12 — Synthesis

12.1. INTRODUCTION

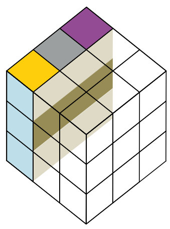
CH2014-Impacts was initiated in the Swiss scientific community to leverage recent advances in the development of Swiss Climate Change Scenarios (CH2011, 2011) and impact models for a quantitative treatment of climate change impacts. The participating researchers offered their scientific contributions in response to an open invitation to all institutions in Switzerland engaged in research relevant to climate change impacts. The result is a "sample of opportunity" of impact assessments, which covers diverse issues, but has no claim to be comprehensive or representative for the entirety of potential climate change impacts in Switzerland.

This synthesis attempts to combine the report's results into a coherent picture (Figures 12.1–6). It starts with a survey of the evolution of impacts along the CH2011 time frame of **short-term** (2035), **mid-term** (2060), and **long-term** (2085) periods, according to the central importance of time in planning and decision making. Then, a selection of results is discussed with respect to cross-cutting issues, as well as beneficial and adverse impacts in the context of time periods and greenhouse gas scenarios. Finally, crucial limitations are addressed, including impacts missing from the present report and the restricted scope of the individual and independent assessments.

‹ Some agricultural pests such as the codling moth will thrive under a warmer climate, putting pest management under pressure (photo: Ilona Ugro.)

12.2. TIME PERSPECTIVE

The explicit treatment of **short-term** impacts (time period 2035) in this report is an important advancement as it corresponds to the time frame of many business and political decisions, and allows identifying areas where need for early adaptation exists (insets illustrate the possible combinations of greenhouse gas scenario and uncertainty level for each time period; Chapter 2). For the 2035 period it



does not matter with regard to impacts which of the three greenhouse gas scenarios is considered, as they all evolve along a common climate path largely determined by the inertia in the global physical climate system and the economy, which delays the effect of vast differences in socio-economic developments and emissions among the scenarios. Most projected impacts in this period are relatively small compared to the complete range of projections, as might be expected due to the limited extent of short-term climate change. For example, the number of generations of the agricultural pest codling moth shows no short-term impact at all (Figure 12.2, Chapter 9). There are, however, important exceptions: The cryosphere exhibits profound impacts already for 2035, in continuation of recent trends; with respect to the reference period 1980–2009, the projected reduction of snow cover reaches about 1/3, and glacier melt 1/2 of the maximal impacts projected (A2, 2085, Figure 12.1, Chapter 5). In the health sector, the maximal impact on the number of hospitalizations is projected already for the period 2035.

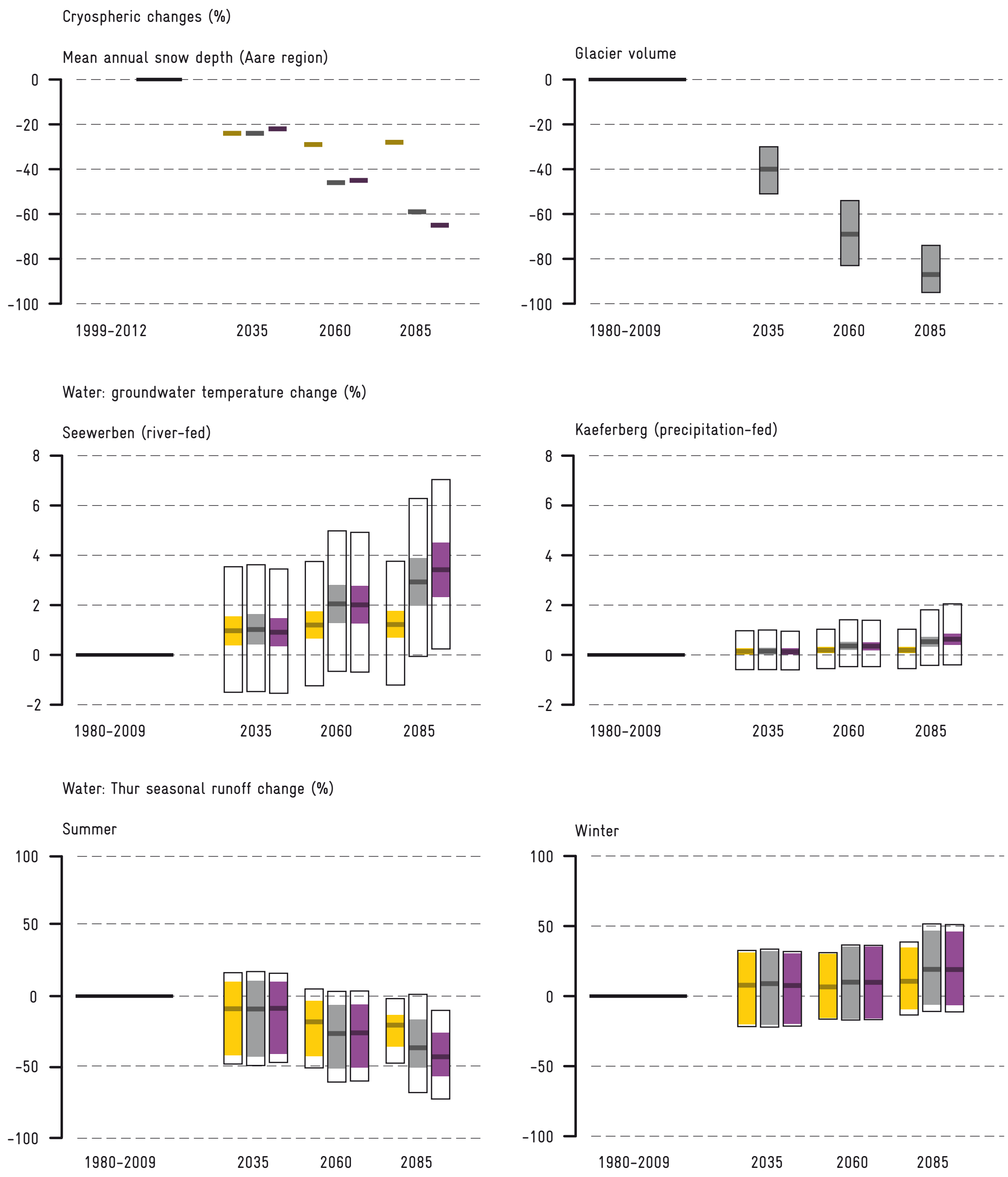
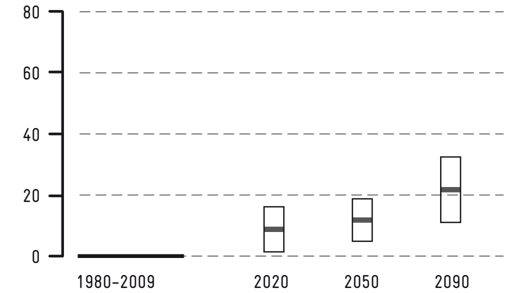


