"The CIRCLE Research Topic List" or Del. IV b-1 (precursor) –Report of CIRCLE's transnational research funding initiatives

Dagmar Schröter

Table of Contents

1 Introduction

This report summarizes the process of finding the most relevant potential research topics for CIRCLE in the area of climate change adaptation research. We present the final list of most relevant potential research topics, including an explanation about why we have included them in the "CIRCLE research topic list".

2 Finding the most relevant potential CIRCLE research call topics

The search for potential CIRCLE research topics was initiated at the 1st CIRCLE Annual Progress Meeting, Sept 2006 in Vienna, Austria, when the advisory board[1] gave its first consultation on this issue in the form of a brainstormed list of potentially relevant topics.

[1] Chaired by Markku Rummukainen, Swedish Meteorological and Hydrological Institute, Norrköping, Sweden, and Roland Psenner (co-chair), University of Innsbruck, Innsbruck, Austria.

In a next step, this list was reviewed by the CIRCLE scientific coordinator[2], and restructured, as well as amended, through

- Consultation in interviews with further experts in the field,
- An extensive review of peer-reviewed and "grey" literature (e.g. reports),
- A review of currently funded research programmes in this field, such as e.g. specific sections in the EU Framework Programme 7, as well as national research programmes, as summarized in the CIRCLE Report Del. I a 1 (Extended Country Report),
- Stakeholder input through reviewing past transdisciplinary projects,
- Input from research meetings, conferences and workshops[3],
- Review of previous and ongoing CIRCLE group calls (see section 2.2),
- Thought and discussion.

Then the new list of topics was sent to the advisory board members via email, and comments, corrections and additions were invited. The list was then edited a 3rd time, and presented again at the 2nd CIRCLE annual progress meeting, Oct. 2007 in Toulouse, France. After a plenary presentation of the topics, the list was discussed in three break-out groups. In these groups a summarised version of the topic list was used in a prioritisation exercise (see section 2.1). Furthermore, comments, additions and corrections were again collected and encouraged via mail after the meeting. The version of the CIRCLE topic list presented below is the result of this intensive prioritisation and consultation process.

2.1 Prioritising topics

The list of potential CIRCLE research topics grew quite long in the process of research, review and consultation. However, CIRCLE will only be able to organise calls for the most relevant topics from a much-shortened list which is derived from the comprehensive list of research needs. Hence, prioritisation was needed.

As a first step in this we performed a prioritisation exercise during the annual progress meeting, Oct. 2007 in Toulouse, France. We formed three break-out groups, which consisted of a group of advisory board members, and two groups of mixed observers and CIRCLE project partners. The draft list of potential CIRCLE research topics was presented in plenary, and handed out (1) in a summarised version (containing all topics, but less text), and in an elaborate version (containing full explanatory text) serving as a background document. In the break-out groups, which were led by a 'neutral' moderator, the topic lists were discussed, commented and amended. Participants were then given 54 self-adhesive dots[4] and were asked to attach these dots to specific topics according to their appraisal of importance of the topics among the whole list. There was no restriction of the number of dots attached to a specific topic, apart from the maximum number of dots being 54. A total of 48 topics were to be considered. We then analysed the prioritisation exercise in terms of total ranking, and prioritisation by group. Here we focus on the appraisal by the advisory board members in particular, due to their specific research expertises. However, all ranking results are given in the Appendix.

---

[2] Dagmar Schröter, Umweltbundesamt, Vienna, Austria.

[3] Two examples: *Biodiversity – Climate Interactions: adaptation, mitigation and human livelihoods,* Royal Society and the UK Global Environment Change Committee Biodiversity Sub-Committee workshop, Royal Society, London 12-13 June, London, UK; and *The Role of Mountains in a Climate of Change – Growing conflicts or growing consensus about the use of resources?* – Workshop Series 2048, 24-26.05.2007, University Center Obergurgl, Austria.

[4] Advisory board members used red dots, observers green dots, and CIRCLE partners blue dots.

Finally, a final prioritised list was created by the scientific coordinator. This list is based on the prioritisation exercise and further input from Advisory Board members, colleagues, as well as careful consideration.

Topics that were thought to be very important by advisory board members are marked as 'red hot topic' (among the top ten) or 'hot topic' (among the top fifteen, advisory board rank given in brackets, labelled #). Topics that were not part of the prioritisation exercise because they were added afterwards are marked 'new'. Ranking by non-advisory board members (i.e. observers and partners, rank labelled "OP") and total ranking (according to all exercise participants, rank labelled "T") and are also given.

2.2 CIRCLE "group calls"

In addition to the finding of common potential CIRCLE research topics (part of work package 4, FULFIL), specific partners within CIRCLE cooperate on the basis of a common interest that is usually based on geographic region (work package 3, GROUP). So far, CIRCLE has launched a "Mediterranean call" in summer 2007 and "Nordic call" in autumn 2007. Other calls are currently in preparation, such as an "Atlantic call", a "Mountain call", and a call on "Cooperation with Developing Countries". Naturally work packages 3 and 4 continuously work together.

3 CIRCLE's main research interests

3.1 Research on Potential Impacts, Vulnerability and Adaptation Strategies

CIRCLE's main interest is in climate change adaptation. Therefore, the research CIRCLE is interested in should feed into the transdisciplinary[5] development of adaptation strategies, including an appraisal of the risks and barriers to such potential strategies. The ultimate goal of CIRCLE is to help create strategies to adapt to climate changes, firmly rooted in research-based knowledge and understanding of potential impacts and vulnerabilities.

