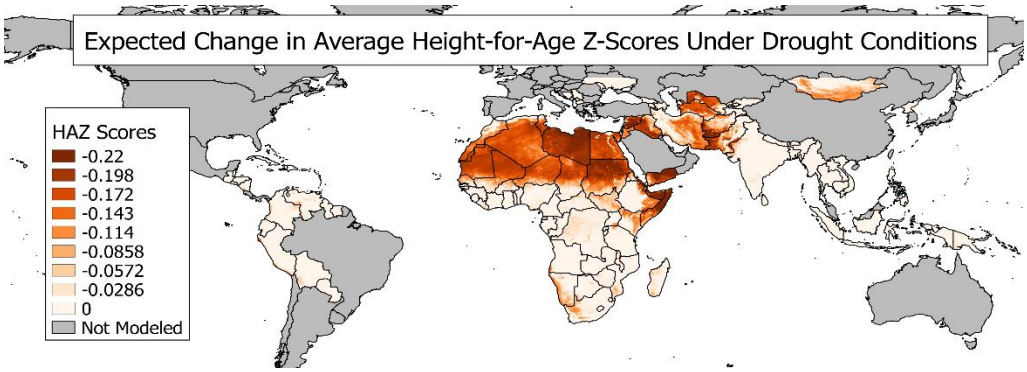


Figure: Areas where drought is expected to affect child nutrition outcomes. Values given are the expected average change in Height-for-Age Z-Scores among children under 5 years old.

Conclusions. This study sheds new light on how policymakers can work to make communities more resilient to climate shocks. For example, forest cover and plant productivity were found to mitigate the impacts of shocks, showing that protecting local environments and preventing land degradation can have a "safety net" effect for climate resilience. Furthermore, our spatial models of child malnutrition increases can be combined with various RCP projections to anticipate where climate change could have the worst impacts and where multinational and non-profit organizations could target future nutrition-support efforts.

Multiple benefits from advanced forest management in the Brazilian Amazon: The coupled BGC-MAN/G4M approach

Camila Thiemy Dias Numazawa, Polytechnic School of the University of Sao Paulo, Brazil
Email: numazawacamila@gmail.com
IIASA Supervisor: Stephan Pietsch (ESM), Andrey Krasovskii (ESM)

Introduction. Forest Management Regulations adopted in the Brazilian Forest Code are mandatory since the 90s. The Brazilian Amazon forest has on average the highest carbon density in the world. It is important to evaluate the performance of implemented forest management strategies. In this project, we estimated forest regrowth, harvest amounts, carbon stock, and potential economic value of wood biomass and charcoal production using the IIASA-ESM-CLR models and field data.

Methodology. Primary data including harvesting intensities from 13 distinct plots located in the Brazilian Amazon rainforest were used to calibrate and estimated the projected forest growth using the BioGeo Chemistry model (BGC-MAN) over a time-horizon of 120 years. Firstly, we performed the BGC-MAN runs to generate a database with key input and output parameters. Secondly, using the database we proposed a methodology to calibrate the Global Forest Model (G4M) for high-resolution application in Amazon Basin. The analysis included five scenarios: The Legal Reserves as the reference scenario, with one cutting cycle (M1cc) over the entire period, with three 30-year timber rotation periods (M3cc), and two scenarios (for M1cc and M3cc) with collecting the harvesting residues for charcoal production. For each scenario, we quantified the net primary productivity (NPP), net measure of ecosystem exchange (NEE), biomass regrowth and coarse woody debris.

Results. We presented modelling results for the harvesting intensity and recovery capacity in a data-driven comparison with the reference scenario (Figure 1). Although there could be a decreasing biomass stock when compared to the Legal Reserve, the NPP and NEE were found higher in both scenarios with 3 rotation periods. Additionally, the results indicated a potential economic gain from the charcoal production by harvesting logging residues (~75% of total logging residues) which could reach ~45% of the total value of stems.

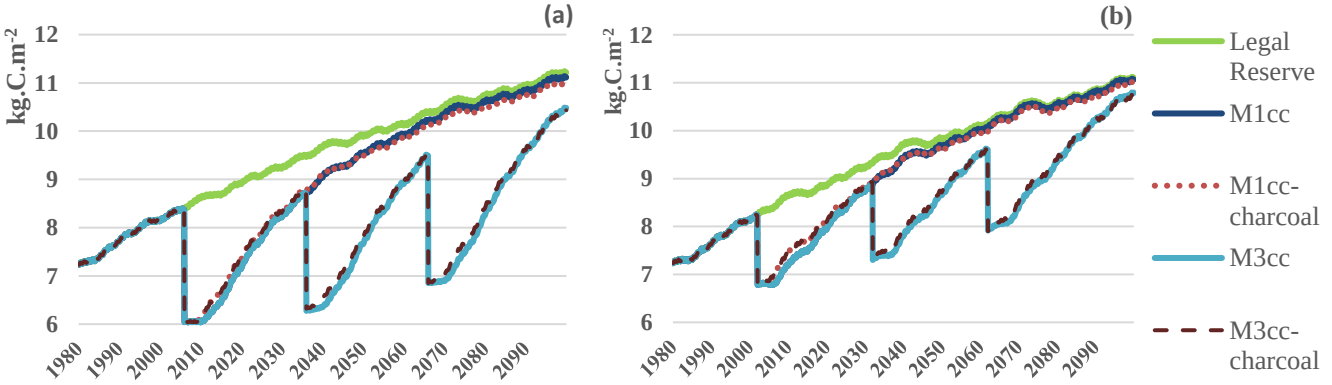


Figure 1: Biomass regrowth over a time horizon of 120 years in different treatment scenarios in Forest 5 (a) with a harvesting intensity of 30m³.ha⁻¹ and in Forest 7 (b) with a harvesting intensity of 15m³.ha⁻¹ (reduced impact logging technique).

Conclusions. Our modelling results show that advanced forest management in the Brazilian Amazon provides socio-economic and environmental benefits by financing sustainable timber and non-timber production, generating jobs, preserving biodiversity, and increasing carbon sequestration, that is of high importance for climate change mitigation.

Evaluation of ecosystem services of forests in the Chernobyl Exclusion Zone

Bohdana Dubrovets. National University of Life and Environmental Sciences of Ukraine
Email: dana528@ukr.net
IIASA Supervisors: Anatoly Shvidenko (ESM), Dmitry Schepaschenko (ESM), Florian Kraxner (ESM)

Introduction. The world's most catastrophic nuclear disaster occurred on April 26, 1986 at the Chernobyl Nuclear Power Plant. It caused radioactive contamination of many million hectare of land in Ukraine, Belarus, and Russia, and its impact was recognized in different continents. Currently a Chernobyl Radiation and Ecological Biosphere Reserve (ChREBR) is organized around the Station (~227 thousand hectare). Knowledge of the ecosystem services of forests (ES) of the ChREBR provides important information about state, vitality, productivity, role in environment protection, and possibility of transition to sustainable land/ forest management in radioactively contaminated territories of densely populated surrounding regions.

Methodology. Major objectives of the study included 1) development of portfolio of ecosystem services/ disservices for territories of the ChREBR; 2) assessment of land cover/ forest vegetation dynamics for the period 2006-2016; and 3) assessment of carbon budget of forest ecosystems. Dynamics of both land/ forest cover categories and major indicators of forest ecosystems were assessed for three zones of intensity of contamination (zones of (1) protected; (2) restricted, and (3) moderate regimes for ecological and forest management actions) based on data of forest inventories and available remote sensing products. Carbon budget of forests was estimated based on the methodology developed by IIASA.

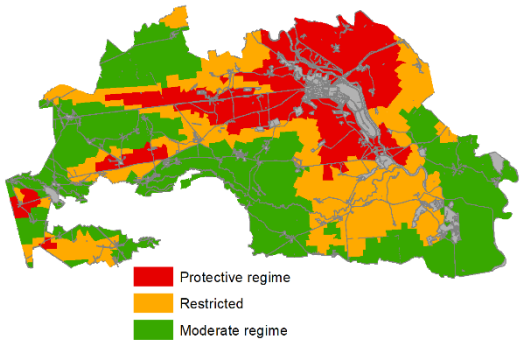


Figure 1. Zones of ChREBR

Results. Portfolio of ecosystem services was developed following the overall classification proposed by the 3rd Millennium Ecosystem Assessment (2005) with spatial differentiation of forest services and disservices. The regulating services (which included *inter alia* accumulation of radionuclides; water, soil and atmosphere protection/ regulation; impact on dynamics of the population dose) play the most important role in the total structure of the services/ disservices. The changes of individual land classes were substantial. The forested area increased at 5.1 thousand ha basically on the cost of an encroachment of trees in abandoned agriculture lands. The average total live biomass of forests (LB) increased from 68.7 to 77.9 Mg C ha^{-1}, and the Net Primary Production (NPP) from 641 to 663 g C m^{-2} yr^{-1} that exceeds the growth rate for the study's period in forests of surrounding territories. The amount and structure of LB in zones 2 and 3 did not differ significantly (however the amount of green parts of the ecosystems was substantially higher than on average for forests of surrounding territories). Forests of zone 1 reveal a clear decline in productivity. During the study's period forests of the ChREBR served a net carbon sink at 133 g C m^{-2} yr^{-1} (including 87 % in live biomass, 7 % in dead wood and 6 % in soil).

Conclusions. Results of this study show that direct negative impact of radioactive contamination on forest of the ChREBR is now clearly recognized in the zone of maximal contamination. Forests of the rest of the Reserve have more intensive rates of growth and productivity than surrounding areas that supposes possibility to use the carbon sequestration service as the potentially most important one.

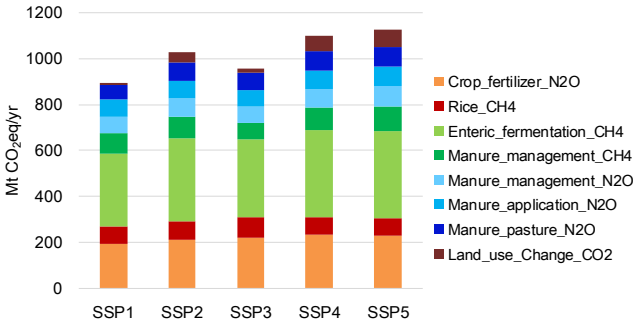
Past changes and sustainable pathways of land use in agricultural systems in China

Hao Zhao, Chinese Academy of Science, Center for Agricultural resources research, China
Email: haozhao0805@gmail.com
IIASA Supervisors: Petr Havlik (ESM), Michiel van Dijk (ESM)

Introduction. China's integrated, long-term, large-scale investment into sustainability programmes has achieved considerable positive impact on land use system in the past decades (Bryan, 2018). However, in the future, with the rapid economic development and demand changes, China's development through highly intensive land use systems could bring the past efforts to naught. In this project, a partial equilibrium model – GLOBIOM – is in the first step enhanced and validated with China's dataset. In the second step, it is applied to five socioeconomic pathways to quantitatively project the future of the Chinese agricultural system, and related land use changes and other environmental impacts in order to identify future challenges the Chinese land use sector will be facing.

