PROJECT
CS07 Tailoring climate information for impact assessment
COM21 Climate change sketchbooks
COM27 Climate Impact Atlas

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Climate Impact Atlas promotes the use of climate information in policy making

The Climate Impact Atlas is an effort to disclose spatial information on climate change impacts. It contains information about projected impacts of regionalized climate change scenarios, including flooding, ecosystem shifts and agricultural production.

Climate change increases the vulnerability of the Netherlands. Not surprisingly, adaptation of spatial planning is high on the political agenda. Integration of knowledge on climate change into spatial planning is difficult due to the gap between science and policy and because the issues involved are uncertain, long term and multisectoral of nature. Dutch provinces all share the intention to develop 'climate proof' policies. In this article, we describe experiences during the development of the "climate impact maps".

Objectives

The aim of the Climate Impact Atlas (CIA) is to promote the use of scientific information on climate change in spatial planning and decision making. Provinces are required to include climate change into their "revisions of spatial plans" in the Netherlands. In connection with this, the development of the atlas was initiated by four Dutch provinces, within the framework of the Dutch 'Climate Changes Spatial Planning' and 'Knowledge for Climate' research programs. Since the impacts do not stop at Provincial borders and there is considerable uncertainty about the impacts, there was a need for a consistent way of generating and presenting state of the art information on climate change impacts.

The Climate Impact Atlas

The impacts of climate change affect a wide range of sectors, therefore an interdisciplinary team of researchers was involved in the development of a first generation CIA. The climate impact atlas consists of a large number of maps disclosed via an online Geoportal. The maps in the atlas are divided into three categories:

1) *Primary effects*: meteorological variables such as average summer- and winter precipitation are included, but more importantly data was included on extremes such as the number of days per year with > 15mm rain, number of tropical days, summer days, frost days, etc. All variables are presented for the current situation (1976-2005), and for the future (2020, 2050 and 2100) for the four climate change scenarios for the Netherlands, developed by KNMI[1]. Data for the future are

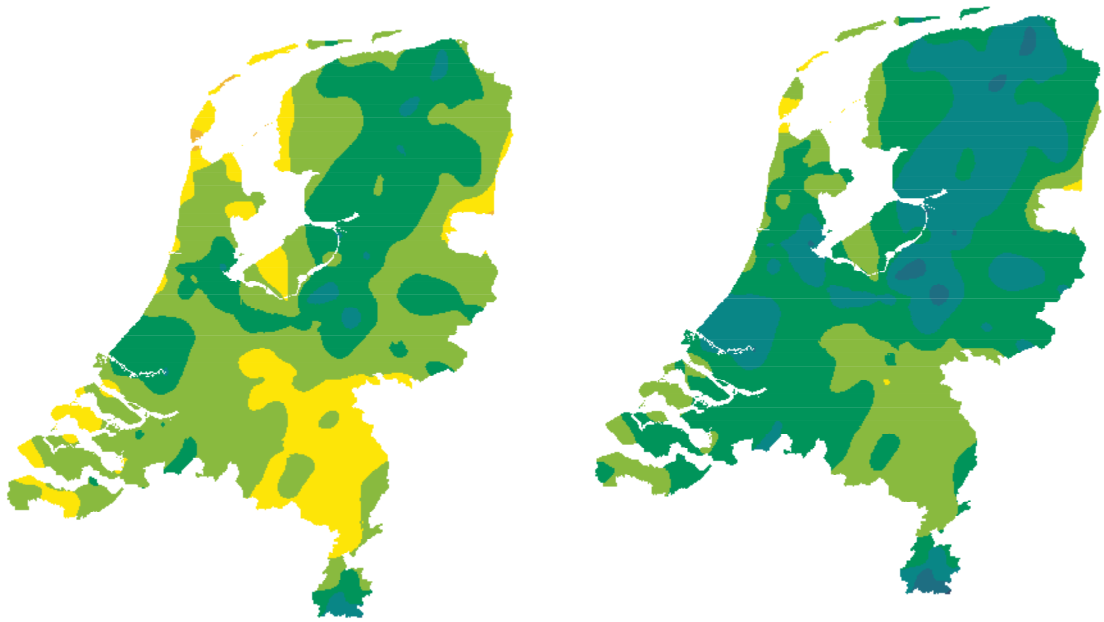

FIGURE 1. Average summer precipitation (April-September) in the current climate (1976-2005) and in 2050 for the W and W+ scenarios, based on transformation of time series to the scenario's and automatic interpolation of meteorological stations without additional climatological knowledge. Regional differences in the future are associated with regional differences in the current climate.

