Nat Hazards (2009) 50:211–233
DOI 10.1007/s11069-008-9333-4

ORIGINAL PAPER

IUPA: a tool for the evaluation of the general usefulness of practices for adaptation to climate change and variability

P. Debels · C. Szlafsztein · P. Aldunce · C. Neri · Y. Carvajal · M. Quintero-Angel · A. Celis · A. Bezanilla · D. Martínez

Received: 12 October 2007 / Accepted: 27 November 2008 / Published online: 20 December 2008

Abstract A prototype multi-purpose index is proposed for use in the evaluation of practices for adaptation to climate variability and change. The Index of Usefulness of Practices for Adaptation (IUPA) allows the user to assign weights and scores to a set of user-defined evaluation criteria. Individual criterion scores are aggregated into a final index value. Both the final value and the individual parameter scores provide useful information for improved decision making in the context of climate change. An innovative aspect of IUPA is that guidance is given to the user through the inclusion of recommendations on evaluation criteria and criterion-specific weight factors. These have been defined by a panel of experts from the Latin-American and Caribbean Region (LAC). Application of the index is demonstrated for an existing adaptation practice from the Coquimbo Region, Chile. The IUPA tool is recommended for use in the evaluation of

P. Debels (✉)
Centro de Ciencias Ambientales EULA-CHILE, Universidad de Concepción, Barrio Universitario S/N, P.O. Box 160-C, Concepción, Chile
e-mail: pdebels@udec.cl
URL: www.eula.cl

P. Debels
Centro de Investigación y Estudios del Medio Ambiente CIEMA, Universidad Nacional de Ingeniería, Managua, Nicaragua

C. Szlafsztein
Centro de Geociências, Universidade Federal do Pará, Belém, Brazil

P. Aldunce
Departamento de Ciencias Ambientales y Recursos Naturales Renovables, Facultad de Ciencias Agronómicas, Universidad de Chile, Santiago, Chile

C. Neri
Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México, México City, DF, Mexico

Y. Carvajal · M. Quintero-Angel
Escuela de Ingeniería de los Recursos Naturales y del Ambiente EIDENAR, Universidad del Valle, Cali, Colombia

adaptation practices in their design, implementation and post-implementation phase. It is practical for a quick first assessment or when limited financial resources are available, making the tool especially useful for practitioners in the developing world. The index is flexible both from the perspective of its construction and use. Additional expert opinions can easily be included in the future versions of the tool.

Keywords Climate change · Adaptation · Index · Multi-criteria · Decision making · Latin-America and the Caribbean · Chile

1 Introduction

It is now widely recognized that climate change is a major issue human societies will need to face during the twenty-first century (Vincent 2007). An update on the evidences of a changing climate has recently been given in the fourth assessment report AR4 of the Intergovernmental Panel on Climate Change (IPCC 2007a, c). Even when uncertainty continues to exist over the exact magnitude of the changes that will occur, it can be foreseen that changes will continue for hundreds of years, even if a stabilization of greenhouse gas emissions can be achieved (IPCC 2007b; Reilly et al. 1994; Sterr 2000).

In this same context, more and more indications appear that climate change may be influencing the frequency and severity of natural catastrophic events (IPCC 2007a). Rising socio-economic costs associated with damage from e.g. extreme (hydro) meteorological events are a clear reflection of the society's current and potential future vulnerability to a phenomenon such as climate change. Impacts and associated events, however, tend to affect in a disproportionate way the developing countries and least developed sections of the society, increasing even more the existing inequalities in the world (Haddad 2005). The former appears as a consequence of the fact that vulnerability of human society is related to processes and conditions—as determined by physical, social, economic and environmental factors—that increase its' susceptibility, or that of a community making part of it, to be negatively impacted by one or several threats (UN ISDR 2005).

In order to reduce vulnerabilities, a timely adaptation to probable new environmental conditions under climate change becomes imperative. Adaptation can be defined as: 'adjustments in human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities' (IPCC 2001). It is an integral part of the implementation of the United Nations Framework Convention on Climate Change (UN 1992), and 'requires urgent attention and action on the part of all countries' (UNFCCC 2002).

A. Celis
Centro de Estudios Sociales y Ambientales, Buenos Aires, Argentina

A. Bezanilla
Centro de Física de la Atmósfera (INSMET), La Habana, Cuba

D. Martínez
Autoridad Nacional del Ambiente de Panamá, Ciudad de Panama, Panama

D. Martínez
CATHALAC, Ciudad de Panama, Panama

It becomes thus clear that, in the next decade, it will be of uttermost importance to carry out and intensify actions that allow diminishing society's vulnerability to climate variability and change. Climate adaptation refers to a wide range of behavioural adjustments (involuntary or planned) that households and institutions take—including practices, processes, legislation, regulations and incentives—to mandate or facilitate changes in socio-economic systems, aimed at reducing vulnerability to climatic variability and change (Burton et al. 2002; Leary 1999).

Many of these actions require the formulation and implementation of one or a group of adaptation practices, policies and strategies (Smit and Wandel 2006). Adaptation practices may vary considerably among regions, countries and social groups: all of these may react to climatic variability and change in different forms.

Many historical cases of human adaptation to the host environment exist (Burton et al. 2006) and may serve as an example; numerous works describe and analyze the past and new adaptation options in different regions, for a variety of sectors: agriculture, water resources, ecosystems, coastal areas, human settlements, energy and industry, insurance and other financial services, human health, etc. (Kane et al. 1992; Reilly et al. 2001; Droogers 2004; Orlove 2005). However, these works do not systematically provide specific guidance on the criteria that may help evaluating the general *usefulness* and potential for *success* of past, current and future adaptation options (Tompkins and Adger 2005).

Effective adaptation practices are responsive to a wide variety of economic, social, political, geographic and environmental conditions, so criteria for *success* may be context-specific (Dessai and Hulme 2007). From this perspective, it may thus seem inappropriate to provide a unique guideline in a fixed format and prescriptive style for the evaluation of the effectiveness of all possible adaptation strategies. Rather, what is required is a common framework of concepts, linked together in a flexible manner, e.g. in the form of a tool that helps policy makers and practitioners in the design, implementation or evaluation of the usefulness and chances for success of adaptation strategies and measures.

2 Objectives

This article describes the development and implementation of a prototype, multi-criteria composite index that is proposed as a simple, flexible tool useful for a first quick evaluation, critical review, multi-objective optimization and for improved decision making specifically in the field of adaptation to climate variability and change.

3 Theoretical and methodological background

In what follows, a short description is given of the basic concepts that were addressed during the development of the proposed evaluation index.

3.1 Expert judgment

Expert judgment is an approach for soliciting informed opinions from individuals with particular expertise. Integral to many decision-making tools, it is used to obtain a rapid assessment of the state of knowledge about a particular aspect of, and to produce position papers on, issues requiring policy responses. The solicited expert knowledge may be based on the outcome from hypothesis testing in case studies, on observations and empirical knowledge, on the results from models as well as on their extra- or interpolation, or it may be generated through interviewing key informants or by means of deductive reasoning (Smit and Wandel 2006). Often applied when there is insufficient time to undertake a full study, it is important, however, to be aware of its *subjective* nature. Selection of a *representative sample of experts* that cover the full spectrum of opinions on an issue is therefore recommended (UNFCCC 2005).