Methodology. GLOBIOM is an economic model designed to address various land use related topics at global scale (Havlík et al., 2014). It covers all the main land use sectors, which are crops, livestock, forestry, and bioenergy. The output with 2° spatial resolution grids were aggregated to 8 Chinese Agro-ecological agricultural regions. We validated this data with China's provincial dataset from 2000 to 2010, then used OECD outlook data to calibrate future trend of agriculture. The socioeconomic scenarios (SSP1 to SSP5), which are based on storylines, population and GDP projections from the five SSPs covering pathways (Riahi,2016) under sustainable development, regional rivalry, inequality, fossil fuel development, as well as the middle-of-the-road development were compared.

Results. In the calibration phase, we improved in particular the land use representation by adding 32 Mha of pasture and 21 Mha of forest in China for the period 2000-2010. In the baseline scenario, SSP2, cropland will decrease by 10 Mha in 2050 on account of the increase of land productivity by 47%. Growing livestock production causes a series of problems, such as higher expansion of pastures, more trade of protein rich feeds, and more GHG emissions. In 2050, the ruminant GHG emissions will account for 67% of total emissions from land system (figure). Furthermore, at regional level, future crop production will concentrate in North China Plain that is an environmental hotspot now. Livestock production mainly in Southwest of China, which is the shield of ecology conservation.



Conclusions. This study successfully validated the GLOBIOM model for China at the subnational level and demonstrated a comprehensive way to project national land use sectors development under alternative SSPs. Under baseline scenario, China needs less cropland but more pasture. Livestock production will be a significant part in agricultural system, which would rely on imports for a considerable amount of livestock feed. However, regional problem will be serious. Policymakers should concern about the regional issues and government coordination will contribute to sustainable development in the land system.

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Harnessing the full potential of biomass residues: a cost-benefit analysis of improved palm oil supply chain in Sumatra-Indonesia

Fumi Harahap, KTH Royal Institute of Technology, Energy and Climate Studies, Sweden
Email: harahap@kth.se
IIASA Supervisors: Sylvain Leduc (ESM), Sennai Mesfun (ESM)

Introduction. Oil palm is Indonesia's largest source of agriculture biomass. In 2013, 260 million tonne of solid and liquid biomass residues were generated from the production of crude palm oil, the main product in palm oil mill. The untreated biomass residues implies high GHG emissions from biomass decomposition process and un-captured economic potential from the bio-products resulted from these residues. The study aims at evaluating the cost and benefit of improved palm oil supply chain in Sumatra island, Indonesia. We consider the application of upgraded biomass conversion technologies (combined heat and power – CHP, anaerobic digestion, and composting) to fully utilise the palm biomass residues (empty fruit bunch, palm kernel shell, palm mesocarp fibre and palm oil mill effluent) for producing electricity and biofertiliser.

Methodology. We use the BeWhere model, a geographically explicit techno-economic optimization model, to assess the cost and benefit of the improved palm oil supply chain. The model minimizes the total cost of the entire supply chain in Sumatra from producing raw material (fresh fruit bunch - FFB) to bio-products in palm oil mill, which consists of capital cost, O+M cost, biomass transport cost and electricity transmission cost. We do not consider the export of bio-products outside Sumatra. The amount of crude palm oil is controlled by existing capacity of the mills while the electricity from biomass sources is constrained by the district's demand. The analysis takes into account carbon cost of emitting CO_2 and social cost i.e. peat fires and haze loss, water supply disruption loss and biodiversity loss. The benefit is based on the bio-products sale and industry's multiplier effect. We examine scenarios driven by supply, electricity demand and external prices (carbon tax, electricity from biomass and fossil fuels).

Results. The preliminary result shows the optimal 65 mills to supply excess electricity to the grid with improved CHP system of 3 & 6 MW of installed capacity, Fig 1. The entire palm oil supply chain in Sumatra demonstrates a total economic gains of 4.3 billion USD (47 USD/t-FFB). The system could also meet 17% of Sumatra's electricity demand. A higher FFB supply (achieved through improved plantation yield of farmers) could double the economic gains. When all mills are possibly connected to the main electricity grid, 100% electricity demand in Sumatra can be met by utilising the palm biomass residues while avoiding 26 $MtCO_2eq$.

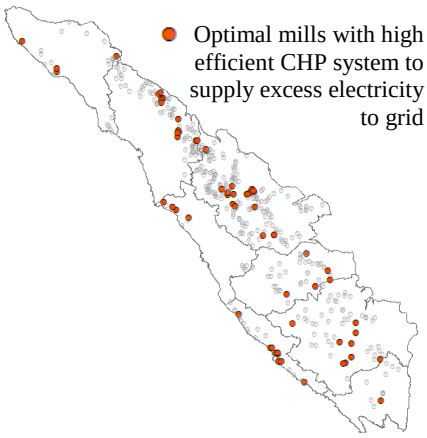

Fig 1. Existing palm oil mills in Sumatra

Conclusion. Harnessing the full potential of palm biomass residues can contribute to low carbon development, increase regional economic gains which eventually create job opportunities in Sumatra. The study confirms that Sumatra has sufficient number of palm oil mills and to gain full economic potential of the industry, the future investment and government support could concentrate in increasing plantation productivity, improving efficiency of biomass processing technologies and grid connectivity.

Greenhouse gas mitigation strategies in Tanzania's dairy sector

James Hawkins, Lancaster Environnent Centre, Lancaster University, UK
Email: hawkins@iiasa.ac.at and *j.hawkins1@lancaster.ac.uk*
IIASA Supervisors: Stefan Frank (ESM), Petr Havlik (ESM)

Introduction. Studies [1] have found that there exist synergies between productivity improvement and reductions in greenhouse gas (GHG) emissions intensities in the agricultural sectors of developing countries, implying an opportunity for coordinating country level economic development strategies with climate financing policies under the UNFCCC. Previous dynamic simulation analyses [2,3] provide strong justification for improved feed and livestock productivity as a means of reducing emissions per unit product and improving food security. However rebounds in production have the potential to partly offset or even negate these improvements in emissions intensities, thus leading to higher aggregate GHG emissions [4].

Methodology. The study couples a partial equilibrium model of the dairy sector with a landscape GHG emissions accounting framework to assess potential climate policy interventions in the Tanzanian southern highlands and the resultant impacts on supply, demand, and GHG emissions. Direct (non-CO_2) emissions include enteric fermentation (CH_4), manure (CH_4, N_2O), and crop and grassland soils (N_2O). CO_2 emissions from expanding crop and grasslands are considered to assess the indirect effect of the dairy sector on emissions from land use change. The dynamic livestock model (LIVSIM) is used to estimate livestock productivity changes with improved management. Simulations up to the year 2030 are run to assess the impacts of various interventions on these outcomes.

Results. Preliminary (base) model simulations estimate a 99% increase in supply and a 78% increase in demand for milk in the southern highlands between 2015 and 2030, with the gap representing trade (increases in exports). Under the base scenario, the estimated (direct and indirect) emissions intensities range between 1.9-2.3 kg CO_2eq kg milk^{-1}, with variation based on livestock production system. Given that feed intensification is a main focus of both climate policy discussions as well as development strategies in the dairy sector, a preliminary scenario representing a 15% increase in (concentrate) feed yields, combined with a 10% subsidy (on the same feeds) was quantified. This simulation leads to both a supply rebound and an increase in aggregate emissions of ~3%, relative to the base scenario, despite slight declines in emissions per kg milk.

Conclusions. Preliminary results suggest that the trade-offs between improved productivity and rebounds in production will be pivotal in determining whether Tanzania can reduce aggregate emissions in the dairy sector concurrent with its current (non-climate) development objectives. Efforts to reduce deforestation (e.g. through REDD+) and associated CO_2 emissions are required in order to provide assurance that improved feed and livestock productivity actually lead to net emission reductions.

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Automatic selection of geo-tagged photos on social network sites to support land cover classification

Moataz Medhat ElQadi, Monash University, Australia.
Email: moataz.mahmoud@monash.edu
IIASA Supervisors: Myroslava Lesiv (ESM) and Christoph Perger (ESM)

Introduction. Land cover maps have important applications in various fields. However, there are many discrepancies between these maps(Fritz et al., 2011). Geo-wiki portal allows citizen scientists to review and reconcile these discrepancies based on satellite imagery, which are sometimes hard to interpret (See et al., 2013). Previous research suggested using geotagged photos to aid in land cover estimation(e.g. Estima and Painho (2013)) but fell short of overcoming the inherit data quality issues arising from the use of data provided by non-specialists for purposes other than scientific research, a problem that was tackled in (ElQadi et al., 2017) albeit for a different application. Another property of existing literature on the use of geotagged social network photos to help understand land cover is prototyping in well-studied developed urban areas (e.g. Portugal, New York, and California). Our aim is to develop a framework to find and filter adequate imagery that can help determine land cover in underdeveloped regions subject to interest in studying their land cover

Methodology. In this work, we use cloud-based computer vision services to analyse the visual content of geotagged photos on Flickr and generate descriptive tags for that content. We then use these tags to train an Artificial Neural Network (ANN) to predict a photo's adequacy for land cover classification

Results. We successfully applied our methodology to four African countries with varied geographic, demographic, and economic characteristics. However, these countries, namely, Egypt, Kenya, Zambia, and Côte d'Ivoire are all subjects of a real-world practical interest in obtaining land cover photos. Our methodology proved helpful in obtaining and filtering land cover photos in these countries with an accuracy ranging between 0.78 and 0.88. We also showed that classification models developed in one country can be used to filter photos from a neighbouring country which saves the effort exerted in the manual data labelling required to build a new model, at the expense of some accuracy

Conclusion. We suggested, implemented, and tested a framework for identifying relevant photos for land cover classification. The developed framework was also published as web services that are now used in Geo-wiki to present users with relevant photos that can help determine land cover, we also made our classification models available in the public domain to allow the research community to capitalise on our methodology, while saving time and resources needed to build the models

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Modeling and visualization of optimal locations for hydropower in Sumatra in the context of global warming 1.5℃and 2 ℃

Ying Meng, Southern University of Science and Technology, China
Email: mengying1011@126.com
IIASA Supervisor: Sylvain Leduc (ESM), Florian Kraxner (ESM)

Introduction. Paris Agreement raised an action to limit any future increase in global-mean temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit to 1.5 °C, recognising that this would significantly reduce risks and impacts of climate change (UNFCCC 2015). One of the key impacts of global warming will be on water resources (Arnell and Gosling 2013), which will in turn influence the availability and stability of hydroelectricity production (Zeng et al., 2017). Sumatra, as an Indonesia island in Southeast Asia, is vulnerable to global warming (sea level rise). Therefore, it is essential to consider the impacts of global warming effects on the hydropower potential estimation and figure out the best positions for the hydropower plants in Sumatra to relieve energy crisis.

