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ORIGINAL ARTICLE

# Providing a decision focus for global systems analysis

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**Abstract** With the globalization of the world's economic, transportation and communication systems, many problems that were once considered local or national have become globalized. Examples are the recent financial crises, energy and food security, global warming, and terrorism. There are two challenges with studying these global problems. First, most research institutions studying global problems have a sectorial focus (e.g., health, energy, food, or water) and, therefore, they are likely to ignore interconnections between sectors. Second, there is a tendency of researchers to emphasize the scientific aspects of their studies and to pay less attention to the policy or decision relevance of the results. Systems analysis has been developed and practiced by several global institutions to overcome the first problem. Decision analysis has been developed to address the second problem and it has been applied in different contexts by many institutions worldwide. This paper advocates a merger of systems analysis and decision analysis to make systems analysis of global problems more relevant for decision making. It begins by identifying some of the most urgent global problems and outlines how systems and decision analysis have been used to address these problems. It then examines three specific global problems and illustrates how a merger decision analysis can provide a decision focus for systems analysis. Throughout the paper, obstacles to the implementation of this approach are discussed. The paper concludes by

During the past decades, the author has been involved with systems analyses of many policy issues on local, national, and global scales. All too often, the author has observed that excellent studies failed to impact important decisions or policies. During his recent term as Director of the International Institute for Applied Systems Analysis (2009–2012), a world leader in global systems analysis, he therefore promoted the notion that systems analysis should become more policy relevant by linking it to specific policy contexts and decision makers. This paper provides some thoughts on how systems analysis can become more decision focused and what obstacles systems analysts face in the process. This article was supported by the International Institute for Applied Systems Analysis.

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arguing that global research institutions should identify and prioritize global problems and find solutions by combining concepts of systems and decision analysis.

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**Mathematics Subject Classification** 91 - game theory, economics, and social science · 93 - systems theory, control

## Introduction

During the past decades, the world has become increasingly interconnected through global transportation and communication networks, international supply chains, and economic and financial dependencies. As a result, many problems that were once thought to be local or national are now becoming increasingly global. Examples are climate change, energy, water and food security, economic crises, and terrorism. This paper focuses on global problems that are of interest to policy makers worldwide because they are shared by many countries and their solutions require international resources and cooperation.

The landscape of these problems has been defined with remarkable consistency by several authorities (World Health Organization 2002; United Nations 2005; Holdren 2008; Beddington 2008; IIASA 2009). While these reports define the landscape of global problems well, they also acknowledge that solutions are hard to find and even harder to implement, because solutions to global problems are dependent on the cooperation of many countries, either through international treaties or through leadership and contributions by selected countries.

Finding solutions to global problems can benefit from formal analysis. Common tools are systems analysis, policy analysis or decision analyses. Systems analysis usually focuses on the "system" that provides the context for a problem, e.g., the energy system, the agricultural system, or the climate system. By modeling the behavior of a system, systems analysis can help to identify important trends and promising options. Policy and decision analysis focus on the decision problem at hand emphasizing the need for analysts to work with decision makers and stakeholders to identify options, analyze their likely impact and evaluate them in the light of multiple conflicting objectives and uncertainty.[1]

The purpose of this paper is to provide guidance on how to improve the decision focus of global systems analyses. The main mechanism is to inject an element of decision analysis into framing a systems analysis and in communicating its results to decision makers. This is not an easy task and parts of this paper will discuss

[1] Policy and decision analysis both aim at supporting decision making. Policy analysis focuses on high-level strategic policies (e.g., strategies to reduce carbon emissions worldwide) and uses cost-benefit or cost-effectiveness analysis as its main tools. Decision analysis includes policy decisions, but also considers more specific decisions (e.g., the specific level of biofuel standards) and it uses a broader range of tools, including risk analysis and multiattribute utility analysis. In the remainder of this paper, we will refer to these decision focused analysis approaches as decision analysis with the understanding that this includes policy analysis as well.