3.2 Multi-criteria decision making

Cost-benefit, cost-effectiveness and multi-criteria procedures are frequently applied for ranking or rating the relative merit of possible adaptation options (Smit and Wandel 2006). Multi-criteria assessment techniques have been previously used in the specific context of climate change (Alberini et al. 2006; Brooks et al. 2005; Carreno and Cardona 2007; Sullivan and Meigh 2005). One specific example is the adaptation decision matrix (ADM), which was developed to evaluate the relative effectiveness and costs of adaptation options (Mizina et al. 1999). In the ADM, users are asked to specify a set of evaluation criteria, and then weight the criteria. Assignment of numerical scores by the user indicates to what extent the different criteria (*policy options*) are met in the case of different adaptation measures. These assignments can be based on expert judgment or in-depth research for scenarios of both current climate and climate change. A single numerical value ($\sim$index) obtained by a weighted integration of the scores for the different criteria can then be compared to relative costs in order to make an assessment of cost-effectiveness. The possible final outcome is thus not unique, but dependent on both the—often subjective—assignment of weights and parameter scores, as well as the selected integration method.

3.3 Use of indexes for assisting the decision-making process

In the case of multiple evaluation criteria, a complementary single, integrated index value may make information more easily and readily understood than the original long list of numerical values or non-quantitative, descriptive interpretations of the criteria. Integrated indexes also facilitate comparison when different alternatives are being evaluated. Consequently, indexes are considered to be very useful for transmitting information to general audiences as well as for practical decision making (Brooks et al. 2005; Carreno and Cardona 2007; Connor and Hiroki 2005; Stambuk-Giljanovic 1999). In the fields of natural and social sciences, they have been used for a wide array of applications, e.g. water quality (Debels et al. 2005), socio-economic deprivation (Bell et al. 2007), and climate adaptation policies (Eriksen and Kelly 2007).

3.4 Defining the usefulness of adaptation practices

Adaptation in the context of human dimensions of climate change usually refers to a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing climatic condition and its associated stresses, hazards, risks or opportunities (Smit and Wandel 2006).

The concept 'adaptation practices' covers an ample set of such actions and adjustments, in response to or anticipating a changing climate and its impacts. Such actions or adjustments include, but are not limited to: social processes, engineering works, changes in agricultural practices, development of early warning systems, more efficient use of natural resources (e.g. water), etc. Adaptation practices may thus vary widely according to the sector and region/country of application, and the associated social context and scale.

An adaptation practice can be considered useful if it integrates positively within a more general context of sustainable socio-economic development and is beneficial—whether climate change occurs or not—for both target population and society. However, what is useful or successful for a specific group of stakeholders today, may lose this character in the future, or may not be equally useful for other stakeholders working at other (spatial or temporal) scales, or facing other kinds of problems. From this perspective, it can be stated that the evaluation of the usefulness of an adaptation practice responds to a judgment that will be dependent on the spatial, temporal and social context in which the adaptation occurs or is desired. While it is important to bear the former observation in mind, as a first introduction we refer here to a suggested set of normative evaluation criteria for judging the success of adaptation practices at different scales, as it is given by Adger et al. (2005): 'effectiveness', 'efficiency', 'equity' and 'legitimacy'. Also according to these authors, the relative importance attached to these (or similar) criteria will vary between countries, between sectors within countries and over time as attitudes and expectations change.

4 Development of the IUPA index

4.1 Characteristics of the IUPA index

The proposed 'Index of Usefulness of Practices for Adaptation' (IUPA) for evaluating the *usefulness* and potential for *success* of current and future options for adaptation to climate change and variability is build on similar principles as other existing tools, such as e.g. the ADM of Mizina et al. (1999): it makes use of both expert judgment as well as multi-criteria decision making, and is relatively simple in terms of its construction and implementation. The IUPA, however, differs from existing tools as it combines the following three characteristics: (i) it specifically addresses the topic of adaptation to climate change by explicitly considering the uncertainty aspect of this phenomenon through the (suggested) inclusion of evaluation criteria such as 'robustness of the solution', 'flexibility' and 'resilience'; (ii) it is highly flexible in its construction and use; and most importantly, (iii) it directly assists the user in the evaluation of an adaptation practice by providing suggestions on evaluation criteria to include, as well as on their relative importance. This specific guidance provided to the user originates from a knowledge pool, which was generated by a team of professionals with different geographic and thematic backgrounds, and may help to reduce subjectivity in the application of the IUPA while still allowing sufficient flexibility to adapt the tool to local conditions and goals. For any practical case study, the effects of subjectivity in the user assignment of parameter weights and scores may also be further reduced by allowing different user panels to independently apply the index, which then needs to be followed by a comparison of the results. Under its current form, the knowledge pool is directly useful to end users, but it was conceived in such a way that it can easily be expanded with additional contributions from experts and stakeholders working on adaptation to climate change in other parts of the world.

4.2 Matrix development and calculation of the IUPA index value

The matrix used for calculating the IUPA index value is developed by tabulating the criteria for evaluating the usefulness of a particular adaptation practice ('*variables*') against criterion weights and scores, a process through which a matrix of n rows by m

columns is obtained. A detailed description of the meaning of the different rows and columns of the IUPA matrix is given in Appendix I.

An integrated index value for the IUPA is obtained by (i) multiplying individual variable scores with the assigned variable weight; and by (ii) consequently summing the weighted individual parameter scores ('*weighted sum*'):

$$\mathrm{IUPA} = \frac{\sum_{i=1}^{n} C_i \times P_i}{\sum_{i=1}^{n} P_i}$$

where n represents the total number of criteria (variables), C_i is the score (value between 0 and 10) assigned to criterion i, and P_i is the weight of the ith criterion in the total index score (value between 0 and 10; an indicator of its' relative importance in the global evaluation of the practice's usefulness).

4.3 Expert panel involved in the development of the IUPA matrix

An important aspect of IUPA is the provision of user guidance in the evaluation process: this guidance consists of (i) the suggested inclusion of specific evaluation variables, and (ii) the provision of suggested variable weights. Suggested evaluation criteria ('variables') and weights for the current version of the index (IUPA v1.0) are based on the outcome from multiple discussion rounds held by a team of eight professionals (practitioners and researchers) related to the climate change sector. The members of this team belong to a research network sponsored by IAI (Inter American Institute for Global Change Research) and come from the following countries: Argentina, Brazil, Chile, Colombia, Mexico, Panama, Cuba and Belgium. They bring in their personal visions, based on their experience from work in the LAC within the following disciplines: geosciences, hydrology, atmospheric sciences, water management, social sciences and environmental management/disaster management.

4.4 Selection and ranking of the evaluation criteria ('variables')

4.4.1 Suggested evaluation criteria

The criteria proposed as appropriate for the evaluation of the general usefulness of adaptation measures are given in Table 1.

4.4.2 Suggested weight factors

In the context of the overall integrated evaluation of the usefulness of a given adaptation practice, not all variables should be considered as being equally relevant (Alberini et al. 2006; Booysen 2002; Sullivan and Meigh 2005; Vincent 2007). This aspect can be addressed through the use of expert-based weighting systems (e.g. Brooks et al. 2005) or, as in the IUPA case, by taking into account the relative importance (as perceived and defined by the expert panel) of each one of the variables in the overall evaluation. A suggested set of weight factors (mean value of the suggestions of a multi-disciplinary panel of eight experts) was elaborated by covering all the variables contained in Table 1. A summary of the results from this process is given in Table 2.

