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FINADAPT scenarios for the 21st century

Alternative futures for considering adaptation to climate change in Finland

Timothy R. Carter, Kirsti Jylhä, Adriaan Perrels,
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FINADAPT Working Paper 2

FINNISH ENVIRONMENT INSTITUTE

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FINADAPT Working Paper 2

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Foreword

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"[1]. The IPCC lists two reasons why adaptation is important in the climate change issue. First, an understanding of expected adaptation is fundamental in evaluating the costs or risks of climate change. Second, adaptation is a key response option or strategy, along with mitigation. Even with reductions in greenhouse gas emissions, some climate change is regarded as inevitable, and it will be necessary to develop planned adaptation strategies to deal with the associated risks as a complement to mitigation actions.

In Finland, there has been substantial progress during the past decade in investigating the potential impacts of climate change on natural and human systems. In contrast, there has been much less attention paid to adaptation. This was recognised by the Finnish Parliament as early as 2001, when it recommended that a separate programme for adaptation to climate change be initiated. As a result, a task force co-ordinated by the Ministry of Agriculture and Forestry completed Finland's first National Strategy for Adaptation to Climate Change in 2005.[2]

At about the same time as the Strategy document was being drafted, a research consortium named FINADAPT also began its work. The goal of the consortium, involving 11 partner institutions co-ordinated by the Finnish Environment Institute, was to undertake an in-depth study of the capacity of the Finnish environment and society to adapt to the potential impacts of climate change. FINADAPT was funded for the period 2004-2005 as part of the Finnish Environmental Cluster Research Programme, co-ordinated by the Ministry of the Environment. It comprised 14 work packages (WP) covering: 1) co-ordination, 2) climate data and scenarios, 3) biodiversity, 4) forests, 5) agriculture, 6) water resources, 7) human health, 8) the built environment, 9) transport, 10) energy infrastructure, 11) tourism and recreation, 12) economic assessment, 13) urban planning, and 14) a stakeholder questionnaire. The primary objective of FINADAPT was to produce a scoping report based on literature reviews, interactions with stakeholders, seminars, and targeted research.

The present report is a supporting document for FINADAPT, describing a set of storylines that characterise alternative future environmental and socio-economic conditions in Finland during the 21st century. The storylines are quantified for a number of key indicators in the form of scenarios. These have already been applied in a number of the FINADAPT work packages, but are also available to anyone else with an interest in future vulnerability to environmental change in Finland.

Timothy Carter, Consortium Leader
Helsinki, November 2005

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[1] IPCC, 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (eds)]. Cambridge University Press, Cambridge and New York, p. 982.

[2] MMM, 2005. *Ilmastomuutoksen kansallinen sopeutumisstrategia* (Finland's National Strategy for Adaptation to Climate Change) [Marttila, V., Granholm, H., Laanikari, J., Yrjölä, T., Aalto, A., Heikinheimo, P., Honkatuki, J., Järvinen, H., Liski, J., Merivirta, R. and Paunio, M. (eds)], Ministry of Agriculture and Forestry, Helsinki (available in Finnish, 276 pp. and English, 280 pp.) http://www.mmm.fi/sopeutumisstrategia/

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FINADAPT SCENARIOS FOR THE 21ST CENTURY: ALTERNATIVE FUTURES FOR CONSIDERING ADAPTATION TO CLIMATE CHANGE IN FINLAND

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Summary

A set of three scenarios of environmental and socio-economic conditions in Finland during the 21st century is presented. The scenarios were developed to provide a contextual framework for research into adaptation to climate change in the FINADAPT project. They have similarities to the IPCC SRES global scenarios, but they also differ from SRES because they are national in scope and they account for climate policy. The scenarios are labelled: *Global Markets*, assuming low greenhouse gas levels, high economic growth with rapid technological development (related to SRES A1T); *Sustainability*, assuming low greenhouse gas levels, sustainability goals with slower economic growth than Global Markets and rapid technological development (related to SRES B1); and *Retrenchment*, assuming high global greenhouse gas emissions, a world in blocs with unbalanced wealth, rapid population growth and obstacles to technological proliferation and trade (related to SRES A2).

The scenarios span four time frames (climatological averaging periods in brackets): present-day (1971-2000), near-term (1991-2020), mid-term (2021-2050), and long-term (2071-2100), and the requirements for adaptation are then treated as if they apply in 2005 (present-day), 2020, 2050 and 2100. Quantitative scenario information on socio-economic development, climate, CO_2 concentration, nitrogen deposition and land use change has been provided, with detailed data available from the FINADAPT web site or from relevant partner institutes.