obstacles both on the side of the systems analysts and on the side of the policy makers that contribute to the difficulties. This paper begins with a very broad look at global problems, distinguishing between drivers of changes, problem areas, and the impacts on individuals, society and future generations that problems can cause. For selected problem areas, we then identify in more specific terms:

- The nature of the problem
- The decision makers who can do something about the problem
- The alternatives that they can control
- The objectives that they should pursue

For each problem area, we will also provide examples of ongoing systems analyses that can and should be continued in the spirit of bringing systems analysis closer to decision makers. In the process, we will discuss issues and difficulties with implementing a decision-focused approach within systems analysis.

## Global problems

The United Nations (2005), in its "Millenium Development Goal (MDG)" report, formulated goals for global problems:

- eradicate extreme poverty and hunger,
- achieve universal primary education,
- promote gender equality and empower women,
- reduce childhood mortality,
- improve maternal health,
- combat HIV/AIDS, malaria and other diseases,
- ensure environmental sustainability,
- develop a global partnership for development.

The UN also identified eight specific targets associated with each goal—for example, to halve the proportion of people living on less than $1/day by 2015 (baseline 1990).

**Table 1** Global life-years lost by selected causes

| Causes of death | Global life-years lost (millions) |
|---|---|
| Childhood and maternal malnutrition | 200 |
| High blood pressure and related causes | 150 |
| Unsafe sex | 80 |
| Smoking | 50 |
| Unsafe water | 50 |
| Indoor smoke | 35 |
| Alcohol | 30 |
| Urban air pollution | 6 |
| Global climate change | 5 |

A more specific analysis of the magnitude of several causes of premature deaths was provided by the World Health Organization (see Table 1; WHO 2002; adapted from Holdren 2008).

In his inaugural address as president of the American Association for the Advancement of Science (AAAS), Holdren (2008) presented a similar list of the following global problem areas:

- poverty,
- preventable disease,
- impoverishment of the environment,
- pervasiveness of organized violence,
- oppression of human rights,
- wastage of human potential.

In addition, he mapped out science and technology efforts to improve the human condition in each of these areas.

Beddington, in a presentation to the International Institute for Applied Systems Analysis (2008), had his own list of global issues:

- climate change,
- urbanization,
- population,
- poverty,
- water demand,
- food demand,
- energy demand.

Building on these efforts, the International Institute for Applied Systems Analysis (IIASA), in its strategic plan for the second decade of the millennium (2009), identified the following coupled global problem areas as high priorities for study:

- energy and climate change,
- food and water,
- poverty and equity.

There clearly is substantial overlap among these lists. In addition, as IIASA and others have recognized, many of these problem areas are tightly coupled. For example, energy and climate change are closely connected, as 80 % of greenhouse gas emissions are due to the combustion of fossil fuels (Global Energy Assessment 2012). Similarly, 70–80 % of the global fresh water supply is used for agriculture (UN Water 2013). As IIASA's strategic plan recognized, most interesting problems and their solutions lie at the intersection of multiple problem areas.

The lists above mix, to some extent, causes and effects in the formulations of problems. More specifically, one can distinguish drivers of global change (e.g., increased urbanization), problems caused by these drivers (e.g., increased urban pollution) and the ultimate value relevant impacts (e.g., increased health impacts on the urban population). Table 2 provides a list of drivers of global change, problem areas, and impacts.