Methodology. In this study we use a grid-based method to calculate gross hydropower potential using elevation, discharge and flow information. Daily hydrological simulations are performed with PCR-GLOBWB. At the same time daily climate data from HadGEM2-ES under RCP6.0 emissions pathway has been used for the period 1971-2099 as input. Additionally based on the hydropower potential, we identify the optimal areas suitable for hydropower plants (excluding the protected areas) using the techno-economic model (BeWhere) considering the power demand, power supply from existing plants, investment of setting up of hydropower plants, cost of operation and maintenance and transmission distance in Sumatra under both global warming 1.5℃ and 2 ℃ scenarios. Moreover, power demand and electricity grid has been separately considered as the main factor to drive model.

Results. The preliminary results show that the gross hydropower potential in Sumatra is around 3,800MW. However, the potential is strongly correlated to the changes in discharge. So as global warming 1.5℃ and 2 ℃, discharge separately decreases by 28% and 61% and hydropower production have decreased by 20% and 25%**.** This will come to cause a large gap between power supply and demand in the future. Additionally, when excluding the location of hydro power plants within protected areas, the potential can drop down to 1,000MWh in a stringent scenario.

Conclusions. Hydropower, as a renewable and clean energy, has a larger developing potential in Sumatra. Optimal locations of hydropower plants under different global warming scenarios could support energy security and promote sustainable development. Our result can also contribute to help policy-makers gain insight into potential hydropower development together with consideration of regional energy demand.

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Sustainable oil palm biomass co-firing in Malaysia towards cleaner energy production in near future: A spatially-explicit optimization

Muhammad Nurariffudin, Universiti Teknologi Malaysia, School of Chemical and Energy Engineering
Email: mohdidri@iiasa.ac.at
IIASA Supervisors: Sylvain Leduc (ESM), Piera Patrizio (ESM)

Introduction. Recent energy target set by Malaysian government to increase the existing renewable energy (RE) shares from 2% to 20% by 2025 has demanded the rapid transition towards a more cost-effective renewable option. The current policy instrument that supported this development still only governs the specific dedicated RE system, neglecting the opportunity of leveraging the capital and the high capacity of existing coal plants for mitigation strategy through fuel switching practice such as co-firing. This approach, however, does experience several technical issues mainly in the supply chain of biomass resource that requires effective management system for significant reduction of cost. This raises the question on what are the levels of economic and policy readiness of this technology to be integrated in Malaysian power plants in near future. This work is conducted to address the aforementioned issues by assessing the feasibility of adopting co-firing solutions into the existing coal capacity in Malaysia through the whole system analysis approach.

Methodology. The IIASA's BeWhere model is adapted for the case of co-firing in the existing coal-fired power plants in Peninsular Malaysia. The model is modified to include a time-dependent resource planning element in the spatially-explicit supply chain of oil palm biomass that considers yearly dynamic period (2019-2025) with the selection of pre-treatment technology and its capacity for the establishment of biomass collection centers. The model employs a dynamic modelling approach to account for the inventory profile of oil palm biomass availability and its consumption for power generation in each year. The biomass considered in this work (i.e. empty fruit bunch from palm oil mills, oil palm frond and trunk from the plantation) are upgraded through several pre-treatment technologies that define the co-firing rate restriction in each power plant. Several scenarios are developed to assess the effectiveness of the policy instrument to foster the technology deployment through carbon price and Feed-in-Tariff (FiT) mechanisms, with the consideration of annual biomass and fossil fuel prices fluctuations.

Results. The preliminary results have demonstrated that co-firing technology has the potential to be integrated in Malaysian power plants, starting from low to high level of policy supports. Without any policy support, the model preferred a 100% coal-based energy production to achieve a minimum overall cost. The main factor behind this occurrence is due to the current level of fossil fuel price that is being surpassed by the equivalent cost of supplying biomass to power plants that is inclusive of biomass purchase cost, pre-treatment technology cost and biomass logistic cost. Incentivizing the renewable-based electricity production or penalizing the emission with carbon tax can assist the transition towards biomass co-firing technology development.

Conclusion. Achievement of some portion of 20% RE mix target can be made possible through governmental intervention in policy system to support fuel switching strategy in Malaysia. The current FiT system can be expanded to include co-firing as one of the technologies in the scheme. Also, integrated system which considered both subsidy and penalty-based policy instruments can help to further promote RE development in the country.

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BeWhere Model: http://www.iiasa.ac.at/bewhere

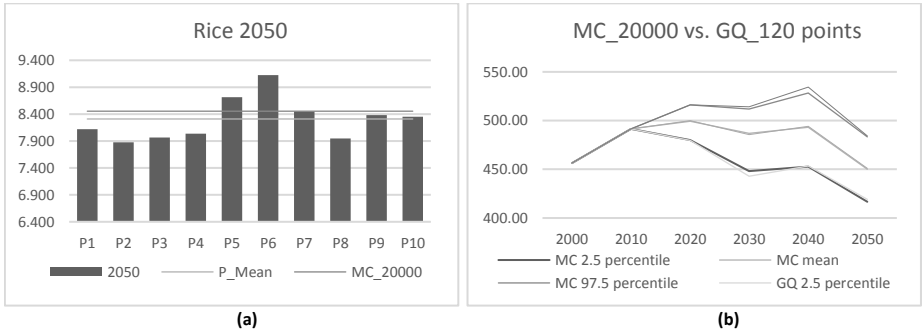
Application of Gaussian quadratures in the Global Biosphere Management Model (GLOBIOM) as an efficient approach to uncertainty analysis

Davit Stepanyan, Humboldt University of Berlin, Germany
Email: davit.stepanyan@hu-berlin.de
IIASA Supervisors: Andre Deppermann (ESM), Tatiana Ermolieva (ESM)

Introduction. GLOBIOM is a bottom-up partial equilibrium model with global coverage addressing agricultural, forestry and bioenergy sectors. Being a deterministic model, GLOBIOM is based on various assumptions regarding key exogenous parameters and variables that make the results highly dependent on these assumptions. One way to overcome this dependency is the application of stochastics into the model allowing to quantify the uncertainty around the point estimates of key exogenous parameters and variables. The aim of this project is to incorporate an efficient method of uncertainty analysis called Gaussian Quadratures (GQs) along with a novel technique for decreasing the approximation error that compared to other methods (e.g. Monte Carlo) requires far less computational and data management costs and guarantees a high level of accuracy.

Methodology. Two of the most used methods of uncertainty analysis in simulation models are *Efficient formulae (e.g. Gaussian Quadratures (GQs))* and *Probabilistic formulae (e.g. Monte Carlo (MC) simulations).* Although the latter approach is an effective method and simple to apply, it requires large computational capacity as thousands of iterations are required for each stochastically treated exogenous variable (Haber, 1970), which makes this approach very expensive for large-scale simulation models such as GLOBIOM. GQs is an approach designed by Stroud (1957) and compared to Probabilistic formulae, requires a minimal number of points (2n, where n is the number of the stochastically treated exogenous variables) to approximate the central moments of a joint probability distribution. To test a novel approach for decreasing the approximation error of the GQs, we apply an Indonesian country level model based on GLOBIOM and introduce yield variability for the six most important crops.

Results and Conclusions. The results demonstrate the ability of GQs to produce highly accurate results with a considerably lower number of iterations compared to MC (Fig. 1). Figure 1(a), however, demonstrates the possible inaccuracies of using single GQs methods (see Artavia, et al. 2015). Therefore, we have applied a novel approach for decreasing the approximation error by randomizing the selection of the GQs points. Overall, the results indicate that GQs is an efficient and trustworthy method of uncertainty analysis in simulation models as GLOBIOM.



(a) (b)

Figure 1. (a) CV of rice price in Indonesia in 2050, results by P1:P10 ten different series of GQs, GQs_120 is the value after applying the error reduction technique, MC_20000 is the result using 20000 MC iterations by a probabilistic formula. (b) Fan charts of soybean prices generated by GQs and Monte Carlo methods.

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World Population
(POP)

Skills resilient to impending automation: The future of (human) work

John Luke Irwin, Pardee RAND Graduate School, USA
Email: jlirwin@rand.org
IIASA Supervisors: Anne Goujon (POP), Asjad Naqvi (ASA)

Introduction. Technological disruptions appear to be occurring at an accelerating pace. Physical automation and artificially intelligent algorithms are impacting the future landscape of jobs, resulting in the "hollowing out the middle" phenomenon (Michaels et al. 2014). It is essential to know which skillsets are the least likely to be automated in the near term to assess the potential for worker displacement and to predict the needs of worker training and retraining. However, the current worker skill mix and the future desired skill mix are largely unknown, resulting in a high risk for retraining and a discrepancy in program availability. A better understanding of automation-resilient skills, training needs, and availability by industries and professions will promote policy solutions.

Methodology. Using four rounds of the representative German "Acquisition and utilization of vocational qualifications" survey (1991, 1998, 2006, and 2012), time and task data were scored according to a framework of activity categories: non-routine analytical, non-routine interactive, routine cognitive, routine manual, and non-routine manual (Autor et al. 2003). Additionally, a separate framework including technological skills but excluding the differentiation between physical tasks was used (McKinsey, 2018). Scores were normalized and compared across time, education level, German state-level geography, and job codes. Results were compared with previous work on earlier rounds of these methodologies and datasets (Spitz-Oener, 2003).

