Integrated Assessment of Global and Regional Changes – A Bayesian Expert Judgment Elicitation Approach

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Abstract The academic world witnesses today a strong trend of fragmentation and specialization. It is not enough to say that one is a specialist in limnology, nor in eutrophication or in bluegreen algal blooms, but better so, e.g., in hepatotoxins produced by bluegreen algae that form mass outbreaks in eutrophicated lakes of polyhumic nature. This is a very natural inclination, being as well necessary in many ways one can easily argue. However, the tendency faced by those involved in policy-making and management of natural resources, social issues, the environment, and so on, is just the opposite in many ways. With the character of problem-solving and policy-making when working with global and regional changes, interdisciplinary comprehension is substantial—in a sharply augmenting manner—for reaching overall views and visions over the highly fragmented, mosaic-like scientific knowledge. It is indispensable to address questions such as what is known, uncertain and unknown, what would be the value of new information on the myriad of different details of the entity, how things are interconnected in large perspectives—in space, time, and over disciplines—and where the key points, risks, and policy handles really lie. Along with the recognition of the problematique due to the two above-mentioned tendencies, the quest for integrative approaches that help make scientists and policy-makers to communicate better has been here for a while, but the development work lies far behind the needs. This paper presents a Bayesian network approach to expert judgment elicitation and analysis. It has been developed for integrative studies within complex, environmental, social, and natural resources management problems. Experience from climatic change impact assessment on watersheds, and from the interconnections of global urbanization, water, land, poverty and available policy options is summarized.

1. INTRODUCTION

Global and regional changes—related to the climate, ecology, human demography, and societies—are issues that cross several decades and are characterized by extreme complexities and uncertainties. The high level of uncertainty involved in the scientific analyses, in addition to the complexity that obligates interdisciplinary research, call for integrated studies and analytical approaches that address these features. This constitutes a great challenge to scientific community. Many of these same characteristics are also very evident in policy making concerning the abatement of the potentially most detrimental and serious problems associated, and when adapting the way in which society deals with them. This must all be done on the basis of the best knowledge available.

A high number of driving forces, impacts, and policy tools must be taken into consideration. They constitute a complicated network of interconnections and interdependencies (Figure 1). The present mainstream methodology, however, is dominated by deterministic approaches, which tend to allow discipline-specific, mechanistic studies with limited appreciation to the vast uncertainties and complex, interdisciplinary interconnections between nature, technology, and society, as well as the involvement of different stakeholders.

For planners and policy-makers, it is imperative to address questions such as what is known, uncertain, unknown; what is the value of new information on the myriad of details, how things are interconnected in large perspectives—in space, time, and over disciplines—and where the key points, risks, and policy handles really lie. Conceivable outcomes are severely handicapped without a judgment, expectancy, ranking or estimate of their probabilities, by indicating which outcome is more probable than the another. Policy related studies should be transparent, unambiguous, analytical, and falsifiable. These are the basic requirements of a clear responsibility allocation and political acceptability, providing also the ground for testing, merging, and accumulation of scientific knowledge that can then be used in policy processes.

The quest for integrative approaches that help policy-makers and scientists communicate better has been here for a while (Falkenmark & Lindh 1976, Biswas 1983, Postel 1992, Somlyódy 1995, Somlyódy et al. 1997), but the methodological development work lies far behind the needs. In contrast to most contemporary approaches, this study uses an expert-judgment based approach. One argument for this is that in complex problem solving, humans should be supported to make use of multi-directional, associative thinking (Rowe & Boulgarides 1983, Rowe & Watkins 1992). However, based on educational paradigms, typically only one-way, logical thinking is supported, although its major power is in the analysis of small-scale phenomena and issues.

During an expert judgment process an observer interprets a situation by naming objects (system's states) and assuming associations (causalities) between them. When considering an object in this context, he sees it simultaneously as a single unit and as a detail in interaction with the remaining context; these two are not always mutually consistent. The Bayesian expert judgment elicitation approach proposed uses belief network techniques (Pearl 1988, Varis 1994, 1995), and produces a network model, which allows a probabilistic, integrative analysis of the problem, and provides a shared platform for a learning process on complex problems.

