

# **Methodology for Integrated Assessment of Climate Change Impacts and Adaptation Options**

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*A framework is presented for describing scientific method for the integrated assessment of climate change impacts and adaptation options, drawing on a recent survey of method in integrated sustainability assessment [1]. Evaluation criteria for scientific methods should be directly related to their functional roles. Scientific research should satisfy internal quality criteria, but often also must inter-relate with other scientific work as well as policy decisions, both public and private. Making explicit the functional role of an individual component of scientific research within a wider process is a first step towards the development of explicit quality criteria. This is invariably non-trivial because those wider processes are often developed concurrently. Further, systematically identifying their functions reveals when alternative methods are competing or complementary. This paper identifies some important functions within an integrated assessment process in general, with application to climate change impact and adaptation options in particular. It consequently derives some very general quality criteria against which an assessment can be evaluated, but which must be made specific in any particular application.*

## **Introduction**

There are many methods potentially applicable to integrated assessment in general or climate change impacts and adaptation options in particular. Comparison and contrast is complicated because such methods often perform different functions, and vary widely in their generality of applicability and specificity of prescriptive recommendations. Many crucial functions are often not subject to formal method at all, but rather are performed within informal social processes, including experts exercising their professional judgment. Methods can be evaluated against many evaluation criteria: rarely will one outperform another on all criteria [1].

Eckley [3] for example, suggests that scientific assessments should be evaluated against three main criteria: credibility (whether the information produced is believed to be accurate), salience (whether the information is relevant to significant concerns) and legitimacy (whether the process is socio-politically justifiable). Rothman and Robinson [4] present eight criteria for climate change assessment, including the extent of: “horizontal” integration, “vertical” integration, recognition of multiple baselines, recognition of feedback, inclusion of human adaptation options, compatibility with qualitative analysis, influence by policy demands, and stakeholder participation.

The applicability of such criteria is properly judged only by understanding the functional roles played by the various elements of an assessment process. This report explicitly identifies some important functions within an integrated scientific assessment process. These are sometimes subject to consciously elaborated method, but in practice are often not (although they may be explicitly identified), or performed implicitly and unconsciously by default. The latter cases possess the greatest potential for the improvement of assessment process quality.

## Important Functions in Climate Change Impact Assessment Identified

Many of the conclusions drawn here appear trivially true. It is often only when applied in practice that their relevance becomes clear. The most obvious function within a scientific assessment is developing a relevant *description* of some aspects of the real world that we care about as *significantly important*. For climate change assessment we might investigate Australian agriculture because it is important economically due to export earnings, and socially by providing nutrition. We might investigate the energy generation sector because it both supports a socially valued lifestyle and is a significant contributor to climate change, which has significant undesirable impacts.

In terms of internal (generally accepted scientific) quality criteria, a good description is one that is accurate, precise, generally applicable, covers a wide scope of behaviour, and simple. All else equal, a weather model that correctly forecasts rain events with 80% accuracy is better than one with 60% accuracy. Millimetre precision at a spatial resolution of 10km and temporal resolution of minutes is better than centimetre precision at resolution of 100km and hours. Validity under all conditions is better than under El Nino conditions only, and prediction of rainfall, wind, temperature, insolation and pressure is better than rainfall only. A finite element analysis computer simulation is not preferred if a simple algebraic manipulation derives the same result.

However, additional, external quality criteria apply within a wider assessment process. In particular, the description must be *relevant* (compare Eckley's "salience"[3]). In order to be relevant to assessment, the scientific description must identify existing or future predicted conditions in sufficient detail that they can be assessed in terms of their desirability or otherwise. For example, a model of agricultural productivity response to rainfall, no matter how accurate and precise, will be of limited utility if more important (politically, socially, economically?) impacts are increased flooding in urban areas. An agricultural model suited to predicting likely consequences for immediate export earnings, may not predict long-term soil fertility. Thus a good description represents relevant behaviour that is valued.

Unfortunately it is rarely *a priori* obvious what will turn out to be relevant (although experts in the behaviour of the relevant system can provide good initial guesses). For example, in the South-East Queensland Healthy Waterways study [2] it was initially unknown whether the nitrogen or phosphorus cycle was most relevant to the trophic response to water pollution and to the evaluation criterion of water quality. While initial science suggested that nutrients were likely relevant to the scientific description, it was unknown which one in particular was limiting in the South-East Queensland context. Ensuring relevance is facilitated by the explicit articulation of evaluation criteria (dollars earned, joules of energy saved, entropy change, water quality index value, employment generated, biodiversity conserved). At the very minimum, a necessary function within integrated assessment is the selection of categories of relevant behaviour that the scientific description must represent. Of course, the selection of which behaviours should be considered relevant cannot be entirely objective (but is potentially subject to improvement).

