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# Response to "To what extent, and how, might uncertainty be defined" by Norton, Brown, and Mysiak

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In a previous issue of Integrated Assessment, Walker et al. (2003) proposed an uncertainty analysis framework (hereafter called the W&H framework), the aim of which was to provide a conceptual basis for the systematic treatment of uncertainty in model-based decision support activities, such as policy analysis, integrated assessment, and risk assessment. The six authors came from different disciplinary backgrounds, all of which used different partial typologies of uncer-

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tainty. As a result of their experiences with these partial typologies, they felt the need to develop a more comprehensive and generic multidisciplinary uncertainty typology for model-based decision support. This resulted in the W&H framework, which provides a heuristic tool that can be applied in decision support situations to classify and report, within a consistent and comprehensive framework, on the various dimensions of uncertainty that are of relevance and potential importance to the decisions being made. The framework was primarily intended to promote systematic reflection on a wide range of types and locations of uncertainty in order to minimize the chance that relevant key uncertainties are overlooked, and to facilitate better communication among analysts from different disciplines, as well as between them and policymakers and stakeholders.

In the current issue of Integrated Assessment, Norton et al. (2005) present a critique and evaluation of the W&H framework. Their critical assessment of the Walker et al. paper reflects disappointment that the paper does not succeed in meeting up to the expectations of "offering an operational interdisciplinary framework for assessing uncertainties in models used for decision support" and fails to achieve its central aim of providing "a systematic treatment of uncertainty in decision support in order to improve the management of uncertainty in decision making processes". The most strongly articulated argument by Norton et al. is that Walker et al. do not relate classes of uncertainty to methods of uncertainty analysis or propagation. Norton et al. stress (and we agree) that systematic analysis of the propagation of uncertainty is of key importance because different types of uncertainty need not be additive but can, through complex interactions, amplify or dampen one another. According to Norton et al., if a method to classify uncertainty is not accompanied by some means to follow up its implications for model-based decision support, it is inherently limited as an operational tool.

In addressing these criticisms, it is important to distinguish among (1) the identification and communication of uncertainty, (2) the assessment of the propagation of uncertainty in model calculations, (3) the assessment of quality of the knowledge produced in terms of its fitness for a given case, and (4) the judgement of the implications of uncertainty for decisionmaking. While an adequate treatment of each of these tasks is necessary if uncertainty is to be properly accounted for in decisionmaking, the tasks are quite different and pose different challenges. The W&H framework was born out of a desire to integrate the wide variety of terminology being used in different disciplines to communicate uncertainty into a comprehensive and generic coherent conceptual framework. Underlying this aim is the belief that in the absence of an integrated framework, practitioners inevitably fall back on one of the many classification systems that have been proposed. Because they operate with a single, less complete classification system, practitioners often fail to identify and take into account important aspects of uncertainty characterising their assessments. The ambition of Walker et al. is therefore to establish a comprehensive and coherent typology of uncertainty, described by a unified vocabulary, in the hopes that it can be used by practitioners to systematically diagnose and communicate the complete range of aspects of uncertainty that can characterise decision support activities.

While the scope of the W&H framework is primarily focused on identifying and communicating uncertainty, the authors readily acknowledge the importance of assessing the implications of uncertainty for decisionmaking. In their discussion, Walker et al. point out that further analysis of the uncertainty diagnosed is necessary in order to assess the relative influence of the various aspects of uncertainty on the outcomes of interest. As pointed out by Norton et al., this analysis should include an examination of potential interactions between different sources of uncertainty. The methods that can be used to do so have begun to be dealt with in more recent accounts of how the W&H framework can be used in practice (Krayer von Krauss, 2005; Krayer von Krauss & Janssen, 2005; Janssen et al., 2005). Krayer von Krauss (2005) illustrates how the W&H conceptual framework was applied through expert elicitations focusing on two different case studies related to the risk assessment of genetically modified crops. At the Netherlands Environmental Assessment Agency (RIVM), a team of uncertainty experts headed by Dr. van der Sluijs embedded the W&H framework in an "uncertainty guidance system" that is being applied on a regular basis by assessors at the RIVM (van der Sluijs et al., 2003; Petersen et al., 2003; Janssen et al., 2003; van der Sluijs et al., 2004). The system involves a code of conduct that provides a structured approach to the analysis, interpretation, documentation, and communication of uncertainties and limitations in the available knowledge and methods used in the entire process of a given environmental assessment study. The uncertainties and limitations dealt with include those running from problem framing through reporting the results and conclusions of a study, along with the systematic assessment and communication of the implications of these uncertainties on the robustness and scope of resulting knowledge claims and policy conclusions. This uncertainty guidance system uses the W&H framework in combination with a diagnostic checklist that is coupled to a toolkit of methods for uncertainty analysis and to hints and suggestions that aim to give the user some guidance in coping with uncertainties in a systematic and explicit way. Of course, assessing the influence and propagation of the various types of uncertainty, particularly the qualitative aspects, remains a challenge, and further work is required in this area (Krayer von Krauss, 2005).