Sufficient information on potential impacts and vulnerabilities is a necessary pre-requisite of research on adaptation strategies. In some topic areas the development of adaptation strategies is hindered by the lack of information on potential impacts and vulnerabilities to climate and other global changes. Science needs to further our understanding of what it is that we need to prepare to adapt to. Research on potential impacts and vulnerabilities, for the sake of developing adaptation strategies is therefore an (implicit) theme of the following list of potential CIRCLE research topics. However, often information on potential trends in climate change and its impacts is sufficiently available to start a discussion among relevant actors and scientists. Adaptation strategies can and should therefore be developed *in parallel* to further research into potential impacts and vulnerabilities. Given that potential impacts and vulnerabilities are sufficiently known and understood, we believe the main research questions of interest are:

1. How can we adapt to climate induced risks and changes?
2. What are the side effects of potential adaptation strategies (positive and negative)?
3. What are the main barriers to implementing promising strategies? How can these be overcome?

[5] We refer to approaches as ‚transdisciplinary' when different parts of society (incl. academia) are co-operating, in order to meet complex challenges. Solutions are devised in collaboration with multiple stakeholders. Through mutual learning, the knowledge of all participants is enhanced. Transdisciplinarity is a new form of learning and problem solving.

3.2 General suggestions for Research & Development projects on Climate Change Impacts, Vulnerability and Adaptation

In review of the recent conceptual and methodological literature, and with the link between science, policy and practitioners in mind, we suggest to base research & development projects on climate change impacts, vulnerability and adaptation strategies on the following 10 principles.

1. Consider climate change impacts in concert with other ongoing environmental and socio-economic pressures (e.g. land use changes, atmospheric pollution and deposition);
2. "Transnationality principle" of the EU ERA Net approach: National borders should not define study areas when climate impacts cross these borders, e.g. international water catchments and flood management ;
3. Analyse multiple scenarios of the future, in order to account for scientific uncertainty and to reflect the range of behavioural options;
4. Base research on both past observed data *and* future scenarios;
5. "Multidisciplinarity principle" of the EU ERA-Net approach: Consider environmental and socio-economic impacts of climate change in concert;
6. Where possible, consider the socio-economic costs and opportunities of climate change impacts against costs and opportunities of adaptation;
7. Favour transdisciplinary approaches, i.e. research and assessments should include representatives of all key stakeholders from the onset of the project;
8. Regard traditional knowledge (e.g. from indigenous people) as an important contribution to understanding and managing climate-related risks;
9. Develop research and assessment products in an iterative process of social learning, targeted at transdisciplinary audiences;
10. Produce research and assessment outputs to inform policy-making and management which are of the highest possible scientific quality, salient, credible and legitimate, and follow dissemination strategy targeted at stakeholders' needs.

4 Potential CIRCLE research call topics

4.1 Optimizing the practical use of climate change adaptation research

Three of the „red hot topics" (ranked 1, 2 and 5), i.e. topics that were among the top ten choices of advisory board members, concern the general issue of usefulness of scientific research to policy makers and practitioners. This strong signal reflects the experience of many actors in the field of climate change research and management that scientific knowledge as such is often not the limiting factor in adaptation strategies. Instead, progress in discussions and decision-making is hindered by insufficient transdisciplinary communication and dissemination. Secondly, scientific information is often not sufficiently targeted at the questions stakeholders have, and at the spatial and temporal scales they need to consider. Therefore we urgently have to engage in two parallel activities: (1) set-up and improve the communication platforms and dissemination tools used in science-policy-practitioner interfaces, and (2) target research more specifically at users' questions and concerns.

In order to make progress in this challenging endeavour, here is a list of relevant research questions and sub-questions:

-  How can we bridge the gap between climate adaptation research and the implementation of its results in local/regional/(trans) national policies and applications towards response measures? **(red hot topic #1, OP 1, T 1)**[6]
    - What lessons can we learn about stakeholder participation in transdisciplinary projects? A meta-project could analyse various approaches to stakeholder participation in a comparative study, which could be used for improvement of transdisciplinary communication and dissemination.
    - How do private enterprises in various sectors all over Europe believe to be affected by climate change? What are their needs regarding information on climate change adaptation?
    - What are the advantages and weaknesses of different tools for decision-making processes, such as science-policy interfaces, multi criteria analysis, scenario development, decision support systems? A comparative project appraising these techniques could inform practical applicability and improve their use and design.
    - What are the relevant local, regional and European policies and regulations from a diversity of ministries and governmental bodies that affect environmental management and climate change adaptation on local, regional and European scales? How do these operate alone and in concert? What restrictions and incentives do these regulations and policies pose for decision makers from specific sectors?
    - Which institutions could serve as "bordering" or "translating" institutions between science and policy?
-  How can we bridge the gap in scale from European-wide research efforts (such as those in the EU Framework Programmes) and specific local implementations? This effort should help to learn the lessons from all scales, and to generalise in a sensitive way where possible. **(red hot topic #2, OP 18, T 8)**
-  Each sector-specific project should consider the multiple links between different sectors, e.g. water, agriculture, nature conservation and so on. However, a meta-project could analyse these interactions and draw the main lessons from this. **(red hot topic # 5, OP 11, T 7)**
- What can we learn from past/ongoing adaptation efforts? We need to monitor, document and critically analyse case studies of adaptation measures. (new[7])
- Judging from past experience, which research products are most useful to stakeholders? How can information products best inform the implementation of adaptation measures on local levels? For example, how can maps of local impacts be made useful for decision makers and at the same time be communicated with honesty and frankness about their uncertainties? (new)
- Which policies and regulations need to be altered in order to mainstream climate change issues? (new)
- What will the overall costs (multi-sectoral) of climate change be, against the costs of adaptation? (new)