**Table 2** Drivers of global change, problem areas, and impacts

| Drivers of change | Problem areas | Impacts |
|---|---|---|
| **Demographic** | **Basic needs** | **Individual** |
| Population growth | Food | Meeting basic needs |
| Education | Water | Health |
| Aging | Housing | Wealth |
| Migration | Energy | Happiness |
| **Socio-economic** | **Health** | **Societal** |
| Economic growth | Diseases | Human rights |
| Economic development | Malnutrition | Democracy |
| Urbanization | Infant Mortality | Peace |
| Globalization | *Obesity* | Security |
| **Socio-technical** | **Inequities** | Equity |
| Technological innovation | Poverty | **Future generations** |
| Energy transformations | Illiteracy | Economic sustainability |
| Nuclear proliferation | Gender inequality | Socio-political sustainability |
| Global warming | Race and ethnic inequality | Ecological sustainability |
| **Political-cultural** | **Crime** | |
| Political transformations | Homicides | |
| Economic transformations | Other violent crimes | |
| Religious movements | Corruption | |
| Environmental movements | **Environment** | |
| | Pollution | |
| | Congestion | |
| | Loss of ecosystems | |
| | **Global risks** | |
| | *Systemic economic risks* | |
| | Technological disasters | |
| | Natural Disasters | |
| | *Climate Change* | |
| | *Epidemics* | |
| | *Biodiversity loss* | |
| | **Conflicts and wars** | |
| | *Terrorism* | |
| | Genocide | |
| | Regional conflicts | |
| | Nuclear conflicts | |

Some of the problem areas in Table 2 have existed for many decades and are unlikely to disappear soon (e.g., malnutrition, infant mortality, illiteracy, corruption, pollution, natural disasters and regional conflicts). Others are relatively new and are due to the increased interconnectivity of the world (e.g., systemic economic risks, climate change, biodiversity loss) or they emerged as new phenomena on the global scene (e.g. global epidemics, terrorism, and obesity).

It is also noteworthy that some of the problems have shifted over the past decades. In the 1970s, there was substantial concern with providing basic resources for a growing population, including some very dire projections about the consequences of a population "explosion". More recent research suggests that the world population will level off at about 9 billion people by the mid to late century (Lutz et al. 2001), suggesting that there are sufficient resources to supply the energy, food, and water for the world population for many years to come. There are, nevertheless, important emerging issues of equitable distribution of resources and of the long-term sustainability of providing for future generations.

## Decision-focused systems analysis

*Systems analysis* provides a structured approach to think about global problems and a set of quantitative models and tools to analyze problems, develop options, and to find solutions. An example of a global systems analysis is the Global Energy Assessment (2012) that describes the global energy system, its connection to important societal issues, and the need for and consequences of possible interventions to transform the energy system. "Systems thinking" starts with the notion that systems and problems should be conceived broadly and holistically, that most important problems are embedded in complex and large scale systems, and that technical, human, and social aspects of the systems are often closely interlinked. The quantitative models and tools of systems analysis include models of dynamic systems, optimization and simulation, probabilistic analyses, and large data set processing and visualization tools. The evolution of computer technology has opened new opportunities to apply these models and tools to an increasing range of complex problems and systems. The main purpose of systems analysis is to describe the behavior of complex systems and to predict the impacts of interventions on important features of the system that affect human and societal well-being.

Much of systems analysis is based on science and does not have a specific decision or policy focus. In fact, there often is a stress between conducting scientific studies vs. engaging in research that is directly relevant for policy or decision making. Scientific organizations like the Intergovernmental Panel on Climate Change (IPCC), for example, emphasize their scientific objectivity and independence from political influence. In addition, systems analysts tend to receive stronger peer support from scientific research than from applied, policy-focused research. Thus, systems analysis has often failed to bridge the gap between science and policy.

Policy and decision analysis are two disciplines which were intended to bridge this gap without giving up scientific soundness and integrity. They were developed in the same spirit and with the same goals: To support decision makers to make better decisions in the face of uncertainty, multiple objectives, conflicting stakeholder interests, and complex environments. In the following, we will refer to these disciplines as decision-focused analysis or simply decision analysis, with the understanding that this covers a broad range of models, methods, and tools.