Building further in the spirit of the integrative approach of the W&H framework, van der Sluijs et al. (2005) present a framework to combine quantitative and qualitative analysis of uncertainty in models, and Refsgaard et al. (accepted) present a new framework for the systematic analysis of model structure uncertainty. Of course, the issues and caveats raised by Norton et al. should be taken into account in these developments. In particular this should be done by making the developers aware of (a) the inextricable linkages between uncertainties in inputs, model parameters, structure and solutions, (b) the intrinsic limitations in assessing uncertainties when extrapolating beyond the immediate model scope, and (c) the importance of interactions between different sources of uncertainty. Nonetheless, we maintain that simply identifying and communicating the full spectrum of uncertainty is a critical first step. It can already provide useful inputs to the adaptive decisionmaking schemes now so frequently being advocated. (See, for example, Walker et al., 2001.)

Norton et al. argue that the W&H framework is no more successful than previously proposed classification schemes, because 1) it does not address the diversity of meanings associated with terms such as 'uncertainty' and 'ignorance' in the context of model-based decision support, and 2) it does not explore how these concepts are assessed and used by different groups of modellers, including model developers and model users (e.g. 'academics' versus 'practitioners'). They further argue that Walker et al. are insufficiently precise about the 'level' dimension of uncertainty, potentially allowing for problematic interpretations of terms such as 'ignorance'. It is true that the discourse on uncertainty is characterised by disagreement on the definition of key concepts such as uncertainty and ignorance. However, it is also characterised by the fact that the many concepts in use do not seem to fit into a coherent conceptual framework. What is the relationship between concepts such as 'ignorance', 'model uncertainty', and 'natural variability'? While these concepts are frequently mentioned in the literature, there is little discussion of how they relate to one another. Thus, in addressing the criticisms of Norton et al., we must once again recall that the goal of Walker et al. was to integrate the many existing partial monodisciplinary classification schemes into a generic comprehensive, yet coherent, multidisciplinary framework. The goal was not to further articulate any particular classification scheme. With this in mind, it was important that the definitions provided in Walker et al. be sufficiently broad to allow for some variations in the interpretation of the concepts involved to accommodate different local meanings and nuances in different disciplines and fields of application.

The establishment of a coherent integrated conceptual framework seems an appropriate first step towards conventionally agreed upon definitions of the various aspects of uncertainty. This being said, it is obvious that in the short term, the interpretive flexibility allowed by the broad definitions used by Walker et al. makes it difficult to apply their conceptual framework consistently. Indeed, investigations using the W&H framework to diagnose the uncertainty characterizing the risk assessment of genetically modified crops revealed a large diversity of expert opinions on uncertainty (Krayer von Krauss et al., 2004). In the absence of precise, conventionally agreed upon definitions of the concepts involved, it is difficult to determine whether this diversity of opinion is attributable to genuine disagreement amongst experts, or simply to differences in how experts interpret the various concepts. This problem can to some extent be remedied by asking experts to justify their opinions.

The final criticism offered by Norton et al. is that the W&H framework omits some important sources of uncertainty. Given the ambition of Walker et al. to establish a comprehensive typology of uncertainty, this is perhaps the most serious criticism put forth by Norton et al. However, the validity of the criticism hinges upon the interpretation of the (admittedly broad) definitions used by Walker et al. For example, Norton et al. claim that the W&H framework fails to consider the different ways in which goals (concepts) are translated into decision criteria (entities) and then into observable quantities (data and models). We would argue that the translation of qualitative descriptions of the system of interest into quantitative data and models introduces a subtle assumption into the decision support exercise, which is that the quantitative system is indeed equivalent to the qualitative system of interest. The extent to which this assumption is true will influence the level of uncertainty characterising the model structure (including the choice of which variables, parameters and relationships to include in the model). Similarly, Norton et al. point out that the uncertainties associated with extrapolation are essentially case dependent, and their evaluation is impossible without either extending experiments into a larger region of state space or making untested assumptions about regularity of behaviour over that space. Here we would argue that, depending on the case, a decision support exercise based on untested assumptions about the regularity of behaviour could be characterized by scenario uncertainty on the model structure, the inputs to the model, the parameters, and therefore also the model outcomes. Thus, while the examples provided by Norton et al. do point to the need for establishing more precise, conventionally agreed upon definitions, they do not justify the claim that the W&H framework omits some of the potentially most important sources of uncertainty. Instead of merely stating this criticism, it would have been helpful if they had included some constructive suggestions on how the W&H framework could be improved.