---

[6] The red pepper serves as an „eye catcher" for topics that were considered among the ten most important potential CIRCLE research topics by CIRCLE advisory board members. In brackets information of the rank of a topic according to different groups is given: The advisory board members' ranking is labelled by „#", the ranking by CIRCLE observers and partners is labelled „OP", and the total ranking is labelled „T". A table with all ranking results is given in the Appendix, section 4.11.

[7] Topics that were added after the prioritisation exercise are marked „new" – they were not part of the ranking process.

4.2 Urban areas

A second region of highest interest is research on climate change adaptation in urban areas and centres. This is where many of the climate change concerns "come together", because of high consumption rates, population densities and complexity of the infrastructure. Also, many urban dwellings are near coasts, adding a whole set of issues regarding sea level rise (see section 4.3). Focussing on urban centres hence means also focussing on supply with natural resources, such as water, materials (food, fibres, etc.), and specific ecosystem services (e.g. recreational opportunities, retention areas, microclimate enhancing zones), as well as energy and safety (see sections 4.4, 4.6, 4.7 and 4.8).

The following is a list of most relevant topics that should be able to provide useful insights to the transdisciplinary development of climate change adaptation strategies in urban planning itself:

-  What implications does climate change adaptation have for urban and spatial planning, building construction and management practices in urban landscapes? For example, how can spatial planning in urban centres be improved, funded and implemented to mitigate the effects of heat waves on the human-environment system? What are the side effects and barriers of implementation of these strategies? **(red hot topic #3, OP 5, T 4)**
    - How can building construction be altered to reduce climatic stresses and improve energy efficiency? What are the side effects and barriers of implementation of these strategies?
    - How can management practices in urban landscapes avoid heat islands and offer relief areas? What are the side effects and barriers of implementation of these strategies?
-  How should spatial planning best consider shifts in the distribution of flood prone areas? What are the side effects and barriers of implementation of these strategies? **(red hot topic # 4, OP 3, T 3)**
    - How can building construction flood-proof endangered buildings? What are the side effects and barriers of implementation of these strategies?
    - How can urban landscapes be managed to decrease flood risk? What are the side effects and barriers of implementation of these strategies?
- How can urban centres throughout Europe best learn from each other? (new)

4.3 Coastal zones

European coasts are highly developed zones of intense human activity and unique natural character. In addition to their vital links to inland activities, systems, resources and ecosystem services, coastal zones face the additional direct influence by the sea. Climate change related changes in sea level and ocean currents are areas of great importance and high scientific uncertainty, due to the complexity of the system and the non-linear nature of essential processes, such as the melting and break-up of large ice-sheets. Coastal management will have to live with wide ranges of possible outcomes. It is therefore evermore important that communication platforms including scientists, policy makers and practitioners are built and maintained, at the same time as research is striving to shed further light on the following questions, which will deliver the basis for transdisciplinary adaptation strategy building:

-  What are the anticipated impacts of sea level rise on different parts of the European coasts? **(red hot topic # 7, OP 10, T 9)**
    - Where and when will issues such as salt water intrusion, loss of wetlands, the safety of coastal infrastructure become critical?

- What is the risk reduction potential of maintaining water retention areas particularly around urban centres to cope with sea surges? What are the positive and negative side effects of retention area maintenance? What are possible barriers for implementation of this strategy?

- What are the possible impacts of alterations in the North Atlantic Oscillation (NAO), the Thermohaline Circulation (THC) and the gulf stream on Atlantic/coastal Europe, as well as general ocean warming particularly with regard to fisheries and the tourism sector? **(hot topic # 15, OP 19, T 19)**
- What is the sensitivity to climate change of specific coastal ecosystems, such as wetlands, estuaries, deltas, and lagoons etc? **(hot topic # 15, OP 13, T 13)**

4.4 Natural resources

4.4.1 Water

Water is an essential element for many vital processes within the human-environment system. It can be seen as an *non-living* renewable resource, even though *living* systems have a great influence on its production, consumption and regeneration. Water is a resource that connects all sectors within the human-environment system, since water is needed for energy production (e.g. cooling of nuclear power plants), agriculture, industrial production, navigation, domestic use, and other living systems (forests, wetlands, etc.; see other subsections of section 4.4, sections 4.2, 4.3 and 4.9). Water is also linked to the safety and the health sector in various ways (as beneficial and destructive force; see also sections 4.5 - 4.8). Sustainable, transboundary water management hence is among the most difficult societal challenges.

In the following we provide a list of research questions and sub-questions that will hopefully produce results to best support transdisciplinary and transboundary water management under climate change in Europe.