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based on transformations of historical data from meteorological stations (see: http://climexp.knmi.nl/Scenarios_monthly/) and spatially interpolated (figure 1).

2) *Secundary effects*: a set of maps representing the impacts of the meteorological changes (primary effects) on hydrological variables such as soil moisture content (drought), salinity, water depth (floods and peak rainfall), see figure 2.

3) *Tertiary effects*: maps that indicate potential impacts on agriculture, nature conservation, flood damage etc. These maps are often generated through a combination of (secondary) impact maps and vulnerability maps of land use functions. This category of maps requires subjective choices about the severity of impacts, (e.g.) dealing with uncertainties and weight factors that are required when combining impact maps with vulnerability maps. The tertiary impact maps can be used to identify areas where proposed investment policies may face future damage or opportunities due to climate change (figure 3).

To indicate potential impacts of droughts on agriculture and nature, the map of figure 2 is combined with maps indicating the possibilities for irrigation, water quality requirements, crop drought sensitivity and sensitivity of nature types to droughts. Figure 3 presents the results of such a combination of maps, which is referred to as 'tertiary impact map'.

So-called tertiary impact maps such as the one in figure 3 are used by Dutch provinces to perform climate impact scans, highlighting areas where adaptation is more urgent. An increasing number of provinces and regions are performing such scans, leading to an increased political support for action. Communication on, and dissemination of impact maps and robustness maps was occasionally difficult. The maps often contained political sensitivities and in some cases the quality of the CIA maps was not good enough to be used at the local level.

Lessons learned from the design process of the maps

Setting up the CIA required close cooperation between the research community and policy makers (end users). The translation of climate information into practice requires 3 essential components[2]: salience (the perceived relevance of the information), credibility (the perceived technical quality of the information) and legitimacy (the perceived objectivity of the process by which the information is shared).
Below we discuss the relevance of these components for the CIA.

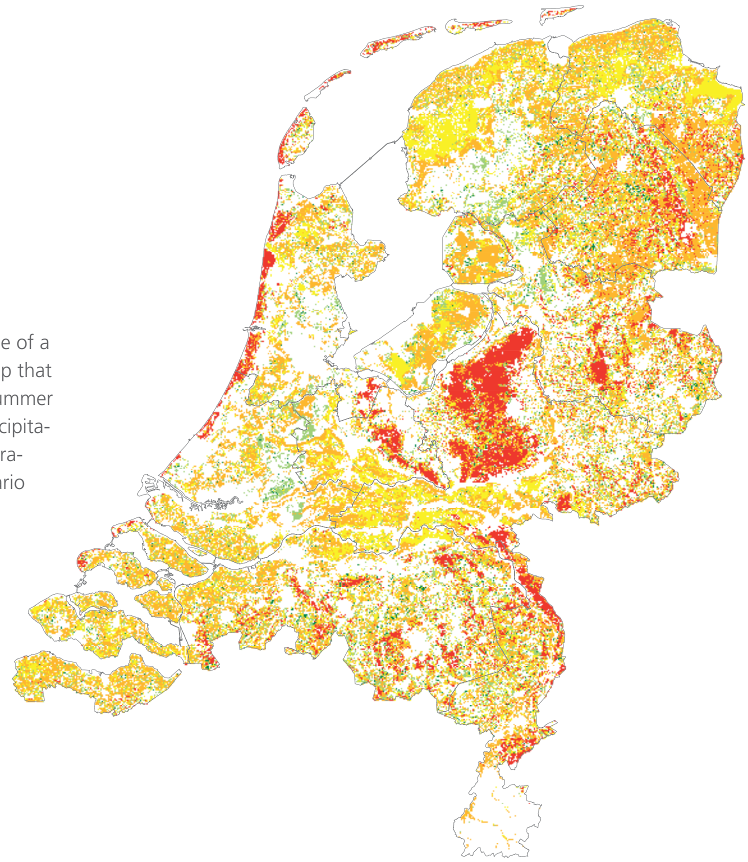

FIGURE 2: An example of a secondary impact map that shows the average summer soil water deficit (precipitation minus the evaporation) in the W+ scenario in 2050.