1. Introduction

The objective of this document is to present a set of alternative, internally-consistent *scenarios* of environmental and socio-economic changes in Finland during the 21st century. These offer different perspectives on the future of Finland given certain assumptions about societal development and environmental change. The scenarios are designed to support the activities of FINADAPT partners by providing reference conditions for investigating future vulnerability to climate change and appropriate adaptation responses.

Each scenario comprises both qualitative and quantitative elements. The qualitative elements are in the form of narrative *storylines* describing plausible developments in demography, economic structure, land use, technology and governance in Finland. The storylines are used as a basis for constructing quantitative scenarios for a range of indicators.

The approaches employed to develop the FINADAPT scenarios draw heavily on the results of the FINSKEN project (Developing Consistent Global Change Scenarios for Finland – Carter et al., 2004), supplemented by new information generated for the National Climate Change Adaptation Strategy (MMM, 2005) and for the European Commission-funded ATEAM (Advanced Terrestrial Ecosystem Analysis and Modelling) project (Schröter et al., 2005).

The next section describes the criteria employed in selecting the scenarios and the approaches used in their construction. Sections 3-7 then outline the five indicators for which quantified scenarios are presented: socio-economic conditions, climate, CO_2 concentration, nitrogen deposition, and land use change. The final section re-iterates some of the potential applications of the scenarios and discusses how they might be elaborated and refined in the future.

More information about the scenarios and links to specific data sources can be found at the FINADAPT web site[3].

[3] http://www.environment.fi/default.asp?node=16118&lan=en

2. Description of scenarios

2.1. Criteria for selecting storylines and scenarios

The FINADAPT scenarios have similarities to the global scenarios developed for the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES - Nakićenović et al. 2000). This is convenient for providing quantified scenarios from existing sources (e.g. for atmospheric composition and climate). However, in some aspects they also differ from the SRES scenarios. First, they apply to a national and sub-national scale, while the SRES scenarios were developed globally and for four world regions. This requires describing futures that are appropriate to Finnish conditions, while at the same time seeking some consistency with global developments. Second, the SRES senarios do not consider climate change mitigation policies explicitly designed to reduce emissions of greenhouse gases. In contrast, the FINADAPT scenarios attempt to reflect the reality of international policy discussions, embracing options that consider mitigated alongside unmitigated futures. Third, and perhaps crucially for this application, the SRES scenarios do not account for the ways in which adaptation to climate change may influence society and the economy, nor how these modifications may feed back onto the environment.

The storylines to be selected should be:

1. sufficiently distinct from each other with respect both to their implied climate impacts and to their socio-economic assumptions;
2. by and large identifiable with the IPCC SRES global scenario families; and
3. credible and of significance for strategic climate policy making in Finland.

To fulfil the first of these criteria, it is necessary to view potential scenarios from the perspectives both of the projected global changes in climate and the socio-economic conditions that are consistent with these changes, both globally and in Finland.

2.2. Selecting climate scenarios

From a climate change point of view an important issue is whether the carbon dioxide (CO_2) concentration stabilises by the end of the 21st century[4] or does not stabilise[5]. Climate scenarios for Finland, embracing a wide range of SRES emissions, were presented in the FINSKEN project (Jylhä et al., 2004). A good part of the SRES A1 scenario family and virtually all variants of the A2 scenario family have CO_2 emissions trajectories that do not show stabilisation. However, a large number of variants in the B1 and B2 scenario families as well as the technologically-orientated A1T family do show CO_2-stabilisation, albeit through policies that are not explicitly targeted towards this goal on climatic grounds. Only the B1 and A1T scenarios achieve stabilisation as low as 550 ppm by the end of the 21st century, and from the point of view of emissions, climate and sea level these have been suggested as "a pragmatic surrogate for stabilisation scenarios" by Swart et al. (2002). Finally, a possible extreme climate outcome (thought to be of low probability but presumably rendered most

[4] Stabilisation policies also need to take account of other greenhouse gases than CO_2, though much of the published literature focuses on CO_2 stabilisation alone.

[5] It may also stabilise much later, at significantly higher concentration levels

likely under the highest rates of emissions growth) is a sudden shift or bifurcation in the climate system. One such scenario is an abrupt cessation of the North Atlantic thermohaline circulation, which could conceivably bring about a cooling of climate in northern Europe while the rest of the world continues to warm (e.g. Rahmstorf, 1995; Stocker et al., 2001; Wood et al, 2003). This is not included among the set of FINADAPT scenarios.