-  Is the fresh water supply (quality and quantity) to domestic, industrial, hydropower, navigation and agricultural uses threatened in the immediate and long-term future? How is the water cycle and balance going to be impacted by climate change? **(red hot topic #3, OP 2, T 2)**
    - How can freshwater supply be ensured in emergency cases (long lasting heat waves and drought periods)? How can electricity supply be secured during long lasting drought periods (loss of energy production in combination with increased demand for energy)?
    - For example, industrial water use has mostly been ignored in recent studies, although e.g. during the heat wave 2003 in Europe electricity supply was severely endangered by low river flow and consequent lack of cooling water for power stations. We need a comprehensive analysis of water supply (quality and quantity) considering all extractions, demographic and life-style changes, technological developments (e.g. desalinisation, sewage water reuse), as well as climate change. This analysis will highlight water competition between different sectors and user groups.
    - Such comprehensive analysis should inform the development of adaptation strategies for the various groups of actors and economic sectors, including municipalities, industrial users, hydropower producers, water transport planners, and farmers. For example, can water be prized differently to better consider water usage and all its external costs?
- How can disruptions in the sewage system by accumulation of mud in pipes or flooding of sewage treatment plants be avoided?

- Since river catchments cross borders, the development of adaptation strategies needs to consider transnational communication and transnational water management. How can different countries in the same catchment reconcile their own interests with the common cause of equitable, sustainable water use?
- How can we maintain high water quality, given the combined impacts of climate change, land use change, and pollution? What impacts do glacial melting, additional wash-out of substances from soil due to flooding, as well as algal blooms due to higher temperature have on water quality? How can we deal with unanticipated but dramatic increases of pollutant concentrations in water catchments due to glacial melting, e.g. health-threatening increases of the nickel concentration of high Alpine lakes?

4.4.2 Agriculture

In Europe agriculture serves the double purpose of food and fibre production, as well as maintaining traditional cultural landscapes that we value, and that attract tourists (see also sections 4.4.4 and 4.9). As in all other sectors, climate change impacts on agriculture cannot be seen in isolation; other drivers will act in concert. This is especially important since our ability to directly influence drivers like land management and land use change is greater than our immediate handle on climate change. In contrast to the developing regions of the world, land area is not anymore a prime-limiting factor in Europe (due e.g. to technological advances such as increased agricultural efficiency), i.e. Europe's flexibility in how to manage its lands is greater than in other regions. Therefore Europe has potential for positive changes in land uses that may partly counteract negative climate impacts.

In the following we list the research topics CIRCLE found most relevant for the purpose of a transdiciplinary search of sustainable adaptation strategies in the agricultural sector.

-  Which agricultural production areas in Europe will be impacted in what way by the combined pressures of socio-economic, legal, land use, and climatic change? **(red hot topic # 6, OP 9, T 6)**
    - How will the Common Agricultural Policy (CAP) of the EU and climate change play out together? In what way can future CAPs be improved?
-  How can we prevent soil erosion as a result of more frequent droughts and extreme rainfall events? How can the agricultural sector adapt to increased variation in and loss of productivity? **(red hot topic # 9, OP 4, T 5)**
    - How can different irrigation and drainage technologies avoid salinisation, degradation and desertification?
    - How can agriculture in the Mediterranean region adapt to future droughts and heat waves?
    - Do organic farming practices provide benefits in sustainable management of climate change impacts? Can the water use efficiency be increased via organic farming? Or is organic farming particularly vulnerable to climate change, e.g. due to restrictions of the use of fertilisers after a drought period? Will climate change bring additional pest calamities that pose particular challenges to organic agriculture? What are the environmental, economic and social benefits and risks of increasing the areas of organic agriculture in Europe?
- Will climate change bring new pest calamities or eliminate old risks through pests? (new)
- Will technology be able to cope with new agricultural challenges brought about by climate change, such as the ones listed above? (new)
- How could Northern European regions capitalize on opportunities that come with climate change? **(hot topic # 13, OP 38, T 36)**

- What is the potential for growing biomass energy crops in Europe, considering competing land uses (e.g. food production), changing climatic zones of crop suitability and soil requirements, and a changing energy system? **(hot topic # 12, OP 13, T 12)**

4.4.3 Forestry

Forestry in Europe will face both positive and negative influences of climate change. While increased temperatures and increased carbon dioxide concentrations in the atmosphere will increase aboveground growth in some areas, this positive effect will be counteracted by biomass and soil carbon losses through droughts, increased decomposition and increased frequency of biomass fires. As in agriculture, an additional area of great uncertainty is the development of pest calamities and the possible arrival of new pest species. Again similar to agriculture, forestry in Europe is a sector with many benefits to people, from wood and fibre production to biomass energy production, recreational opportunities, water purification and retention, slope stability maintenance (particularly in Alpine areas), and other ecosystem services. It is a challenge to manage forests with regards to all these demands and the additional pressures and opportunities of climate change.