Results. From 1991 to 2012, the skills mix of the German labor force has become skills-polarized, with greater proportions of workers performing tasks that require either unstructured cognitive skills (non-routine analytical, non-routine interactive), technical skills, or unstructured manual skills (non-routine manual). The geographic analysis was inconclusive due to data restrictions; state-level data did not indicate differences in skill mixes, which are more likely to emerge at a sub-state level. Workers who completed college degrees use mostly unstructured cognitive skills, while the skill mixes of those with vocational training or no training are much more heterogenous, including using a substantial proportion of routine manual and routine cognitive skills. Technological skills are growing across all education and job-code groups.

Conclusions. The changing skills mixes across time suggest a growing trend towards workers increasingly using skills that are unstructured (non-routine), including cognitive, socio-emotional/interactive, and manual. This skills polarization is more likely to reward those who complete a collegiate education. Using these activity and skills frameworks can also be useful for identifying profession likely to be susceptible to automation and job displacement in the near future, such as clerical workers and transportation technicians.

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Dynamics of interactions between human capital, demographic structure and economic growth of South Korea

Hyunjae Kang, Stony Brook University, USA
Email: kang.hyun-jae@stonybrook.edu
IIASA Supervisor: Warren C. Sanderson (POP)

Introduction.

How was the rapid economic transition of the Republic of Korea possible? Several factors such as human capital, demographic structure, and economic policies have been analysed in the literature. However, the effects of interactions between the above factors on economic growth remains unexplored. I propose a calibrated economic model based on qualitative investigation on the interactions and assess each factor's role in economic growth.

Methodology.

This study adopts an interdisciplinary approach based on qualitative and quantitative methods to answer the research question. To analyse the interactions between human capital, demographic structure, and economic policies, I investigated the timelines of economic transition for the ROK between 1953 and 1990. In the foundational period, educational expansion preceded demographic transition. The sustained, high rate of economic growth coincides with the growth of the export sector in which demographic transition occurs as well. To incorporate the interactions of the determinants of economic transition, the Solow-Swan growth model is used. To assess each effect, counterfactual analyses are suggested based on the calibrated model.

Conclusions.

The government-led promotion of exports was successful and played a crucial role in the economic transition of the ROK. Specifically, tariff-free advantage and special loan opportunities were provided to export-related firms, which boosted the growth of the export sector. Human capital stock delivered by the preceding government was an important precondition of the economic transition. A growing number of working-age people in the economy played a role in supplying an adequate labor force to the export industry. Counter factual scenarios on economic growth of the ROK are (i) with the absence of human capital expansion, (ii) without demographic structure change and, (iii) without substantial change resulted from the economic policies.

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Is it worth weighting for?
Health expectancies in Europe based on education-adjusted weights

Sonja Spitzer, Vienna Institute of Demography at the Austrian Academy of Sciences, Austria
Email: sonja.spitzer@oeaw.ac.at
IIASA Supervisors: Sergei Scherbov (POP), Warren Sanderson (POP)

Introduction. Life expectancy keeps increasing in Europe. We live longer, but do we live healthier? This question is frequently tackled by analysing health expectancy, an indicator that captures the number of years a person can expect to live in good health. The concept was developed half a century ago (Sanders 1964, Sullivan 1971) and has received increasing attention since then. For example, the European Commission stated their goal to add two years of healthy life for the average European by 2020 (European Commission 2011). Health expectancies usually combine information on mortality with prevalence rates of good health from survey data. A key problem with this approach is that the education distribution of survey participants rarely resembles the distribution in the actual population. This mismatch is crucial given the strong positive correlation between education and good health. We analyse if and how health expectancies differ when the actual education structure in the population is considered.

Methodology. To explore if the deviation in the education distribution affects health expectancies, two sets of post-stratification weights are computed and compared, one of which is adjusted for education. These weights are calculated using iterative proportional fitting. Population totals by education for the weights are taken from censuses provided by Eurostat. Based on the two sets of weights, two sets of prevalence rates are calculated taking health indicators from the Survey of Health, Ageing and Retirement in Europe (SHARE). These prevalence rates are then used to measure and compare health expectancies applying Sullivan's method. Calculations are done for 13 European countries in 2011, separated by gender and five-year age group starting at age 50.

Results. In most of the country samples provided by SHARE, highly educated individuals are overrepresented and less well-educated individuals are underrepresented. Due to the positive correlation between education and good health, the prevalence of good health decreases in these countries when education-adjusted weights are applied. Consequently, health expectancies decrease in these countries once the actual education distribution in the population is considered. Yet when calculating confidence intervals, these differences appear to be non-significant. In some of the countries, less educated individuals are overrepresented, resulting in an increase of health expectancies once education-adjusted weights are applied. Only two country samples resemble the education distribution in the census. Consequently, health expectancies do not differ by weighting strategy in these countries.

Conclusions. The education distribution of survey participants often deviates from the distribution in the population. This is also the case in most country samples provided by SHARE. Once weights are applied to account for this deviation, prevalence rates and consequently health expectancies differ from calculations without education-adjusted weights. Yet these differences do not appear to be significant in our framework. Future studies could fruitfully explore if results vary when differences in life expectancy by education are also considered. The fact that not only prevalence rates, but also mortality is subject to variations by education, warrants future investigation.

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Regional variation of disability burden in India based on new indicators, 1991-2011

Ankita Srivastava, Jawaharlal Nehru University, India
Email: ankita.srivastava148@gmail.com
IIASA Supervisors: Guillaume Marois (POP), Nandita Saikia (POP)

Introduction. There have been serious concerns expressed about the challenges to current economic and social arrangements with an ever more elderly population. However, the concepts and measurements used in that literature have remained largely unchanged for over half a century. The traditional measures of aging tell us how many years a person has already lived. But this is an incomplete measure as it ignores the changing characteristic of people. Recently, Sanderson & Scherbov (2010, 2007) presented a new forward-looking definition of age called "Prospective Age" is concerned about the future. Everyone with the same prospective age has the same expected remaining years of life.

Methodology. To show various measures of dependency and situation of elderly in India and its states, we used data from The Census of India, Office of Registrar General of India for the period 1991 to 2011. And for the computation life tables, we used Sample Registration System base abridged life tables for the period 1991 to 2011. Firstly, we have computed prospective old age dependency ratio (POADR, defined as the number of people in age groups with life expectancies of 15 or fewer years, divided by the number of people at least 20 years old in age groups with life expectancies greater than 15 years). To investigate the effects of disability, we used a measure analogous to Old Age Dependency Ratio (OADR), the adult disability dependency ratio (ADDR, defined as the number of adults at least 20 years old with disabilities, divided by the number of adults at least 20 years without them.

Figure1: POADR & OADR in selected Indian states based on TFR level 1991-2011 (Total Population)

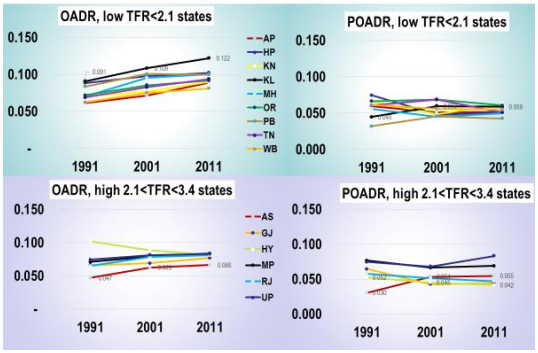
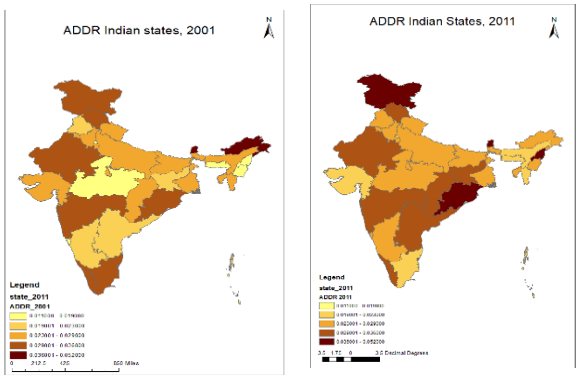


Figure 2



Results. Figure 1 shows the comparison of conventional measure OADR to the new measure POADR, 1991-2011 based on high and low TFR states. For instance, the OADR increased rapidly for Kerala from about 9 percent in 1991 to about 12 percent in 2011, while the POADR does not exaggerate the trend, it increases from about 5 percent in 1991 to 6 percent in 2011. Looking at high TFR states, we found OADR dependency ratios is lowest Assam (about 6 percent) but using POADR this ratio found lowest for Haryana (about 4 percent). Figure 2 shows the distribution of ADDR for year 2001 and 2011. From 2001-2011, disability has increased in some states like Sikkim, Arunachal Pradesh, Orissa, and Jammu & Kashmir on the other hand for the states Gujarat, Tamil Nadu, Assam and Mizoram there is improvement in disable person. Unlikely other development indicator there is less clustering based on ADDR.

Conclusions. Traditional measures of population aging, such as conventional OADR, provide a highly incomplete picture of aging and can result in poorly designed policies. POADR is an alternative measure that account for life-expectancy changes show slower rates of aging than their conventional counterparts. Moreover, it gives more accurate regional picture. Disability-adjusted aging measures ADDR are another alternative to compute aging measures, at regional level.

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Risk and Resilience (RISK)

Modeling semi-arid pastoral social-ecological systems – An integrated GIS and agent-based approach

Yuping Bai, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
Email: baiyp.15b@igsnrr.ac.cn
IIASA Supervisors: Wei Liu (RISK), Guenther Fisher (WAT), Asjad Naqvi (RISK)

Introduction. Covering 15% of the Earth's land surface and home to 14% of the global population (UN, 2011), semi-arid grassland regions are characterized by high climatic variability and ecological vulnerability. Recurrent extreme weather events deeply shape the decision-making of semi-arid societies and communities and their nature-resources-based traditional livelihoods, which face increasing challenges under recent as globalization and climate change accelerates (IPCC, 2012). In this study, I developed an integrated GIS and agent-based model of semi-arid pastoral social-ecological system (SAPSES) to simulate system responses to various policy and climate situations, using the traditional pastoral areas in Inner Mongolia, China, as a demonstration.

Methodology. SAPSES was developed in Netlogo, a multi-agent programmable modeling environment. Herder household behaviors (e.g., herding livestock in locale or roaming around communal pasture, livestock sales, fodder purchase) are captured in the socio-economic sub-system; grassland degradation and recovery under varying grazing pressures is captured in the ecological sub-system. Four policy experiments were designed, namely a. Open-access, b. Privatization, c. Privatization with carrying capacity control and subsidy and d. Common property management with carrying capacity control and subsidy, representing the main grassland management policies implemented in China during the past 40 years. Each policy is stress-tested under four climate experiments with varying frequency and intensity of snow storm to simulate the policy-climate interactive effects on in SAPSES.