As well as describing significant behavioural outcomes, an integrated assessment of climate change must also include a representation of relevant *adaptation options*. A good scientific description will be able to predict the behavioural consequences of choosing among alternative adaptation options with sufficient accuracy to distinguish amongst significant differences in the desirability of those alternative consequences. For example, a model of agricultural response to rainfall might represent the consequences of alternative choices of crops, crop rotation schemes, or irrigation patterns. A bolder investigation of adaptation options might consider the economic consequences of switching land-use patterns from agriculture to eco-tourism. A better description is one that enables a wider scope of adaptation options, represents them more precisely, and does so more simply (and these criteria are invariably in tension).

Unfortunately, again, it is rarely *a priori* obvious what potential adaptation options will turn out to be relevant (although experts in the behaviour of the relevant system can provide good initial guesses). Perhaps there is no alternative choice of crops that will result in satisfactory agricultural productivity under future climate conditions (requires agricultural expertise). Perhaps education regarding alternative irrigation practices will succeed where economic incentives will not (requires sociological expertise). It may be impossible to know without either undertaking the analysis in full detail or by simply running the policy as an experiment. Ensuring relevance of the scientific description is facilitated by the explicit articulation of adaptation option categories. At the minimum, a necessary function within an integrated assessment is the selection of adaptation options categories, sometimes done implicitly (and perhaps as a do “nothing” option). Again the selection of which adaptation options should be considered cannot be entirely objective (but is potentially subject to improvement).

The above outlines at least three (internal) functions associated with integrated assessment of climate change and adaptation options. Scientific research produces a description that performs the function of (fallible, imprecise) *prediction of* behavioural consequences that can be *evaluated* in terms of desirability, often in order to *identify* particular adaptation options as being preferable to other alternatives.

### **Integrative Functions in Climate Change Impact Assessment**

And thus there are at least three types of integrative processes associated with climate change integrated assessment: the construction of D) a relevant *integrated description* that is integrated combination of relevant partial descriptions, V) a relevant *integrated evaluation* that establishes the relative desirability of predicted outcomes as an integrated combination of relevant partial evaluations, and A) a relevant *integrated adaptation* that is an integrated combination of relevant adaptation options. Each of these functions must themselves be *mutually integrated* so that they are compatible with one another. Even if evaluation and adaptation recommendation are not considered strictly part of the scientific investigation, it is still important that the scientific description can support the relevant processes that perform them. Furthermore the entire assessment process itself must be E) appropriately *integrated within its own* institutional, social and political *environments* (these will be more or less important depending on the specific context of the assessment).

Developing an integrated description entails at least three steps: D1) the selection of features of the real world to describe as relevant (eg a river catchment, an geographical region), D2) the selection of a representation format for the integrated description (eg a hydrological computer model, a scenario narrative) and D3) the identification of specific parameters that for the description within the previously selected format (eg specific surface flow and infiltration characteristics, a specific elaborated scenario). Well developed methods are typically applied only for step three. A good description will not only be accurate, precise, general and simple, it will also be relevant. Explicit awareness of what behaviour is, or might be, of significant interest and hence relevant, is particularly helpful in directing steps one and two.

Being explicit about what behaviour might be important requires at least the selection of V1) categories of value (agricultural productivity, employment, ecological health) if not also V2) surrogate variables for representing them (market value of the rice crop, percent of survey participants employed more than one hour per week, a biodiversity index) and conditions deemed unacceptable (violation of consumer sovereignty, property rights, international treaties, or political interests). Formal evaluation methodologies (such as cost-benefit analysis, citizen jury or political decision) typically only deal with V3) aggregating the predicted values of the surrogates into an appraisal of relative acceptability. A good evaluation will take into account all matters of genuine significance to the appropriate stakeholders (and it too will be precise, general, wide in scope, simple, valid and reliable). A good evaluation method may also aggregate such considerations in an appropriate way.

A relevant description will suggest possible adaptation options (but the identification of adaptation options will suggest real world features likely important to the description). Adaptation option analysis requires at least A1) selection of potentially relevant categories of adaptation (changed agricultural methods, changed economic activity, migration, infrastructure redesign) and A2) selection of specific adaptation options, and adaptation strategy structure (contingent, dynamic, decentralised, aperiodic, iterative, learning, locally informed). Formal decision assistance methods typically deal only with A3) identifying desirable (eg optimal) adaptation strategies given some specific integrated evaluation method. Appropriately identified adaptation options potentially make a significant positive difference to the evaluation of predicted behaviour, without violating conditions deemed to be unacceptable (and will be precisely specifiable, wide in scope, simple, generally accessible).