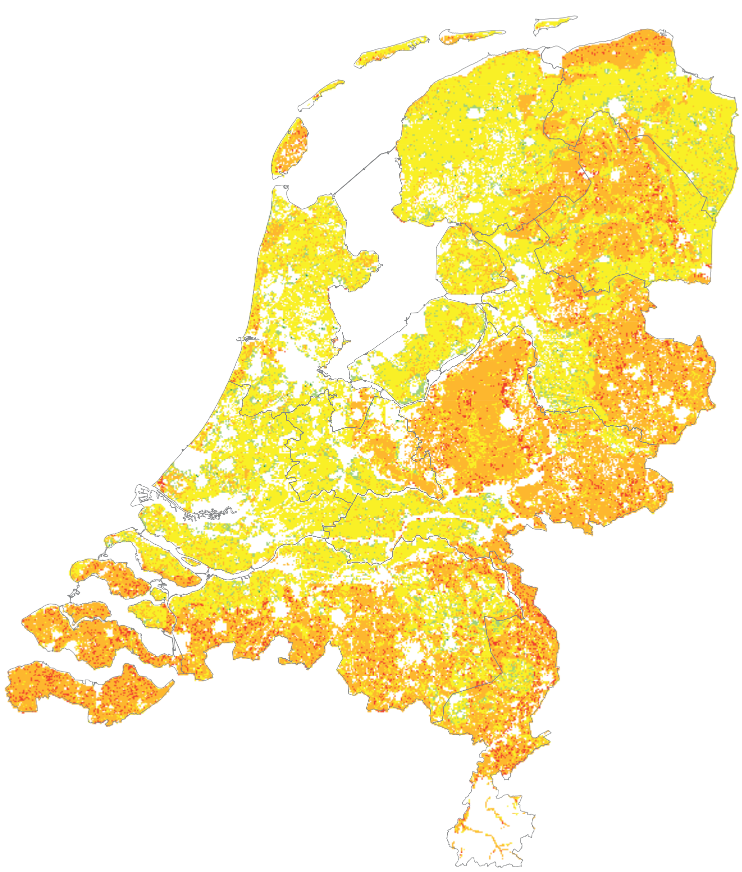

FIGURE 3: Example of a map in the Climate Impact Atlas, indicating the robustness for drought in 2050 under the W+ scenario. In this example, robustness is determined by the sensitivity of agriculture and nature to drought, the impacts of climate change on average water deficits and the possibilities for irrigation.

To increase the salience or relevance of the information, and to avoid a 'data dump', a series of interviews was held at the very start of the project to clarify the information requirement. It became clear that specification of the information requirement is not straightforward. For instance, the end users were interested in a drought map. Hydrologists however, need to know which parameters they need to visualize: water availability in the root zone, ground water levels, in what period of the year, for a standard year or in cases of severe drought periods etc. The first round of interviews resulted in a long list of wishes of climate change issues to be addressed by the atlas but it took more elaborate discussions about relevant issues and indicators to narrow down to a realistic number of issues and indicators. Rather than just offering maps and information, we applied a framework to better understand the potential use of information in different decision making and planning situations. For this purpose an additional series of workshops was organized on the available information and maps and to discuss the first generation impact maps for the 3 main issues: spatial planning, ecosystems, and agriculture.

The use of scientific information and the best way to present it depends on the decision making setting and the type of problem at hand[3]. Hisschemöller (1993) identifies four typical problems along two dimensions (Table 1). One dimension refers to the (lack of) certainty concerning the knowledge about the subject and possible solutions. The other dimension refers to the (lack of) consensus on relevant values that are at stake. Each of the four types of problems requires a different approach. In case of well-structured problems, a high degree of stakeholder participation is not recommended. Yet if the problems and knowledge are unstructured, a high degree of participation is required. For example, if there is a clear problem (need for a new road) and there is a clear overview of the consequences of all alternative ways to build the road, then the main activity is to take a (formal) decision on building the best possible alternative. When it is not clear that building a road is necessary, or maybe other alternatives such as a railroad are suggested, such a formal decision is more difficult to make. The process of making the CIA appeared to have many characteristics of semistructured or unstructured problems.