Table 1 Evaluation criteria (variables) selected for inclusion in the IUPA

Name of the variable	Description of the concept	Definition of the indicator	Qualitative expressions
Accomplishment of the objectives	The achievement of the objectives is used to reflect the progress and performance of an adaptation practice (Nichols and Martinot 2000)	Degree to which the problem is addressed and solved by the practice	Total accomplishment Partial accomplishment Non-accomplishment
Implementation time for the adaptation process	Setting of *time horizons* is needed when defining a strategy, policy, or measure, and also for monitoring the implementation of an adaptation strategy (Niang-Diop and Bosch 2004)	Time required for the implementation of the adaptation practice and/or until results are obtained	Short term (e.g. 0–2 years) Medium term (e.g. 2–5 years) Long term (e.g. 5 or more years)
Total cost	Research on adaptation to climate change has mostly focused on the costs of adaptive responses, using the cost implementability of the measures to rank the relative merit of possible adaptations (Paavola and Adger 2006)	Total economic value of the design, implementation, execution, performance monitoring and evaluation of the adaptation practice	Low total cost Medium total cost High total cost
Robustness or flexibility of the solution	The robustness of an adaptation practice reflects the degree to which the solution is insensitive to uncertainty in climate change. Flexibility reflects the ability to change the practice in response to altered circumstances (Adger et al. 2005). Both are especially important indicators in the context of adaptation practices to climate change, as they specifically address the associated uncertainty (magnitude, frequency and, to a lesser extent, direction of change). They are somehow complementary, in the sense that in the absence of robustness, flexibility will become more important, and vice versa	Does the proposed solution takes sufficient consideration of the uncertainty aspect of climate change? Is the solution robust? Does the solution remain useful under less or unexpected manifestations of climate change? Can the solution easily be adapted if conditions are changing or different from expected?	High robustness and/or flexibility Moderate robustness and/or flexibility Low/no robustness and/or flexibility
Level of autonomy (in deciding and acting)	Successful adaptation practices are frequently characterized by the ability of decentralized decision making and action taking in both planning and response (Helsloot and Ruitenberg 2004), reason for which the autonomy variable is considered to be relevant in the evaluation process	Degree of freedom and capacity of the stakeholders during the process of defining and implementing the adaptation practice (absence of limitations or restrictions of e.g. economical, political and technical origin)	High Medium Low

Table 1 continued

Name of the variable	Description of the concept	Definition of the indicator	Qualitative expressions
Proportion of beneficiaries	Considering the existent social differences in the region, it is important to try to assist the biggest possible part of the affected population (Nichols and Martinot 2000)	Number of beneficiaries of an adaptation practice with respect to the total population from the given location which is or will be experiencing the problem that requires adaptation	High proportion Medium proportion Low proportion
Continuity in time	Persistence/sustainability in time of the outcome of the adaptation process (Eriksen and Kelly 2007)	Time span during which the adaptation practice keeps on being effective, after having been implemented	Long Medium Short
Level of resilience	The level of resilience describes the capacity of a society to deal with change and continue to develop (Stockholm Resilience Centre 2007). It thus constitutes an important indicator in the context of the evaluation of the usefulness of adaptation practices	Level to which the adaptation measure or strategy conserves, restores and/or contributes to adequate levels of resilience	High Medium Low
Integration with other policy domains, programs or projects	Whenever possible, adaptation to climate change and variability as a stand-alone action should be avoided; whereas its integration within a wider array of policy domains should be promoted (Apuuli et al. 2000)	Level of integration of the adaptation practice with other policies, programs or projects that are being planned or developed in the study region.	Good integration with several policy domains, programs and/or projects Some level of integration is achieved (with at least one other policy field, program or project) The practice is a stand-alone initiative, no integration is envisaged or achieved
Participation of the target population	The participation, along with the government, of vulnerable local communities and individuals in general in the adaptation practice design, planning and implementation is crucial	Involvement of the target population in the different phases of the adaptation process (e.g. through participative workshops; awareness and/or capacity building; implementation of actions	From the onset of the adaptation process Towards or at the end of the adaptation process Almost no, or only occasional participation

Table 1 continued

Name of the variable	Description of the concept	Definition of the indicator	Qualitative expressions
Attention to the most vulnerable groups	Within a society, not all people are equally at risk. Certain individuals, categories or population groups may be particularly vulnerable to disaster. The more vulnerable groups frequently include: women, children, the elderly, immigrants, the poor, etc. (Parker 1993; Szlafsztein 1995)	Attention received by the most vulnerable population group within the target population (e.g. children, elderly, handicapped)	Prioritary attention Igualitarian attention No or little attention
Level of environmental protection	An important challenge in the development or selection of adaptation practices is ensuring that they do not stress natural systems unnecessarily (de Loe et al. 2001)	Level to which the adaptation measure or strategy conserves, restores and/or contributes to the protection and sustainable use of natural resources	High Medium Low or Null
Repeatability	Methodologies and results of adaptation practices can be shared, respecting the peculiarities of diverse geographical areas or population groups	Possibility for transferring and applying the practice to other geographical areas or population groups	The practice can easily be repeated or transferred to other cases or geographical areas With moderate additional efforts, the practice can be adapted and repeated in/transferred to other cases/regions The practice is highly adapted to local conditions and therefore intransferable or unique
Incorporation of local/traditional knowledge	The traditional or local knowledge relates with the local beliefs and experiences acquired by the population of the area affected from historical times (Riedlinger and Berkes 2001)	Level of consideration of local/traditional knowledge in the design or implementation of the adaptation practice	Local/traditional knowledge has been considered and/or incorporated Local/traditional knowledge has not been considered and/or incorporated

Table 2 General suggestions for weight factor values for the different evaluation criteria: mean values, standard deviations and variable classification based on a sample of eight opinions

Variables	Average weight factor	Standard deviation	Variable class
Accomplishment of the objectives	8.3	1.0	A
Implementation time	6.8	0.7	A
Total cost	6.6	1.3	A
Robustness and/or flexibility	8.9	0.8	A
Level of autonomy	7.1	1.5	A
Proportion of beneficiaries	7.1	1.6	A
Continuity in time	7.8	0.9	A
Level of resilience	8.4	1.2	A
Integration	7.5	1.4	A
Participation of target population	8.5	1.1	A
Attention to most vulnerable groups	7.9	1.2	B
Level of environmental protection	6.8	1.0	B
Repeatability	5.6	1.8	B
Incorporation of local/traditional knowledge	6.0	1.9	B

Based on these results, the variables contained in Table 2 were assigned to two different classes. Class 'A' consists of variables whose inclusion in the evaluation process should be considered *highly recommended*. Class 'B' constitutes a set of 'complementary variables' whose inclusion in the evaluation process is *suggested*. The matrix allows additional flexibility, by offering the user the possibility to include class 'C' variables, i.e. variables that have been identified by the user(s) and/or by his/her entourage as being important for the specific case under study, and whose inclusion in the matrix was originally not suggested by the panel of experts.

5 Objectives and projected use

5.1 Objectives and potential uses

The proposed index can be used to evaluate the general (or specific) usefulness of adaptation practices previous to, during and after the implementation phase. Results from its application can be used for defining corrective or complementary actions (in the case of adaptation practices that are currently being implemented), or for modifying or choosing alternative practices (for adaptation efforts that are currently in the planning phase). Application of the index may also prove useful when developing project proposals and/or when requesting or approving financial aid. Table 3 gives an overview of the potential uses of the IUPA index. The assignment of scores to the individual evaluation variables of the index can be based on the opinions of local practitioners or experts (allowing for a quick, first assessment), or on the outcome from more in-depth research.