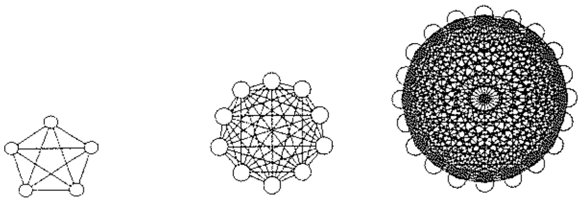

Figure 1. The number of interconnections grows rapidly as the complexity of the systems increases

2. THE BAYESIAN ELICITATION APPROACH

The starting point is a rating sheet that includes the most relevant attributes for the problem under study and a set of outcomes describing possible future development of the attributes. For each attribute, a discrete probability distribution is assessed by the expert(s), describing the expected change in the respective attribute. Thereafter, using a cross-impact matrix, the expert(s) judge(s) the interdependencies between each pair of attributes. A scale from -1 to 1 is used, in which -1 represents complete negative interdependency, 0 represents no interdependency, and 1 complete positive interdependency (Eq. 1). It implies how large a proportion of the attribute variance is explained by the variance of the conditioning variable, including the causal interpretation of the direction of the influence. Accordingly, the sum of the absolute values of all the link strengths affecting an attribute may not exceed 1. These interdependency parameters (link strengths) are given in 2 directions, from attribute A to attribute B, and v.v.

The probability distributions and link strengths are connected to a Bayesian belief network, which updates the expert-inserted prior distribution for each attribute using the information from other parts of the net; i.e. probability distributions in other attributes and the interdependencies between each node pair. The updated probability distribution, the posterior, should not diverge too greatly from the prior. If it does, as often turns out, it indicates the presence of inconsistency in the assessment. 3 sources of inconsistency exist: the terminology used is not unambiguous, resulting in possible misunderstandings and unclear definitions, e.g., in time scales; the model structure is problematic; and the expert is inconsistent. The last one implies that the expert cannot be consistent in assessing all the attributes and their interactions.

2.1 The Assessment Protocol

The assessment protocol includes the following steps.

1 Definition of the impact matrix. In many cases, an impact matrix is available or can be derived from the assessment guidelines or other similar sources. If it is not available, the preparation of these sheets requires a careful analysis and a plenty of literature review.
1.1 Select the relevant variables and structure them semantically or functionally.
1.2 Select the number and (either numerical or linguistic) values for the outcomes. For each node (attribute) the number must be the same.

2 Assessment
2.1 Assess prior probabilities for each outcome and node.
2.2 Assess links between each node pair in 2 directions.

3 Evaluation
3.1 The posterior distributions indicate the priorities.
3.2 The differences between prior and posterior distributions indicate the presence of inconsistencies in the assessed quantities.
3.3 Optional adjustment of the matrix to be consistent.
3.4 Optional sensitivity studies to links (causalities) and to prior distributions (states of the system).

2.2 Belief Networks

Belief networks belong to the Bayesian family of computational techniques that has emerged from artificial intelligence research. Characteristic to them—belief networks, causal networks, Bayesian networks, qualitative Markov networks, influence diagrams, and constraint networks—is the principle of networking nodes (here *attributes*) representing conditional, locally updated probabilities (Horwitz et al. 1988, Pearl 1988, Shafer 1990, Szolovits & Pauker 1993). The local updating principle allows construction of large, densely coupled networks without excessive growth in computation. The networks can be constructed to operate interactively and on line. Recently, they have spread to many application areas, including resource and environmental management.

2.3 Computational Details

The mathematics of the approach are based on the generalized belief network methodology by Varis (1995). It is extended from the approach by Pearl (1988), and allows varied ways to perform integrated analyses (Figure 2). More details of the methodology itself and its potential applicability in environmental and resource management modeling are given by Varis (1995, 1997).