Here is a list of research questions that should support sustainable forest management and inform the transdosciplinary quest for adaptation strategies in forestry:

-  How to manage the carbon balance of a forest given anticipated increased aboveground growth vs. increased carbon losses from soil and forest fires? **(red hot topic # 9, OP 22, T 17)**
- How to adapt to increased risk of forest and biomass fires that affect forests, abandoned and agricultural lands, and threaten settlements and infastructure? Can forests be managed differently to decrease the risk, e.g. can different species in new plantations make a change? How can fire-raising for strategic reasons (e.g. rededication of land property) be combated? **(hot topic # 14, OP 6, T 8)**
- How to sustainably manage burnt areas?
- How will we best manage European forests for the supply of multiple potential ecosystem services, such as e.g. carbon sequestration, forest productivity, water retention, purification and supply, soil stabilisation, recreation and biodiversity maintenance? What is the role of long-term technology and innovative management practices in this? (new)
- What is the impact of climate change on forest pest and calamity frequency? How can we adapt to possible negative trends in this?
- How to manage climate change induced regional shifts in forest tree species' suitabilities?

4.4.4 Biodiversity and nature

In Europe, speaking of „nature" means speaking of a more or less intensely used traditional landscape. Over centuries diverse cultural traditional landscapes, as an amalgam of people and nature have evolved, and are living prove of our inseparability from nature. These landscapes are also the basis of the high quality of life in Europe, attracting many tourists from within Europe and all over the world. Particularly the Alps, though geologically a young mountain range, are culturally among the oldest mountains in the world. In this extremely heterogeneous environment, people and nature have formed a diverse entity that is famous for its cultural and natural richness.

Many drivers have an important impact on biodiversity and European landscapes, for example land use changes, nitrogen deposition and other pollution. More recently climate change has been recognised to come increasingly into play. In order to continue to successfully manage our cultural landscapes and "natural spaces", we cannot neglect to study any of these drivers, as well as their combined impacts.

In the following we list those research topics that should support the transdisciplinary quest for sustainable adaptation strategies in the nature and biodiversity conservation sector.

- What will be the impacts of climate change on ecosystem reserves, particularly those that represent climatic gradients or climatically unique locations? What are the effects of climate change on ecosystem service provision through the nature reserve? How do we deal with unavoidable changes? Can and should we rededicate reserves or change their borders, to account for geographical shifts of habitats? **(hot topic # 15, OP 31, T 31)**
- Which European habitats are threatened in their existence by climate change? For example, which European wetlands will be lost or changed in undesired ways? Particularly, will we face a substantial negative feedback on the climate system through habitat loss, e.g. by increased methane releases from wetlands in a warming Europe?
- What will be the climate change impacts on biological invasions by alien species? How can we manage invasions under a changing climate?
- How will ecosystem service provision outside nature reserves be affected by climate change and other relevant pressures (land use change, atmospheric deposition, eutrophication etc)? How can these changes be managed to sustain a healthy human-environment system, i.e. an environment that ensures our livelihoods and well-being?
- Can diverse traditional, cultural landscapes be maintained in spite of climate change and other pressures, what are the potentials and threats?
- Does climate change pose a threat to genetic diversity? How can we counteract this threat? (new)
- Current biodiversity models need to be improved: Future climate envelope models as well as dynamic vegetation models should be enabled to take into account drivers besides climate (land use change, land management, elevated atmospheric carbon dioxide, atmospheric nitrogen deposition, increasing ozone concentrations in the lower atmosphere, etc.), as well as species interactions, and migratory abilities of individual species.
- What are relevant climate impacts on the inanimate nature, such as geological values, geomorphic processes, and landforms? How can we prevent these impacts or adapt to their consequences?

4.5 Finance and insurance

Insurance and re-insurance companies have identified climate change as an issue of importance some time ago. The finance sector is also increasingly aware of this new challenge. We do not believe that publicly funded scientific research should sponsor private, profit-oriented enterprises. However, the global nature of the climate problem, as well as the separation of those who cause it collectively, and those who suffer from its effect individually calls for some new approaches in insurance and reparation opportunities. This is where science and policy have come into play to co-operate with private enterprises for the benefit of all, not only of the specific companies.

In the following we list some research topics that may provide useful insights for the transdisciplinary development of beneficial adaptation strategies for society as a whole.

-  How can insurance be planned, given that past trends of hazard frequency and risk can no longer be extrapolated? How can we deal with new risks and changed hazard probabilities? **(red hot topic # 8, OP 30, T 20)**
    - Which products and services of the (re-)insurance sector have to be further developed or adopted to account for new or increased vulnerability as well as altered frequency distributions?
    - When is it feasible to design insurance against extreme events? How can these insurances be made affordable for various user groups, such as farmers, ski resorts, inhabitants of flood-prone regions?

  - How can instruments for climatic damage reparation be designed (compensation strategies)? Are community funds (on local, national or EU scale), or even a global fund (e.g. financed by emission trading revenues) a way to fulfil a moral obligation (all cause climate change, but some suffer most badly)? Or is the market capable to develop all necessary tools by itself?
  - Can new and better-adapted insurance systems be developed based on private-public partnerships? (new)

- How can climate change be considered in credit risk and project finance assessment? **(hot topic # 12, OP 33, T 33)**

4.6 Health and Quality of Life

Health and quality of life are at the base of society's well-being. Climate change poses a threat to this base. It is therefore vital that we prepare our health care system and adapt our life styles also to this new challenge, in addition to other important trends, e.g. in demography.