Table 3 Potential uses of the IUPA tool

Potential use	Description
General evaluation of a practice	Evaluate the usefulness of adaptation practices in the different phases of implementation by identifying strengths and weaknesses and determine the possibilities and opportunities for improving them. Analyze the extent to which the outcome from the implementation meets the initial expectations
Comparison of alternatives	Evaluate both the general and criterion-specific usefulness of a series of different adaptation practices for an existing or potential situation
Support tool during the phase of project formulation	Use as a check-list or screening tool in the formulation of project proposals
Assistance in the fund-raising process	Use of the tool by both applicants and donor agencies and institutions to screen and evaluate proposals
Communications tool	Exchange information on adaptation practices and their (expected) performance, strengths and weaknesses with stakeholders—ranging from individuals or local organizations to the international community of climate change and adaptation professionals—during the different phases of project planning and implementation

5.2 Opportunities and limitations

As was shown in Table 3, the IUPA index covers a wide field of potential applications. The combination of '*expert judgment*' and '*multi-criteria decision making*' through the calculation of an integrative index value can indeed be seen as a 'straightforward and structured, but somehow *subjective* form' of generating support material for a multitude of decision-making processes. In this context, however, it is important to stress: (i) the subjective nature of expert judgment, and thus the consequent benefits arising from the consideration of multiple opinions; (ii) the distinctive importance of both individual parameter scores as well as the final index value (meaning the index value should not be used without due consideration of the different individual parameter scores); and (iii) the potential impact of several existing methods for aggregating individual variable scores into a final index value. With respect to this last point, we refer to discussions in the literature (e.g. Hallock 2002) on the (dis)advantages of the different methods, such as e.g. the eclipsing or over-emphasizing of a single low variable score. The choice of method employed in determining a composite index value should thus ultimately depend on the nature and scope of the particular study (Ginsberg et al. 1986), and corresponding adaptations to the proposed index can be made (here we propose the simple integration method indicated under Sect. 4.2). The proposed index should therefore not be unrestrictedly used without due consideration of its characteristics and limitations.

Through the incorporation in the matrix of the outcome from a consultation process (in terms of suggested weight factors for the different evaluation criteria), the opinions from a group of experts from the LAC Region are made available to a broad group of practitioners and researchers from the climate change and adaptation sector, which hold a potential interest in the use of the proposed IUPA index. The consultation process focused on identifying useful criteria for the general evaluation of practices that have a potentially wide field of both geographical and thematic application, while maintaining their usefulness for application in more specific case studies. It may therefore be recommended to include additional criteria and weights for evaluating practices that address very specific types of change-related vulnerability, or when particular practices need to be applied to very specific geographic regions. In this sense, the information provided by the panel is intended to be used as guidance for end users, and these suggestions can be followed, or case-specific adaptations can be made. Users themselves can modify the index, or form their own consultative group(s) and conformingly introduce modifications to the suggested list of criteria and associated weight factors. In an ongoing effort, new contributions from researchers and practitioners from the different fields involved in global climatic change research can be collected and used to develop a more extensive pool of opinions on variables and variable weights. This can then be used to formulate new suggested weight values, as well as to assess the magnitude of convergence/divergence in existing opinions ($\sim$subjectivity) with respect to the relative importance of specific evaluation criteria.

6 Case study description

In order to illustrate the usefulness and flexibility of the IUPA index, an example application of the index is made for a selected case study from the LAC Region. First, a short description of this case study is given in what follows.

6.1 Case study: improving disaster management related to natural hazards: Coquimbo, Chile

The selection of this case study is based on the perception that improving disaster risk management (related to current climate variability) can be an effective tool for adapting to (future) climate change.

Coquimbo, one of Chile's 15 administrative regions, is located in the northern part of the country. With a total surface area of 40,580 km^2 and 603,210 inhabitants, approximately 22% of the region's population is considered rural. Major economic activities in this part of the country consist of agriculture, logging and mining. Over the last decades, the region has experienced an important rural–urban migratory process. The regional poverty level is 13.1%; 2.8% of the population is considered to be destitute (MIDEPLAN 2006).

A considerable part of the region consists of rugged terrain, subject to an ongoing desertification process. The regions' transitional climate (from a Mediterranean hyper arid desert to a wetter climate towards the south; (Paskoff 1993; Scheider 1982)) goes associated with highly variable annual precipitation rates. Frequent droughts are often followed by short periods of intensive precipitations. In such occasions, rainy events increase the risk of disasters, affecting both population and infrastructure.

The particular physical, climatic, social and economical characteristics of the region all contribute to the vulnerability of part of its population to these hazardous extreme rainfall events. The main disasters related to these phenomena in the area are devastating floods and the occurrence of landslides (La Red 2003). The risk of disaster is spread unevenly over the regional territory, due to spatial differences in topography, hydrography, precipitation patterns and socio-economic conditions. Impacts range from bridge and road cuts, which result in the isolation of people and villages, breakage of telephone networks and power grids, destruction of water systems, flooding of rural areas causing damage to agriculture, and flooding of urban areas resulting in damaged houses, homeless and injured people, or even casualties.

One of the main factors hindering an adequate management of this kind of disasters in the area was the fragility of existing communication networks: with a considerable number of localities becoming isolated during disasters (due to e.g. road and bridge cuts), failure of traditional communication networks such as telephone lines constitutes an important limitation for adequately attending the needs of affected inhabitants.

From an organizational point of view, it is the Municipality who is located closest to the most vulnerable local communities. In this sense, it is also the municipality who provides relief whenever sufficient resources and capacity are available at this level. For addressing major disasters, higher hierarchical levels, however, may become involved. Even under such conditions, in order to be able to adequately address the problems of affected local populations, it is the municipality who needs to be informed first about the impacts and needs at these different localities. It is also between those two levels—municipalities and localities—that most communication problems during disaster have occurred in the past.

In 1998, the Regional Emergency Office, OREMI, undertook the initiative to establish a system which aimed at maintaining fluid communication during disaster. Fluid communication is considered to be essential for improved coordination of efforts and collaboration between agencies across the territory. The projected system consisted of the implementation of an improved radio communication network. By incorporating existing systems, coverage of the network could be maximized. A communication node was established in each municipality of the region, through which radios installed at the different localities belonging to that municipality could be integrated. In case of necessity, communication from the municipality upward can be achieved by traditional means (telephone), or by means of radio, through the implementation of additional nodes up to the level of the Regional Government.

Most importantly, municipalities now maintain an open communication channel for real-time contact with the different localities under their responsibility. In case of disaster, the affected population can clearly inform municipal decision makers about local damages and problems. This allows municipalities and, in case of need, higher hierarchical levels to adequately plan and establish priorities for action, as a function of the most urgent needs. Through the implementation of the system, more effective and egalitarian relief efforts can be achieved.

Besides the achievement of the project’s first aim (open communication channels as a means to improve disaster management), additional aspects that were considered were (i) enhanced coordination/cooperation between different societal actors, in both vertical and horizontal directions; (ii) improved stakeholder capacity building by means of training sessions on the use of the new communication system, as well as other general aspects relevant to improved risk management; and (iii) education of the target population in order to enable local empowerment (organization of the community in case of emergency; familiarity of the target population with the newly established communication channels and procedures for action; changing people’s apathy concerning (pro)active participation in disaster management and prevention, and promoting shared responsibility over disaster management).

7 Results and discussion

Currently, the adaptation practice has been implemented in the Coquimbo Region. Application of the IUPA methodology to the Coquimbo case study allowed for a rapid first assessment of the different aspects of the adaptation measure, both from the perspective of individual evaluation criteria, as well as from an integrative point of view. Similar as in other evaluation frameworks (e.g. evaluation of the sustainability of natural resources management systems; see López-Ridaura et al. 2002) applications can be made cross-sectionally (e.g. comparing an alternative and a reference practice at the same time), or a longitudinal analysis can be conducted in which the practice is analyzed both before, in between, and after modifications are planned or introduced. The IUPA index was used here to perform a post-implementation evaluation, in order to detect potential weaknesses or problems which may still be remediated, but which were not anticipated during design (see also Table 3: Potential uses of the IUPA index). A basic simulation was then made in order to show how modifications could (hypothetically) affect the outcome obtained with the evaluation tool. Conclusions can then be directly used for improving the Coquimbo practice, but lessons learned may equally be useful for the design and implementation of similar practices in other parts of the country, or the world.

