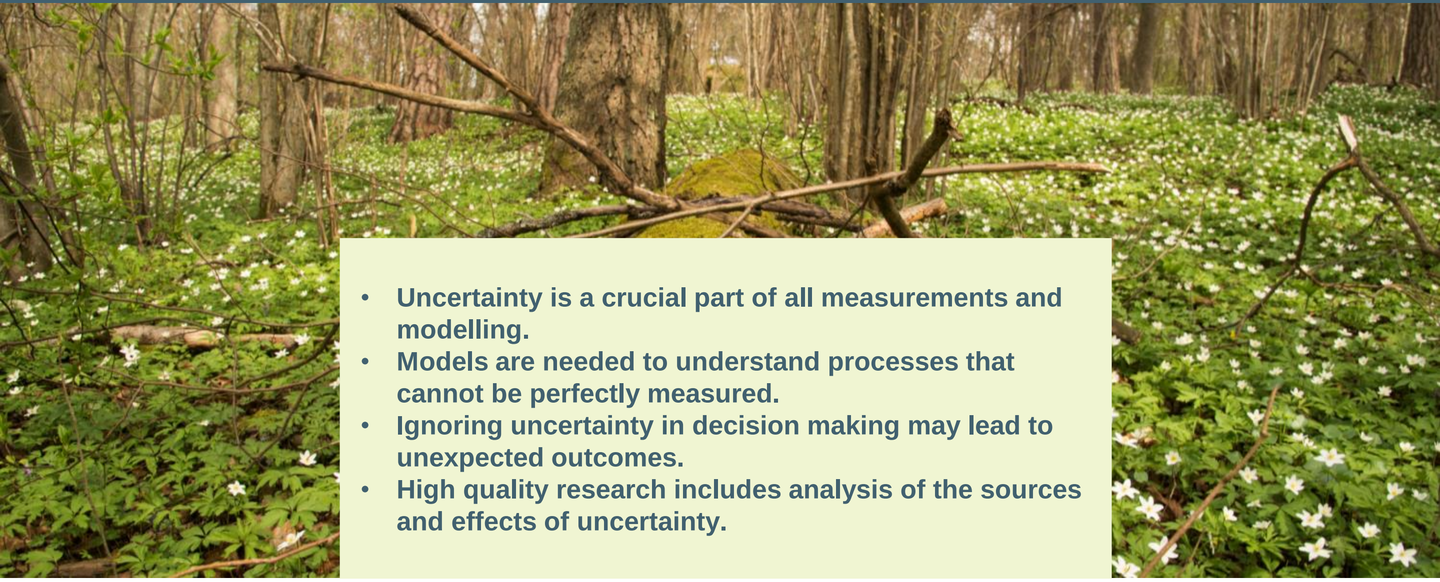
Uncertainty in modelling and its effect on decision making



- **Uncertainty is a crucial part of all measurements and modelling.**
- **Models are needed to understand processes that cannot be perfectly measured.**
- **Ignoring uncertainty in decision making may lead to unexpected outcomes.**
- **High quality research includes analysis of the sources and effects of uncertainty.**

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Decision making under uncertainty

Uncertainty is a crucial part of measurements and modelling in all applied natural sciences. Uncertainty should be considered when interpreting results and in the decision making based on it. Uncertainty means that the quantity of the studied variable is not known exactly, but within some range or probability.

Models provide necessary information for decision making. With models, we gain more insight into processes that cannot be perfectly measured, such as climate change or the growth of forest and carbon stocks. We can also use models to explore how these processes might change in the future depending on the decisions we make today.

If uncertainty is neglected, we might draw false conclusions about how our decisions affect natural processes. Considering uncertainty in decision making is efficient use of resources and leads more likely to reaching the targets.

Quantifying uncertainty is a crucial part of high quality research

Uncertainty arises both from data and models

The uncertainty of model outputs arises from various reasons. The uncertainty of **model input data** or the initial state of the system can be estimated using measurements. Because measurements are usually only available for a limited number of locations or points of time, the data need to be generalized to cover larger areas or longer periods.

Measurements can also be used to calibrate models and quantify their **structural uncertainty**. Since models are a simplification of reality, they are always to some extent uncertain.

The natural variability of weather, for example, causes uncertainty in models using weather data as their input. In addition, the uncertainty of climate and weather models has to be incorporated into the model projections driven by them.

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More information:

Kujala, H. et al. 2023: Role of data uncertainty when identifying important areas for biodiversity and carbon in boreal forests. Ambio https://doi.org/10.1007/s13280-023-01908-2

Junttila, V. et al. 2023: Quantification of forest carbon flux and stock uncertainties under climate change and their use in regionally explicit decision making: Case study in Finland. Ambio https://doi.org/10.1007/s13280-023-01906-4

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How to deal with uncertainty?