The scientific credibility of the information is another important aspect. Climate impact maps were constructed in consultation with a multidisciplinary group of professionals and scientists

TABLE 1. The problem typology, relating the degree of structuredness of problems to the level of certainty and agreement on knowledge and to the level of agreement on values and objectives (after Hisschemöller, 1993).

	Agreement on values and objectives	Disagreement on values and objectives
Certainty and agreement on knowledge	Structured problem	Semi structured
Uncertainty and disagreement on knowledge	Semi-structured	Unstructured problem

from the research networks of the Dutch Climate Changes Spatial Planning and Knowledge for Climate programs. The team of researchers provided information on changes in meteorological variables and secondary effects (i.e. damage to agricultural production, ground water levels, river discharge) for a wide range of sectors. The main aim of these maps is to support the many political and economical discussions regarding the adaptation to climate change.

Legitimacy reflects the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests[4]. The maps and the proposed methods were applied and tested in a number (6) of workshops with stakeholders, end-users and researchers. A web based 'Geoportal' (www.klimaateffectatlas.wur.nl) is developed to disclose all information to the end users and also to the general public.

The development of climate impact atlases became a useful process for creating awareness and a uniform sense of urgency among policy makers and their staff. About half of the project budget was allocated for interaction between scientists and policy makers/end users during a substantial number of meetings and workshops. This was necessary to further specify information needs, to gain understanding of the complexity of adaptation issues. Both the developers and end users learned that defining the right set of impacts, indicators and scenarios needs to be done together. Stakeholders alone can't specify the exact knowledge needs, and scientist alone can't provide the appropriate answers. Researchers of different backgrounds learned to cooperate in transdisciplinary teams which, for most of them, has been a useful and pleasant experience which has led to enhanced creativity and scientific quality of their results.

Conclusions and recommendations

The CIA offers easy access to regionalized state-of-the-art knowledge on the impacts of climate change. The CIA is work in progress and still a number of impacts have not been addressed properly. We have learned that setting up a nationwide atlas requires 4 crucial elements:

Close collaboration between science and policy. Before jumping into the science, it is vital to understand the type of problems at hand to produce salient information. Where structured problems can be solved through science (optimization), un-

It took more elaborate discussions about relevant issues and indicators to narrow down to a realistic number of issues and indicators.

	Agreement on values and objectives	Disagreement on values and objectives
Certainty and agreement on knowledge	**Structured problems:** • flood risk prevention • peak rainfall damage prevention Main activities: gathering data, analysis, empirics and ratio. Maps as decision tools	**Semi-structured problems:** • Fresh water supply and its distribution over functions • Changing relations between agriculture and nature Main activities: consensus building, using maps as a discussion tool
Uncertainty and disagreement on knowledge	**Semi-structured problems:** • how to include climate change in spatial policy plans? • How robust are Natura 2000 targets? • What are the impacts of extreme events on agriculture? • How robust are ecological networks? Main activities: investigating uncertainties and sensitivities. The CIA serves as a support tool to advocate knowledge	**Unstructured problems:** • Urban heat island effect • Opportunities for tourism Main activities: investigating scenarios and alternatives, identification of preferences and goals. Maps as discussion tools to help identify and clarify objectives and preferences

TABLE 2.
The issues mentioned by the provinces characterized in terms of structuredness of problems. For each category the main activities and the potential roles of the CIA were discussed.

structured and semistructured problems require more interaction.

A multidisciplinary approach. Although trivial, cooperation between disciplines (hydrology, ecology, meteorology, spatial information sciences, decision and policy sciences) is essential. Tailoring of information is important which depends on objectives, requirements and the context in which the information is to be used. Integration of information on impacts is often difficult, due to different ways of handling climate change and uncertainties (use of climate and spatial scenarios), differences in spatial resolution and so on.

Visualization. Translating science and data to maps improves communication and use of science and data. By now a lot of information about climate change and impacts available, yet it is often difficult to express the information in a spatial way. Spatial presentation is important since spatial planners are used to working with information that is presented in maps.

Leave the 'predict then act' principle. Be prepared to accept uncertainties. There is always the urge to produce more accurate data and better predictions. However, dealing with climate change and adaptation will always leave some level of uncertainty.

Adaptation issues are not to be solved through more science and data alone. Incomplete data and uncertain maps can indeed be helpful in investigating robust adaptation strategies.

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