*Decision analysis* starts with a problem and decision focus. It involves direct interactions with decision makers and stakeholders to properly frame the problem, identify the alternatives (policies, decision options) and develop objectives by which alternatives are to be evaluated. Decision analysis involves a wide range of quantitative models and tools, including cost-benefit analysis, cost-effectiveness analysis, multiattribute utility analysis, risk analysis, decision tree analysis, game theory, Bayesian networks, probabilistic simulation and more. Decision analysis also uses systems analysis models and techniques and there is, in fact, a fair amount of overlap between the sets of models and tools used in decision and systems analysis. Decision analysts usually work very closely with decision makers often with many interactions and iterations starting from the problem formulation, to the identification of decision alternatives and objectives, through the analysis process, to the interpretation and communication of the findings and the ultimate implementation.

Over many years of applying decision analysis to complex problems, the following eight-step process has proven to be useful (see, for example, von Winterfeldt and Edwards 1986; French 1988; Belton and Stewart 2002):

1. identify the problem or opportunity,
2. identify the decision maker(s) and stakeholders who have an interest in and/or are affected by the decision,
3. identify the alternatives (decisions or policy options) under the control of the decision maker,
4. identify the decision maker's and other stakeholders' objectives and criteria to compare alternatives,
5. assess how the alternatives perform with respect to the objectives and criteria,
6. assess how risks and uncertainties affect the performance of alternatives on the criteria,
7. assess the tradeoffs among criteria,
8. evaluate the alternative using the information collected in 1–7 and conduct sensitivity analyses to inform decision makers and stakeholders.

Steps 1–4 are usually referred to as the problem structuring steps (von Winterfeldt and Fasolo 2009). Steps 5 and 6 often include extensive systems analysis modeling to estimate the costs, benefits, and other impacts of the alternatives under consideration, including associated risks and uncertainties. (e.g., Bedford and Cooke 2001). Step 7 is crucial to evaluate alternatives across multiple objectives and criteria. Identifying the tradeoffs between criteria involves market considerations as well as an assessment of the willingness-to-exchange between non-market criteria. While informed by the markets and willingness-to-pay studies, most decision analysts assign the ultimate responsibility to defining the tradeoffs to the decision maker(s). Together with an assessment of the relative value or utility changes within each criterion, these tradeoffs allow the construction of a value or utility function (see Keeney and Raiffa 1976; Keeney and von Winterfeldt 2007). Combining the results of all steps 1–7, one can obtain an overall evaluation and ranking of the decision alternatives (step 8) as well as any display and analysis of the performance of the alternatives using variations of inputs variables in a sensitivity analysis.

A simple version of decision analysis is a cost-benefit analysis. More sophisticated versions can involve a complete multi-criteria decision analysis and/or a detailed uncertainty analysis. Whatever method one uses, the key idea is to gain insights into the advantages and disadvantages of the decision alternative and to inform the decision maker, not to prescribe a specific decision or to advocate a particular recommendation. The ultimate goal of decision analysis is to provide insights and clarity for making the decision, not to make the decision.

The entry point of a decision analysis can be the recognition that a driver of change causes problems that might be solved by changing the driver's trajectory. For example, when over-population was a problem in India and China, policies to reduce birth rates were being contemplated, considering alternatives as diverse as education campaigns to encourage voluntary birth control, distribution of condoms, or restrictions on the maximum number of children through economic sanctions. One can also start with options to manage impacts. For example, knowing that many individuals suffer health effects from malaria infections (impact), decision analysis can be used to analyze options to reduce malaria deaths. In most cases, though, decision analysis starts with a problem or an opportunity. For global problems, we focus, therefore, on the middle column of Table 2.

There are many examples of decision analyses in environmental, technology, and risk problems listed in Table 2 (for an overview, see Keefer et al. 2007). In the climate change area, for example, the Center for Climate and Energy Decision Making at Carnegie Mellon University (CCEDM 2013) has studied the policies to reduce the climate impacts of energy options. IIASA (2013) has studied the feasibility and desirability of transformations of the world energy system (Global Energy Assessment 2012). Resources for the Future (RFF 2013) has conducted many cost-benefit analyses of environmental policies at all spatial levels. The Electric Power Research Institute (EPRI 2013) has studied options to reduce pollution from energy sources over many years. The Center for Risk and Economic Analysis of Terrorism Events (CREATE 2013) at the University of Southern California has studied the effectiveness of measures to counter terrorism involving nuclear, radiological, and chemical attacks.