The perception of the index users with regard to the performance for the different evaluation criteria of the previously described Coquimbo adaptation practice is reflected in Fig. 3, through which the individual, non-weighted parameter scores are graphically visualized. In addition, the IUPA matrix itself also provides the integrated index score (Fig. 1).

As can be seen from Figs. 1 and 3, even when the obtained final IUPA index value resulting from this evaluation process for the Chilean case study was quite high (value = '7.4'), a certain level of heterogeneity exists among individual variable scores. For this reason, in the IUPA-based revision process, attention was first given to the individual variable scores and their corresponding weight factors, in order to identify those weaknesses which most represent opportunities for further improvement of the overall performance ($\sim$integrated index value) of the practice.

The recommended way to proceed in the detection process of the more relevant weaknesses is to start by looking at the radial graph (Fig. 3): the user can easily identify those variables for which a relatively low score was obtained by searching for those locations where the bold line moves inwards, towards the centre of the graph. Once a variable with a low(er) score has been identified (or a score for which improvement could be achieved or would be desirable), the user can then have a look at the corresponding weight factor in the second radial graph (Fig. 2). Improvements in aspects of the practice, which are described by a variable to which both a low score and high weight factor were assigned, are most likely to contribute to an overall improvement of the 'real-world' performance of the adaptation practice.

Application of this process to the Coquimbo case study shows that the variable with the lowest score (in this case, a user-assigned value of '2') is 'incorporation of local/traditional knowledge (B4)'. This may draw the designers' or users' attention to the fact that this or similar future practices may benefit from the inclusion of such particular aspects in their design. However, the weight assigned to this variable by the regional users of the index, '4', is also low, and lower than the weight factor value recommended by the expert panel (which was '6'). A conclusion from the former may thus be that increased attention to local or traditional knowledge in the (re-)design and implementation of this particular practice may be desirable; however, other aspects are esteemed to have a major impact on the practice's overall usefulness for this specific combination of [geographic region] × [adaptation case]. It may therefore be more beneficial to address these other aspects first. By doing so, it can be seen that the more important variables 'level of stakeholder autonomy in decision making' (A5; weight = 6), 'continuity in time of project outcome' (A7; weight = 8) and 'participation of target population' (A10; weight = 9) also obtained relatively low scores of '5', '6' and '6'. Problems or weaknesses associated to these variables can now be analyzed, and ways to improve these aspects of the practice can be sought.

Index for the evaluation of the Usefulness of Practices for Adaptation - IUPA v1.0

Case Study: Improving Disaster Management, Chile

I			II					III					
VARIABLES			SUGGESTIONS OF THE PANEL					EVALUATION BY THE USER					
		NAME OF THE VARIABLE	SUGGESTED WEIGHT (0-10)	SUGGESTED RELEVANCE	n	σ	level of agreement	ASSIGNED WEIGHT	ASSIGNED RELEVANCE	SCORE (design phase)	WEIGHTED SCORE (design)	SCORE (post-implementation)	WEIGHTED SCORE (post-)
A	B	C	D	E	F	G	H	I	J	K	L	M	N
A SUGGESTED "CORE" VARIABLES	1	ACCOMPLISHMENT OF THE OBJECTIVES	8.3	HIGH	8	1.0	M	9	HIGH		-	8	72
	2	REQUIRED IMPLEMENTATION TIME	6.8	MEDIUM	8	0.7	H	7	HIGH		-	8	56
	3	TOTAL COST	6.6	MEDIUM	8	1.3	M	7	HIGH		-	9	63
	4	ROBUSTNESS AND/OR FLEXIBILITY OF THE SOLUTION	8.9	HIGH	8	0.8	H	10	HIGH		-	9	90
	5	LEVEL OF AUTONOMY (IN DECIDING AND ACTING)	7.1	HIGH	8	1.5	M	6	MEDIUM		-	5	30
	6	PROPORTION OF BENEFICIARIES	7.1	HIGH	8	1.6	L	9	HIGH		-	8	72
	7	CONTINUITY IN TIME OF PROJECT OUTCOME	7.8	HIGH	8	0.9	H	8	HIGH		-	6	48
	8	LEVEL OF RESILIENCE	8.4	HIGH	8	1.2	M	10	HIGH		-	8	80
	9	INTEGRATION WITH OTHER POLICY DOMAINS	7.5	HIGH	8	1.4	M	8	HIGH		-	8	64
	10	PARTICIPATION OF TARGET POPULATION	8.5	HIGH	8	1.1	M	9	HIGH		-	6	54
B SUGGESTED "COMPLEMENTARY" VARIABLES	1	ATTENTION TO MOST VULNERABLE GROUPS	7.9	HIGH	8	1.2	M	9	HIGH		-	9	81
	2	LEVEL OF ENVIRONMENTAL PROTECTION	6.8	MEDIUM	8	1.0	M	7	HIGH		-	7	49
	3	REPEATABILITY	5.6	MEDIUM	8	1.8	L	5	MEDIUM		-	8	40
	4	INCORPORATION OF LOCAL/TRADITIONAL KNOWLEDGE	6.0	MEDIUM	8	1.9	L	4	MEDIUM		-	2	8
	5		-	not defined				-	not defined		-	-	-
	6		-	not defined				-	not defined		-	-	-
	7		-	not defined				-	not defined		-	-	-
	8		-	not defined				-	not defined		-	-	-
	9		-	not defined				-	not defined		-	-	-
	10		-	not defined				-	not defined		-	-	-
C USER ADDED VARIABLES	1	STRENGTHENING COOPERATION AMONG STAKEHOLDERS	-	not defined				8	HIGH		-	7	56
	2		-	not defined				-	not defined		-	-	-
	3		-	not defined				-	not defined		-	-	-
	4		-	not defined				-	not defined		-	-	-
	5		-	not defined				-	not defined		-	-	-
	6		-	not defined				-	not defined		-	-	-
	7		-	not defined				-	not defined		-	-	-
	8		-	not defined				-	not defined		-	-	-
	9		-	not defined				-	not defined		-	-	-
	10		-	not defined				-	not defined		-	-	-
								IUPA - integrated scores			0.0		7.4

Fig. 1 Coquimbo practice—matrix application

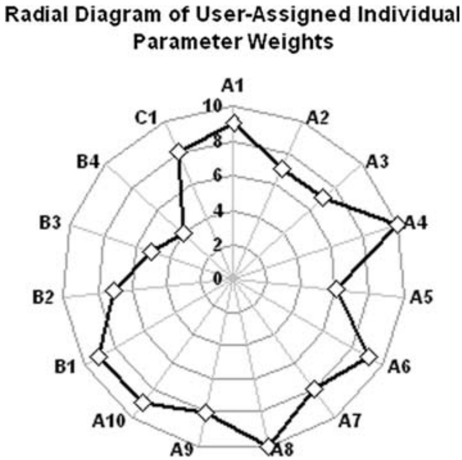

Fig. 2 Graphical overview of parameter weights

For the specific case of the Coquimbo practice, a clear connection between the previously mentioned variables could be detected. For example, field verifications showed the continuity of the practice's implementation and outcome to be erratic; in certain localities the radio was found to be inoperational, a fact which is at the basis for the assignment of a lower score to variable 'A7'. This problem was mainly associated to the lack of (access to) exchange batteries, or due to improper equipment maintenance and repair. In addition to this, it was also detected that participation of the target population in decision making in the early phases of project design was rather limited. For this reason, and independent from the analysis made for variable 'A7', a lower score was also assigned to 'A10'.

