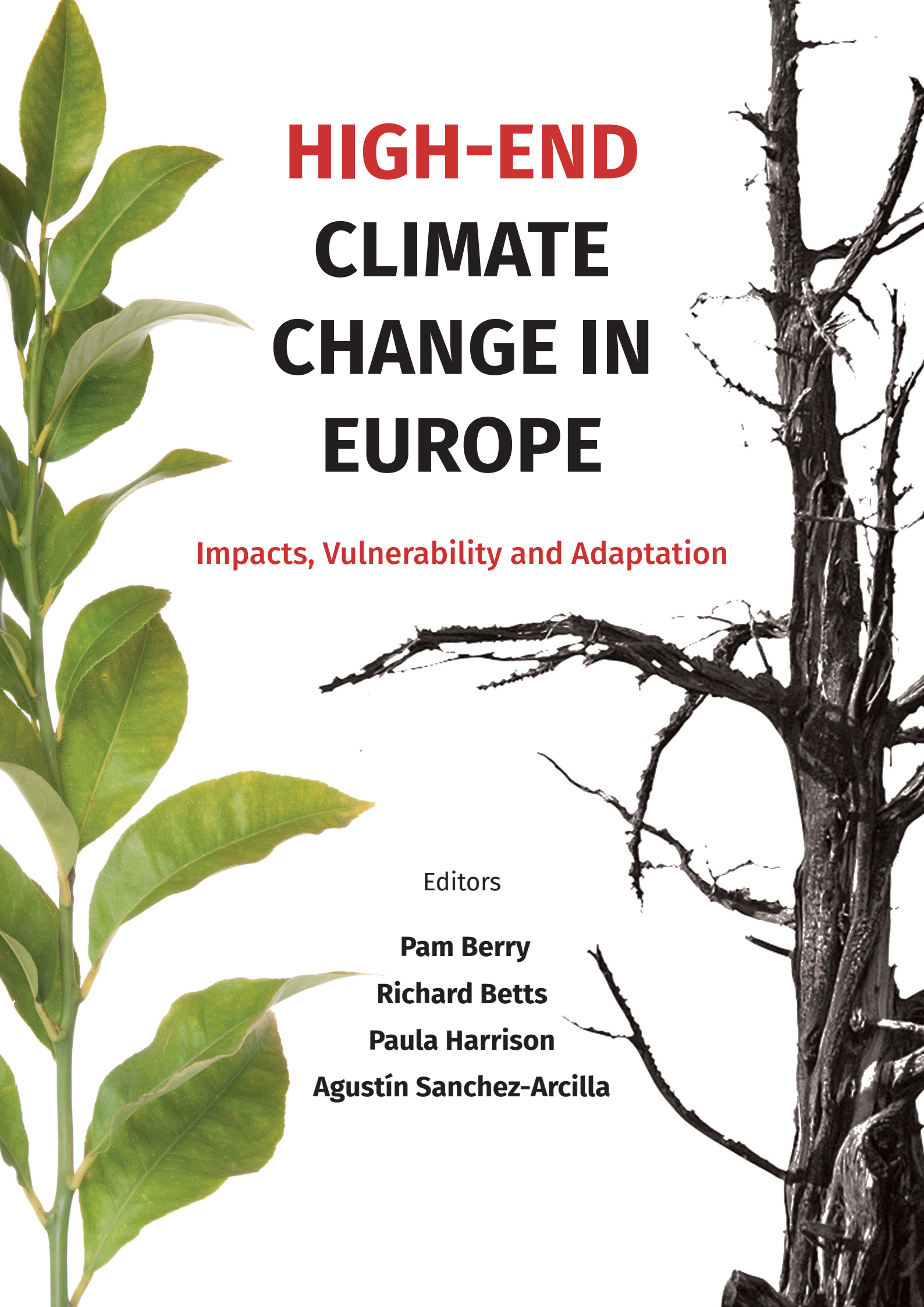

HIGH-END CLIMATE CHANGE IN EUROPE

Impacts, Vulnerability and Adaptation

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Executive summary

In 2013, the European Commission funded three major projects to assess climate change impacts, adaptation and vulnerability for "high-end scenarios" - defined as global warming exceeding 2°C relative to pre-industrial. These projects are: HELIX (High-End cLimate Impacts and eXtreme); IMPRESSIONS (IMPacts and REsponses from high-end Scenarios: Strategies for Innovative SolutiONS) and RISES-AM (Responses to coastal climate change: Innovative Strategies for high-End Scenarios - Adaptation and Mitigation), which between them involve over 150 researchers from leading scientific institutions across Europe and also in Africa, Asia and America.

Drawing on a very wide range of expertise from many disciplines in both the natural and social sciences, we are developing new understanding of the implications and risks of exceeding 2°C, the challenges and opportunities of adaptation to such a warmer world, and the extent to which risks can be reduced if warming is held as close as possible to 1.5°C.

