Benefits of Systems Science for Policy Support

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Shall I Compare Thee To A Summer’s Day?

by William Shakespeare

Shall I compare thee to a summer’s day?
Thou art more lovely and more temperate.
Rough winds do shake the darling buds of May,
And summer’s lease hath all too short a date.
Sometime too hot the eye of heaven shines,
And often is his gold complexion dimm’d;
And every fair from fair sometime declines,
By chance or nature’s changing course untrimm’d;
But thy eternal summer shall not fade
Nor lose possession of that fair thou ow’st;
Nor shall Death brag thou wander’st in his shade,
When in eternal lines to time thou grow’st:
So long as men can breathe or eyes can see,
So long lives this, and this gives life to thee.
THE EARLY 1970s

Sources: nuclearweaponarchive.org, The Guardian
A GLOBAL RESEARCH INSTITUTE

- Established as a scientific bridge between East and West
- After Cold War ended focused on multiple dimensions of global change
- Now embarked on the new research strategy for the next decade
International, independent, interdisciplinary

Research on major global problems

Solution oriented, integrated systems analysis
EXAMPLES OF EARLY RESEARCH

MAJOR
GLOBAL
CHALLENGES
FOOD

- 925 million people were undernourished in 2010 (FAO)
- By 2030, the world’s population will have increased by one billion (IIASA)
- Agriculture accounts for 70% of freshwater withdrawals (UN Water)
WATER

• 884 million people have inadequate access to safe freshwater (WHO & UNICEF)

• Water use has been growing at more than twice the rate of population increase in the last century (FAO & UN-Water)

• Hydropower supplies about 20% of the world’s electricity (ICOLD)
ENERGY

- 2.5 billion people are without access to modern energy (IIASA/GEA)
- World primary energy demand expected to increase by 36% between 2008 and 2035 (IEA)
- Energy production and consumption contributes over 80% of global GHG emissions (IIASA)
CLIMATE CHANGE

Eleven of the last twelve years (1995–2006) rank among the twelve warmest years in the instrumental record of global surface temperature; since 1850 (IPCC)

Average temperatures predicted to increase by 1.1 to 6.4°C by 2100 (IPCC)

70 million Africans could suffer from devastating floods as a result of climate change (IPCC)
POVERTY AND EQUITY

- Over 24,000 children die each day due to poverty (UNICEF)

- 80% of humanity lives on less than $10 a day (World Bank)

- “Hunger is a cause of poverty, not just a consequence of it” (FAO)
INEXTRICABLY LINKED

- Energy & Climate Change
- Food & Water
- Poverty & Equity
IIASA’S SYSTEMS SCIENCE APPROACH
RESEARCHING GLOBAL CHALLENGES

• Integrated
• Interdisciplinary
• International
• Independent
• Solution-oriented
• Long term
• Trade offs

= Systems Analysis
## ADVANCED SYSTEMS ANALYSIS

### PAST SUCCESSES
- Dynamic Systems
- Multi-criteria decision analysis
- Adaptive dynamics theory
- Game theory
- Agent-based modeling
- Stochastic optimization

### NEW RESEARCH
- Advances in Modeling Dynamic Systems
- Extreme events, Systemic Risks and Robust Solutions
- Integrated Modeling and Decision Support
- Advanced Systems Analysis Forum
IIASA helps to put the puzzle together
NOBEL PRIZE WINNERS

Professor Tjalling Koopmans and Professor Leonid Kantorovich
Nobel Prize in Economics
(1975)
NOBEL PRIZE WINNERS

Professor Paul Crutzen
Nobel Prize for Chemistry (1995)
NOBEL PRIZE WINNERS

Professor Thomas C. Schelling
Nobel Prize for Economics (2005)
NOBEL PRIZE WINNERS

Intergovernmental Panel on Climate Change
Nobel Peace Prize (2007)
INTERDISCIPLINARY

- 28% Natural Scientists
- 35% & Engineers
- 37% Social Scientists
- Mathematicians and others
PARTNERS