A discussion by the practitioners on the outcome shown in Fig. 3 allowed establishing the link between the different weaknesses, as it can be reasonably assumed that major levels of local autonomy ('A5') and a more adequate integration of the target population in the design of the adaptation practice ('A10') might have resulted in higher probabilities for an early detection of these potential sustainability risks ('A7'). Measures might have been

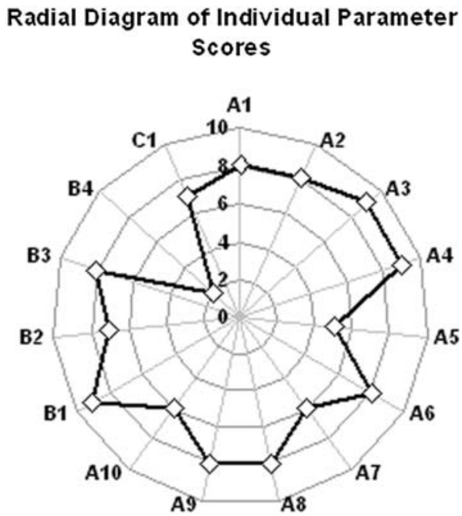

Fig. 3 Graphical overview of parameter scores

planned and undertaken already from the design phase in order to address additional local capacity building needs, as well as in order to guarantee major local financial and technical autonomy ('A5') throughout the project's implementation: currently, at several localities persons in charge do not count with sufficient economical means, nor do they dispose of trained technical staff in order to guarantee continuous operation of the implemented radio systems. This makes them dependent on and subject to political willingness and priority-setting at higher political and administrative-organizational levels (starting from the Municipalities); it seems to be plausible to expect that for this reason, at certain localities the initiative was 'temporarily' abandoned, as more 'urgent problems' needed to be addressed 'first'.

Application of the IUPA index to this particular case study and its' associated evaluation criteria checklist shows how the choice of useful modifications to the design and implementation of the adaptation practice can be steered by an analysis of the user-assigned individual variable scores and weights. Improvements for this or similar practices may thus consist of the incorporation of the target population starting from the early phases of (re-)design or modification of the practice (variable 'A10'), in order to better address the aspects of continuity (variable 'A7') or other problems that might occur, and in order to find means for assuring major (financial and operational) autonomy at the level of the final end-users (variable 'A5').

Expected effects from such projected improvements, as a result of this revision process, can be reflected not only in an updated version of the radial diagrams, but also in a new final integrated index value: increased participation and autonomy of local responsibles and target population (let us suppose a new user score of '8' for both 'A5' and 'A10') may lead to expectations for a higher sustainability of the project outcome (we suppose a new user score of '8' for variable 'A7' here). Applying the IUPA index ('design' or 'pre-implementation/modification phase') would lead to a new improved final IUPA index value of '7.9'. Of course, as this assessment is subjective and made rapidly, such expectations will have to be monitored against future results (by means of a new post-implementation evaluation), or more detailed studies addressing these specific aspects can be requested. For revision purposes of the outcome of the index application, however, it is important to indicate here how discrete, even small improvements in the final index score should be positively regarded, as they may be indicative of significant improvements in certain aspects of the adaptation practice. Another important observation is that, due to the applied integration method, really low index scores will only be obtained in case of general failure (or negative evaluation) across all evaluation criteria. For this reason, users should thus always try to maximize the IUPA score as much as possible during (re-)design. This should be done by carefully analyzing the performance of all variables contained in the index.

Other aspects of the Coquimbo adaptation practice that were not discussed before have been analyzed by means of variables such as 'total cost' (A3; weight = 7), 'robustness and/or flexibility' (A4; weight = 10) and 'attention to the most vulnerable groups' (B1; weight = 9). These were all positively evaluated (user scores of '9'); as such, they are indicative of particular strengths of this practice, and may be used as an inspiration for future, similar efforts. Focusing on the performance of the practice with regard to two criteria which are particularly relevant in the context of climate change (i.e. 'robustness and flexibility' and 'resilience'), we can comment on the following: in many adaptation cases to climate change, robustness is not easily achieved (Dessai and Hulme 2007). In the case of the Coquimbo practice, even when complementary actions will be needed as the practice by itself is clearly not sufficient in order to address all problems related to disasters originating from extreme hydrometeorological events (as a matter of fact, the practice mainly addresses one major objective, i.e. better management through improved communication), one distinct advantage of this particular adaptation measure is that the implemented system is quite robust, i.e. insensitive to the uncertainty aspect associated to climate change. In the case of ‘level of resilience’ (A8; weight = 10), care should be taken as to how this variable is interpreted: for the Coquimbo case, the high score for this variable reflects the fact that in the opinion of the users, the practice does considerably contribute to achieving adequate levels of resilience. Users have focused their attention here in the discrete contributions to resilience made by the practice itself, rather than in the fact whether the practice as a stand-alone measure would be enough for achieving high resilience levels (which it clearly is not). If users would have put the focus on the final, global level of resilience achieved, a lower score would have been assigned.

In order to conclude this section, a final observation is made with regard to the inclusion of expert panel-suggested weight factors in the IUPA tool: in this case study, for 10 of the 14 suggested evaluation criteria (classes A and B) the user-assigned weight factor values fall within the same qualitative class as the corresponding expert-suggested weight factors (see Columns E and J; Fig. 1). In all other cases, they fall in an immediately adjacent class. It seems thus reasonable to assume that the expert-suggested weight factors have provided a certain level of guidance to the Chilean practitioners when completing the matrix. However, the possibility offered to the end user to take the final decisions with respect to the case study specific weight factors for the different evaluation criteria has clearly been taken advantage of, as can be seen by comparing the values from Columns D and I (Fig. 1). Discrepancies between expert-panel and end-user criterion relevance classes do not consistently correspond to those criteria where the level of agreement among the members of the expert panel (with regard to the assignment of the weight factor value, see Column H; Fig. 1) was lower or lowest. Flexibility of the index is also demonstrated through the inclusion of one additional, user-defined evaluation variable for this practice (‘strengthening stakeholder cooperation’). Further research (including an extension of the pool of expert opinions and an application of the tool to a larger number of case studies) may elucidate the real value of the included expert suggestions for a more generalized applicability of the developed IUPA tool.

8 Conclusions

During the past decade, considerable attention has been given to the issue of mitigating the risks of climate change, principally by addressing the aspects related to the future emissions of greenhouse gases. Limited international success in this field makes it necessary to address the climate change issue by means of a mixed approach, in which mitigation options and the implementation of adaptation strategies are combined.

Designing and implementing adaptation practices to respond to climate variability and change is indeed becoming increasingly necessary. A major challenge, however, still consists of optimizing their design, as well as of their presentation to and introduction into the agenda of policymakers and practitioners.

The work presented in this article focused on the development and application of a prototype composite index, i.e. a simple tool which aims at assisting decision makers, practitioners and other stakeholders in the overall analysis of a given adaptation option and its alternatives.

With the proposed IUPA tool, the overall performance of adaptation practices, as well as particular strengths and weaknesses, can easily be analyzed based on a (flexible) set of pre-defined, weighted evaluation criteria. In this sense, the IUPA tool condenses the opinions on the relative importance of selected evaluation criteria, emitted by a group of experts with different geographic and thematic backgrounds. Through the incorporation of recommended evaluation criteria and the assignment of corresponding, suggested weight factors, this information is readily made available to a broader group of potential stakeholders. Users can then combine this information with their personal perceptions or opinions (as was shown through the example) in order to conduct a rapid analysis on the overall usefulness of a given practice. The degree to which the recommendations of the expert panel will be followed may vary from user to user, as well as among case study types. It is recommended that the 'knowledge pool' of expert opinions, which has been used for the current version of the index (v1.0), is further extended, by incorporating the opinions of a larger number of experts; interested individuals or organizations can easily contribute in this sense by sharing their vision with the authors of this article.