We are examining impacts and adaptation relevant to a number of areas addressed by policy: food, freshwater, forestry, coastal protection, nature conservation, urban areas and infrastructure, human health and foreign policy. We are also considering cross-cutting impacts, challenges and opportunities for transformational change as a response to multiple, interacting risks.

This report presents the findings of these three projects as of early 2017.

Agriculture

- High-end climate change will potentially have strong and lasting effects on the agricultural sector and consequently on food markets and food security across the globe, and also in Europe.
- The existence of future food production tipping points for the European agriculture sector depends on the complex scenario-dependent inter-play between future food demand, net food imports, and European agricultural productivity.
- European land-use appears more sensitive to future socio-economic change than climate change. The spatial distribution of impacts on arable and livestock systems will depend on the relative impacts of future change on agricultural and forest profitability (locally and regionally) and the availability of irrigation water. Increasing water stress may lead to increased competition for water in many catchments, as a result of reduced water availability due to climate change and/or increasing water demand (from agriculture, public water supply and the environment).
- Autonomous adaptation is expected to feature northwards and north-westwards shifts in agricultural systems as land suitability and productivity change. High-end climate change may pose important challenges and opportunities for the livestock sector in Europe. Heat stress is likely to increase in indoor and outdoor livestock and poultry, including during transportation.
- Many species and habitats will be directly or indirectly (positively and negatively) affected by high-end scenarios. Many pollinators, critical for producing good crop yields, may lose climate space, especially in southern Europe.

Freshwater

- Annual mean runoff is generally projected to increase in northern Europe and decrease in southern Europe. In the central latitudes of Europe, there is no clear agreement between models on either

increases or decreases in annual mean flows.

- In projections with a high emissions scenario, the population annually affected by river floods in Europe increases from approximately 216,000 people per year in 1976-2005 to between 500,000 and 640,000 per year around 2050, and 540,000 to 950,000 per year around 2080. The projected damage costs of river flooding increases from approximately 5.3 B€ per year in 1976-2005 to 20 to 40 B€ per year around 2050, and 30 to 100 B€ per year in 2080. Much of the uncertainty range arises due to socio-economic scenario assumptions, especially the economic damages.

- Adaptation efforts aimed at trying to avoid floods may not be effective in the long term. An alternative approach to reduce the flood risk could favour measures targeted at reducing the impacts of floods, rather than trying to avoid them.

- Drought prone areas increase with global warming particularly in the Mediterranean region. Low flows are projected to become less extreme in northern Europe but more extreme in Southern Europe. In some cases, low flows may decrease even in areas where annual mean flows increase.

- Projected increases in the severity and duration of freshwater shortages, especially for the southern part of Europe, have several implications for agriculture, forest and ecosystems, domestic supply, power supply and tourism.

- Among the most impacted countries, there is a high model consensus that substantial areas of Spain are projected to face a large increase in the duration of extreme prolonged droughts.

Coastal protection

- Even if emissions and temperatures stabilise, sea-levels will continue to rise. Climate change mitigation may help to reduce the rate of sea-level rise to manageable levels, but adaptation is required to help cope with the residual rise.

- Coastal monitoring (e.g. tide gauges, beach surveys) is required to determine the environmental state, and whether acceptable thresholds of risk are being reached. This would help determine if and when adaptation needs to change in order to achieve the management goal.

- Intervention for successful adaptation will be most effective if it is bespoke, balancing financial, economical, societal, equitable, governance, legislative and environment interests. Soft engineering and nature-based solutions are increasingly encouraged for a sustainable coast, but have only been proven in a limited number of pilot cases. Further research is required into resources and effectiveness of nature based solutions (NBS). It is recognised that not everywhere can be protected.

- Flexibility is required in adaptation, with multiple choices to achieve a management goal (e.g. defined risk levels). Adaptation pathways provide one structured way to achieve this. These can be challenging to generate due to barriers in planning for adaptation.

- Governance, societal and cultural acceptance of flexible change present the greatest barrier for adaptation, particularly over the longer term (> 50 years). This is particularly difficult as it is hard to envisage and act on long-term change, when short-term needs are greater and more immediate than the long-term sustainability of the coast.

- Priorities will depend on policy criteria, ability to pay, societal preference and technological feasibilities. Areas with high exposure of people and assets (e.g. cities) demand more stringent protection and adaptation as risk levels are high. Lower population densities are less likely to be protected at the same level, and other ad-

aptation options need to be explored. This will lead to equity issues, particularly if adaptation is paid from national budgets to which all citizens contribute.

Forestry

- Some climate-induced changes in European forests are expected to occur relatively smoothly over time, whereas others may occur as "shocks", passing thresholds or tipping points.

- In the climate change scenarios considered here, there is a clear north-south gradient regarding the impacts of climate change on forests, excluding other factors such as CO_2 physiological effects and nitrogen deposition. High latitudes and elevations potentially benefit from climate change, and forests at low latitudes potentially lose as a result of projected shifts towards drier conditions, particularly in the Mediterranean region. Different regional climate outcomes could result in different impacts.

