Uncertainties and causes of uncertainties in climate change adaptation

Key Messages

- Uncertainties relate to situations where it is impossible to exactly describe state of future outcomes.
- In climate change adaptation, uncertainties arise from different sources, e.g. natural climate variability, future emissions, modelling, behavioural, socio-economic and technological responses and ecological dynamics.
- Uncertainty can arise from multiple causes and situations: the lack of information or on the contrary the abundance of information with conflicting different pieces of information, measurement errors, linguistic ambiguity, or the subjectivity of opinions
- Reducing uncertainties is a major challenge in climate change adaptation. Some uncertainty can be reduced by acquiring knowledge while intrinsic (aleatory) uncertainty cannot be reduced.

Context

Uncertainty is a state of having limited knowledge where it is impossible to exactly describe existing state or future outcome (Hubbard, 2014). It applies to predictions of future events, to physical measurements already made, or to the unknown. The IPCC glossary of Working Group II defines uncertainty as a state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable.

Two basic categories of uncertainties are considered in the literature. An aleatoric uncertainty is one that is presumed to be the intrinsic randomness of a phenomenon. Epistemic uncertainty is associated with the lack of knowledge about the properties and conditions of the phenomena underlying the behaviour of the systems. This uncertainty manifests itself in the model representation of the system behaviour, in terms of both (model) uncertainty in the hypotheses assumed and parameter uncertainty of the model. Sub-classifications of these two categories of uncertainties may be introduced depending on the context of the study.

The recent IPCC report adds to that classification two more types of uncertainty and as a result formulates three forms of uncertainties: due to the absence of prior agreement on framing of problems and ways to scientifically investigate them (paradigmatic uncertainty), lack of information or knowledge for characterizing phenomena (epistemic uncertainty), and incomplete or conflicting scientific findings (translational uncertainty).

This Insight discusses sources of uncertainties in climate change adaptation.

Policy and methodological developments

Causes of uncertainty

In order to identify uncertainties in an adaptation project, the following main causes of uncertainty must be considered (Zimmermann, 2000; Zio and Pedroni, 2012):

- Lack of information (or knowledge) and/or data on the phenomena, systems and events to be analyzed. This is considered to be the main source of uncertainty. There could be limited information available not just about the input parameters of the model, but also about the structure of the model itself. This causes the deep uncertainty in relation to climate change.
- “Abundance” of information. The problem arises due to existence of many alternative data sets and variety of models that are not entirely compatible and/or provide different assessments. Choosing among this variety is a hard and sometimes impossible task for the analyst.
- Conflicting nature of pieces of information/data. It may happen that some pieces of available

information and data suggest one behaviour of the system, while others suggest a different one. The same could happen in the case of existence of several alternative models describing the same system but generating contradictory results.
- Measurement errors. The measurement of a physical quantity (temperatures, precipitation, etc.) is generally affected by uncertainty due to an imprecision of the analyst who performs the measurement or a mechanical tolerance of the instrument adopted.
- Linguistic ambiguity. All languages contain words that have different meanings depending on the context of analysis. For example, this causes uncertainty in communicating risks.
- Subjectivity of opinions. Uncertainty may derive from the subjective interpretation of the available pieces of information and data by the analyst: different analysts may provide different interpretations of the same piece of information and data depending on their cultural background, personal preferences, and competence in the field of analysis.

Climate change impacts and uncertainties

When designing climate-sensitive investments, decision-makers use weather and climate data. Attempts to model the future climate in terms of temperature face problems associated with many causes of uncertainty e.g. lack of knowledge about the climate system, measurement errors, and/or subjectivity of analyst opinion. As the result, no single climate model is able to produce reliable and global climate statistics for the future. In this way climate change represents a dramatic increase in deep uncertainty for decision-makers. Climate change uncertainties relate to:

- Natural climate variability resulting from natural processes within the climate system which cause changes in climate over relatively short time scales.
- Future emissions of greenhouse gases arising from uncertainty over the scale of future global emissions of greenhouse gases by human society, and thus the scale of future radiative forcing.
- Modelling/scientific uncertainty arising from incomplete understanding of Earth system processes and incomplete representation of these processes in climate models.