Figure 12.1: Selected climate change impacts (Chapters 5 and 6). Greenhouse gas scenarios are indicated by yellow (RCP3PD), grey (A1B), and purple (A2) color; bold colored lines correspond to the medium climate change estimate, and a colored bar shows the climate uncertainty range where available. Black outlines include impact modeling uncertainty to the extent that it is considered in each study (corresponding to two standard deviations in statistical estimates)

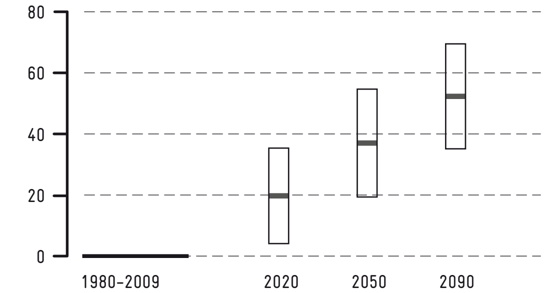
› **Figure 12.2**: Selected climate change impacts (Chapters 7-9) as in figure 12.1. Time ranges slightly deviating from the standard scenario periods were used for bird species turnover (20-year means).

Biodiversity: bird species turnover (%)

1000 m asl

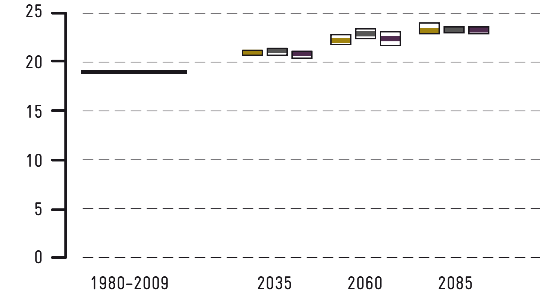


2200 m asl

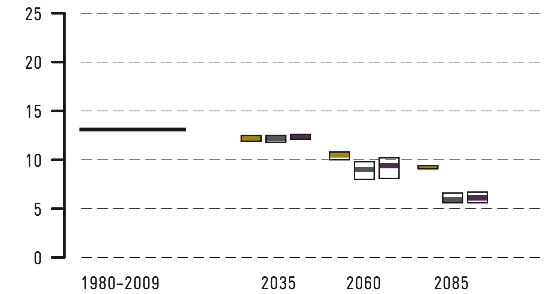


Forests: avalanche and rockfall protection (basal area, $m^2\ ha^{-1}$)

Dischma at 2200 m asl

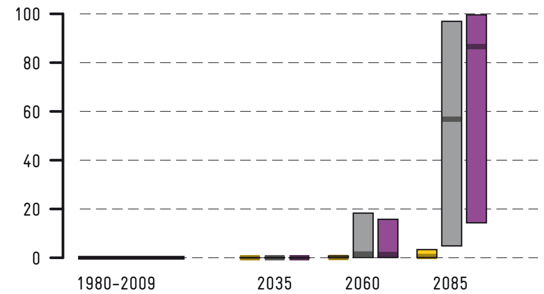


Saas at 1000 m asl



Agriculture: risk of codling moth 3rd generation (%)