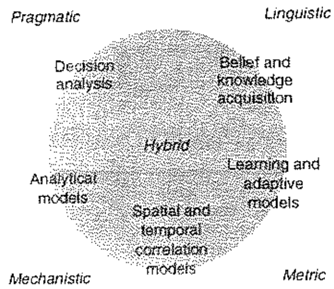

Figure 2. Belief networks allow hybrid modeling. The generalized belief network approach (Varis 1995) allows the combined use of several, methodological and paradigmatic (italics) facets often seen as being far from one another.

A belief network consists of nodes that can be arbitrarily connected with links. Prior probabilities assigned to the outcomes are updated with information linked from other parts of the net, yielding the posterior probability distributions. Those are calculated using 2 independent likelihood messages, as the product of them and the prior probability. The properties of nodes, links, and networks relevant to the elicitation approach are as follows.

Each *node i* in a network contains

- A vector of possible (discrete) outcomes $\mathbf{y}_i$ that are here defined as inputs (from *Step 1.2*).
- An evidence vector $\mathbf{e}_i$, with probabilities $e_1,...,e_k$ assigned to k outcomes (from *Step 2.1*).
- A posterior probability distribution $\mathbf{Bel}_i$ (analyzed in the Evaluation phase, particularly in *Step 3.1*).

The prior probabilities assigned to the outcomes are updated with information linked from other parts of the network, yielding the posterior probability distribution.

A *link* transfers information from one node to another. It is defined as the link matrix $\mathbf{M}_{i|j}$ between two variables i and j, denoting the conditional probability of i given j. In the simplest case of a unidirectional chain, $\mathbf{M}_{i|j}$ equals a Markov chain state transition matrix.

It is practical to give the strength of each link using a parameter (*Step* 2.2) instead of inserting values for each matrix element. The distribution of i should preserve the moments of the distribution of j, expected value, skewness, kurtosis, but not variance. The following approach fulfills these requirements. Define a link strength parameter $\eta_{j|i} \in [-1, 1]$, $i \neq j$ to be used as an input. A symmetric, $k \times k$ link matrix $\mathbf{M}_{j|i}$ is constructed as its function. For $\eta \geq 0$, the diagonal (Eq. 1a) and off-diagonal (Eq. 1b) elements of $\mathbf{M}_{j|i}$ are obtained by

$$m_{q,r} = \frac{1}{k} + \eta\left(1 - \frac{1}{k}\right) \quad , q = r = 1, \ldots, k \quad (1a)$$

$$m_{q,r} = \frac{1}{k-1}\left[1 - \frac{1}{k} - \eta\left(1 - \frac{1}{k}\right)\right], \quad q \neq r \quad (1b)$$

For $\eta < 0$,

$$m_{q,r} = \frac{1}{k} + \eta\left(1 - \frac{1}{k}\right) \quad (1c)$$

$$m_{q,r} = \frac{1}{k-1}\left[1 - \frac{1}{k} - \eta\left(1 - \frac{1}{k}\right)\right], \quad q \neq k - r \quad (1d)$$

Network Propagation. Two independent likelihood messages (π and λ messages) are computed. The updated belief is obtained as the convolution product of these messages and the prior belief. The nodes are linked with link matrices that can be direction-specific. This approach does not update messages in cases where the propagation direction is changed. Therefore, the ordering of the nodes is essential. Computationally, the two propagation directions are symmetric.