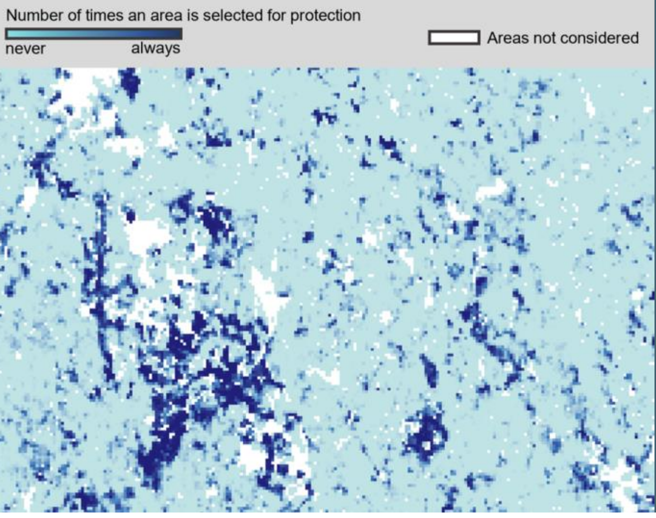

Figure 1. This map describes the local variation of simulated forest conservation values. The dark blue areas are forests that have likely high conservation values irrespective of modelling uncertainty. Other than forested areas were not considered (denoted with white colour).

How to interpret uncertainty?

A researcher reporting results and the related uncertainty carefully is not an uncertain researcher – on the contrary. Including uncertainty estimates in results improves their quality and usefulness in decision making. Consequently, the limitations of the research are better understood.

In society, qualitative or quantitative targets are often set, for example, to maintain a certain level of forest carbon sink. Instead of assuming that given actions always lead to the same outcome, the probability of reaching the target with the chosen actions should be considered.

If the uncertainty ranges of two separate outputs or projections are clearly separate, we can say that there is a significant difference between those outputs. If the known ranges do overlap, we might not be able to say if the two outputs really differ from each other (Fig. 2).

How to handle and reduce uncertainty?

When faced with uncertain information, we have different options. First, collecting more data may allow us to improve the accuracy of the estimates. Gathering more data, however, takes time and resources, which are limited.

The uncertainty might also stem from processes that cannot be known or measured, such as future events. In such cases, we can use scenario analyses to picture how the process will develop under alternative assumptions. Scenario analyses can, for example, describe how forest carbon sinks will develop under high or low harvesting levels, and guide decision makers on which actions to take (Fig. 2).

With repeated random sampling of possible model inputs, we can identify solutions that are robust to uncertainty, i.e., they will always generate a similar outcome, regardless of data and model uncertainty. For example, we can identify which forest areas remain important for biodiversity, irrespective of future forest development. (Fig. 1).

Often we end up with unresolvable uncertainty in our models and estimates. In such cases, it is worth considering how big a risk we are willing to take. What is at stake when we make the decision and how much risk is too much? Sometimes, using the precautionary principle and choosing the least risky option can be the best way forward.

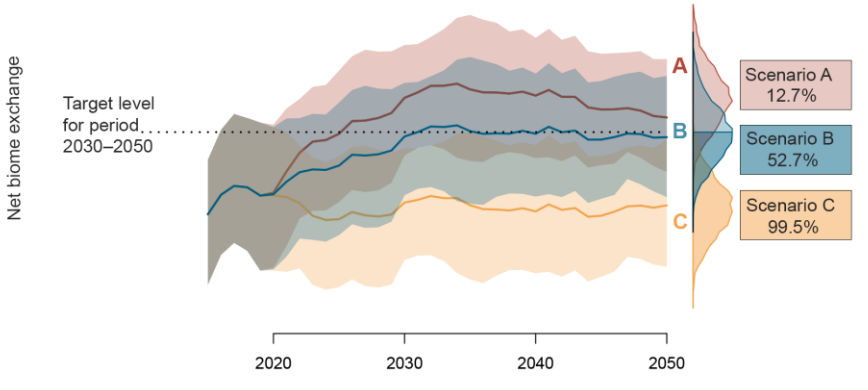

Figure 2. An example of simulated projections and uncertainty distributions of forest carbon balance with management scenarios A, B and C. The target level of forest carbon sink for the period 2030–2050 is marked with a black dashed line. The outcomes of scenarios A and B cannot be distinguished reliably because their uncertainty distributions overlap. The outcomes of scenarios A and C, on the other hand, are significantly different because their uncertainty distributions are clearly separate. The target level can be reached if the simulated scenario outcome stays below the dashed line with a high probability (12, 52 and 99% in scenarios A, B and C, respectively).

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