Changins



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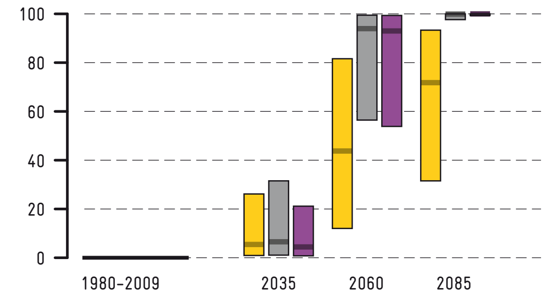
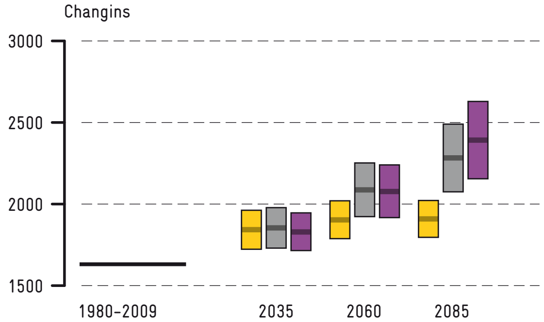


Agriculture: suitability for grape cultivation (Huglin index)

Changins



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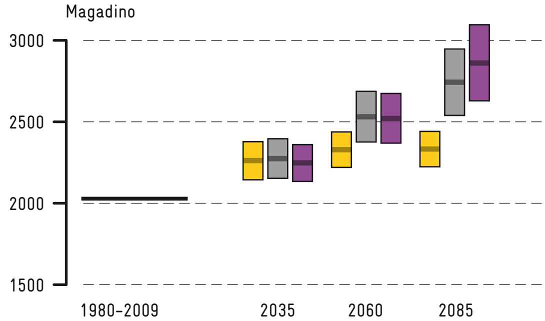
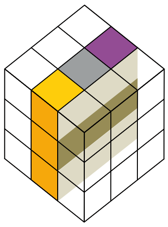


This report's limited set of studies already shows that short-term impacts must not be neglected – an aspect that the earlier impact assessment for Switzerland OcCC (2007) with its mid-century focus did not systematically explore. Though short-term impacts tend to be small in a century-long perspective, their relevance is heightened by the relatively shorter time for adaptation, and by the impact already experienced today (i.e., during the reference period 1980–2009). The assessment of short-term impacts remains challenging as the uncertainty of impacts is already large due to the natural decadal variability in the climate system.

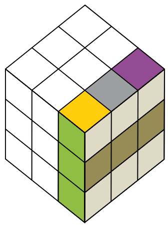
In the **mid-term** period (2060), the effect of political intervention to reduce climate change (known as climate change mitigation) emerges, as seen by comparing the mitigation scenario RCP3PD to the non-intervention



scenarios A1B and A2. The benefit of climate change mitigation is already felt widely as well, in that RCP3PD limits most impacts to the level of 2035 (Figures 12.1–3). In contrast, most non-intervention cases show progressively intensifying impacts, in tune with rising temperatures, and reach roughly half of their maximum projected extent. Deviations from this behavior are seen in complex responses such as those simulated for the health and energy sectors (Figure 12.3). An important special case is glacial ice whose volume has melted already by about 75% in the projection for scenario A1B (Figure 12.1), in line with earlier assessments (e.g., OcCC, 2007).

The 2060 time period roughly corresponds to the mid-century focus of OcCC (2007), and quantitatively projected impacts largely confirm the earlier, more qualitative findings of that assessment. This applies, e.g., to the changes in glacial ice and snow cover, and their consequences for runoff regimes and for winter tourism, respectively (Figure 12.1).

The 2085 scenario period affords a **long-term** perspective, which may at first glance seem less immediately policy-relevant than the more imminent future, but tends to reveal important long-reaching issues. For example, forest management must adapt early on to grow forests that will thrive under future



climate. Similarly, long-lived buildings should be planned with the heating and cooling needs of a warmer climate in mind. Finally, mitigation of long-term climate change requires that greenhouse gas emissions be reduced as soon as possible.

The consistent use of this time horizon is a crucial step ahead with respect to OcCC (2007). The 2085 period is marked by a further unfolding of the differences between greenhouse gas scenarios. The importance of global climate policy becomes apparent as the gap between RCP3PD and the non-intervention scenarios A1B and A2 widens. RCP3PD reveals the full effect of mitigation in the period 2085, with projected impacts showing signs of saturation. A hint of inertia is suggested by the response of, e.g., the codling moth (Figure 12.2). Inertia is also expected to play a role in glacier melting and its far-reaching consequences, though it cannot be assessed on the basis of the available results, which do not cover the RCP3PD scenario. The projections for the two non-intervention scenarios begin to separate in the 2085 period, with A2 showing stronger impacts than A1B. However, this difference is small compared to the uncertainty. The scope of climate change impact in Switzerland over this century is thus sufficiently captured by those studies that consider A1B alone (e.g., Figure 12.1 for glaciers and Figure 12.2 for biodiversity). However, this judgment does not carry over into the 22nd century, where the differentiation at the high end of climate change scenarios will become very important, due to the long time scales involved in the response processes of the climate system.