Results. Open-access (a) leads to the tragedy of overgrazing, severe grassland degradation, and poverty. Grassland privatization through fencing (b) ameliorates grassland degradation but can't help escape the disaster-poverty trap. Adding carrying capacity control with subsidy (c) helps improve economic outcome more than reduce land degradation, due to spatial pervasion of degradation. Switch to common property management (d) effectively reduces land degradation and also helps increase system robust ness to climate risk stress.

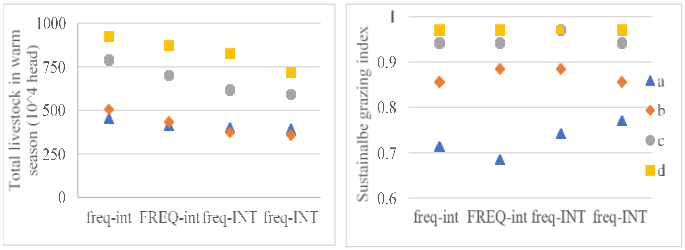

Fig.1 Economic/ecological performance under varying policy& climate situations (note: in x-axis that capitalized means HIGH)

Conclusions. SAPSES modelling environment is modelized and can flexibly include different combinations of sub-systems according to research questions and data availability. In the next step, I will further calibrate the effects of existing policies over the past 40 years and simulate the progression of system and the effects of new adaptation policies, such as disaster insurance, under plausible future climate scenarios. In the long run, SAPSES can be coupled with climate model to simulate the interrelationship and feedback between land use change and climate change at large scale.

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Quantifying climate vulnerability and risks of agricultural systems: A case study in India.

Kedar Kulkarni, Doctoral Student, Oregon State University
Email: kulkarnk@oregonstate.edu
IIASA Supervisors: Stefan Hocrainer-Stigler (RISK), Georg Pflug (RISK)

Introduction. Over the last four decades, Indian agriculture has witnessed a rise in crop productivity. This can be largely attributed to technological innovation and crop diversification coupled with better irrigation and fertilizer usage. While the number of farms has also increased over the years, the share of large farms has declined at an increasing rate. These factors, along with the changing weather, constitute most of the production risk faced by a farm. Quantification of these risks is thus imperative for assessing the vulnerability of farms and to frame policy. In this project, we exploit a rich panel dataset from India to evaluate the impact of climate change and farm inputs on the vulnerability of agricultural systems using higher-order partial and quantile moments.

Methodology. We present a threshold indicator concept of vulnerability i.e. the probability of crop output falling below a well-defined threshold. Lower and upper partial moments are then generated with respect to this threshold. For the quantile moments, we decompose the risk exposure into four quantiles where we define downside risk (upside potential) as the risk located in the lower 10 (upper 10) per cent of the probability distribution. We approach the VDSA ICRISAT database to construct a panel dataset for the period 1965-2002 and test the effects of farm size, crop diversity, rainfall, irrigation and fertilizers on production risk. The estimation strategy begins with the specification of the mean output function in the translog form for the additive-error model. High-order partial and quantile moments are then obtained from the residuals of the mean regression. Econometric analysis of the partial and quantile moments follows.

Results. The results from the mean output regression indicate a positive relationship between precipitation and crop productivity and a negative relationship between irrigation and crop productivity. Furthermore, we also find an increase in crop diversity and farm size reduces productivity. The findings from the high-order partial and quantile moments indicate that irrigation reduces the downside risk but also reduces the upside potential. With respect to farm size and crop diversity, we find both to decrease the downside risk and the upside potential. We also find that precipitation decreases the downside risk while increasing the upside potential. Fertilizers are found to positively affect crop yield but also increase the downside risk as well as upside potential.

Conclusions. Overall, our findings establish that high-order moments provide a relevant lens to capture the risk associated with unfavorable scenarios as opposed to the mean indicators. Based on the partial and quantile moments analysis, we identify irrigation, farm size and crop diversity to be risk-decreasing inputs while precipitation and fertilizers can be deemed as risk-increasing inputs. These results subscribe to the notion that high-order moments can serve as a flexible and empirically robust way to assess climate vulnerability of agricultural farms and provide an opportunity to advance the empirics on better understanding farm decision-making under uncertainty.

Integrating the social dimension into the governance of the energy transition: The social impact assessment in renewable energy projects in Mexico

Nain Martinez, UC Berkeley, the United States/Mexico
Email: nain.martinez@berkeley.edu
IIASA Supervisors: Nadejda Komendatova-Amann (RISK), Susanne Hanger (RISK), Elizabeth Tellez-Leon (RISK)

Introduction. In the last decade, academic debate around renewable energies has shifted from their economic and technical viability to the political and social problems that arise from their implementation. The diversity of sociopolitical challenges surrounding the energy transition policies demonstrates the relevance of its social dimension (Reusswig et al., 2018). However, historically, the governance of the energy system has been based on considerations of a technological, engineering and economic nature, excluding social aspects (Miller & Richter, 2014). Thus, through the analysis of how the **Social Impact Assessment** (**SIA**) was implemented in the Mexican renewable energy sector, this article provides empirical evidence on the challenges of policies aimed to include social aspects into the governance of the ongoing energy transition.

Methodology. The data is based on semi-structured, in-depth qualitative stakeholder interviews (N = 28). ***1***), stakeholders' mapping was conducted by the first author who worked for one year as a research advisor of the project "*Communities and Renewable Energy*" in Mexico City. ***2)*** An interview protocol was created based on literature on participatory governance. were conducted in person in 2018 in Mexico City with government officials (5 interviews), NGOs (8), private sector (6), consultants (4), experts (3), and International Organizations (2). ***3)*** The transcripts of interviews were analyzed following the method of thematic analysis.

Results. As a result of the interviews analysis, we identified four key areas that affect the performance of SIA. 1) **The policy framework in the energy sector**, where the lack of internalization of the social dimension in the energy policy and governance diminish its effectiveness. 2) ***Elaboration of the SIA***, where the absence of methodologies to assess cumulative or synergistic social impacts and mechanisms to resolve controversies between the beneficiary and affected groups, as well as the relationship between consultants and companies, reduce the quality and reliability of the study output. 3) ***Evaluation of the SIA***, where the structure of the Secretary of Energy (SENER) and the regulatory design limit the capacity of SENER to make a comprehensive evaluation. 4) ***Management of social impacts***, where the absence of regulatory mechanisms for monitoring the practice of companies, and the lack of internationalization of social management in the private sector, diminish the its real effects.

Conclusions. After three years of implementation, the principal stakeholders perceive that the SIA has been unable to address social issues in renewable energy projects. The SIA requires improvements in its institutional and regulatory design as well as the practices of governmental officers, the private sector, and consultants. Also, it needs a better level of involvement of civil society and, particularly, of communities that are still marginalized of the decision-making process. However, it has generated some positive effects, including recognition of social issues as a relevant topic of the energy agenda, and a learning process on social management by the leading actor in the sector.

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Historical responsibility, carbon majors, and loss & damage

Kian Mintz-Woo, Independent Scholar
Email: mintzwoo@princeton.edu
IIASA Supervisors: Thomas Schinko (RISK), Reinhard Mechler (RISK)

Introduction. "Loss & Damage" (L&D) is the policy term encompassing, on one interpretation, adverse effects associated with climate change impacts beyond our ability to adapt (Mechler et al. forthcoming, Mechler and Schinko 2016). This project had dual aims: firstly, to justify a relatively stronger level of responsibility for financing L&D measures from historical emitters, as compared with responsibility for financing adaptation or mitigation measures; secondly, to apply this reasoning to "carbon majors" (primarily investor- or state-owned enterprises with disproportionate historical emissions) (Heede 2014). Specifically, the project aimed to determine what proportion of CO_2 and CH_4 are sourced from the carbon majors given different years for the ending of excusable ignorance, years selected based on climate science dissemination.

Methodology. For the first aim, the project considers three categories of adverse climate effects: those which still could be prevented through mitigation (given sufficient contemporary mitigation), those which still could be adapted to (given sufficient contemporary adaptation), and those which now can neither be adapted to nor mitigated (requiring L&D instruments). The method is conceptual analysis, particularly drawing on the polluter pays principle and the principle that responsibility is diluted when the potential to address a harm is shared amongst different agents. For the second aim, Heede's dataset of carbon majors was obtained and statistically assessed in R. Percentages of the total historical CO_2e emissions were calculated using the Carbon Dioxide Analysis Information Center (CDAIC) covering CO_2 from 1751-2014 (Marland et al. 2015) and the European Commission Joint Research Center's EDGAR v4.3.2 covering CH_4 with AR5 GWP-100.

Results. For the first aim, it was argued that harms resulting from lack of mitigation or adaptation would not be the full responsibility of historical emitters. First, historical emissions alone are insufficient to cause any effects which could still be prevented today through mitigation. Second, non-historical emitters could have duties to assist in funding adaptation to prevent harms, implying that there is some shared responsibility. These considerations contrast with L&D, where harms are fully caused by historical emissions, suggesting that L&D measures should be covered by historical emitters to a greater relative extent. For the second aim, it was found that the percentage of historical emissions traceable to the carbon majors is relatively robust to setting endpoints for excusably ignorance. For instance, all known carbon and methane emissions traceable to carbon majors represent 66% of combined CDAIC and EDGAR CO_2e estimates of known *cumulative* historical CO_2 and CH_4 in CO_2e (1751-2014). Trimming the carbon major emissions to post-1979 includes 48% of cumulative historical CO_2e (1979-2014); trimming to post-1988 still includes 39% CO_2e (1988-2014).

Conclusions. If L&D is especially the responsibility of historical emitters and carbon majors are robustly the source of significant historical emissions (even accounting for excusable ignorance), this conclusion suggests a justification for taking carbon majors to be significantly responsible for addressing L&D. In particular, it could justify a role for carbon majors assisting in the financing of L&D measures.