2.3. Selecting socio-economic scenarios

From a socio-economic point of view, it is difficult to construct mitigation scenarios for a small open economy such as Finland, while maintaining consistency with scenarios for large world regions, which themselves assume no climate policy intervention. The targeted mitigation measures that achieve stabilisation might depart from the assumptions underpinning the unmitigated A1T or B1 worlds, and could require a reassessment of the socio-economic and technological drivers facilitating such scenarios. Moreover, because of the small contribution of Finland to European and global emissions, in principle there are many alternative socio-economic scenarios that could be selected at national scale to be consistent with each of the global SRES scenarios[6].

Here a two-tier description is used[7]. First a further specification of the SRES global scenarios is needed, meaning that a more specific selection of scenario sub-types from the different scenario families is made, to which European socio-economic key indicators are added (e.g. on the basis of available studies such as of de Mooij and Tang, 2003). Second, for the selected scenarios (which are already quantified for many variables at European scale), the remaining manoeuvring space for Finland in each of the selected scenarios is assessed and plausible levels for key indicators are selected. A key assumption is that Finland will have some room to deviate from European average ratings, for some a bit more than others, but large differences for a larger portfolio of indicators are assumed to be impossible for both socio-economic and political reasons.

2.4. Mapping Finnish conditions onto SRES worlds

Finland in an A2 world. A2 implies a world in blocs. The proliferation of up-to-date technology and trade confronts both political and social-cultural obstacles. The consequent slower increase of welfare and slower decrease of population growth[8] imply a high emissions world with an unbalanced distribution of wealth. The relative position of Finland in an A2 world needs to be assessed further. Presumably export led growth is too weak to boost productivity growth, whereas the geo-political situation probably diminishes the potential of migration as a means to compensate for the ageing of society. In such circumstances Finnish socio-economic performance might be below the EU average.

Finland in an A1 world. In A1 high economic growth can be attained thanks to a practically unhampered trade. Yet, the size and focus of R&D efforts varies within the A1 scenario family. In A1B (Balanced) there is a reasonable - but not radical - R&D effort over a wide

[6] At this stage we do not consider grand feedback mechanisms between the climate and socio-economic system which may lead to significant changes in the evolution of the concentrations.
[7] Note that the scenarios cover a wider policy perspective than the FINSKEN socio-economic scenarios (Kaivo-oja et al., 2004), which were based on SRES. However, elements of those scenarios will be accounted for here.
[8] At the January 2005 IPCC expert meeting on emission scenarios it was mentioned by several speakers that the growth of the global population in the A2 scenario family is possibly too high (IPCC, 2005)

range of products. As regards energy, the efforts are spread over conventional, nuclear and renewable resources. The result is increasing welfare, a stabilisation of global population and also a better global convergence in welfare compared to A2, but the commitments to the boosting of sustainable technologies and practices are not strong enough to get the GHG concentration stabilised. Within an A1B world Finland is assumed to be a relatively progressive country with respect to development and application of sustainable technologies, hence the indication A1B/T for Finland. There is an alternative in the SRES A1 family, A1T (Technology), in which more focused and fast technology development in conjunction with a quicker stabilisation of the global population (thanks to the fast R&D progress and take up) leads to stabilisation of the GHG concentration by the end of the 21st century. It is also worth noting that the SRES A1FI scenario posits a fossil fuel intensive future, with little attention paid to emissions reduction. This scenario family produces the highest emissions of the SRES set, but is regarded for this exercise as highly improbable, given the already accelerating uptake of new technologies by many developing countries.

Finland in a B1 world. In the B1 scenario family it is assumed that both global and national politics are driven by a comprehensive sustainability philosophy. Technological development is still fast, but its focus and spread are tied to environmental conditions (notably regarding sustainability performance). The same applies to trade, which is still regarded as an important source of welfare generation, but not as unconditionally as in the A1 scenario family. This results in a slower pace of economic growth, compared to A1. Yet, in per capita terms it is still second only to the A1 family. The stabilising world population, the somewhat lower economic growth and the very strong commitments to sustainability-focused R&D result in stabilisation of the GHG concentration by the end of the 21st century.

2.5. Scenarios for FINADAPT

From a Finnish perspective the distinction between an A1T and a B1 world may not be so large, even though they imply marked differences in technological and environmental policies. With respect to policy development needs, it is relevant to know what strategic choices, in terms of content, timing and dose, would feature anyhow in Finnish policies regardless of an A1T or B1 world. In other words what are robust strategy elements?