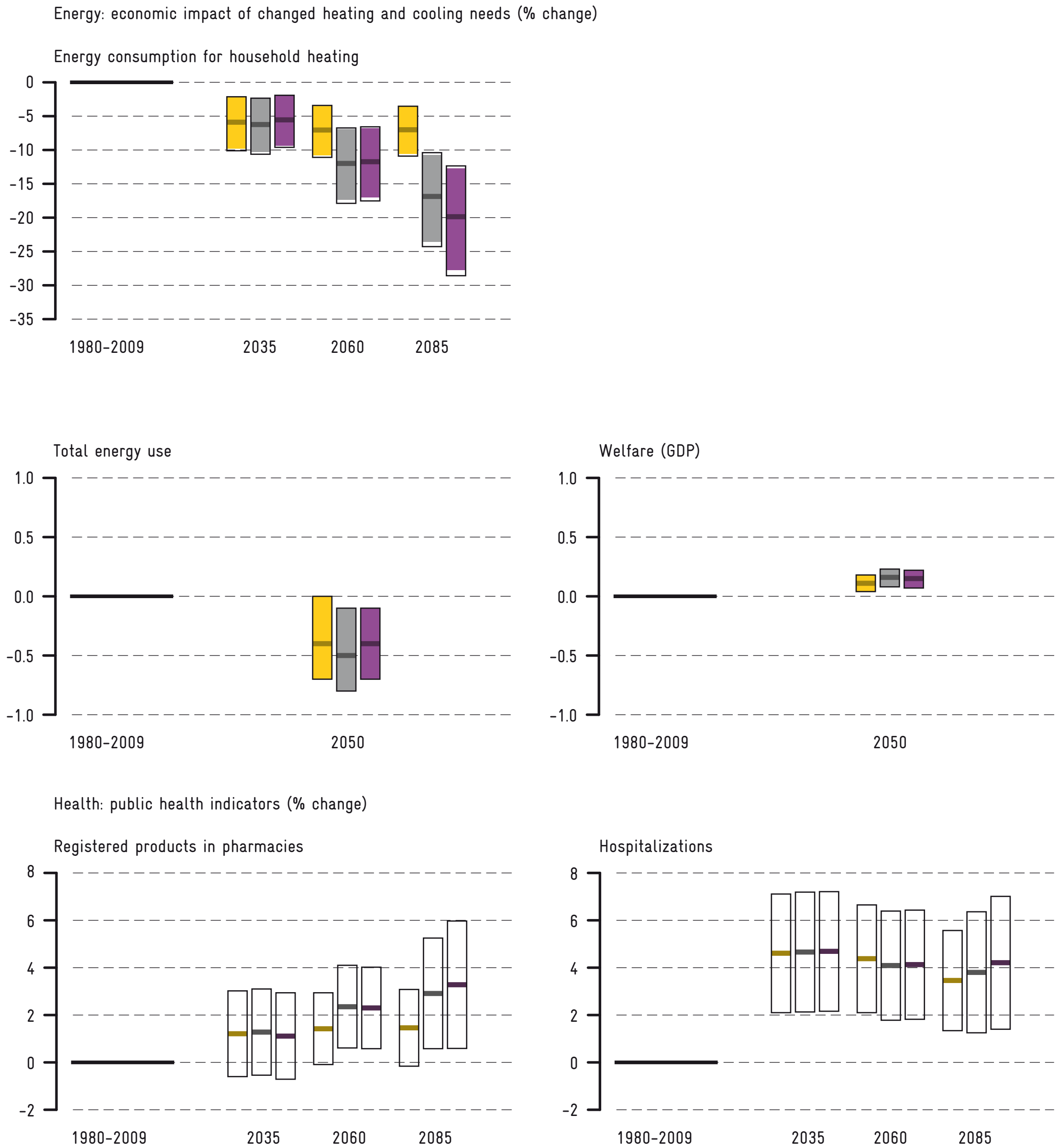


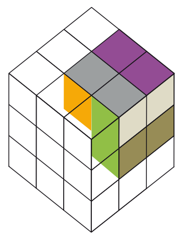
Figure 12.3: Selected climate change impacts (Chapters 10 and 11). Greenhouse gas scenarios are indicated by yellow (RCP3PD), grey (A1B), and purple (A2) color; bold colored lines correspond to the medium climate change estimate, and a colored bar shows the climate uncertainty range where available. Black outlines include impact modeling uncertainty to the extent that it is considered in each study (corresponding to two standard deviations in statistical estimates). A time period slightly deviating from the standard scenario periods was used for energy impacts (year 2050).