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Systems view on creativity - dynamics of emerging perceptions

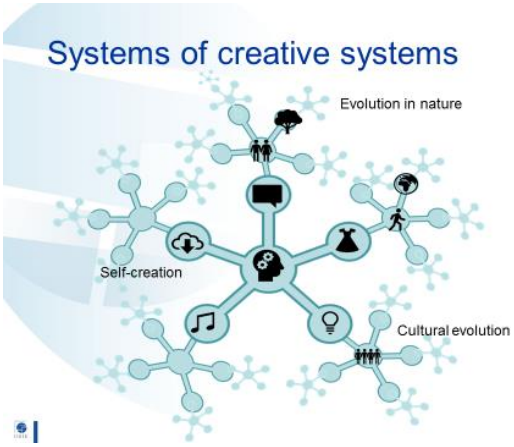
Laura Mononen, University of Jyväskylä, Finland
Email: laura.m.mononen@jyu.fi
IIASA Supervisor(s): Brian Fath (ASA), Gerid Hager (ESM), Gloria Benedict (ESP)

Introduction. In the prevailing world, we live with increasing complexity, where we need to re-orient ourselves to solve and create better solutions to our problems. Systems view on creativity is suggested to have potential to bring about this change and to help us to create conditions and environments for our diversity to flourish and new solutions to emerge (Montuori & Donnelly 2016 2011; Csikszentmihalyi 2014). It is aiming to bring about a holistic and practical view on creativity, to complement the intra-disciplinary research. However, it is demanding us to change our perception of creativity itself. This presentation is giving an overall view on central themes of creativity from systems perspective based on the major theories and models in the field.

Methodology. The project is part of an ongoing doctoral thesis, which is using integrative (Torraco 2005) and transdisciplinary literature view (Montuori 2013), snowball sampling (Lecy & Beatty 2012) and grounded theory (Strauss & Cobin 1998) as methods and rich picture as tool for understanding. It aims to answer the question: how has creativity been researched from a systems view previously and what do we mean when we speak about creativity from a systems perspective? Since the topic has been researched in different academic fields, it is aiming to analyse the critical aspects and to create a synthesis of different approaches. The overall goal is to create a comprehensive framework for practical purposes and find out, what are the missing research gaps of the prevailing theories and models.

Results. The research project found diverse systems models and theories, which operate on different levels of complexity (individual, social and ecology of creativity) and on different epistemological grounds (Systemic and system theoretical). The initial review suggested that the origins of a systems view on creativity emanate from ecological psychology, systems sciences, and social approach on creativity. The coding revealed key processes including: Self-creation; cultural evolution and evolution in nature. Further coding is expected to inform more specific structures and interactions of these general processes.

Conclusions. The theories of creativity from a systems view are being developed in diverse fields, which are only weakly in interaction with each other. However, the integration of the theories and models into coherent framework seems to be possible. Further research on the epistemological foundations and level of complexity of these theories is needed, to gain knowledge on the similarities and differences. In addition, there is a need for conceptual analysis of the definitions of creativity used in the systems theories and models.



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Stability and Change in Common Pool Resource Management: Exploring the role of worldviews

Sara Turner, Pardee RAND Graduate School, USA
Email: sturner@prgs.edu
IIASA Supervisor: JoAnne Linnerooth-Bayer (RISK), Piotr Magnuszewski (RISK)

Introduction. Experimental games are now a standard tool for studying decision-making processes in common pool resource problems (Ostrom 2005). Efforts are underway to enrich the treatment of social complexity inside these games to better capture player heterogeneity in beliefs, culture, and values to explain gaps between research findings and observations in applied settings (Saunders 2014). One branch of this research agenda has focused on the role of cultural and value heterogeneity in behaviour (Barnes-Mauthe et al., 2013). I expand on this work by more richly characterizing the relationship between measures of player characteristics, harvest behaviour, and communication in an experimental CPR game developed at IIASA (Bednarik et. al, 2017).

Methodology. Game chat data from a series of games run in 2017 by IIASA researchers was qualitatively coded for themes and processes (Bednarik et al., 2017). Relative frequencies of codes were compared with measures of total harvest behaviour, and survey-derived measures of group characteristics defined by the theory of plural rationalities. Findings from the initial phase of research were used to develop and pilot a new version of the game which is intended to better capture the social complexity of common pool resource management problems.

Results. Characterization of game behaviour suggested that groups could be categorized according to the level of coordinated behaviour they were able to achieve within the game. Qualitative assessment of themes suggested that language use differed significantly between more and less coordinated groups. Consistent with past research, higher levels of coordination and higher total harvests were associated with increased language use related to calculation of optimal harvest, planning, communication to clarify plans, and general encouragement among players. These language use characteristics were further associated with higher group scores on measures of individualism. While language use patterns among groups that scored more highly on other dimensions of cultural theory also demonstrated correlations with specific language use patterns, these patterns were not as closely related to measures of behaviour considered in this study.

Conclusions. I develop two primary hypotheses for future testing. First, while distinguishing patterns of language use were identifiable for all groups proposed by cultural theory, scores on individualism were most strongly positively correlated with coordinated behaviour. I hypothesize that groups with stronger individualist tendencies may have been able to calculate and communicate the benefits of coordination in ways that enabled greater coordination and higher total sustainable harvest. Furthermore, the presence of distinguishing language patterns with minimal relation to measures of total harvest or equality suggests that while players referred to these concerns within the context of the game, they were not associated with behaviour. I hypothesize that one reason for this may be the structure of the game itself, which encouraged a specific interpretation of the core decision problem. Future work with a revised version of the game is intended to test this hypothesis.

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Transitions to New Technologies (TNT)

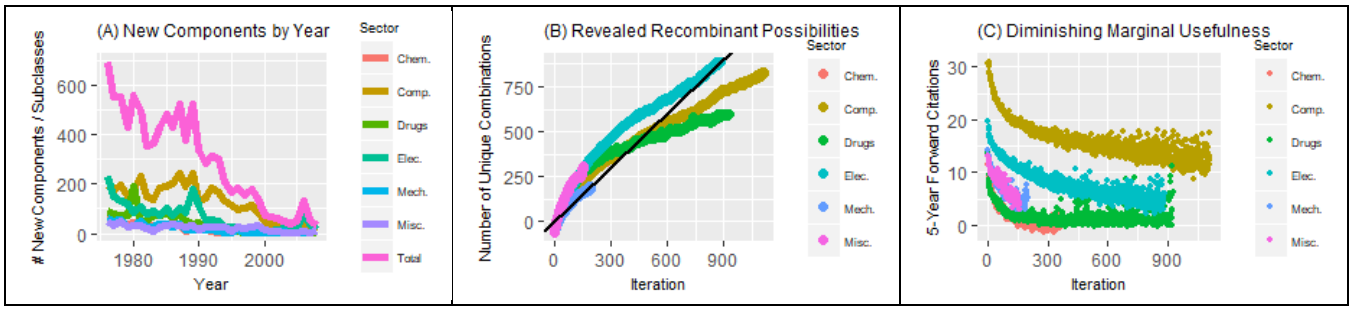
Creativity constrained: The exhaustion of the inputs of invention

Christopher Esposito, University of California Los Angeles
Email: cresposito@ucla.edu
IIASA Supervisor: Arnulf Grübler (Transition to New Technologies)

Introduction. Because the creation of new technologies is essential to address major environmental and economic challenges (Solow 1956, Romer 1988, Grübler 1998), it is alarming that new technologies are increasingly difficult to invent and employ (Gordon 2017; Bloom et al. 2018). In this research, I trace the causes of the half-century slowdown in technological change upstream by investigating if inventors' efforts are constrained by a shortage of inputs (technical components) used to create new technologies. Adopting an evolutionary perceptive in which new technologies are developed by arranging existing components in new ways (Arthur 2009), U.S. Patent and Trademark Office (USPTO) patent records reveal that the growth of unique technological components has tapered off since 1976, and that each technological component has a finite number of practical uses. Together, these results raise the possibility that many of the component inputs used to develop new technologies have been exhausted.

Methodology. Using all utility patents issued by the USPTO 1976-2013, I test for input exhaustion by (a) exploring how the number of component-based inputs grows over time, and (b) calculating the range of technologies in which the average component can be used. The growth in inputs is given by calculating the number of new subclass codes, which loosely correspond to physical components, introduced to the USPTO's classification scheme each year. The range of components' potential uses is calculated using two methods. First, I measure the *revealed recombinant possibilities* (RRP) of components by counting the number of unique other components that inventors successfully combine each focal component with. Second, I use an impact measure (forward citations) to calculate the number of times that each component can be used before its marginal usefulness becomes insignificant.

Results. Results figures A-C confirm that: (A) the growth in component inputs has declined since 1976, (B) components can be combined with a finite number of other components, as indicated by the downward concavity of the RRP curves which shows that inventors find fewer new combinations for focal components the more they use them, and (C) the usefulness of focal components declines rapidly after these components are introduced.



Conclusions. Because the range of uses of individual components is finite (figures B-C), and the growth of components is in decline (figure A), inventors may be running out of the technological inputs needed to produce new inventions. Further research is needed to investigate why fewer new components are being created and what actions policy makers can take to increase the production of these building-blocks of new technologies.

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Identifying technological knowledge depreciation rates with patent citation data: The case of PV industry

Jie Liu, East China University of Science and Technology, China
Email: ahliujie@126.com
IIASA Supervisors: Arnulf Grubler (TNT), Tieju Ma (TNT)

Introduction. Technological knowledge can be gained (learned), but it can be also lost. Two main reasons explain why knowledge depreciates: 1) knowledge is lost (e.g., through staff turnover) and 2) knowledge becomes obsolete (e.g., through rapid innovation). Knowing how fast knowledge depreciates is important for decision makers: they need to decide how to "recharge" the knowledge of an organization (e.g. via R&D, Research and Development). This study develops a method to identify technological knowledge depreciation (obsolescence) rates with patent citation data. We use the solar PV industry as a case study. The rates calculated with our method are comparable to the few available literature estimates on technology depreciation rates in the PV industry, but its underlying data are more widely available and its method more replicable for a wide range of countries.

Methodology. Patent data of the solar PV industry from 1965 to 2015 was derived from the Thomson Innovation global patent database. Patent applications for one invention in multiple countries were recorded as one observation. For each patent record, its birth date and location are recorded as its earliest patent application date and country for the invention, which corresponds most closely to when and where the knowledge was created. Following Higham, Governale, Jaffe, and Zulicke (2017), we separate also the citation-inflation and preferential-attachment-type growth kernel effects out from the time-dependent citation distribution to obtain an unbiased real depreciation-related knowledge aging function. In this way, we can monitor knowledge depreciation of PV industry.