By making decision analysis an integral part of systems analysis, we can increase the likelihood that systems analysis findings are used and make a difference in the real world. There clearly are many other opportunities to apply decision analysis to the problem areas listed in Table 2. For example, in the climate change area, interesting policy issues involve the use of biofuels and the tradeoff between agricultural use of land vs. energy production. Another important issue is how to avoid the two million premature deaths that are created annually by indoor smoke inhalation from traditional cooking on wood and biomass fires. In the natural disaster area, comparing options to mitigate against disasters, improve response and recovery, and innovative insurance schemes are worth exploring.

Including decision analysis in systems analysis requires the involvement of decision makers throughout the analysis process, especially in the problem structuring steps 1–4. All too often decision and systems analyses are conducted with limited interactions with the decision makers (see left part of Fig. 1, adapted

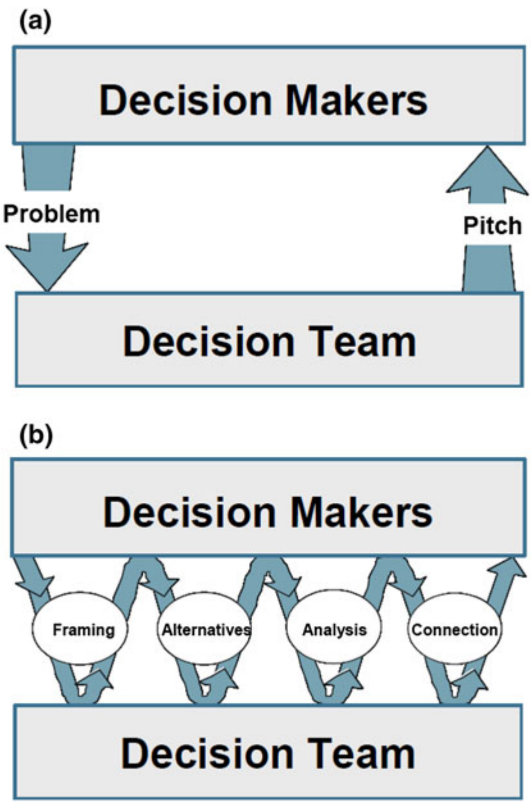


**Fig. 1** Limited (**a**) and multiple interactions (**b**) between a decision analysis team and decision makers (adapted from Spetzler 2007)

from Spetzler, 2007). As decision analysis has evolved, it has proven useful to have multiple interactions with decision makers, as shown in the right part of Fig. 1.

While involvement of decision makers is crucial for the success, it is also important to interact with stakeholders—those interested in and/or affected by the decision. Stakeholders can bring to the table their own concerns and ideas for options as well as expertise that can enhance the decision makers' perspective and broaden the analysis framework. This is not an easy task. It requires an active interest by and access to decision makers and a willingness and ability of the systems analysts to adapt to the decision frame seen from the perspective of the decision maker—especially the alternatives, objectives, and time frame for decision making. It also requires a continued interaction of the analyst and the decision makers and stakeholders throughout the analysis process from problem framing to implementation of the preferred solution.

There are many obstacles along the way, some due to the decision maker concerns, and some due to the analysts themselves. On the decision maker's side, it is not uncommon to find a concern that a decision analysis may reduce his or her flexibility in making the ultimate decision. This is especially true when decision makers have hidden agendas that lead them to preferences that they do not want to reveal. Decision makers also often have time frames regarding the consequences of their decisions that are much shorter than those considered by the analysts. In addition, it is almost always the case that decision makers want to act quickly, usually within days, sometimes within months, rarely with much longer lead time.