12.3. CROSS-CUTTING ISSUES

Of the illustrative selection of eleven independent impacts summarized in Figures 12.1–3, seven can be judged as adverse (snow, glaciers, groundwater, codling moth, species turnover, pharmacy sales, and hospitalizations), two as beneficial (grape cultivation and energy consumption), and another two are ambivalent (river regimes and protection against avalanches and rockfall). This is roughly representative for the mixture of impacts across the report. The beneficial and ambivalent examples point to opportunities in certain areas, such as wine production (Figure 12.2), and challenges in others, such as water supply in summer (Figure 12.1). The report provides several examples of potentially deleterious impacts that can probably be alleviated to a considerable extent with proper management: the adaptation to the increased reproduction of pests (codling moth in agriculture and bark beetle in forestry), the management of biodiversity shifts (species turnover), or the use of artificial snow to extend shortening skiing seasons (Chapter 5). Accordingly, the importance of foresight and management is highlighted in several chapters of this report (Chapters 6 and 7–9). This implies the need for an assessment of the cost of such adaptive measures, as well as potential undesired side effects. Adaptation costs are not assessed in this report but are expected to be potentially substantial.

The impact studies assess to a various degree the uncertainties arising from climate and impact modeling (Figures 12.1–3). Climate uncertainty (Chapter 2) affects the extent of the individual projected impacts, but hardly ever their assessment as beneficial or adverse. The relatively few studies in this report that assess impact modeling uncertainty already provide valuable information. They strongly suggest that the impact of a projected climate change is often just as uncertain as the climate projection itself.

The above survey of scenario time periods shows that unmitigated climate change and its impacts (scenarios A1B and A2) evolve over a very long time. Many impacts may give the appearance of a moderate development well into the mid-century. OcCC (2007) suggests overall beneficial agricultural impacts for moderate warming, tentatively defined as a rise of the mean annual temperature in Switzerland by up to 3°C with respect to the reference year 1990. When this limit is exceeded, the balance tends to tip to adverse impacts. Applied to the CH2011 scenarios (which use a similar reference period) this would mean that both non-intervention scenarios (A1B and A2) hold in store “immoderate” change with drastic impacts, though these crop up only toward the last time period (see inset showing the combinations of scenario, time period and uncertainty level where warming exceeds the “moderate” extent of 3°C). For the presented examples too, it is to be expected, albeit not explicitly assessed, that it will become increasingly harder to avoid damaging impacts and reap potential benefits when warming



exceeds “moderate” levels (e.g., Chapter 9). The only truly “moderate” scenario in CH2011 (2011) according to the above tentative definition is the mitigation scenario RCP3PD. This underscores the importance of global climate change policy for Switzerland.

Most of the impacts assessed in this report are driven by temperature change. This is due to the pervasive influence of temperature on all climate-dependent processes as well as the relative weakness of the precipitation change signal as simulated by the climate models, and the incomplete treatment of potentially important extreme precipitation events, storms, or droughts. The one clear trend in precipitation is a reduction in the seasonal mean in summer. The lack of summer precipitation in combination with warming results in dryness with widespread and, depending on the site-specific conditions, potentially severe impacts, as demonstrated in the forest assessment (Chapter 8). Water scarcity may be an issue for agriculture and biodiversity as well although it is not explicitly assessed in the corresponding chapters of the present report (Chapters 7 and 9).

Further insights are gained by considering impacts not in terms of time period and greenhouse gas scenario but in relation to average annual temperature change (Figures 12.4–6). This perspective exploits the central role of temperature. Some cases, e.g., groundwater temperature and suitability for grape cultivation, suggest simple relationships between impacts and mean temperature change. Other responses are more complicated, showing signs of inertia and nonlinearity, as well as the influence of the change in precipitation and associated uncertainty (e.g., river runoff). In any case, the extent or even the sign of the impact can depend strongly on site-specific conditions. For example, the projected impact on forest ecosystem services (Chapter 8) and biodiversity (Chapter 7) depends strongly on elevation; likewise, the warming of groundwater depends on whether groundwater is recharged by river water or precipitation only (Chapter 6). Further, the variety of observed responses demonstrates that the results of the quantified impacts do not generalize easily to additional objects of study such as other species, agricultural products, ecosystems, etc.

12.4. LIMITATIONS AND CHALLENGES

The "sample of opportunity" of assessed impacts collected in this report inherently leaves out many important aspects. For example, the biodiversity assessment (Chapter 7) could be extended by a range of additional important species (amphibians, insects, etc.) and an ecosystem-oriented perspective (with regard to wetlands, meadows, etc.). Similarly, many agricultural issues (Chapter 9) remain to be quantified (e.g., crop- and irrigation-related issues). The narrow focus of the energy and health chapters (Chapters 10 and 11) should be widened to a more comprehensive treatment of these sectors under climate change (e.g., physiological underpinning of climate impacts, or renewable energy production). Finally, the topics geomorphology (e.g., slope stability), transport, insurance, and summer tourism are essentially absent from the report. In general, coverage decreases along the cause-effect chain of impacts from the physical environment to biological and ecosystem changes and further to socio-economic impacts.