IIASA collaborates with almost 300 institutions from nearly 40 countries
ENERGY & CLIMATE CHANGE: BUILDING ON PAST SUCCESSES

1976

1981

RAINIS helps cut sulfur dioxide

1994

2000

MESSAGE has helped over 80 countries with energy planning

2010
RESEARCH HIGHLIGHTS
Energy and Climate Change
Highly Published
Global Human Capital: Integrating Education and Population

Wolfgang Lutz$^{1,2,3,*}$ and Samir KC$^{1,2}$

Almost universally, women with higher levels of education have fewer children. Better education is associated with lower mortality, better health, and different migration patterns. Hence, the global population outlook depends greatly on further progress in education, particularly of young women.
Carbon payments for forest conservation would dramatically reduce species extinctions.

Changes in forest cover over the twenty-first century, within presumed REDD-eligible regions.

Between 10 and 25% of 4,514 forest-dependent mammal and amphibian species would become extinct.
A NEW EXPLANATION OF BIODIVERSITY
The take-it-or-leave-it option allows small penalties to overcome social dilemmas

Tatsuya Sasaki*a, Åke Brännströma,b, Ulf Dieckmannsc,d, and Karl Sigmunda,e

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Edited by Kenneth Wachter, University of California, Berkeley, CA, and approved December 2, 2011 (received for review September 15, 2011)

Self-interest frequently causes individuals engaged in joint enterprises to choose actions that are counterproductive to the goals of the group. Social dilemmas can be overcome by positive or negative incentives. Even though an incentive-providing institution may protect a cooperative society from defection by free-riders, it cannot always convert a society of free-riders to cooperation. In the latter case, both norms, cooperation and defection, are stable. To maintain cooperation, both defecting norms should be small and the proportion of cooperators should be high. A society of free-riders is then caught in a social trap and the institution is unable to provide an escape route. Indeed, when free-riding is the norm, the system will turn away from unproductive joint ventures. This leads to the decline of exploitative and the emergence of cooperators. If the incentives are too low, this is followed by the comeback of defectors, in a rock-paper-scissors type of cycle (18, 19) (Fig. 2a). However, even a modest degree of punishment breaks the rock-paper-scissors cycle and allows the establishment of the cooperation, cooperators are also able to survive in the initial population of defectors (Fig. 2e–i). Thus, optimal participation allows a permanent escape from the social trap, controlling this shows that optimal participation has little impact on rewarding systems (Fig. 2b–d).

Methods

Specifically, we apply evolutionary game theory (20) to cultural evolution, based on (a) social learning (i.e., the preferential imitation of more successful strategies) and (b) occasional exploratory steps (motivated as small and rare random perturbations). Because the diversity of public good interactions and sanctioning mechanisms is huge, we first present a fully analytical investigation of a prototypical case (21, 22). We posit a large, well-mixed population of players, time to time, a random sample of a ≈ 2 players is faced with an opportunity to participate in a public good game, at 0 < g < α. We denote by m the number of players willing to participate (0 ≤ m < a) and assume that at least 2 players are required for the game to take place. If so, each of the a players decides whether or not to contribute a fixed amount c > 0, knowing that it will be multiplied by (1−1/m)2. We allow for also one other member of the group, which may instead move to the “Free-riding” state (Fig. 6).

In many species, cooperation has evolved through natural selection. In human societies, it can additionally be promoted through institutions. Institutions may be viewed as proposers to offer incentives that enable humans to overcome social dilemmas, as put forward by Ostrom (1). The threat of punishment or the promise of reward can increase the likelihood that players will cooperate. Institutions can also stabilize cooperative action by assigning players to cooperate by contributing to the public good (Fig. 1a–d). If, on the other hand, the incentive is sufficiently large, it compels all players to cooperate by contributing to the public good (Fig. 1f). It is the range in which the size of the incentive is too small (i.e., it has no effect) and selfish players keep defecting by refraining from contributing to the public good (Fig. 1a). If, on the other hand, the incentive is sufficiently large, it compels all players to cooperate by contributing to the public good (Fig. 1f). 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INEXTRICABLY LINKED