What distinguishes A1T from B1 is the kind of failure risk. In A1T there is the risk that with economic growth remaining the overriding objective, the (sustainable) progress of technology is insufficient to achieve stabilisation of GHG concentration. In B1 the demands on "steering policies" regarding societal choices and the gradual redressing of vested interests, may face more resistance than expected, resulting in delay, failure or even breakdown in the curbing of trends. Hence, after a promising start, stabilisation of GHG concentration is nevertheless not attained. These differences in approach to policy making, which we have labelled "Global Markets" and "Sustainability", respectively, are offered as alternative socio-economic pathways towards stabilisation in the FINADAPT scenarios (Table 1)

A high emissions future based on the SRES A2 scenario is included in FINADAPT to demonstrate a plausible outcome of enhanced global inequality and environmental inaction. It also shows how the Finnish environment could be affected by global trends regardless of Finnish climate policy. However, Finnish economic and environmental policies would not be immune from the rest of the world, and a separate socio-economic future needs to be mapped to reflect this situation, which we have labelled a policy of "Retrenchment".

Table 1. Summary of scenarios and their positioning with respect to the SRES scenarios. Other potentially interesting scenarios not adopted for FINADAPT are indicated in italics.

Scenario	SRES A2	SRES A1	SRES B1
Low/stabilised emissions	–	"Global Markets" A1T ← Finland →	"Sustainability" B1
Intermediate emissions	–	*A1B globally & A1B/T in Finland*	–
High emissions	"Retrenchment" A2 globally & A2 Finland	–	–
Bifurcation	*Climate shock (e.g. cooling over Finland due to the cessation of the North Atlantic thermohaline circulation)*		

2.6. Interesting scenarios not selected for FINADAPT

There are, of course, many plausible futures that lie somewhere in between the three storylines outlined above. These are shown as intermediate emissions scenarios in Table 1, but are not selected as alternatives for FINADAPT in order to limit the number of scenarios. For example, the business-as-usual (BaU) scenario currently used as the reference for preparing climate policy in Finland in many respects resembles an A1B world. Even with policies in Finland aspiring towards A1T, a global realisation of A1B would still imply a failure to achieve CO_2-stabilisation. Implications of the A1B scenario for impacts and adaptation lie somewhere between the stabilisation case and the A2 case. Since few climate simulations describing this scenario were available during the project[9], it was not formally adopted, but its potential usefulness as a reference scenario should not be overlooked.

Similarly, the possibility of a major bifurcation in the climate or socio-economic systems, such as an abrupt cooling of the climate, cannot be excluded. However, there are still large uncertainties surrounding such outcomes. Even though exploratory studies at a global scale are starting to emerge (e.g. Keller et al, 2004) there has been little research into these in Finland to date. Thus we have chosen not to adopt such a scenario here, but instead we have flagged this issue as a subject for future research.

2.7. Time horizons

Three future time horizons are considered in FINADAPT: near-term (to 2020), mid-term (to 2050) and long-term (to 2100 and beyond). These differ somewhat from the periods adopted in the FINSKEN project (Carter et al., 2004), though the overall 100-year time horizon is the same. In addition, a consistent specification of the present-day conditions is also desirable. Scenarios for different indicators can vary in their specification of future time periods (see Box 1), and their selection is guided by the specific aims of the scenario exercise.

In Table 2 we have attempted to indicate what types of quantitative or qualitative information might be available for each of these time frames. The climate system and the socio-economic realm each have their own gradient in terms of ability to rely on actual observations, sophisticated model simulations, prospective calculations and tentative indications. Since climate projections are statistically indistinguishable under different emissions scenarios up to 2020, only one set of climate scenarios is required in this time frame. Divergence may start after that (in the mid-term).

[9] A large number of new simulations forced by the A1B emissions scenario have recently been conducted with global climate models, and will be evaluated in 2007 in the forthcoming IPCC Fourth Assessment Report.

Box 1: Scenario time horizons

The SRES scenarios extend from the internationally agreed base year for calculation of greenhouse gas emissions (1990) out to 2100. Similarly, estimates by the IPCC of the greenhouse gas and aerosol concentrations, radiative forcing of the atmosphere, climate changes and global sea-level rise resulting from these emissions also extend over the same period (IPCC, 2001).