Extreme weather events concern a cross-sectoral group of impacts that this report does not explore explicitly, owing to limitations of the CH2011 scenarios (Chapters 2 and 3). Extreme events are expected to contribute to impacts on forests, biodiversity, health, etc., as much as changes in average conditions (e.g., OcCC, 2003; 2007; IPCC, 2012). Prominent examples of impacts that are not treated here include the risk of heavy precipitation, hail storms, floods, heat waves, droughts, etc.

Between the individual impact studies there are several areas of overlap. Glacier melt is an important factor in the seasonality change of runoff regimes (Chapter 6). Changes in the distribution and prevalence of tree species are treated statistically under the aspect of "species turnover" in vascular plants (Chapter 7), as well as with process-oriented complex forest models (Chapter 8). Surface and groundwater changes (Chapter 6) are relevant for drinking water supply and quality and therefore have health implications (Chapter 11). The different assessments are broadly consistent with respect to these overlapping aspects. However, they do not use completely harmonized assumptions apart from the common climate scenarios, and neither do they integrate any relevant results from related chapters. Overlapping aspects provide links which could serve to tie these quantitative results together into a consistent cross-disciplinary assessment, uncovering and eliminating inconsistencies in the process. Therefore, a tighter integration of impact models is desirable for the future.

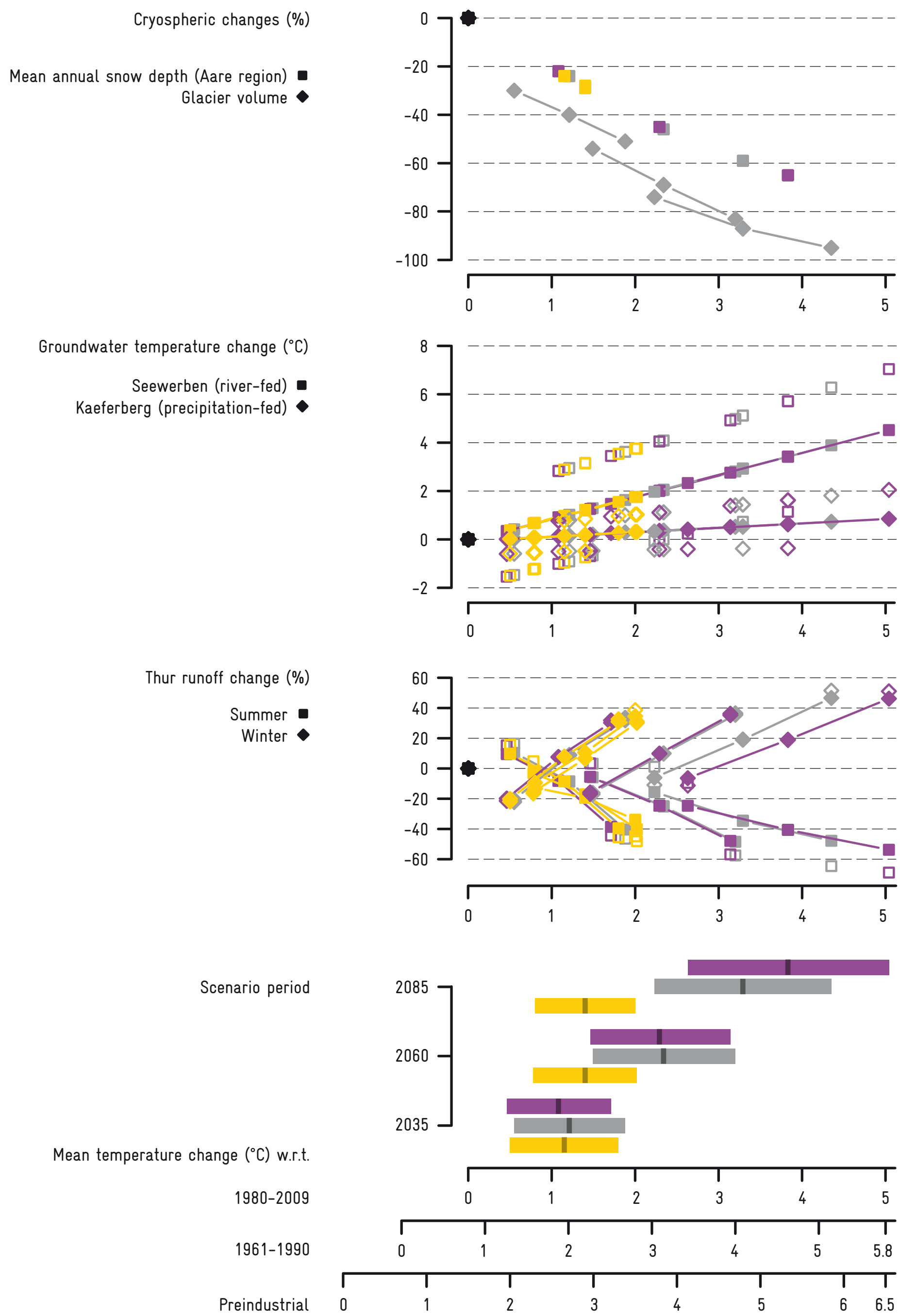
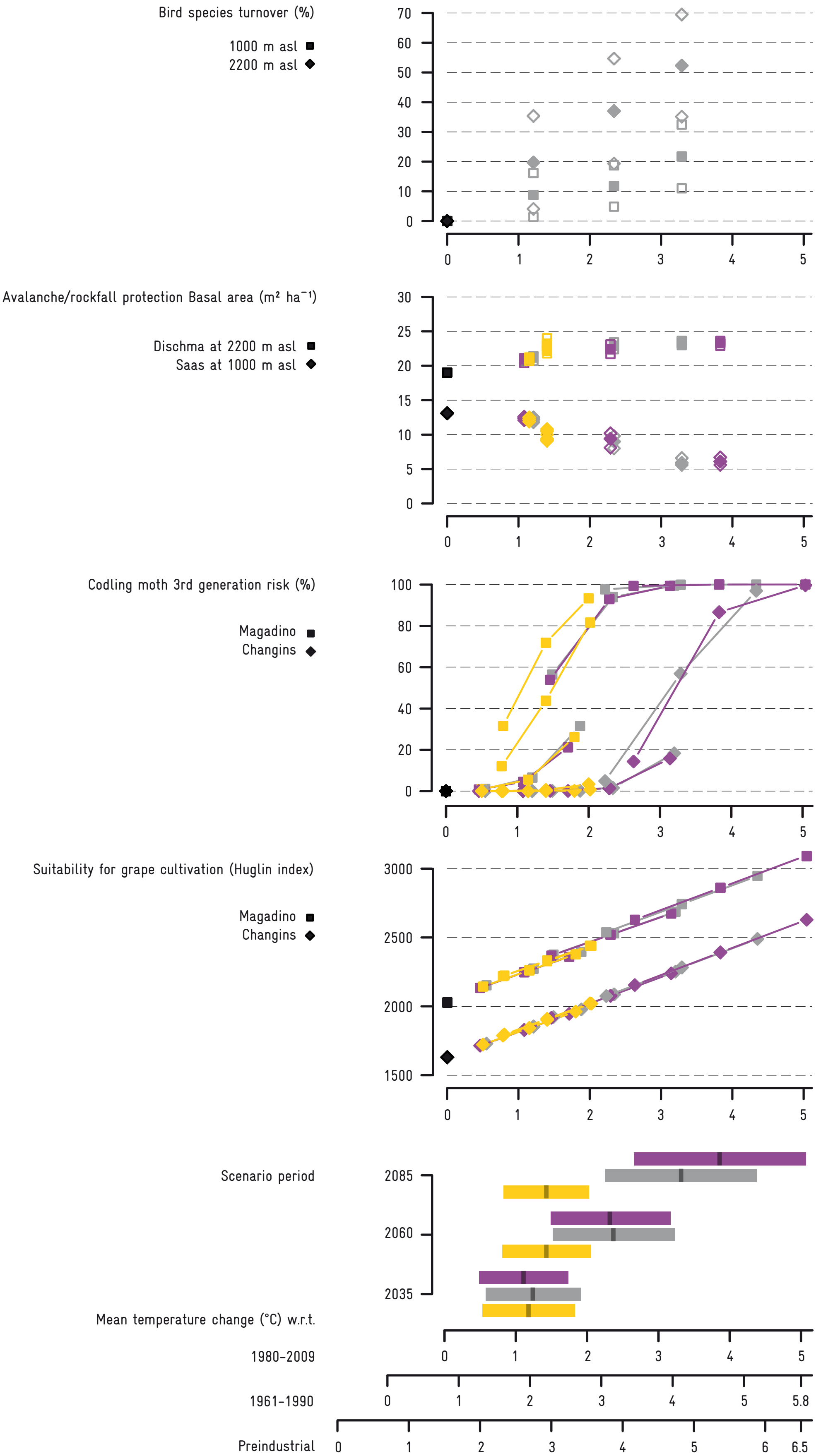


Figure 12.4: Climate change impacts from Chapters 5 and 6, plotted against mean annual temperature change in CH2011 scenarios (average of regions CHNE, CHW, and CHS). Greenhouse gas scenarios are indicated by yellow (RCP3PD), grey (A1B), and purple (A2) color. Estimates for different climate uncertainty levels (low, medium, and high) are shown with solid symbols connected with lines; open symbols correspond to additional impact model uncertainty where quantified (two standard deviations for statistical estimates). For glaciers and river runoff it is assumed that the greatest impact is associated with the upper end of the temperature range and vice versa.