Energy & Climate Change

Food & Water

Poverty & Equity
Global Energy Assessment

Toward a Sustainable Future

Global Energy Assessment
2030 Energy Goals

- Universal Access to Modern Energy
- Double Energy Efficiency Improvement
- Double Renewable Share in Final Energy

Aspirational & Ambitious but Achievable
Global Primary Energy
no CCS, no Nuclear

Energy savings (efficiency, conservation, and behavior)
~40% improvement by 2030
~55% renewables by 2030

Nuclear phase-out (policy)
Oil phase-out (necessary)

Source: Riahi et al, 2012
Energy savings (efficiency, conservation, and behavior)
~40% improvement by 2030
~30% renewables by 2030

Oil phase-out (necessary)

Limited Intermittent REN

Limited Bioenergy

Bio-CCS – “negative CO₂

Source: Riahi et al, 2012
Global Primary Energy

Sub-Saharan Africa

~50% renewables by 2030

Source: Riahi et al, 2012
~50% efficiency and decline of coal by 2030

Source: Riahi et al, 2012
Global Primary Energy

Europe

~30% renewables by 2030

Source: Riahi et al, 2012
Final Energy Transformations

- **Other Low Carbon** (Nuclear, Fossil-CCS)
- **Fossils** (Gas, Oil & Coal)
- **Renewables** (Wind, Solar, Geothermal, Bioenergy)
Universal access is a pre-condition for overcoming poverty and feasible if all stakeholders work together.

Energy transformation will bring multiple co-benefits for health, security, climate change.

Financing requirements are huge but achievable with right and sustained policies.

Towards a more Sustainable Future
SYNERGIES OF MULTIPLE ENERGY OBJECTIVES

Added costs of ES and PH are comparatively low when CC is taken as an entry point.

Integrated Climate-Pollution-Security Policies

“Single minded” approaches for multiple challenges.
GAINS identified 16 key air quality measures that, together with CO₂ mitigation, increase chances to stay below the 2º target

Global temperature 1900–2070

Reference Scenario
IEA World Energy Outlook 2009

CO₂ Measures
IEA 450 ppm scenario 2009

Near-term Measures
IIASA set of 16 measures for CH₄ and black carbon

CO₂ + Near-term Measures

These 16 measures are
– win (for air quality),
– win (for near-term climate change)
– win (for economic development)

Source: Shindell et al., Science (2012), 335/6065:183–189

http://gains.iiasa.ac.at
Only Energy Security  
Only Air Pollution and Health  
Only Climate Change  
All Three Objectives  

Total Global Policy Costs (2010-2030)

Added costs of ES and PH are comparatively low when CC is taken as an entry point.

Source: McCollum, Krey, Riahi, 2012
Global Energy Assessment
INEXTRICABLY LINKED

Energy & Climate Change

Food & Water

Poverty & Equity
FOOD & WATER: BUILDING ON PAST SUCCESSES

Database of Russian forest and land resources


Shrinking Fish
Trans-sectoral and multi-disciplinary systems thinking in water.....
Water - Energy – Environment – Health Nexus

In the U.S. and Europe, 91% and 78% electricity is currently produced by thermoelectric (nuclear and fossil fueled) power plants, which require water resources for cooling.

We found a summer average decrease in capacity of power plants with 6.3-19% in Europe and 4.4-16% in the Southeastern U.S. depending on cooling system type and climate scenario for 2031-2060.