When propagating the π messages, all messages coming to a node j from node i are denoted by $\mathbf{p}_{j|i}$ and messages leaving node i are denoted by π_i. For any node j, preconditioned by any node i ($i < j$):

$$\mathbf{p}_{j|i} = \mathbf{M}_{j|i}\, \pi_i \quad (2)$$

The elements of the likelihood vectors $\mathbf{p}_{j|i}$ and π_i are:

$$\pi_i = \begin{bmatrix} \pi_i^1 \\ \pi_i^2 \\ \pi_i^3 \end{bmatrix} \quad \text{and} \quad \mathbf{p}_i = \begin{bmatrix} p_{j|i}^1 \\ p_{j|i}^2 \\ p_{j|i}^3 \end{bmatrix} \quad (3)$$

For elements r, the π_i^r message is the scaled vector product (joint distribution) of the message $\pi^r_{i|1..i-1}$ and $\mathbf{e}_i^r$.

$$\pi_i^r = \pi_{i|1..i}^r = \alpha e_i^r \pi_{i|1..i-1}^r \quad (4)$$

where α is a scaling constant, scaling the sum of the k vector elements of π_i to unity. The incoming message $\pi_{i|1..i-1}$ is the joint distribution of all the messages, $\mathbf{p}_{i|1}$ to $\mathbf{p}_{i|i-1}$, from the node's $i-1$ predecessors:

$$\pi_{i|1..i-1}^r = \prod_{k=1}^{i-1} p_{i|k}^r \quad (5)$$

Starting from the first node, the $\mathbf{p}_{1|0} = \mathbf{1}$ and $\pi_1 = \mathbf{e}_1$, $\mathbf{p}_{2|0.1} = \mathbf{M}_{2|1}\pi_1$, and so on.

The direction is reverse in the λ messages. The rest is computationally similar. All messages coming to node i from node j are denoted by $\mathbf{l}_{i|j}$ and messages leaving the node j are denoted by λ_j. For node i, preconditioned by node j, with $i < j$

$$\mathbf{l}_{i|j} = \mathbf{M}_{i|j}\, \lambda_j \quad (6)$$

The λ_j message is the joint distribution of the message $\lambda_{j|j+1..n}$ and the evidence $\mathbf{e}_j$.

$$\lambda_j^r = \lambda_{j|j..n}^r = \beta e_j^r \lambda_{j|j+1..n}^r \quad (7)$$

where β is a scaling constant. The incoming message $\lambda_{j|j+1..n}$ is a convolution of all the messages, $\mathbf{l}_{j|j+1}$ to $\mathbf{l}_{j|n}$, from the node's $n - j$ successors:

$$\lambda_{j|j+1..n}^r = \prod_{k=j+1}^{n} l_{k|j}^r \quad (8)$$

For each node j, the posterior belief distributions $\mathbf{Bel}_j$ can now be calculated on the basis of the prior distribution $\mathbf{e}_j$, updating it with the information from the sub-network above $\pi_{j|1..j-1}$ and below $\lambda_{j|j+1..n}$, the node:

$$Bel_j^r = \gamma \pi_{j|1..j-1}^r e_j^r \lambda_{j|j+1..n}^r \quad (9a)$$

where γ is a scaling constant. The same equation can be written as a vector product of the two likelihood messages and the evidence vector:

$$\mathbf{Bel}_j = \gamma\, \pi_{j|1..j-1} \bullet \mathbf{e}_j \bullet \lambda_{j|j+1..n} \quad (9b)$$

Consistency iteration. In case it is preferred to have fully consistent results (*Step* 3.3), the following iteration scheme can be used. It should be performed following the ordering of the nodes. Often it is necessary to go the network through more than once. For a case with 3 outcomes, the following equations can be used:

$$\mu_i^* = \mu_i + a \cdot cv_i \cdot \left(Bel_y^1 - Bel_y^3\right)\left|Bel_y^1 - Bel_y^3\right| \quad (10a)$$

$$\eta_i^* = \eta_i + b \cdot \left(Bel_y^2 - 1/k\right) \quad (10b)$$

where a and b are convergence parameters, Bel^r_y is the posterior probability of outcome r, μ_i is the mean of the prior distribution of node i (a control variable), η_i is the estimated link strength, and * refers to an updated iteration value.