Any processes that assist in the integration of an assessment process within its own socio-political environment (such as stakeholder participation) requires at least E1) selection of the potentially relevant categories of the context to take into consideration (institutional, stakeholder, research social context) and E2) selection of the types of interaction processes that will be undertaken (workshops, surveys, committees), in addition to E3) determination of the specific environmental interactions. Most of the literature on methods in this area appears to deal with steps E2) and E3).

Given this framework, the distinction between “top down” and “bottom up” approaches to integrated assessment is arguably a distraction. These are alternative approaches to the functions D1, V1 and A1. In a “bottom up” approach, detailed

knowledge of the behaviour of affected systems - that is, knowledge of impacts and adaptation options - inform what types of climate change descriptions should be elaborated in more detail. In a “top down” approach detailed knowledge of likely climate change scenarios inform what types of impacts and adaptation options should be elaborated in more detail.

In practice, due to finite resource limitations, an iterative bootstrapping process is required, with existing (relatively immature, including expert informal) understanding of likely climate changes drivers, impacts and adaptation options all simultaneously informing which aspects of climate change, impacts and adaptation options should be selected for more detailed elaboration, so that a more mature, more relevant understanding can be developed. (The South-East Queensland Healthy Waterways study represents a model example of such iteration, see Brinsmead [1], Appendix A.2). What is of significance is not whether the process is top down or bottom up, but whether the resultant description represents relevant real world features, and whether it does so sufficiently accurately for its purpose.

### **Assessment Quality**

In considering the quality of an assessment it is useful to distinguish quality of assessment outcome, and that of assessment process (the methods used). This section addresses the former. From recognition of the function of a scientific description within an integrated assessment of impacts and adaptation options it is apparent that the main quality criteria include *the extent to which the description is able to support making legitimate predictions (preferably with specified confidence and precision) that are (fallibly) sufficiently accurate regarding all significantly relevant behavioural consequences of climate change and relevant adaptation options, and which is valid over a wide range of conditions*. How these criteria should be specified will depend on the particular context. Note that these criteria are equally applicable to the evaluation of “hard” quantitative models and “soft” qualitative narratives (cf. [4]). In this sense the distinction between quantitative and qualitative representation is not directly important (though observe that quantitative models are typically more precise, but narrower in the scope of behaviours represented, than qualitative descriptions).

Other criteria suggested for this purpose typically subserve the above conditions. For example, whether or not the process is participatory [4] can alternatively improve the accuracy of predictions or scope of possible adaptation options (by incorporating local knowledge) or it can ensure that the behaviours predicted are those that are relevant (to the participants). The extent to which the assessment is multi-sectoral (ibid) increases the scope of behaviours predicted and hence the extent to which all significant consequences are represented. Ensuring that appropriate causal linkages including feedback (ibid) is represented improves the accuracy of prediction and the range of conditions over which the description is valid (because some parameters can be represented as feedback variables rather than static environmental boundary conditions). Explicit representation of uncertainty specifies the degrees of confidence and precision of the predictions. Whether or not, and the extent to which, the assessment process is iterative [1] typically correlates with the extent to which the scope of the description is sufficient to include all relevant behaviours and adaptation

options (it is typically impossible to know in advance which, of a wide range of possible candidates, will be empirically significant). Legitimacy [3] is an external quality criterion that applies to how successfully the assessment process has been made compatible with its social and political context.

### **Methodological (process) quality**

This section addresses the issue of quality of the assessment process (that is, method). In practice many of the important functions (selection of real world features to describe, evaluative categories, adaptation option classes, etc.) within an integrated assessment are performed by default. In such cases there is no explicit recognition of the function. Sometimes the function is explicitly recognized as being performed, but there is no specific method providing guidance. Other times, there is an explicit method, and only then can a method be consciously evaluated for quality.

The greatest scope for the improvement of the quality of integrated assessment is to identify when important functions are being performed without the guidance of explicit method. Thus, an important first step for evaluating an integrated assessment method is to identify whether the functions DVAE:1-3 are even explicitly recognised as taking place, and if so, whether there are some explicit methodological guidelines for that prescribe how they should be conducted. Only if the latter is true is it possible to evaluate the quality of the method as method. Method can be evaluated according to the extent to which it promotes assessment outcome quality criteria - *credible legitimacy, relevant accuracy, relevant outcome scope, relevant adaptation option scope* and *relevant scope of validity*.

### **Conclusion**

The assessment of integrated assessment method requires a sound appreciation of the functional role that scientific investigation plays within a wider (evaluative) assessment and adaptation option identification process. In particular its role is to support making credible and legitimate *predictions* that are sufficiently accurate regarding *all significantly relevant* behavioural consequences of climate change and *relevant adaptation options*, and which is valid over a wide range of conditions. Methods within integrated assessment should be evaluated in terms of the extent to which this functional role is supported.

### **References**

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