› **Figure 12.5**: Climate change impacts from Chapters 7–9, as in Figure 12.4.



Bird species turnover (%)
1000 m asl
2200 m asl
Avalanche/rockfall protection Basal area (m² ha⁻¹)
Dischma at 2200 m asl
Saas at 1000 m asl
Codling moth 3rd generation risk (%)
Magadino
Changins
Suitability for grape cultivation (Huglin index)
Magadino
Changins
Scenario period
2085
2060
2035
Mean temperature change (°C) w.r.t.
1980–2009
1961–1990
Preindustrial

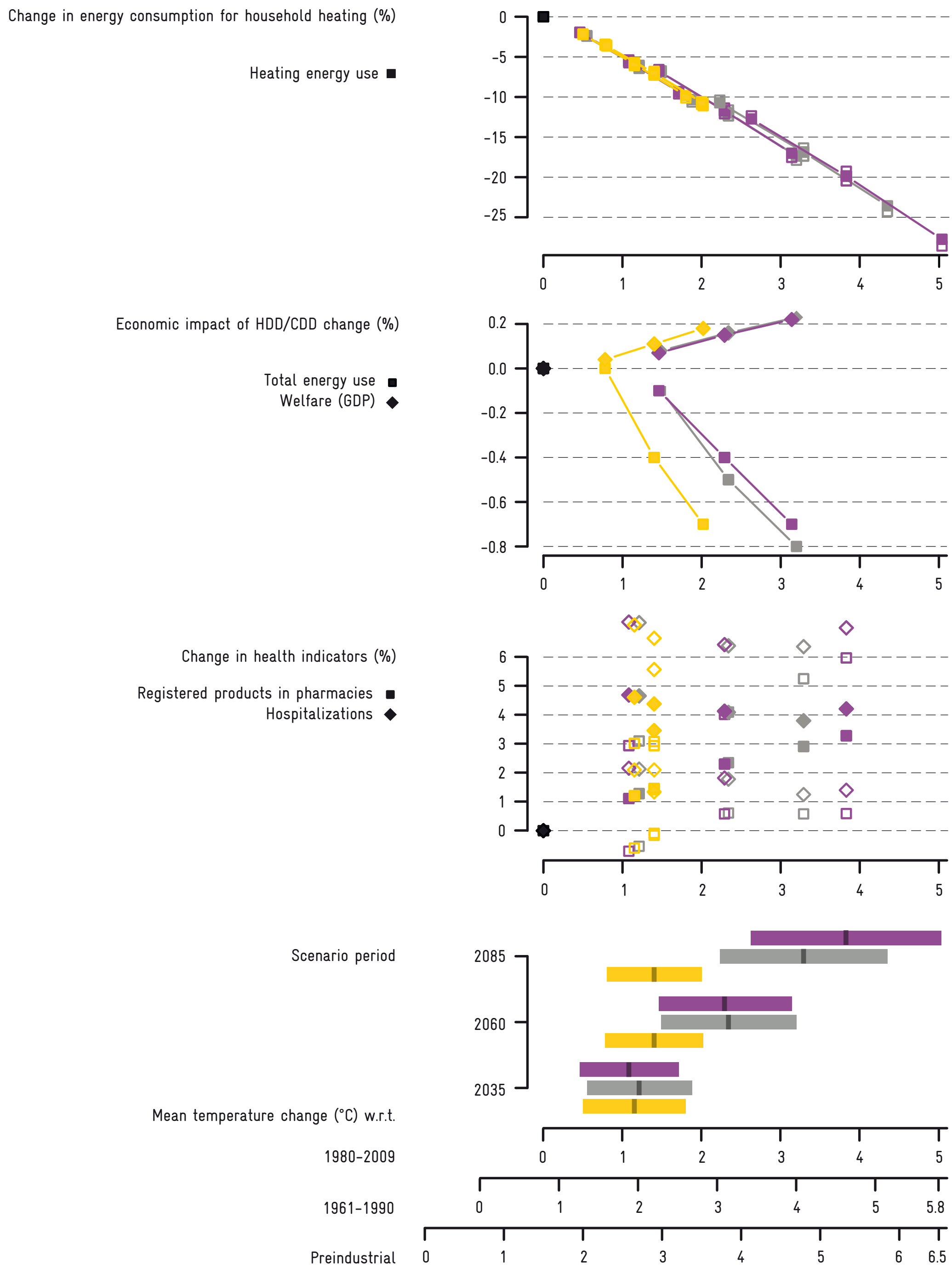


Figure 12.6: Climate change impacts from Chapters 10 and 11, plotted against mean annual temperature change in CH2011 scenarios (average of regions CHNE, CHW, and CHS). Greenhouse gas scenarios are indicated by yellow (RCP3PD), grey (A1B), and purple (A2) color. Estimates for different climate uncertainty levels (low, medium, and high) are shown with solid symbols connected with lines; open symbols correspond to additional impact model uncertainty where quantified (two standard deviations for statistical estimates).