3. CLIMATE CHANGE IMPACT ASSESSMENT

Climate change impact assessment is a task with many aspects, with several methodological and philosophical problems (Laurmann 1991), and with extreme uncertainties. Even the direction of changes, not to talk about quantitative estimates, often remains obscure, when analyzing a specific location or region. For instance, for Northern Europe, the Global Circulation Model (GCM) results are subjected to a very high inconsistencies. Räisänen (1994) found that in winter temperatures for Finland, the discrepancies between simulation results of different GCMs can exceed 10°C, which indeed highlights the importance of expert's role in judging the scenarios taken as the basis of policy recommendations.

Climate change research is a field in which individuals from various disciplines must solve problems together. No education provides expertise in all fields of the natural, technical, social, and management sciences required for policy advice. Holistic analyses are needed from various components of ecological and social systems to ease the communication between specialists in different but often related fields, and to assist in focusing on the most essential impacts and problems.

Climate changes can affect water quality and related resource management issues in many different ways due to high diversity of natural and man-made water bodies, high diversity of societal needs, criteria, and preferences associated with the utilization of waters, and complexity of aquatic ecosystems. Varis & Somlyódy (1996) performed a comprehensive literature review on climatic change impact assessment on lake

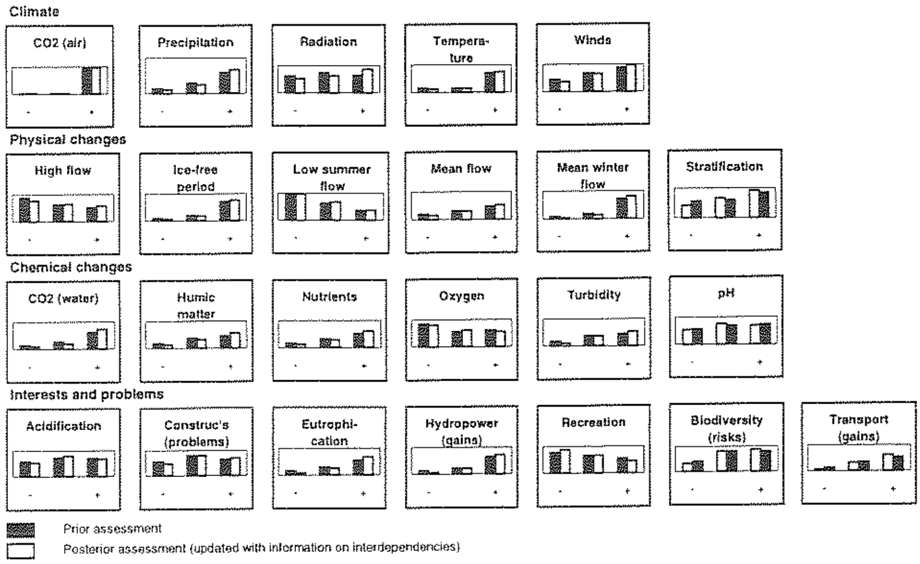

Figure 3. Summary results of climatic change impact assessment for watersheds in southern Finland (after Varis & Kuikka 1997).

and reservoir water quality. Many problems appeared to be at risk of becoming worsened by climatic change, particularly those relating to eutrophication, oxygen depletion, salinization, acidification, and thermal pollution. An extreme uncertainty appeared to exist in each individual case. The research and development of impact assessment methodology should, therefore, be able to handle extreme uncertainties.

To analyze and summarize the many interrelationships of climatic, thermal, hydraulic, hydrologic, chemical, and ecological factors affecting water quality, 2 interconnection matrices were created by Varis & Somlyódy (1996). 20 key determinants were selected and their relationships and influence on 8 typical water quality problems were reviewed and discussed. For most interconnections, no typical direction can be given, due to their complexity; they are a result of many processes. Much of assessment work must hence be done case-specifically. It is the task of the expert to decide which determinants and problems should be included in an analysis.