The index was designed in the context of the evaluation of adaptation practices for addressing the impacts of extreme events as a result of climate variability and change in LAC, but use of the index can be proposed in a much wider thematic and geographic context. Due to its simplicity, the tool is especially useful for quick assessments or when limited resources are available. However, in-depth analysis of aspects related to the individual evaluation criteria will considerably contribute to the final value of the obtained results. When making use of the index, limitations inherent to the methodologies used in its design—and which have been documented above—should always be taken into consideration.

Acknowledgements The authors would like to specially thank the Inter American Institute for Global Change Research IAI for the financial support provided through Grant [TISG-P-1] which is supported by the US National Science Foundation (Grant GEO-0436199). The authors further wish to thank their respective home institutions for all received support. Activities at EULA-CHILE and CIEMA-Nicaragua were developed in the context of the TWINLATIN Project (EC 6FP, Contract No 018436).

Appendix

User manual (description of the matrix structure)

The proposed matrix has been incorporated in an excel workbook called 'checklist IUPA.xls'. Interested readers can obtain a copy of the workbook by sending an electronic message to paldunce@uchile.cl.

Structure of the matrix

The matrix used for calculating the IUPA value consists of 14 columns grouped according to three major topics: (I) 'variables'; (II) 'suggestions of the panel': relative importance of each variable, as perceived by the group of experts; and (III) 'evaluation by the user': user assigned variable weights and scores.

Group I lists and describes the different variables (criteria) that can be evaluated in the evaluation of the usefulness of an adaptation practice. Column A organizes the variables according to three different types: (i) Class A or core variables whose inclusion in the evaluation process is considered 'obligatory'; (ii) Class B or complementary variables that are suggested by the panel of experts; and (iii) Class C or additional user-defined variables that have been identified by the user himself as being important for the specific case under study, and whose inclusion in the matrix was originally not suggested by the panel of experts.

The numerical value given in Column B corresponds to a unique identifier (ID) and does not reflect any kind of ranking or evaluation of importance of a variable by the group of experts. Column C contains the name of the evaluation criteria for the adaptation practices. A short description of the meaning of each variable is contained in Table 1 of the article.

The second group of columns contains suggestions from the expert team with respect to the relative importance of the different evaluation criteria. Column D contains the suggested weight that each variable should have in the calculation of the final index value. The suggested weight for a given variable was obtained by taking the mean of the weights assigned by each member of the IUPA expert panel ($n = 8$). A value close to 0 means a low relevance to the variable under consideration in the evaluation of the global usefulness of an adaptation practice and a weight of 10 indicates highest relevance. Zero indicates that the variable is not being considered in the calculation of the index value. The values suggested in Column D, if considered adequate, can be adapted by the user or modified accordingly; it is the user-defined weight factors (to be entered in Column I of Group III) that will finally be used in the index calculation.

Column E is a qualitative interpretation of the value that has been assigned by the experts to the variable 'suggested relevance'. It is not used in the calculation; its content is automatically generated by the spreadsheet based on 'relevancy' intervals which have been defined by the group of experts (see Table 4 of the article for the used classification criteria). When assigning the final value for the weight factor in Column J, the user is free to follow or not the suggestion to place the user-defined weight value within the corresponding relevancy intervals (Table 4).

The next three columns give additional information on the expert panel opinions with respect to the variable weight. Column F indicates the number of experts ('n') that have emitted an opinion with respect to the variable weight. Column G contains the standard deviation ('σ') of the assigned weights, and gives a quantitative indication of the homogeneity/heterogeneity of expert opinions. Column H, finally, allows a quick interpretation of the degree of homogeneity in the answers from the experts, helping the user to evaluate how recommended it is to follow the suggestions given in Column F (homogeneity classification criteria are given in Table 5).

Table 4 Qualitative interpretation of the value assigned to the parameter 'suggested relevance'

Assigned weight	Suggested relevance
0–4	Low relevance
4–7	Medium relevance
7–10	High relevance

Table 5 Homogeneity classification criteria as a function of the standard deviation of the expert opinions

Code	Interpretation of the expert opinions	Standard deviation of the weight factors assigned by the n experts
H	High homogeneity	$\sigma < 1$
M	Medium homogeneity	$1 \leq \sigma < 1.5$
L	Low homogeneity	$\sigma \geq 1.5$

The third group of columns corresponds to the interactive part of the matrix. The user can assign 'weights' and 'scores' to each one of the selected variables, and by doing so evaluate the usefulness of a given practice, based both on individual variable scores, as well as by interpreting the calculated integrated IUPA index value.

User-assigned weights for each variable and variable score (between 0 and 10) for the adaptation practice under consideration are entered through Column I and Column K, respectively. User-defined weight factors for the different variables can be developed and assigned in a similar way as was done by the expert panel: the user can consult one or a group of local experts and then determine a mean value (ideally experts would have a good knowledge of the specific context of the case area and/or adaptation practice or need); or alternatively, the user can opt to determine and assign the weight factors himself; in this last case, he can base his decision on the expert-panel suggested weight factors, but introduce modifications to these values based on his own knowledge of the specific characteristics and needs for the case study under consideration.

The intermediate Column J corresponds once more to a spreadsheet-generated automatic interpretation of the weight value, this time the weight value that has been assigned by the user. It can be used to quickly evaluate how far the user opinion with respect to parameter relevance differs from the opinion of the expert panel. Column L contains the net contribution of each variable to the final index score, which is obtained by multiplying the weight by score (Columns I and K). Finally, the weighted sum of individual parameter scores leads to the IUPA index value, which is contained in the lowermost cell of Column L.

Columns M and N have a similar functionality as Columns K and L, but are used for evaluating practices in the post-implementation phase. Columns K and L versus M and N facilitate comparison of scores, obtained, for example, for a given practice in its pre- and post-implementation phase. Alternatively, these additional columns can also be used to evaluate the effect of incorporating modifications to a proposed adaptation strategy, or for comparing alternative strategies for dealing with a given adaptation need.

References

Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. Glob Environ Change 15(2):77–86. doi:10.1016/j.gloenvcha.2005.03.001

Alberini A, Chiabai A, Muehlenbachs L (2006) Using expert judgment to assess adaptive capacity to climate change: evidence from a conjoint choice survey. Glob Environ Change 16(2):123–144. doi:10.1016/j.gloenvcha.2006.02.001

Apuuli B, Wright J, Elias C, Burton I (2000) Reconciling national and global priorities in adaptation to climate change: with an illustration from Uganda. Environ Monit Assess 61(1):145–159. doi:10.1023/A:1006330507790

Bell N, Schuurman N, Hayes MV (2007) Using GIS-based methods of multicriteria analysis to construct socio-economic deprivation indices. Int J Health Geogr 6(17). http://www.ij-healthgeographics.com/content/6/1/17

Booysen F (2002) An overview and evaluation of composite indices of development. Soc Indic Res 59(2):115–151. doi:10.1023/A:1016275505152

Brooks N, Adger WN, Kelly PM (2005) The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Glob Environ Change 15(2):151–163. doi:10.1016/j.gloenvcha.2004.12.006