Systems analysts, in contrast, almost always ask for more time to research the issue at hand. Being useful is often less of a concern than being accurate and to survive peer scrutiny of their studies. While most systems analysts have experience with multidisciplinary teams and understand the notion of problem solving, they still feel most at home in their own area of expertise. In addition, interacting with decision makers and stakeholder, many of whom are not technically trained, is difficult for academically oriented systems analysts.

It takes a lot of technical and social skill and experience to overcome these obstacles. Systems analysts usually have ample technical skills. Many decision analysts have technical skills and some also have the social skills to interact with decision makers and stakeholders. As a result, decision and systems analysts, working together, can overcome many of these obstacles.

## Example decision frameworks for three global problems

### Indoor open cooking fires cause premature deaths

#### *The problem*

Approximately, 2 billion people are using open fires fueled by wood and biomass for cooking and to provide light at night. These fires are often indoors with poor ventilation and exhausts. As a result, families, especially women and children are exposed to large amounts of indoor smoke. According to some estimates, 2 million premature deaths occur annually worldwide due to this problem, twice the deaths attributed to malaria (Pachauri 2010; Foell et al. 2011; Frank et al. 2012).

*Decision makers.* One would think that with the estimated annual death of 2 million people, this problem would be a priority of many international agencies. On the whole, this is not the case, perhaps because the problem "falls between the cracks" of institutions committed to more narrowly formulated problems (infectious diseases vs. pollution vs. energy poverty).

Examples of institutions that should be concerned with this problem are the World Health Organization (WHO), the United Nations Industrial Development Organization (UNIDO), various aid agencies across the globe, and, of course, the governments of the countries that suffer from these problems, especially in sub-Saharan Africa and India.

#### *Alternatives*

While the health effects provide the initial motivation to study this problem, it lies at the intersection of a lack of clean energy, poverty, and health. It has a regional pollution and a global climate change component, as some solutions to the health problem also reduce pollution and $CO_2$ emissions. Solutions also help with economic development, education, and improving the life of women and children (women are usually the ones who collect the wood and biomass and they have no time for other educational or economic pursuits).

Possible solutions (alternatives) to this problem are

- improving ventilation systems,
- providing a centralized electricity supply,
- providing de-centralized electricity supplies (e.g., diesel generators for villages),
- providing decentralized gas supply for gas stoves and gas lamps.

*Objectives*

Possible objectives are

- reduce health effects,
- reduce local and regional pollution,
- reduce $CO_2$ emissions,
- reasonable cost.

*An example*

A useful policy or decision analysis could be conducted in collaboration with a national or regional government agency in sub-Saharan Africa or India (for initial work, see Pachauri 2010; Frank et al. 2012). The analysis would first establish the scope of the problem in the region—i.e., how many open fire cooking facilities exist, how many people are affected, what level of smoke pollution exists in these cases, etc. It would then examine some of the regional alternatives (electrification using various possible sources and distribution networks; decentralized distribution of gas stoves with a mechanism for the sale and distribution of gas; and improvement of ventilation). An important part of this analysis would be concerned with estimating the technology penetration in households that have traditionally relied on open fire cooking and lightening. This may require some pilot studies and surveys. Ultimately, the purpose would be to identify the alternatives that save the most lives and are most cost-effective in doing so.

Biofuel production competes with food production for land use

*The problem*

The dependence of many nations on imported oil, the associated trade balance and security issues, and the high $CO_2$ emissions of gasoline powered engines have made the production and use of biofuels an attractive alternative to conventional oil. Biofuels are based on regular agricultural products like sugarcane, corn, palm oil or other agricultural products. For example, Brazil has a successful program of producing ethanol from sugarcane and Malaysia is aggressively promoting the production of palm oil. Because growing agricultural products creates a $CO_2$ sink, burning biofuels in energy production is considered to be carbon neutral. The problem is that biofuel production can compete with regular agricultural food production (Havlik et al. 2011). Some extreme critics even suggest that biofuel production causes worldwide hunger (Fischer et al. 2009).