3.1 A Regional Water Resources Impact Assessment

Using the proposed approach, an integrated assessment of climate change impacts on the watersheds of southern Finland (around 200,000 km^2) was performed (Kuikka & Varis 1997). A panel of 5 climate experts and 8 watershed experts was used; they have been among the leading scientists in the extensive Finnish Research Programme on Climate Change. The study was one of the final phase, integrative assessments of the programme (cf. Kämäri 1997).

The study included 24 attributes (Figure 3) chosen with the panel members. Climate experts were first asked to assess the 5 climate variables. Watershed experts were given this information as an input to the rest of the model, which they were asked to work out. Comprehensive sensitivity analyses were performed, including studies of the roles of the attributes' states (expressed as probability distributions), and the roles of the causalities between the attributes (links). Such analyses were made separately for all 4 groups of attributes.

The greatest uncertainties were seen in the changes of floods, water pH and oxygen concentrations, problems to hydraulic constructions, and the recreational value of watersheds. Positive impacts can be expected in transportation and hydropower production. The relative importance of different causalities was analyzed separately for hydrological, limnological, and interest variables. The causalities between climate and hydrology did not appear very important from the interest standpoint because uncertainty deriving from other sources masked their effects. The causality between temperature and precipitation was important throughout the model; expected changes in temperature and precipitation were important for most variables.

4. URBANIZATION, WATER, FOOD, AND POVERTY STUDY

Many argue that urbanization will even be a more problematic and momentous issue than the population growth itself. Therefore, urbanization has recently received growing attention (Anon. 1996, UNCHS 1996). Of the Earth's population growth of 90 million in a decade, the urban growth will be around 80%. Urbanization will be most drastic in Africa and Asia (Figure 4), and in poorest countries: In 1990-94, the rate was 3.8% for low-income, 2.3% for lower-middle, 2.6% for higher-middle, and 0.3% for high-income economies (World Bank 1996). While the global food production has shown a stagnation since 1990, the pressure to feed the human population is rapidly escalating (Figure 5). The growth of irrigated area has dropped drastically during the past 10 years; it becomes more and more demanding and expensive to take new arable land under intensive irrigation. At the same time, due to unsustainable practices, a bulk—roughly 1/3—of irrigated

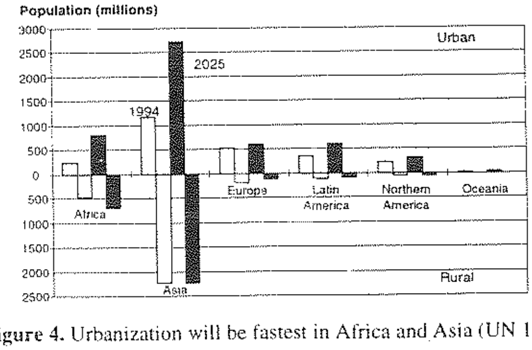

Figure 4. Urbanization will be fastest in Africa and Asia (UN 1994).

land has become unproductive. Moreover, the public opinion towards construction of reservoirs has become very negative in many parts of the world. The vulnerability of the global water and food system to hydrologic extremes and political instabilities is in rapid growth (Figure 6).

Agriculture already contributes more than 4/5 of all consumptive use of water. In 2025, how the rural areas will feed the 2.6 billion urban dwellers more than today plus themselves is a big question. Many examples show that the urban areas have given a priority in water allocation over agriculture due to faster capital recovery. The expectable rise in food prices will balance out this situation to some extent, but this development will unfortunately have the most drastic impact on the poor. With the liberalization of world trade, privatization, and other such global trends, those who have no cash become increasingly vulnerable.

It will be more and more difficult and demanding to meet the growing demand from stagnant or deteriorating supply of water. Decisions and attitudes concerning solutions on capacity such as human development, institutional set-up, water constructions and other technological issues, given the economic and social constraints constitute a challenging entity (Figure 7) with no simple answers.