Scenario needs vary among researchers studying climate change impacts and adaptation, so scenario information is provided for a variety of periods in the future. Although climate model projections are available on the IPCC Data Distribution Centre (DDC) for the entire 21st century, these data have also been averaged for 30-year time slices to assist impact researchers. This is because the World Meteorological Organization recommends a 30-year period as the standard averaging period to capture typical annual variations in weather and climate, including extreme climate events. Hence, the 1961-1990 period has been commonly adopted as a reference period for climate studies. Note that although this has now been superseded by the 1971-2000 period, 1961-1990 is still widely applied as a baseline for consistency with earlier studies. Given that there has been climate warming in many regions (including Finland) during the late 20th century, it is important to compare the climate from the most recent period with that from any earlier period that might have been adopted as a reference.

Climate data on the DDC for the next few decades are represented by the 30-year period centred on the 2020s (2011-2040) and two later time slices by periods centred on the 2050s (2041-2070) and 2080s (2071-2100), respectively. The 2020s are sufficiently near-term to be of relevance for current planning and policy-making in many sectors of society. The 2050s is a suitable time horizon for considering impacts that require longer term planning responses (e.g. forest management, infrastructure projects). The 2080s represents the last 30 years of the century, in which changes in climate and sea level are projected to be greatest, and in which the impacts on natural systems and society are likely to become most pronounced. The FINSKEN project also adopted these 30-year periods in developing scenarios for Finland (Carter et al., 2004).

There can be difficulties in applying these 30-year time slices alongside scenario data which are conventionally reported for individual years (e.g. economic projections). For example, a scenario population in 2055 will be exposed to a climate that varies from year-to-year as it does nowadays. Because the climate simulated for 2055 is a stochastic outcome from a climate model, this cannot be used as a scenario for 2055. Instead, future inter-annual variability around 2055 can be characterised by examining the projected climate during the 30-year period 2041-2070. However, if climate is changing, there will be a trend in these data. For example, climate in the years before 2055 may have been cooler on average than in the years after 2055. One option might be to remove the trend from the data, and assume that the average climate around 2055 is stationary. Another (more challenging) option could be to attach likelihoods to climatic conditions in 2055 based on the 30-year statistics, for example, relating to the exceedance of levels of change regarded as critical for a given impact.

An additional complication arises if adaptation is the focus of a study. In the absence of firm predictions of changed conditions, it would be logical to expect that both natural systems and human systems would be adapted to the conditions to which they have been exposed in previous years. Hence, individual Finnish farmers cultivating a specific crop type in 1990, presumably based their management decisions on their experience of climate (and other conditions) in the previous few years during the 1980s (the past being the guide to the future). In contrast, agricultural land use as a whole in 1990 (in different regions of the country and for different agricultural activities) was an outcome of multiple decisions by different actors over a longer period of time. For consideration of this, it might be important to look at climatic and related data from the 1961-1990 or an even longer historical time period. In addition, it may also be necessary to account for lags in the response of ecosystems or human actors to a changing climate. With adaptation in mind, we have opted in FINADAPT to focus on the end points of four 30-year climatological periods (see Table 2). These periods differ somewhat from those chosen for the FINSKEN scenarios.

Of course, if there are ongoing trends in climate, and if actors are convinced that these will continue into the future, then some degree of anticipatory adaptation might be expected. In this case, future climate should also be accounted for in the analysis, so the use of future time slices, including possible trends, would then be appropriate for characterising conditions at a particular point in the future.

Finally, there are important time lags in the physical climate system that sometimes need to be emphasised in constructing scenarios. For example, the greenhouse gas emissions released into the atmosphere to date have already committed the Earth to global sea level rise of several tens of centimetres throughout the next few centuries, information that is lost in scenarios that extend only to 2100.

Table 2. Data availability for different scenario time frames

Timeframes	Climate change indicators	Socio-economic indicators
Present day (& recent past)		observations
1971–2000	quantitative (observed/simulated)	(for historical perspective)
Near term		quantitative
1991–2020	quantitative (observed/simulated)	(simulated)
Mid-term	quantitative	quantitative
2021–2050	(simulated/scaled)	(simulated/extrapolated)
Long term	quantitative	quantitative
2071–2100*	(simulated/scaled)	(extrapolated/qualitative)

* Some model-based scenarios are for the period 2070-2099

2.8. Scenario indicators

The following indicators were identified as important quantitative determinants of the FINADAPT scenarios:

- Population/demography
- Socio-economic development
- Climate
- Atmospheric composition
- Land use
- Technology

This list was compiled from the requests of individual Partners and formed a basis for scenario construction. All indicators are addressed in the following sections except technological change, for which there were no suitable projections that could be readily developed or adopted.