Results and Conclusion. After adjusting for citation-inflation and separating the preferential-attachment factor, the patent citation data can be fitted well by an exponential aging function. We find that the aggregate PV industry technological knowledge depreciation rate is near 20% per year, but rates vary significantly across different countries. Chinese patent records do not contain citation data, so we could not calculate the rate for China. The rate in Japan is near 30% per year, in the US it is 20%, in Europe (mainly Germany) 16% and in Korea 15%/year. Using the estimated technological knowledge depreciation rates and the knowledge build-up rate via R&D, we calculate the PV technology knowledge stock over time. We find that in the USA erratic R&D expenditures lead to a sharply eroding knowledge stock. In contrast, Japan and Germany have lower, but more stable R&D expenditures compared to the USA, which results in a more efficient knowledge recharge. Technological knowledge depreciation corresponds to technology improvements but also implies the need of a continuous recharge mechanism.

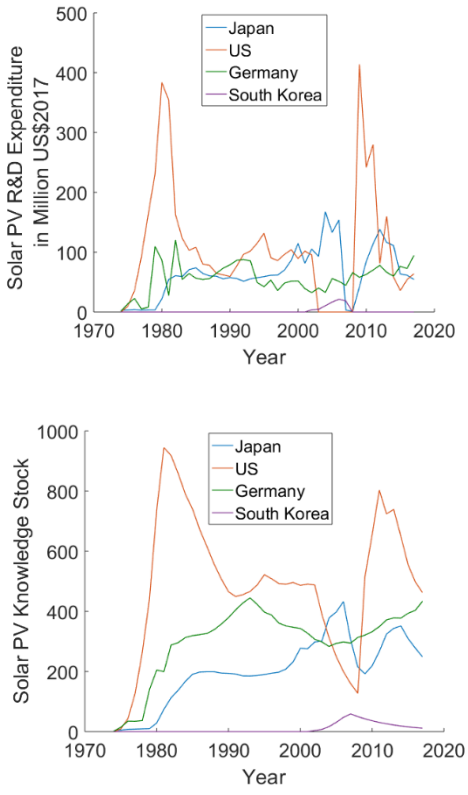

***Figure 1**. Solar PV R&D expenditures (source: IEA, 2018) and knowledge stocks in four countries*

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Water
(WAT)

A novel approach to estimate streamflow depletion caused by groundwater pumping using neural networks

Thomas Boerman, MSc, University of Victoria, BC, Canada
Email: tboerman@uvic.ca
IIASA Supervisors: Peter Greve (WAT), Yoshihide Wada (WAT)

Introduction. Groundwater can be used for a variety of purposes, including the production of drinking water, irrigation water and for industrial purposes. However, long-term persistent groundwater pumping can have negative impacts on small headwater streams and ecosystems which are dependent on a certain amount of streamflow to sustain functioning. Methods for quantifying streamflow depletion (SFD), range from simple, conservative analytical solutions (Hunt, 1999) to complex, numerical groundwater models. The purpose of this study is to develop an alternative method for estimating SFD, using a Neural Network (NN); a machine learning method used to find mathematical relations within a database consisting of cause (input) and impact (output) parameters.

Methodology. In this study the dataset is built on parameters which have causal relationship to the amount of expected streamflow depletion, such as stream-well distance, stream density, and aquifer properties. The output data consist of all the possible sources of water pumped in the pumping well: storage, reduced baseflow, etc. The dataset is obtained from three calibrated groundwater models, situated around Lake Michigan (Feinstein et al., 2018). The model domains are split into smaller *local areas* (LAs), each with a seeded pumping well. The wells are significantly placed apart to ensure the pumping wells don't interfere with each other. Each LA is then used as a different 'sample' to build the database of between 1200 and 1700 samples (dependent on the model). The NN is then trained on the dataset from each model and data from the other models is used estimate the predictive performance of the NN over different regions.

Results. The optimal spacing of seeded wells without interference is estimated to be 50 model cells apart with a LA size of between 24 and 30 model cells (on one side). This is consistent with the LA size used in previous work by Feinstein et al. (2016). The optimal NN performance is obtained by using a 2- or 3-hidden layer NN (depending on the dataset) and using the log cosh function as the cost function. Some output parameters show enough variation throughout simulation time to train the NN (storage) whilst others (water from wetlands) show insufficiently low values for the NN to learn. This is solved by grouping output parameters together. The (preliminary) predictive performance of the NN improves when (1) more predictor parameters are included in the training data and with (2) increasing size of the database.

Conclusions. An alternative method for estimating SFD caused by groundwater pumping using NN is tested. The preliminary predictive performance of the NN is promising and will be increased by prolonging the simulation time of the numerical groundwater models and by increasing the size of the database. The preliminary results show that the NN keeps the same level of accuracy when 'new data' from other regions is introduced. This confirms that the NN model can be used as a predictive management tool across similar geographic regions.

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Integrated modeling of system dynamics and input-output for regional hydro-socioeconomic systems

Kelly Cortney Gustafson, University of Maryland, USA
Email: kgustaf1@umd.edu
IIASA Supervisor: Laixiang Sun (WAT), Kuishuang Feng (WAT)

Introduction. The fundamental necessity of water supply, not only for basic human needs and environmental vitality, but also economic production, creates a serious need to better understand the complex dynamics of our hydro-socioeconomic systems at a regional level. To further our comprehension of the interrelationships between and within our hydrologic, social and economic systems, this research applies an integrated approach utilizing input-output (IO) analysis within a system dynamics (SD) modeling framework.

Methodology. This research merges the economic structure of the MEDEAS model to the coupled natural-human water system of the COWA model. The MEDEAS' economic structure inserts the inter-industrial (indirect) and community-based (direct) economic relationships, inherent in IO, into a SD modeling environment. We installed this structure into the conceptual framework of COWA, which allows for water availability to constrain growth. With this merging, the new modeling framework develops a valuable model integration in which economic impacts can be assessed in the context of water availability and impacts to water resource stocks can be assess in the context of economic decisions or changes. We've applied this model to a watershed region on south-central Arizona, the Phoenix Active Management Area – an area which has one of the fastest growing metro populations despite its relatively limited natural water resources and, therefore, highly dependent on its strict and long-standing water management policies and practices.

Results. The resulting framework utilizes multi-year IO matrix data (obtained from the IMPLAN database) to construct temporal iterations of the region's dynamic economic structure. An exogenous GDP growth rate drives the model's final demand and in combination with the time-linked inter-industrial relationships, a required final production is determined. With a series of sector-based water intensity coefficients (obtained from USGS water use database), a 'required final production' (RFP) is translated into 'require water demand' (RWD) which, in turn, is compared to available water supply (AWS). Available water supply is determined by considering water resource stocks, infrastructure capacities and environmental requirements. When RWD is not in conflict with AWS, the economy will meet all its RFP demands and growth will continue its exogenously driven trajectory. However, when RWD and AWS are in conflict, a series of sector-based priorities instruct water allocations to reduce RWD to a 'real water delivery', considering resource shortages. Once the real water deliveries drop below required water demands, economic production begins to reduce, which subsequently reduces income shares within the labour force. This decline triggers a population response of increased outflow in the form of higher rates of net immigrations from the region – effectively creating a feedback between water shortages and economic growth.

Conclusions. The modeling framework provides a tool for assessing policy decisions and allocation scenarios of regional communities which require integrated approaches to water resource management. Combining the feedback mechanisms of SD with the inter-sectoral relationships of IO has created a valuable modelling approach for hydro-socioeconomic systems which are inherently complex, interconnected and interdependent.

Projecting hydrologic changes in the terrestrial Arctic domain

Merritt Harlan, University of Massachusetts Amherst, USA
Email: mharlan@umass.edu
IIASA Supervisors: Peter Burek (WAT), Lassi Heininen (AFI)

Introduction. The Arctic is warming at twice the rate of the rest of the globe and Arctic sea ice is rapidly retreating, greatly altering Arctic terrestrial ecosystems and cryospheric processes (Anisimov 2007). These pronounced changes give rise to an unprecedented acceleration of the Arctic hydrologic cycle within the Holocene period (Wagner et al., 2011). Despite these rapid changes and the region's fundamental role in global energy dissipation, understanding and prediction of Arctic climate is surprisingly poor and insufficiently validated (National Research Council 2014). This research aims to improve terrestrial modeling of the Arctic through simulating runoff, permafrost, and snow coverage across the pan-Arctic domain to estimate future changes under varying climatic conditions.

Methodology. The Community Water Model (CWatM) (Burek et al., 2016) is a large-scale open-source hydrologic model with several high latitude implementations including 10 vertical snow coverage layers and a frozen soil/permafrost index. In order to evaluate CWatM's performance across the pan-Arctic domain, model results were compared to observed streamflow, permafrost, and snow coverage. The pan-Arctic domain was partitioned into 12 regions, and 20 basins were chosen for calibration and model evaluation. The model was then used to project changes in the Arctic in terms of streamflow and permafrost through comparing four general circulation model projections spanning both a historical (1961-2005) and current/future time period (2006-2100). Two different Representative Concentration Pathways (2.6 and 6.0) were chosen as future emission scenarios.

Results. In terms of CWatM's ability to adequately model the pan-Arctic domain, preliminary findings suggest that simulated hydrologic variables at a regional scale, such as pan-Arctic discharge, permafrost, and snow coverage have a strong correlation with observed data. At the basin scale, most outlets matched observed data, however there remains substantial variability in performance results, with several sub-optimal basins as shown by the wide spread in variation of performance metrics in Figure 1. As for projecting Arctic streamflow and permafrost in the future, the model projects statistically significant increases in streamflow by a factor of 2 for RCP 6.0, and a statistically significant decline in permafrost coverage.

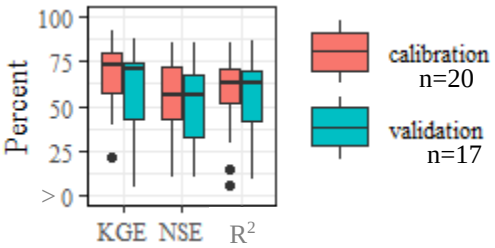

Figure 1. Calibration Performance Metrics

Conclusions. CWatM is an effective tool for modelling the pan-Arctic domain, and can do so in an efficient manner over a high temporal and spatial resolution. Model results confirm that the Arctic hydrologic cycle is intensifying in an unprecendented manner, particularly with regards to permafrost and Arctic Ocean inflow, altering both the local and global landscape.