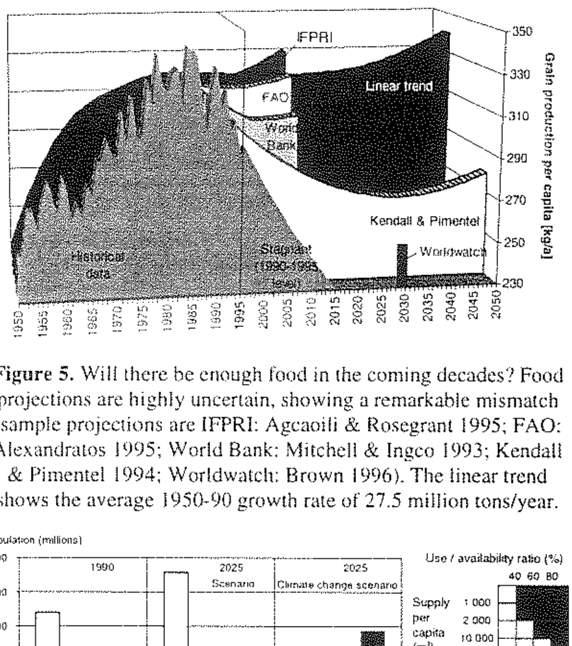

Figure 5. Will there be enough food in the coming decades? Food projections are highly uncertain, showing a remarkable mismatch (sample projections are IFPRI: Agcaoili & Rosegrant 1995; FAO: Alexandratos 1995; World Bank: Mitchell & Ingco 1993; Kendall & Pimentel 1994; Worldwatch: Brown 1996). The linear trend shows the average 1950-90 growth rate of 27.5 million tons/year.

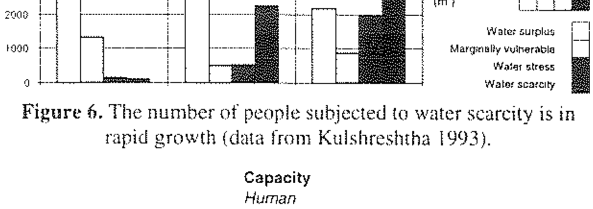

Figure 6. The number of people subjected to water scarcity is in rapid growth (data from Kulshreshtha 1993).

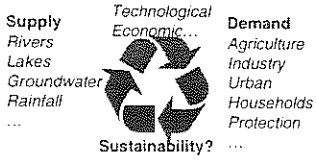

Figure 7. Supply, demand, capacity, and sustainability. The challenges to meet the water demand are tough enough even without the unavoidable quest for sustainability.

4.1 Preliminary Results

In the time frame till 2025 and beyond, 5 driving forces, 10 impact variables—5 on water and land, and 5 in socioeconomy—and 18 policy tools are analyzed (Figure 8, Table 1). These variables were selected after a careful scrutiny of literature. The total number of their interconnections amounts up to 1122. Table 2 shows selected interconnections, that can be used as the starting point of geographically determined and quantitative analyses. It is important to recognize that case specific differences can be and often are great.

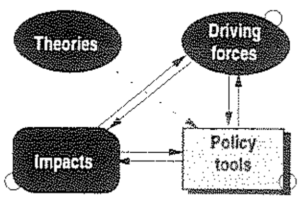

Figure 8. Grouping of the variables. For each solid-line arch, an interconnection matrix has been constructed.

4.2 Further Steps

The study above is the first step in a more comprehensive analysis that will employ the proposed approach. 5 key regions are taken in closer scrutiny: (1) China, (2) S Asia, (3) SE Asia, (4) The Nile Basin countries, and (5) the Sahel West Africa. These account for 85% and 68% of the populations of Asia and Africa, and 60% of that of the globe, but a much higher proportion of humans that will face water scarcity, poverty, and urbanization issues in coming few decades. In addition, a monograph will be edited, that consists of a fact sheet of 1 to 5 pages for each of the variables in Tables 1 - 2.