Projected future changes in river discharge

Future period 2071-2100 relative to control period 1971-2000
Future changes in discharge and water temperatures

Relative changes in mean annual river discharge globally
ECHAM5 A2

Discharge change
- < -50 %
- -50 to 25 %
- -25 to 0 %
- 0 to +25 %
- +25 to +50 %
- > +50 %

Water temperature (°C)

- 21°C - salmon tolerance temperature
- 23°C – cooling water limit
- 25°C – WHO and water quality standard

Introduction – Modeling approach – Results – Conclusions
Water – Climate – Poverty – Equity Nexus

Kenya: extreme rainfall variability around mean
rainfall affects growth.... the case of Zimbabwe
Water – Climate - Poverty – Equity - Nexus
Infrastructure gap in water storage

Water storage per person (m3)

- Ethiopia: 43 m3
- South Africa: 746 m3
- Thailand: 1,287 m3
- Laos: 1,406 m3
- China: 2,486 m3
- Brazil: 3,255 m3
- Australia: 4,729 m3
- North America: 6,150 m3
## The cost of water security

<table>
<thead>
<tr>
<th>Country</th>
<th>Additional Storage needed per person (m³)</th>
<th>Storage investments required per person (US$)</th>
<th>Storage Investments Required (US$ Billion)</th>
<th>Period needed at 5% current GDP investment per year (no pop. inc.) (Years)</th>
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</thead>
<tbody>
<tr>
<td>Lesotho</td>
<td>751</td>
<td>939</td>
<td>1.7</td>
<td>44</td>
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<tr>
<td>Namibia</td>
<td>542</td>
<td>678</td>
<td>1.3</td>
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<tr>
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<td>402</td>
<td>503</td>
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<td>Ethiopia</td>
<td>555</td>
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<td>46.2</td>
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<tr>
<td>Kenya</td>
<td>307</td>
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<td>12.1</td>
<td>24</td>
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<tr>
<td>Tanzania</td>
<td>610</td>
<td>763</td>
<td>27.4</td>
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<td>Uganda</td>
<td>511</td>
<td>639</td>
<td>17.9</td>
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<td>Burkina Faso</td>
<td>152</td>
<td>190</td>
<td>2.5</td>
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<tr>
<td>Senegal</td>
<td>683</td>
<td>854</td>
<td>9.9</td>
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<td>Algeria</td>
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<td>299</td>
<td>9.8</td>
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<tr>
<td>Morocco</td>
<td>128</td>
<td>160</td>
<td>5.1</td>
<td>4</td>
</tr>
</tbody>
</table>
Systems Science and Effective Science to Policy Interface

What is needed in order to get out of our “silos”? and

To fully benefit from Systems Approaches?
ACADEMIC TRAINING AND CAPACITY BUILDING

- New paradigms
- New curricula
- New funding architecture
- Revised academic carrier incentives
Political, Societal and Economic Governance

Trans-sectoral (nexus) policies
Trans-sectoral budgeting & investments
Long term policies & investments
Re-definition of governmental subsidies
Revival of trans-boundary regional cooperation

POSITIVE PARADIGMS
NEW PARTNERSHIPS
IIASA NEW INITIATIVES and NETWORKS
YOUNG SCIENTISTS SUMMER PROGRAM (YSSP)
INTERNATIONAL GRADUATE SCHOOL OF EXCELLENCE

- Global network of 35–45 postdoctoral, across-disciplines fellows working at IGSE-affiliated institutions
- Coordinated 5-year program of work on one complex issue
- Issue proposed by IIASA Global Think Tank
- Postdoc group spends 3–4 months per year at IIASA

Target launch: early 2015
SCIENCE-TO-POLICY COURSE FOR SENIOR POLICY MAKERS

- 2–3 week course at IIASA
- 20–25 senior policy makers and business leaders working on complementary aspects of complex problems
- Interactive sessions with researchers from IIASA and the IIASA network
- Goals: consider solutions, refine next round of research questions
- Target launch: Fall 2014
IIASA GLOBAL THINK TANK

- IIASA convenes international leaders from academia, business, governments, civil society and arts/culture to consider complex global issues
- ~25 members: Nobel Prize winners, (former) heads of state, business leaders, (former) NGO leaders, Icons from arts and music, ..
- Target launch: summer 2014 (see IIASA website)
Thank you and welcome soon at IIASA!
THANK YOU

www.iiasa.ac.at