*Decision makers*

Many countries, institutions, and agencies are making decisions that directly or indirectly affect the development and production of biofuels. Brazil's government, for example, decided in the 1980s to launch an aggressive ethanol production program and has followed this through with various R&D incentives and regulations. The European Union and other countries have set biofuel standards for cars. The United Nation's initiative "Sustainable Energy for All (SE4All)" is developing standards for renewable energy, some of which has to come from biofuels. On the food side, agencies like the UN Food and Agriculture Organization (FAO) in Rome and national agricultural agencies should be involved in the decision making process. Nevertheless, there currently is no agency that is specifically responsible for managing the conflict between biofuel production and food production.

*Alternatives*

While the competition for agricultural land is very real, solutions to avoid the displacement of food production exist when producing biofuels. One way to do this is to use plants and land that otherwise would not be useful for food production. An often cited example (even by critics like Fischer et al. 2009) is to grow sugar cane to produce ethanol in subtropical climates like Brazil. Other alternatives are to restrict biofuel production to land not currently used for food production or to restrict biofuel production to the so-called "second generation" technologies (using biomass, grasslands, and wood chips).

*Objectives*

The problem is characterized by two conflicting objectives: Providing energy security vs. providing food. A more detailed look at the objectives suggests the following:

- reducing dependence on oil imports,
- reducing volatility of fuel prices,
- minimizing impacts on food production,
- minimizing environmental impacts,
- minimizing $CO_2$ emissions.

*An example*

An example policy and decision analysis could be conducted by examining the impacts of regional biofuel for gasoline used in automobiles in Europe (see, e.g., Frank et al., 2012). The analysis would be targeted to support regulatory agencies in Europe in the task of developing a reasonable set of biofuel regulations and standards. A significant amount of analysis would have to be devoted to the amount of biofuels required for each standard or regulation and the sources of these fuels. Other alternatives that would need to be considered are whether the biofuels can be produced from local crops in Europe and, if so, what regulations should be imposed, if any on preventing the displacement of agricultural land for food production. The impact of the possible displacement of food production should be examined in terms of the effects on prices and potential increase of availability of food worldwide. The alternatives should then be evaluated against a broad set of objectives, including energy security, $CO_2$ reduction, impacts on food supply, etc.

Climate change can cause groundwater depletion

*The problem*

Increase in global temperatures will have significant impacts on the global climate, which will, in turn, affect the water supply in many arid and semi-arid areas. In particular, there is a scientific consensus that many of the currently "wet" areas will experience more rainfall, while other, currently "dry" areas will experience longer periods of droughts. This, in turn, can lead to water supply shortages in arid and semi-arid areas, including Africa, India, China, and even in highly developed regions like the South-Western USA.

Specifically, many local and regional water authorities have to plan in the face of significant uncertainties about global climate change and its impact on local rainfall patterns. Some regions are now developing contingency plans and exploring adaptive policies that consider tightening regulations on water use as knowledge about the effects of climate change becomes available (see Gober and Kirkwood 2010; Gober et al. 2010).

*Decision makers*

Decision making on this issue occurs at all levels, from the global to the multi-national, to the regional and local. Global decisions concern policies on the reduction of greenhouse gas emissions, for example, through UN-initiated treaties. The Kyoto Protocol and subsequent UNFCC conventions provide examples of both the successes and the failures of the UN decision making bodies to develop binding agreements on greenhouse gas emissions.

At the multi-national level, many river basins and groundwater aquifers are shared between countries and they require shared solutions. Even without the complicating issue of climate change, many of the countries sharing the same water resources have already have developed institutions to regulate the water use and these institutions can be used to address this additional threat. The most effective mechanisms to control water use in the face of climate change uncertainty are at the regional and local levels. For example, the Arizona Water Authority has oversight over all water resources in its region and it is examining options for managing agricultural, industrial and private water consumption, considering both short-term climate variability and long-term climate change.