The analysis will attempt to detect and examine the following issues in particular:

- The *most important* variables and variable clusters.
- The *relative importances* of different variables.
- The key *knowns, unknowns, threats, risks, opportunities.*
- *Inconsistencies* in present comprehension of the issues, and in policy recommendations.
- The *differences* in the roles of those variables *among macroregions.*
- Possible, interdisciplinary *cycles and feedbacks* that are difficult to find without an integrated analysis.
- Further *development of the methodology.*

5. CONCLUDING REMARKS

- Global and regional changes are results of many interconnected issues, and include a high number of social, economic, political, ecological, technical and other facets.
- They all need specific expertise, technologies, and skills but this is not always enough.
- These facets are the more interconnected the wider time perspective is considered.
- The recognition, appreciation, and comprehension of these interconnections is crucial in the abatement of negative impacts of these changes and when adapting societies into them.
- Scientists, policy-makers, and different stakeholders should be facilitated to communicate better.
- This study is an attempt to develop methodologies for such purposes, and to analyze selected, important regional and global-scale problems that are close to policy making.

Table 1. The variables included in the analysis, except the policy tools, which are given in Table 2.

Code	Variable
df	**Driving forces to world water availability**
1	Population growth
2	Urbanization
3	Climatic change
4	Macroeconomy
5	Industrialization
iw	**Impacts on water and land**
1	Arable land
2	Groundwater
3	Surface water
4	Other ecosystems and the loss of biodiversity
5	Material cycles
is	**Impacts on socioeconomy**
1	Food and water security
2	Political stability and resistance against risks
3	Gender development
4	Reduction of poverty
5	Public health
6	Consumption

Table 2. Sample interconnections: From policy tools to impacts on socioeconomy (above) and v.v. (below). Legends: + positive, - negative, * indeterminate, 2 marks: strong connection/combination.

from v to >	is1	is2	is3	is4	is5	is6
Rural-urban patterns and policies						
Urban primacy	-*	-*	+*	*	*	-
Urban poverty alleviation	+	+	++	++	++	-
Urban agriculture & waste recycling	+	+	+*	+	+	*
Urbanizing rural areas	+*	+	+	+*	+*	-
Rural development& agric transformation	++	++	+	+	+	-
Rural poverty alleviation	++	+	++	++	+	-
Capacity building: Water and land						
Water storage capacity	+	+*		+*	*	-*
Water transfer systems	+	+		+*	*	-*
Water supply, sanit, & wastewater treatm	+	+*	+	+*	+	
Water re-use	+*	+*			+*	+
Intensification of agriculture	+	+	+*	+*	+*	-*
New land to agriculture	+	+	+*	+*	+*	-*
Capacity building: Socioeconomy						
Population policy	+	+	+	+	+	+*
Human resources development	+*	+*	+	+	+	-*
Breaking the dual system	+*	+	+*	+*	+*	*
Institutional development	+	+	+	+	+	*
Outward orientation in economy& society	*	*	*	*	*	*
International commitments	*	+*	+*	+*	+*	

is1	is2	is3	is4	is5	is6	from < to v
						Rural-urban patterns and policies
-*	*	+*	*	*	-	Urban primacy
+	+	++	++	++	*	Urban poverty alleviation
+	+	+	+*	+	*	Urban agriculture & waste recycling
+*	+	+	+	+	-*	Urbanizing rural areas
++	+	+	++	++	*	Rural development& agric transformation
++	+	++	++	++	*	Rural poverty alleviation
						Capacity building: Water and land
++	+*		+*	+*	*	Water storage capacity
++	+		+*	+*	*	Water transfer systems
+*	+	+	+*	+	*	Water supply, sanit, & wastewater treatm
+	+*		+*	+*	+	Water re-use
+*	+	*	+*	+*	*	Intensification of agriculture
+*	+	*	+*	+*	*	New land to agriculture
						Capacity building: Socioeconomy
+	+	++	+		+	Population policy
+	+	++	+	++	*	Human resources development
+*	+	+	+	+	*	Breaking the dual system
+	+	+	+	++	*	Institutional development
+*	+*	+*	++	*	*	Outward orientation in economy& society
+*	+*	+*	+	+	*	International commitments

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