Here are some research topics that should yield results that will be useful in the transdisciplinary search for adaptation strategies:

-  How can we adapt our health care infrastructure to a changing climate? Which elements of our health infrastructure are threatened by climatic changes and their impacts, such as increased frequency of heat waves, hazards such as floods, water shortages, power failures, new/increased vector borne disease? How can we 'climate-proof' our health care system? **(red hot topic # 10, OP 8, T 10)**
  - How can specific targeted information, e.g. directed at particularly vulnerable groups, on heat waves and behavioural adaptation measures be improved?
  - Can lifestyle changes increase our resilience to climatic change impacts? How do consumption patterns (e.g. diet, holiday travel, daily personal transport) contribute to our vulnerability and adaptive capacity?
- Will susceptibility of the human-environment system to specific pollutants become lower or higher with climate change? Do environmental pollution standards have to be changed due to the consequences of climate change? What is the likely future development of emissions of pollutants? These projections as well as interactions between pollutants and climate change need to be taken into account when planning climate change adaptation strategies.
- How can landscape features and urban structures sustain our quality of life in a changing climate and its impacts, such as increased frequency of heat waves, hazards such as floods, water shortages, power failures, new/increased vector borne disease, altered appearance of allergens, considering also other trends such as land abandonment, afforestation, changes in age structure of the population etc? How can we manage landscape features and urban structures to optimise recreational opportunities and minimise the need for long commutes? **(hot topic # 12, OP 18, T 14)**

4.7 Climate induced surprises

Climate change can have surprising effects, such as possibly the sudden increase of nitrate concentration in springs within pristine catchments. Here the source of nitrate is yet unidentified, but may well be related to climate change induced melting processes. There may also be other processes related to climate change that we did not yet think of as sensitive.

In order to avoid unpleasant surprises, some research should be funded to keep an eye out for such surprises – even if this is hard to organise in a straightforward, well-structured manner. Finding a way to

deal with such climatic surprises and setting aside some research money to investigate “crazy issues” was among the top priorities of the CIRCLE advisory board (**hot topic # 11, OP 15, T 12**).

Here are some questions that may help us unravel complex climate-related processes before they cause significant harm:

- What caused the dramatic increase of the concentration of nickel in high Alpine lakes? Was this triggered by melting glaciers containing historical deposits?
- Climate change can also surprise us regarding its rate of change (‘abrupt changes’), e.g. sea level rise and related impacts may occur faster than anticipated due to break-up of large ice sheets in the Antarctic and elsewhere. (new)

4.8 Extreme weather events and shifts in permafrost regimes

Extreme weather events and shifts in permafrost regimes need to be considered in all sectors. It is unwise to single out specific topics in this research area in isolation of links to other sectors. In particular issues related to water and energy supply, as well as general safety will always call for transdisciplinary, cross-sectoral approaches.

The challenge of transdisciplinary, cross-sectoral management is great, and very practical. Far from being able to provide answers, we offer here a set of research questions that may be able to supply insights for the development of adaptation strategies to deal with extreme events across sectors:

- Increased risk of extreme weather events in Europe. **(hot topic # 15, OP 7, T 11)**
    - How effective are our existing early warning systems (for extreme precipitation events, floods and surges, heat waves, forest fires, droughts, storms)? What can be improved, and what are possible strategies for implementation of such improvements?
- How will the risk of flooding in specific regions of Europe change? Based on the answer to this question, projects should develop measures of risk reduction and evaluate their effectiveness, as well as possible negative side effects and barriers in their implementation.
- Which areas in Europe will likely experience increased risk of landslides and soil erosion and other mass movement? Which land management, behavioural and technological strategies can help us mitigate these risks? Are traditional forms of land use helpful to decrease such risks, e.g. keeping shepherded livestock in high mountains?
- How can we adapt to increased risk of heat waves? What immediate societal responses should be triggered to prevent damage and suffering at the onset of a heat wave?
- What are the possible impacts of extreme events on natural systems and the services they provide? Can extremes trigger long-term ecosystem changes in biodiversity, carbon and nutrient cycling, etc.?
- How will receding wintertime snow cover and receding permafrost affect the risks of soil erosion, and land slides in mountain systems and Northern Europe? What adaptation strategies can mitigate possible increases in risk? What are the possible negative side effects of these strategies and barriers in implementation?
- How are permafrost regimes due to change with climate change? What impacts are to be expected on infrastructure and industry (e.g. mineral extractions)? How can we adapt to such changes? (new)

4.9 Tourism

Tourism is an enterprise that may profit private companies as well as larger European regions. To do so sustainably, and to the benefit of all stakeholders, the impacts of tourism on the human-environment system needs to be taken into account, as well as the impacts of global pressures on tourism. Recently

the tourism industry has recognised climate change as an important influence on their business. Many adaptation strategies that are common practice in tourism resorts anyway are now expanded or altered to face climate change as well. We need to carefully consider the need for such strategies, their design and their impact on the human-environment system as a whole.