*Alternatives*

At the global level, the alternatives are national allocations of greenhouse gas emission targets. So far there has been very little progress in that regard. At the multi-national level, the alternatives are treaties on water use, which can be very complex and intricate, involving primarily withdrawal rates and water pollution issues. At the regional and local levels, the alternatives refer to surface and ground water withdrawal allocations as well as to voluntary and mandatory restrictions on water use for agricultural, industry, and household purposes.

*Objectives*

At the global level, the objectives are very complex, including the reductions of the negative impacts of climate change, the impacts on the economies of the participating countries, equity and fairness, and others. At the multi-country river and groundwater management level, the objectives are similar to those in any integrated water management planning agency, including provision of water for agricultural benefit, energy (if applicable), industry, and households, the cost of water management options, the local and regional economic impacts, and equity and fairness.

*An example*

Many regional water authorities in the semi-arid areas are now considering strategies to manage the groundwater supply in the light of potential reduction in rainfall due to climate change. As the scenarios about the severity of climate change impacts on arid and semi-arid areas vary, these strategies have to be adaptive to the evolving knowledge about climate change scenarios (for good examples, see Gober and Kirkwood 2010; Gober et al. 2010). Decision and systems analysis can support this strategic process by developing adaptive decisions and adjustments, as more is learned about the impacts of climate change, population growth, agricultural use, and other factors affecting the climate change and groundwater supply. Within a broader context of an integrated water resource management approach, strategic alternatives would be defined that can range from initiating stricter control now, to a "wait and see" strategy, to an adaptive strategy that responds to evolving information. The strategies would be evaluated against objectives including maintaining the groundwater level for future supply, water providing benefits for agriculture and drinking purposes, costs of the strategies, etc. An important part of this analysis would be an uncertainty analysis regarding the evolution of climate change scenarios.

## Thoughts on a global systems and decision analysis agenda for the next decade

The main point of this paper is that systems analysis can be made more relevant for decision making by using the principles and techniques of policy and decision analysis as an integral part of systems analysis. In particular, going through the steps of decision analysis described in "Decision-focused systems analysis" will provide an analysis framework that is more likely to be useful for decision making. Incorporating decision analysis in systems analysis does not obviate the need for sound science and objective analysis of all the facts and uncertainties. Instead, systems analysis and decision analysis can enhance each other substantially.

Systems and decision analysts cannot tackle all of the problems identified in Table 2. A challenge, therefore, is to select the problems that are most promising, in the sense that analyses are most likely to improve human well-being. This is a meta-problem that also deserves some analysis. For example, it would be useful to prioritize problem areas in terms of their importance (lives at risk, economic impacts, etc.) and in terms of the possible impacts of an analysis in terms of affecting decision than can result in reducing the risks and negative impacts.

The International Institute for Applied Systems Analysis conducted a strategic planning effort to identify the problems that its member countries and staff considered most promising to study (IIASA 2009). In the strategic plan deliberations, IIASA used the following criteria for selecting problem areas:

- importance of the problem area to member countries,
- available resources at IIASA to tackle the problem area,
- likely benefits of using systems analysis on this problem area.

As a result, IIASA identified three problem areas: Energy and climate change; food and water; and poverty and equity. It also gave priority to studying three drivers of change: Population, technology, and economic development.

Once the general problem areas are selected, specific projects have to be selected that show great promise. At IIASA, for example, one such project is on energy poverty, which addresses, among other things, the problem of premature deaths due to indoor smoke inhalation. Another project involved the negotiations about greenhouse gas reductions in terms of the cost-effectiveness for different countries.

More generally, any institution interested in global problems should make a deliberate effort to identify the problem areas that it could potentially study, given its capabilities, select a few that are worthy of study using criteria consistent with its charter, and develop signature projects that are likely to make a real difference through systems, policy and decision analysis.

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