Uncertainty in future emissions of greenhouse gases is currently represented in the research community by the range of scenarios, the most recent set being the Representative Concentration Pathways. Assessment of the effects corresponding to such pathways involves modelling the Earth system's response to changes in greenhouse gas concentrations from natural and anthropogenic sources and, hence, contains the scientific (modelling) uncertainty. Different climate models generate different projections for the same emissions scenario and, hence, provide conflicting information. Model inter-comparison studies generate sets of projections termed ensembles.

Deep uncertainty refers to a situation in which analysts do not know or cannot agree on the following (Hallegatte, 2012):

- Models that relate key forces that shape the future,
- Probability distributions of key variables and parameters in these models,
- Value of alternative outcomes.

Uncertainties in adaptation assessment

Climate change impacts on adaptation projects include three levels of uncertainty (Markandya et al., 2013):

- Evolution and response of ecological or biophysical processes;
- Economic effects due to direct and indirect impacts;
- Technological changes that could lessen both ecological and economic impacts.

The typical accumulation of uncertainties in the process of modelling adaption to climate change is illustrated in the simplified schematic shown in Figure 1. There are three uncertainties associated with modeling of climate change: natural variability, impact of GHG emissions, and inherently climate models. The global climate model generates uncertain inputs to the model of a (sub-) system of interest. There is interaction of the system with climate containing additional policy uncertainty (e.g. regulations and their technological implications) adding to the three uncertainties indicated above. The system might impact markets and social processes e.g. how the climate impacts are perceived by different categories of population, market behavior including social and economic processes. This information generates estimates for social, economic, ecological, etc. impacts of the climate change. Based on these impacts assessment, risks are measured and implementation of adaptation options is simulated, providing feedback to the system and technological development. Technological development is separated from the System as it might have a direct effect on GHG emissions, e.g. new technologies help to reduce GHG emissions in the production process.

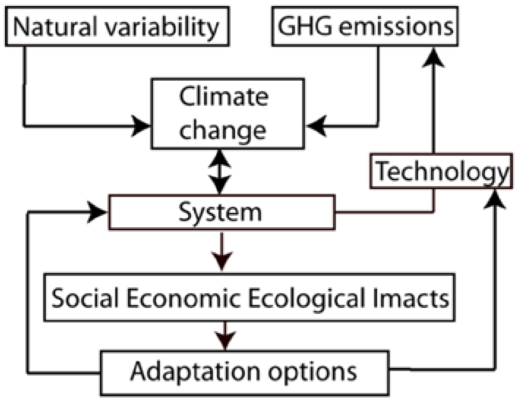

Figure 1. Conceptual scheme of uncertainties' accumulation in adaptation options evaluation carried out within an integrated modelling approach.

Communicating uncertainties

Communication of uncertainties in scientific projections of climate change and climate change impacts can become barriers to the planning and implementation of adaptation measures. One of the reasons for this is that scientific and common interpretations of certain notions and concepts differ from each other. Governments, organizations, private enterprises, and individuals will approach and consider uncertainties differently. It also makes a difference in what scale the uncertainty is considered.

One of the ways to cope with these multiple perspectives and interpretations lies in social learning. Lebel (2010) named two types of uncertainties which are connected with social learning: informational uncertainty (due to the lack of knowledge) and normative uncertainty, which is linked to perception of acceptable risk. Social learning in terms of interaction between researches and stakeholders who have practical experience in a certain sector or region can decrease informational uncertainty about probable climate change impacts and vulnerabilities. Uncertainty arising from perceptions, or normative uncertainty, can thus be reduced through participatory decision process.

Main implications and recommendations

Adequate consideration to uncertainties - and their interaction - is necessary when designing an adaptation project. However, reducing all uncertainties is an impossible task. While reducing epistemic uncertainty by acquiring knowledge or reducing normative uncertainties through participatory processes is possible, aleatory uncertainty cannot be reduced.

It is important to take into account that an overabundance of information or contradicting information also can lead to uncertainty; thus, gathering more data and information to reduce epistemic uncertainties may not always be successful in reducing uncertainty.

To reduce uncertainties that result from different subjective opinions, a clear way of communication and the use of a well-founded vocabulary can help in order to avoid linguistic ambiguity. Transparency generally helps; however, particular care should be given to the way information on scientific methods, statistics and the like are communicated, including ranges and so on. Communication on uncertainty should be different for different types of audiences.

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Further Information
A transparent overview and assessment of the relevant uncertainties for the main policy domains [pdf]
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