In the following we list a number of research questions that may provide useful insights to sustainably manage tourism in a world of climate change:

- Snow fall variability as well as declining snow safety have triggered the development of a number of adaptation strategies in the ski industry (European mountains and Nordic regions), such as snowmaking; slope development to reduce required snow depth; land contouring, e.g. to recapture snowmelt for snowmaking; strategic planting of trees, e.g. 'snow farming'; glacier protection in summer months with white polyethylene sheets; strategic snow grooming and snow making to increase glacier growth; development of north facing slopes; expansion to higher elevations; changing the timing of ski area opening; increased intensity of use of existing slopes; artificial, non-snow ski surfaces (for patching up); cloud seeding (doubtful if this works at all, experiences from Australia and USA can be analysed); ski resort conglomerates; revenue diversification, alternative non-snow activities; indoor ski slopes; snow insurance; and conversion between seasons, e.g. from winter to summer for the lower Alpine resorts. What are the positive and negative side effects of these strategies, as well as barriers for implementation?
- What risks pose avalanches to alpine ski resorts and related infrastructure? How can vulnerable resorts be protected?
- Transport plays an important role for winter as well as summer tourism. What will be the potential impacts on transport infrastructure? What are possible adaptation strategies, considering also synergies with mitigation, such as e.g. new public transport routes into ski resorts that pose a serious alternative for individual car traffic? (new)
- What are the main impacts that may harm or profit the summer tourism industry? Where and when will water scarcity, heat waves, drought, exacerbated infectious diseases, extreme rain events and consequent increased risk of hazards pose problems? Which activities are threatened, e.g. diving, hiking, etc.? What are plausible adaptation strategies for the summer tourism industry? Will there be new opportunities for resorts at the North and Baltic Sea? How to sustainably capitalize on any new opportunities?
- What does "sustainable tourism" (or green tourism) mean in the context of climate change risks? Does sustainable tourism hold potential to help the tourism sector adapt to climatic and socio-economic changes?

4.10 Acknowledgements

We thank the CIRCLE advisory board members, particularly its chair Markku Rummukainen and co-chair Roland Psenner, as well as the participants of the CIRCLE annual progress meeting in Toulouse, France, Oct 2007. We are also grateful for input in particular from the following colleagues: Martin König, Katja Pazdernik, Markus Leitner, Herbert Haubold, Tim Carter, Franziska Matthies, Hubertus Bardt, Gergely Horváth, Ivan Nijs, Marianne Lilliesköld, Mattias Lundblad, Yeshayahu Bar-Or, Telmo Carvalho, Daniel Martin, Fernando Rodríguez, Gregor Laumann, Annette Münzenberg, Jaana Roos, Tiago M. Capela Lourenço, Stéphanie Monjon, Marit Viktoria Pettersen, João S. Pereira, Marina Fischer-Kowalski, Wolfgang Cramer, Colin Prentice, Rik Leemans, Harald Bugmann, Anthony G. Patt, Evan Fraser, Carlo Jaeger, and the participants of the 2007 ALTER-Net summerschool in Peyresq, France.