- Increased CO_2 concentrations have a potentially positive effect on forest productivity. In the absence of acclimation of trees to elevated CO_2, this driver could modulate the impact of climatic change by either further increasing forest productivity (e.g., at high latitudes or elevations), or at least partly compensating for negative climatic effects.

- Forestry can be adapted to the changing climate by switching to climatically better adapted species, and moving towards forestry systems that include more than one tree species at the stand scale.

- European forests and forest products are significant contributors to the European greenhouse gas balance, constituting a major carbon sink that can help to reach EU climate targets.

Nature conservation

- Under high-end climate change scenarios, the combined effects of climatic and socio-economic change pose high risks to biodiversity across Europe. There is considerable risk of major transformations of many ecosystems in southern Europe.

- The greatest scope for gains in biodiversity arises from potential land abandonment, mainly in northern Europe. The magnitude and uncertainty of climate and land-use change in parts of southern Europe, imply a need for intervention to avoid the loss of key connecting habitats and the worst possible outcomes for conservation.

- Rates of climate change under high emissions scenarios would largely be in excess of the ability of species to keep up through dispersal, although the extent to which this becomes a problem will depend on the length of time the climate continues to warm.

- Support for nature conservation at local and national scales has been demonstrated to be an important factor in maintaining the scale and connectivity of natural areas.

- Land for nature conservation fundamentally depends on food demand and the intensity of agricultural production, with intensive production allowing land-sparing for conservation, and extensive production limiting the scope for nature conservation, except through multifunctional land-uses.

- Protecting conservation areas to prevent intensification in one location may lead to knock-on effects on other habitats elsewhere, for some scenarios.

- Nature-based approaches can support transition away from non-renewable to renewable natural capital and can be associated with increased co-production and provision of ecosystem services. The widespread use

of nature-based solutions provides many opportunities for synergies across policy objectives, including benefits to both climate change adaptation and mitigation. As such, nature-based solutions can enable the transition from a resource-intensive towards a more resource-efficient and sustainable development model model.

Human Health

- Higher temperatures could have significant impacts for health and wellbeing including human comfort, particularly in southern Europe.
- Under high emissions scenarios, high temperatures after mid-century would be expected to alter patterns of daily living and working.
- Autonomous adaptation could offset significant impacts but there will be limits to adaptation to higher temperatures.
- Adaptation strategies relating to new build and retrofitting of dwellings has implications for mitigation policy unless energy intensive space cooling is avoided.
- Climate change is projected to increase child undernutrition in sub-Saharan Africa and South Asia, but research is needed to understand the full implications of the high-end scenarios.

Urban

- Artificial surface extent could vary from about 4% of the European land area today, to approximately 4% to 9% of that area by 2100, depending on the socio-economic scenario.
- Population change is a key driver of future artificial surface expansion. However, changes to the demographic profile of this population, their residential preferences and planning legislation have the potential to restrict or magnify patterns of growth. A declining population does not imply a static artificial surface extent in the presence of changing residential preferences.
- The contrasting residential profiles of each socio-economic scenario influence the extent and location of future artificial surfaces. The dense urban networks of Belgium, the Netherlands, western Germany and southern United Kingdom promote concentrations of future suburban development. This is in contrast to the 'hotspots' of development that are more sparsely distributed across, for example, Spain, Portugal and the Nordic countries.
- Sprawling urban development could place greater pressure on sensitive ecosystems as the population in close proximity to protected areas, water bodies and coastal regions increases.

Foreign policy and international development

- Transnational climate change impacts could have substantial effects on Europe. High-end scenarios could imply increased systemic effects of climate change, including cross-sectoral and transnational climate impacts. However, research on the physical as well as governance aspects of transnational climate impacts is still in its infancy.
- Transnational climate impacts still play a minor role in the EU, as well as in Members States' adaptation policies. The potential international dimension of climate impacts may provide incentives for more collaboration between EU Member States, as well as between the EU and other parts of the world.

Policy Insights

- Either avoiding or exceeding 2°C global warming could pose unprecedented challenges as well as new opportunities for societal transformation. Innovative approaches in science and policy may be required. Integrated strategies for these new social-ecological conditions could be achieved, and ensured in the long run, by linking climate-oriented, practical, systemic solutions to sustainable development.

- Sustainable solutions are those that are able to overcome multiple trade-offs between ecological integrity and socio-economic goals in ways which can be turned into positive synergies. Clusters of sustainable solutions can be identified, tested and implemented by integrating multiple forms of knowledge and values in concrete places following transformative visions of the kind of world in which we want to live.

- Conventional and additive approaches focusing on single sectors, scales or either adaptation or mitigation without considering long-term sustainable development may not be enough to cope with the mounting risks and challenges of high-end climate change. Innovative approaches entail combining multiple systems of solutions that not only solve present problems but also learn how to transform current systems arrangements so as to prevent them occurring again.

- Conventional policy appraisal methods are designed for relatively short-term, well-understood policy choices in single sectors and are not feasible for transformative approaches combining multiple systems of solutions. They face severe limitations for assessing the impact of very long-term decisions about adaption and mitigation in the face of large climate risks.