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Modelling the water-energy-economy nexus at provincial scale across China

Xiaoyu Liu, Peking University, College of Env. Science and Eng., China
Email: liuxy17@pku.edu.cn
IIASA Supervisor: Taher Kahil (WAT)

Introduction. Climate change and water scarcity have brought big challenges to many world regions (e.g., China) in recent years. China has formulated many policies to reduce carbon emission from energy consumption and to reduce water scarcity. For example, policies aiming to limit total amount and intensity of carbon emission and water use. However, few studies have investigated the interactions between climate mitigation and water policies in China. This study aims to investigate the combined effects of climate mitigation and water policies on water demand and carbon emission at the provincial scale in China. Four scenarios were analysed for 2002-2030 to explore future trends in water demand and carbon emission, assuming socio-economic developments under Shared Socio-economic Pathways 2 (SSP2), SSP2 with climate mitigation policies (SSP2+CO_2 target), SSP2 with water policies (SSP2+water), and SSP 2 with climate mitigation and water policies (SSP2+CO_2+water).

Methodology. We used the water module in the Integrated Model of Energy, Environment and Economy/Computable General Equilibrium model (IMED/CGE) for China. This module uses historical water demand data and hydrological simulations from IIASA's Community Water Model (CWatM). The water module calculates industrial water demand (IWD) of 20 industrial sectors for 30 provinces China over the period 2002-2030. We use the output value from CGE multiplied by the water intensity from historical data to get the IWD before 2015. After 2015 IWD is obtained by using the formula:

$$WD_{t,p,s} = WI_{t-1,p,s} \times TI_{t,p,s} \times O_{t,p,s}$$

where *WD* is the total industrial water demand in each time step *t*, province *p*, and sector *s*; *WI* is water intensity in the previous time step *t*-1;*O* is economic output; *TI* is technological improvement, $TI_{t,p,s} = \left(\frac{EN(pc,t,p,s)}{EL(pc,t,p,s)}\right) / \left(\frac{EN(pc,t-1,p,s)}{EL(pc,t-1,p,s)}\right)$, *EL* and *EN* are electricity production and energy consumption respectively, *pc* is per capita. (Wada et al., 2011)

Results & Conclusions. The preliminary results show that the industrial water demand (IWD), carbon emission (CE) and GDP under the SSP2+CO_2 target and SSP2+CO_2+water scenarios are lower than those under SSP2 and SSP2+water scenarios after 2015. This is explained by the implementation of the climate mitigation target in 2030. Moreover, IWD, CE and GDP under SSP2 scenario have no difference from SSP2+water, which means water policy doesn't play an important role. The results of this study indicate that mitigation policy is very effective in reducing the industrial water demand and carbon emission while water policy is less effective. Moreover, the effectiveness of the mitigation policies varies among provinces and sectors in China.

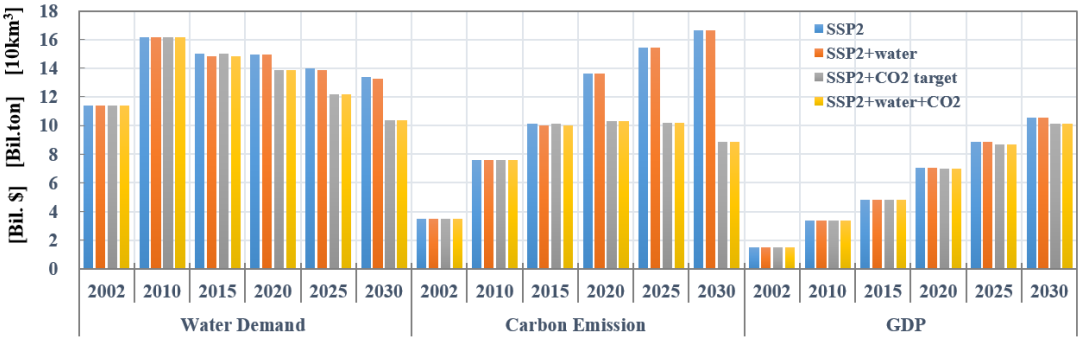

Fig. Industrial water demand, carbon emission and GDP in China under 4 different scenarios

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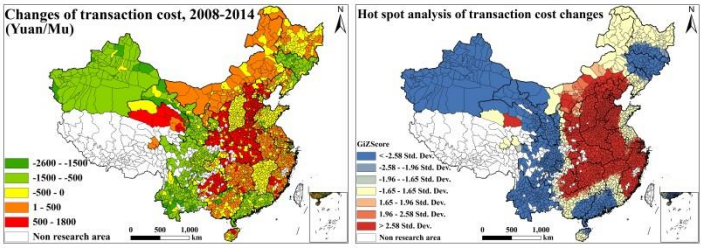
An estimation of the transaction cost of farmland transfer in China

Jiayue Wang, Chinese Academy of Sciences
Email: wangjy.16b@igsnrr.ac.cn
"IIASA Supervisor:" Günther Fischer (WAT) and Laixiang Sun (WAT)

Introduction. With the arrival of the era of Chinese high labor costs, raising labor productivity has become one of the important challenges facing agricultural development in China. Increasing labor productivity calls for the expansion of farm size, which in turn requires the transfer of land management rights among farm households. Chinese government vigorously promoting land transfer and moderate scale management, farmland transfers increased rapidly, and the transfer rate reached as much as 35% in 2016; but in the recent past, there has been a marked stagnation in the farm size expansion process, probably because of excessive transaction costs. There have been only few studies in the past addressing the quantitative estimation of transaction costs of farmland transfer. Thus, there is an urgent need for robust estimation of land transaction costs to provide sound theoretical guidance for China's land system reform.

Methodology. This study combines (i) a focus on the cultivation of major food crops, and (ii) a spatial and temporal analysis at the national level with farmers' household survey at the regional level. For the estimation of transaction costs, we study land rents of agricultural entities of different size and in different geographical regions. Based on the Agro-ecological Zones (AEZ-China) model, the land production potential is evaluated for a variety of rain-fed and irrigated crops. Land is then capitalized according to the income capitalization approach. The relationship between the land capital value and the land rent of small farmers is determined by a farm household model. Finally, the transaction costs can be derived according to the rent differences of large and small land parcel transfers.

Results. (1) For the land transfers among small farmers the key factors to determine land rent include availability of irrigation, transportation conditions and farmland quality. In addition, the opportunity cost of farm labor also affects the rent; farmers with a high opportunity cost tend to transfer land at a lower rent. (2) Concerning different farm sizes, the analysis finds an obvious scale effect. The income of large farmers per unit area is higher than that of small farmers. This is mainly due to differences in inputs used. Total inputs per area decrease with the increase of the farm scale. (3) The estimated shadow price of land is highest for parcels in the range of 0.7-3.3 ha; for parcels with more than 33.3 ha the shadow price is lowest. (4) In terms of geographical distribution, the transaction costs in the central and western regions are higher; while those in the northeast and southeast coastal areas are lower than average. (5) The average transaction cost per mu in 2008 was 879 yuan and 803 yuan in 2014. During 2008-2014, transaction costs were reduced in 40% of the counties and increased in 43%. Hot-spots of transaction cost increases occurred mainly in the important agricultural areas of China's central plains.



Conclusions. In 2008, the transaction cost of land transfers per mu was 1.3 times the land rent. High transaction costs affect the willingness and possibilities of farmers to rent in land and hinders the realization of rational farm size management. By 2014, the spatial distribution of transaction costs had changed substantially, indicating that development and the measures taken by local governments had varying impacts on land transfers. A next step in my research should focus on an analysis of key determinants that can explain the obtained spatio-temporal pattern of land transfer costs. This study also explored different mechanisms of agricultural land pricing. Under the current conditions of an imperfect land market in China, the results can provide factual guidance for improving land transactions and farm scale consolidation.

Modelling river export of nitrogen from land to sea by Yangtze and Indus Rivers

Mengru Wang, Wageningen University & Research, The Netherlands
Email: mengru.wang@wur.nl
IIASA Supervisors: Ting Tang (WAT), Peter Burek (WAT), and David Leclere (ESM)

Introduction. Fast population growth in many Asian countries (e.g., China, India) has resulted in intensive human activities in agriculture and urbanization. This has led to large nutrient losses to aquatic ecosystems, causing water pollution. For example, nutrient export of Nitrogen (N) and Phosphorus by Chinese rivers were reported to increase by a factor of 2-8 between 1970 and 2000 (Strokal et al., 2016). This increasing trend is expected to continue because of the increasing population and economic growth in Asia. The aim of this study is to better understand the trends of river export of N by Yangtze and Indus Rivers and their sources at the sub-basin scale between 2010 and 2050.

Methodology. We used the MARINA (Model to Assess River Inputs of Nutrients to seAs) model to quantify river export of dissolved N by sub-basin and source (Strokal et al., 2016). The model inputs of human activities on land (e.g., agriculture, urbanization) are from the GLOBIOM/EPIC (Global Biosphere Management Model/Environmental Policy Integrated Model) model system (Havlík et al., 2014). Model inputs of hydrology are from the CWATM (Community Water Model) model (Burek et al., 2017). We analysed the trends between 2010 and 2050. For 2050 we used three Shared Socio-economic Pathways (SSPs) for strong, rapid (SSP1) and moderate (SSP2 and SSP3) socio-economic development, and two Representative Concentration Pathways (RCPs) for the lowest and medium (RCP2.6 and 6.0) climate-change induced hydrology. Three combinations of SSPs and RCPs were selected based on SSP-RCP matrix.

Results. Results show that river export of dissolved N by Yangtze River increase between 2010 and 2050 by 30% under SSP2-RCP6.0 and by 40% under SSP3-RCP6.0, and decrease by 10% under SSP1-RCP2.6. River export of dissolved N by Indus River is found to increase by factor a of 1.6 - 2 between 2010 and 2050 under the three SSPs. More than 80% of the dissolved N exported by Yangtze and Indus Rivers are from middlestream and downstream sub-basins. Agriculture and sewage are the main sources of river export of dissolved N. For example, 50% of the dissolved inorganic N exported by Yangtze River is from synthetic fertilizer, and 60% of the dissolved organic N is from sewage and direct discharge of manure in 2010. For the Indus River, synthetic fertilizer and sewage contribute to 65% of the dissolved inorganic N, and sewage contributes to 57% of the dissolved organic N in 2010.

Conclusions. River export of dissolved N by Yangtze and Indus Rivers will likely increase between 2010 and 2050 under selected combinations of SSPs and RCPs. This may lead to a higher risk for coastal water pollution in the future. Agriculture and sewage are the main sources of dissolved N exported by Yangtze and Indus Rivers. Our analysis provides insights in how future trends in coastal water pollution are affected by socio-economic activities and climate-change induced river discharge. The results on the main sources of N export by sub-basins are good basis for developing effective options to reduce coastal water pollution by nutrients from Yangtze and Indus Rivers.

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