Burton I, Huq S, Lim B, Pilifosova O, Schipper EL (2002) From impacts assessment to adaptation priorities: the shaping of adaptation policy. Clim Policy 2(2–3):145–159. doi:10.1016/S1469-3062(02)00038-4

Burton I, Diringer E, Smith J (2006) Adaptation to climatic change, international policy options. Pew Center on Global Climatic Change, New York

Carreno ML, Cardona OD (2007) A disaster risk management performance index. Nat Hazards 41(1):1–20. doi:10.1007/s11069-006-9008-y

Connor RF, Hiroki K (2005) Development of a method for assessing flood vulnerability. Water Sci Technol 51(5):61–67

de Loe R, Kreutzwiser R, Moraru L (2001) Adaptation options for the near term: climate change and the Canadian water sector. Glob Environ Change 11(3):231–245. doi:10.1016/S0959-3780(00)00053-4

Debels P, Figueroa R, Urrutia R, Barra R, Niell X (2005) Evaluation of water quality in the Chillan River (Central Chile) using physicochemical parameters and a modified water quality index. Environ Monit Assess 110:301–322. doi:10.1007/s10661-005-8064-1

Dessai S, Hulme M (2007) Assessing the robustness of adaptation decisions to climate change uncertainties: a case of study on water resources management in the East of England. Glob Environ Change 17(1):59–72. doi:10.1016/j.gloenvcha.2006.11.005

Droogers P (2004) Adaptation to climate change to enhance food security and preserve environmental quality: example for southern Sri Lanka. Agric Water Manag 66(1):15–33. doi:10.1016/j.agwat.2003.09.005

Eriksen S, Kelly P (2007) Developing credible vulnerability indicators for climate adaptation policy assessment. Mitig Adapt Strateg Glob Change 12:495–524. doi:10.1007/s11027-006-3460-6

Ginsberg N, Osborn J, Blank G (1986) Geographic perspectives on the wealth of nations. Department of Geography Research Paper No. 220, University of Chicago, Chicago, pp 17–120

Haddad BM (2005) Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit. Glob Environ Change 15(2):165–176. doi:10.1016/j.gloenvcha.2004.10.002

Hallock D (2002) A water quality index for ecology's stream monitoring program, Technical Report, P No. 02-03-52. Washington Department of Ecology, Environmental Assessment Program, Olympia, WA

Helsloot I, Ruitenberg A (2004) Citizen response to disasters: a survey of literature and some practical implications. J Conting Crisis Manag 12(3):98–111. doi:10.1111/j.0966-0879.2004.00440.x

IPCC (2001) Climate change 2001: impacts, adaptation, and vulnerability, summary for policymakers and technical summary of the working group II report. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 34 pp

IPCC (2007a) Climate change 2007: impacts, adaptation and vulnerability working group II contribution to the intergovernmental panel on climate change fourth assessment report. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 22 pp

IPCC (2007b) Climate change 2007: mitigation of climate change. Summary for policymakers. Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 852 pp

IPCC (2007c) Climate change 2007: the physical science basis. Summary for policymakers. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 18 pp

Kane S, Reilly J, Tobey J (1992) An empirical study of the economics effects of climate change on world agriculture. Clim Change 21(1):17–35. doi:10.1007/BF00143251

La Red (2003) Guía metodológica DesInventar. Red de estudios sociales en prevención de desastres en América Latina, Lima

Leary N (1999) A framework for benefits-cost analysis of adaptation to climate change and variability. Mitig Adapt Strateg Glob Change 4:307–318. doi:10.1023/A:1009667706027

López-Ridaura S, Masera O, Astier M (2002) Evaluating the sustainability of complex socio-environmental systems. The MESMIS framework. Ecol Indic 35:1–14

MIDEPLAN (2006) Encuesta de caracterización socioeconómica nacional, Casen 2006. Región de Coquimbo, Santiago

Mizina S, Smith J, Gossen E, Spiecker K, Witkowski S (1999) An evaluation of adaptation options for climate change impacts on agriculture in Kazakhstan. Mitig Adapt Strateg Glob Change 4:25–41. doi:10.1023/A:1009626526883

Niang-Diop I, Bosch H (2004) Formulating an adaptation strategy. In: Lim B, Spanger-Siegfried E (eds) Adaptation policy frameworks for climate change: developing strategies. Policies and measures. Cambridge University Press, Cambridge

Nichols D, Martinot E (2000) Measuring results from climate change programs: performance indicators for GEF. Monitoring and Evaluation Working Paper 4, Washington, DC

Orlove B (2005) Human adaptation to climate change: a review of three historical cases and some general perspectives. Environ Sci Policy 8(6):589–600. doi:10.1016/j.envsci.2005.06.009

Paavola J, Adger WN (2006) Fair adaptation to climate change. Ecol Econ 56(4):594–609. doi:10.1016/j.ecolecon.2005.03.015

Parker R (1993) Disaster vulnerability in the formal and informal city: lessons from Istanbul. Disaster management. In: Metropolitan areas for the 21st century. Series 1 UNCRD proceedings, Nagoya, pp 271–281

Paskoff R (1993) Geomorfología de Chile semiárido. Universidad de La Serena, La Serena

Reilly J, Hohmann N, Kane S (1994) Climate change and agricultural trade. Who benefits, who loses. Glob Environ Change 4(1):24–36. doi:10.1016/0959-3780(94)90019-1

Reilly J, Stone PH, Forest CE, Webster MD, Jacoby HD, Prinn RG (2001) Climate change: uncertainty and climate change assessments. Science 293(5529):430–433. doi:10.1126/science.1062001

Riedlinger D, Berkes F (2001) Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. Polar Rec (G B) 37(203):315–328

Scheider HJ (1982) Drought, demography and destitution: crisis in the Norte Chico. GeoJournal 6(2): 111–1119

Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Change 16(3): 282–292. doi:10.1016/j.gloenvcha.2006.03.008

Stambuk-Giljanovic N (1999) Water quality evaluation by index in Dalmatia. Water Res 33(16):3423–3440. doi:10.1016/S0043-1354(99)00063-9

Sterr H (2000) Implications of climate change on sea level. In: Lozan J, Grassl H, Hupfer P (eds) Climate of the 21st century: changes and risks. Wissenschaftliche Auswertungen, Hamburg

Stockholm Resilience Centre (2007) Research. http://www.stockholmresilience.su.se/pub/jsp. Assessed 30 May 2007

Sullivan C, Meigh J (2005) Targeting attention on local vulnerabilities using an integrated index approach: the example of the climate vulnerability index. Water Sci Technol 51(5):69–78

Szlafsztein C (1995) Analysis of the "poverty-natural disaster" relationship in the city of Buenos Aires (Argentina). J Nat Disaster Sci 17(1):1–12

Tompkins E, Adger W (2005) Defining response capacity to enhance climate change policy. Environ Sci Policy 8(6):562–571. doi:10.1016/j.envsci.2005.06.012

UN (1992) United Nations framework convention on climate change. UNFCCC Secretariat, Germany, 24 pp

UN ISDR (2005) International strategy for disaster reduction "Hyogo framework for action 2005–2015: building the resilience of nations and communities to disasters. Paper presented at the extract from world conference on disaster reduction, Kobe, Hyogo, Japan, 18–22 Jan 2005

UNFCCC (2002) Delhi ministerial declaration on climate change and sustainable development. In: Eighth conference of the parties to the UNFCCC, New Delhi, Oct, Nov 2002

UNFCCC (2005) Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change. Final draft report SC10341, UNFCCC Secretariat with the service of Stratus Consulting Inc., New York

Vincent K (2007) Uncertainty in adaptive capacity and the importance of scale. Glob Environ Change 17(1):12–24. doi:10.1016/j.gloenvcha.2006.11.009