We maintain that the W&H framework can promote systematic reflection on a wide range of types and locations of uncertainty, can decrease the chance that relevant key uncertainties are overlooked, and can facilitate better communication among analysts from different disciplines, as well as between them and policymakers and stakeholders. For these purposes it successfully integrates many previously independent mono-disciplinary conceptual frameworks for analysing uncertainty and provides a comprehensive and coherent framework for describing and communicating uncertainty in the context of model-based decision support. Its major uses are for consciousness-raising, systematic reflection, and communication—bringing attention to potential sources of uncertainty that are relevant for decisionmaking, not suggesting how uncertainty assessment should be carried out. Developing such suggestions is a logical next step, for which the insights from the W&H framework can be a useful starting point.

# 1 Bibliography

Janssen, P., Petersen, A., van der Sluijs, J., Risbey, J. & Ravetz, J. (2003), *RIVM/MNP Guidance for Uncertainty Assessment and Communication: Quickscan Hints & Actions List*, RIVM/MNP, Bilthoven, the Netherlands. 91

Janssen, P., Petersen, A., van der Sluijs, J., Risbey, J. & Ravetz, J. (2005), 'A guidance for assessing and communicating uncertainties', *Water Science and Technology* **52**(6), 125–131. 91

Krayer von Krauss, M. (2005), Uncertainty in policy relevant sciences, PhD thesis, Technical University of Denmark. 91

Krayer von Krauss, M. & Janssen, P. (2005), 'Using the W&H integrated uncertainty analysis framework with non-initiated experts', *Water Science and Technology* **52**(6), 145–152. 91

Krayer von Krauss, M., Casman, E. & Small, M. (2004), 'Elicitation of expert judgments of uncertainty in the risk assessment of herbicide-tolerant oilseed crops', *Risk Analysis* **24**(6), 1515–1527. 92

Norton, J., Brown, J. & Mysiak, J. (2005), 'To what extent, and how, might uncertainty be defined? Comments engendered by "Defining uncertainty: A conceptual basis for uncertainty management in model-based decision support": Walker et al., Integrated Assessment 4:1, 2003', *Integrated Assessment*. 90, 91, 92, 93

Petersen, A., Janssen, P., van der Sluijs, J., Risbey, J. & Ravetz, J. (2003), *RIVM/MNP Guidance for Uncertainty Assessment and Communications: Mini-Checklist & Quickscan Questionnaire*, RIVM/MNP, Bilthoven, the Netherlands. 91

Refsgaard, J., van der Sluijs, J., Brown, J. & van der Keur, P. (accepted), 'A framework for dealing with uncertainty due to model structure error', *Advances in Water Resources*. 91

van der Sluijs, J., Craye, M., Funtowicz, S., Kloprogge, P., Ravetz, J. & Risbey, J. (2005), 'Combining quantitative and qualitative measures of uncertainty in model-based environmental assessment: The NUSAP system', *Risk Analysis* **25**(2), 481–492. 91

van der Sluijs, J., Janssen, P., Petersen, A., Kloprogge, P., Risbey, J., Tuinstra, W. & Ravetz, J. (2004), RIVM/MNP guidance for uncertainty assessment and communication: Tool catalogue for uncertainty assessment, Report nr: Nws-e-2004-37, Utrecht University. 91

van der Sluijs, J., Risbey, J., Kloprogge, P., Ravetz, J., Funtowicz, S., Corral Quintana, S., Guimarães Pereira, A., DeMarchi, B., Petersen, A., Janssen, P., Hoppe, R. & Huijs, S. (2003), RIVM/MNP guidance for uncertainty assessment and communication: Detailed guidance, Report nr: Nws-e-2003-163, Utrecht University. 91

Walker, W., Harremoës, P., Rotmans, J., van der Sluijs, J., van Asselt, M., Janssen, P. & Krayer von Krauss, M. (2003), 'Defining uncertainty: A conceptual basis for uncertainty management in model-based decision support', *Integrated Assessment* **4**(1), 5–18. 89, 90, 91, 92

Walker, W., Rahman, S. & Cave, J. (2001), 'Adaptive policies, policy analysis and policymaking', *European Journal of Operational Research* **128**(2), 282–289. 91