4.11 Appendix

toipc area	topic #	topic	% AB	% observers	% partners	% total sum	% observers and partners	rank AB	rank observers	rank partners	rank total sum	rank (observers + partners)
Practical Use	46	How to bridge the gap between research and political as well as practical implementation?	8.4	4.2	7.9	7.1	6.5	1	4	1	1	1
Practical Use	47	How to bridge the gap in scale from European-wide research efforts and specific local implementations?	5.3	1.7	2.5	3.1	2.2	2	22	13	8	18
Water	1	Fresh water shortages. Competing uses: domestic, industrial, hydropower, navigation, agriculture.	4.9	3.9	4.6	4.5	4.4	3	6	2	2	2
Urban areas	25	Coping with heat waves.	4.9	3.0	4.0	4.0	3.6	3	10	5	4	5
Urban areas	26	Coping with hazards, e.g. flooding.	4.7	4.1	4.4	4.4	4.3	4	5	3	3	3
Practical Use	48	Analyze interactions between different sectors across Europe.	4.5	1.9	3.2	3.2	2.7	5	20	6	7	11
Agriculture	16	Combined pressures of socio-economic, legal (e.g. CAP), land use and climate change.	4.1	3.0	2.9	3.3	2.9	6	10	7	6	9
Coastal zones	6	Sea level rise and European coasts. E.g. salt water intrusion, loss of wetlands, safety of coastal infrastructure	3.7	2.7	2.8	3.1	2.8	7	12	8	9	10
Insurance & Finance	31	New risks and changed hazard probabilities.	3.5	1.8	0.8	1.9	1.2	8	21	28	20	30
Agriculture	17	More frequent droughts and extreme rainfall events Æ Soil erosion, increased variation in and loss of productivity.	3.1	4.3	4.2	3.9	4.2	9	3	4	5	4
Forestry	22	Managing the carbon balance of forests: increased above ground growth vs. increased losses from soil and fire?	3.1	1.6	1.7	2.1	1.6	9	23	21	17	22
Health & Quality of Life	27	Heat waves, hazards such as floods, water shortages, power failures, new/increased vector borne disease – How can we ‚climate proof' our health care system?	2.9	3.2	2.9	3.0	3.0	10	9	7	10	8
Surprises	45	Climate change can have surprising effects, e.g. the dramatic increase of the concentration of nickel in high Alpine lakes probably triggered by “melting of historical deposits”; regional cooling, etc.	2.7	2.7	2.2	2.5	2.4	11	12	16	12	15
Agriculture	19	Potential for growing biomass energy crops, considering competing land uses, changing climatic zones, soil requirements and a changing energy system? Analysis of side effects?	2.5	2.3	2.7	2.5	2.5	12	16	10	12	13
Health & Quality of Life	29	Heat waves, hazards such as floods, water shortages, power failures, new/increased vector borne disease – How can we sustain our quality of life in a changing climate?	2.5	2.1	2.2	2.3	2.2	12	18	16	14	18
Insurance & Finance	32	How can climate change be considered in credit risk and project finance assessment?	2.5	0.5	1.1	1.3	0.9	12	33	25	33	33
Agriculture	18	Northern Europe: How to capitalize on opportunities?	2.3	0.0	0.8	1.0	0.5	13	36	28	36	38
Forestry	20	Increased risk of forest fires.	2.1	5.0	2.7	3.1	3.6	14	1	10	8	6
Extreme Events	40	Increased risk of extreme weather events in Europe.	1.9	4.6	2.4	2.8	3.2	15	2	14	11	7
Coastal zones	8	Sensitivity of coastal ecosystems. E.g. wetlands, estuaries, deltas, lagoons etc.	1.9	2.5	2.5	2.3	2.5	15	14	12	13	13
Coastal zones	7	Alterations in the North Atlantic Oscillation, Thermohaline Circulation and the gulf stream	1.9	2.1	2.0	2.0	2.0	15	18	17	19	19
Nature Conservation	33	Changes in nature reserves and the services they provide.	1.9	0.8	1.4	1.4	1.2	15	30	23	31	31
Water	2	Fresh water supply in emergency situations (long lasting heat waves and droughts)	1.6	2.3	2.3	2.1	2.3	16	16	15	16	17
Nature Conservation	35	Managing biological invasions under changing climate?	1.6	1.9	1.4	1.6	1.6	16	19	23	23	23
Water	5	Water quality. E.g. glacial melting and impacts of past pollution stored in melting ice.	1.4	2.1	2.7	2.1	2.4	17	18	9	15	14
Extreme Events	44	Impacts of extreme events on natural systems and the services they provide.	1.4	3.2	1.8	2.1	2.4	17	8	20	16	16
Tourism	13	Drought and extreme rainfall events -> increasing hazard risk.	1.4	2.1	1.8	1.8	1.9	17	17	19	21	20
Tourism	15	What does ‘sustainable tourism’ mean in the context of climate change risks? Does it hold potential to adapt to climatic and socio-economic changes?	1.4	2.1	1.8	1.8	1.9	17	17	19	21	20
Tourism	9	Snow fall variability and declining snow safety.	1.4	2.6	1.0	1.6	1.6	17	13	27	25	24
Insurance & Finance	30	Past climatic trends can no longer be extrapolated – How can insurance be planned?	1.4	0.7	0.7	0.9	0.7	17	31	31	38	35
Urban areas	28	Do environmental pollution standards have to be changed?	1.2	0.5	2.2	1.5	1.6	18	33	16	27	25
Tourism	14	Capitalizing on new opportunities for resorts at the North and Baltic Sea.	1.2	0.1	0.3	0.5	0.2	18	35	33	42	40
Nature Conservation	36	Ecosystem service provision outside nature reserves.	1.0	1.9	1.4	1.4	1.6	19	19	23	28	23
Forestry	23	Forest pests and calamities under climate change.	1.0	1.1	1.8	1.4	1.6	19	27	20	30	25
Tourism	11	Water scarcity.	1.0	1.0	1.8	1.4	1.5	19	28	19	32	26
Forestry	24	Regional shifts in species' suitabilities.	1.0	1.4	1.5	1.3	1.5	19	25	22	33	28
Nature Conservation	39	Improve biodiversity models.	1.0	1.2	1.3	1.2	1.3	19	26	24	35	29
Extreme Events	42	Changes in risk of flooding in specific regions of Europe.	0.8	3.7	1.8	2.0	2.5	20	7	20	18	12
Tourism	12	Heat waves.	0.8	1.0	2.5	1.6	1.9	20	28	11	24	20
Water	4	Transnational communication and management	0.8	1.8	1.8	1.5	1.8	20	21	18	26	21
Nature Conservation	37	Maintaining diverse traditional, cultural landscapes under combined multiple pressures.	0.8	1.2	1.0	1.0	1.1	20	26	26	37	32
Extreme Events	41	Receding wintertime snow cover and receding permafrost – risks of soil erosion and land slides?	0.6	2.8	0.7	1.2	1.5	21	11	31	34	27
Forestry	21	Sustainable management of burnt areas.	0.4	2.1	2.2	1.6	2.2	22	18	16	22	18
Extreme Events	43	Increased risk of heat waves.	0.4	2.3	1.5	1.4	1.8	22	15	22	29	21
Tourism	10	Risks of avalanches.	0.4	1.4	0.2	0.6	0.6	22	24	34	40	36
Nature Conservation	34	Threatened European habitats. Negative feedback on the climate system?	0.4	0.3	0.7	0.5	0.6	22	34	29	41	37
Water	3	Disruptions in the sewage system (due to mud accumulation)	0.2	0.9	0.7	0.6	0.8	23	29	30	39	34
Nature Conservation	38	Threats to inanimate nature.	0.2	0.6	0.5	0.4	0.5	23	32	32	43	39

Legend	rank
red hot topic	1-10
hot topic	11-15
	16-20
	21-40

The above Table lists the research topics (column “topics”) as they were formulated on the handout used in the prioritisation exercise (see section 2.1). Each topic was listed under a “topic area” (first column). The following abbreviations apply: % - the percentage of total points given by a specific group to a specific research topic; rank – the rank position of the topic based on the percentage of points given that topic; AB – advisory board.