3. FINADAPT socio-economic scenarios

3.1. Introductory remarks

Work to translate global or continental long term economic scenarios into long term Finnish economic scenarios has begun only very recently. The FINSKEN project provided some data, either by so called "downscaling" of results (both economic and otherwise) (Carter et al, 2004; Gaffin et al, 2003), or through a long-term modelling approach (Kaivo-oja et al, 2004) employing the International Futures (IF) modelling family (Hughes, 2003; 2004). The results from those studies can be used as a reference base, but cannot be used straightaway as input for economic scenario exercises using the conventional economic models applied in government planning. Furthermore, in order to maintain good comparison capabilities with other scenario projects, including those addressing the preparation of climate policy, a reference scenario up to the year 2030 should be harmonised with the updated baseline scenario of the Ministry of Trade and Industry, also known as the WM scenario (MMM, 2005).

The nature of the scenarios and baseline in studies of climate change adaptation is essentially different from what could be practised in the earlier studies of climate change mitigation, such as for the National Climate Strategy (KTM, 2001). When assessing emission reduction policies (i.e. mitigation), the baseline scenario with which the impacts of the policies (the scenarios in that case) are compared is deterministic.

In the case of adaptation the deterministic concept becomes problematic for two reasons. First, the very issue of adaptation concerns possible significant changes in the production environment. A part of these changes are probably not gradual but sudden, whereas the magnitude of the impact is only vaguely known and its timing is unknown. If this was the only factor, various (deterministic) baselines instead of one might still have been sufficient. However, a second difficulty is that some baseline features become easily endogenised, since the process of adaptation concerns not only responding to what happens, but also anticipating and possibly neutralising the consequences. The latter type of anticipatory responses mean that preferred response types and impacts after sudden changes can become path dependent, i.e. the course of the (rest of the) baseline is speculative. In the IPCC SRES scenarios (Nakićenović et al, 2000), which are used as guidelines in this study, baseline and response (automatic *and* policy driven) are combined. In practice, this has its most important consequences for the economic analysis beyond the year 2050. For the time being the position is to apply more tentative or even mainly qualitative economic analysis for the period beyond 2050. This allows us to avoid some of the complexities in long-term modelling, as inter-temporal interaction in the socio-economic realm can be assumed to have only a very minor influence up to 2050. Furthermore, as stated in section 2.6, a bifurcation scenario due to a major ecological event (also leading to significant socio-economic deviations from the original scenario pathway) has yet to be studied in Finland.

The time frames and level of detail for the economic scenarios are organised according to the phases described in Table 2 in section 2.7. Section 3.2 discusses the Finnish particulars of the three selected scenarios.

3.2. From global to Finnish scenarios

Key global conditions embedding Finnish trends. For the assessment of the Finnish national economic development from the year 2000 to 2050 the international context is important for three interrelated reasons. First, as Finland is a small open economy, the conditions for imports and exports are determined outside Finland, with respect both to price levels and to demand potential for Finnish exports. For this reason an economic scenario for Finland should be consistently linked with the economic scenarios for Europe and other principal trade partners.

Second, the expected climate change characteristics in Finland are entirely embedded in the climate change scenarios for Europe, and in particular for northern Europe. The prospective pathways for changes in climate influence the feasible production potentials of many sectors in Europe. Consequently, particular climate change pathways correspond better with some economic scenarios and worse with others.

Third, the way in which societies deal with climate change internationally, i.e. through the establishment of institutional and legislative structures, will influence the manoeuvring space that the unfolding economic development will actually use. Conversely, developments in other parts of the international policy regime (e.g. the WTO) will influence the development of a climate policy regime. Furthermore, in the long run the likelihood of particular climate change pathways is influenced by the extensiveness of the unfolding climate change policy regime and how swiftly it unfolds.

As was already presented in section 2, the following global SRES scenario families form the basis for the Finnish scenarios:

- *Global Markets*: low greenhouse gas levels, high economic growth with rapid technological development (related to SRES A1T, A1B and A1F)
- *Sustainability*: low greenhouse gas levels, sustainability goals with slower economic growth than Global Markets and rapid technological development (related to SRES B1)
- *Retrenchment*: high global greenhouse gas emissions, a world in blocs with unbalanced wealth, rapid population growth and obstacles to technological proliferation and trade (related to SRES A2)

Table 3 provides an overview of the key assumptions regarding population and economic growth at a global level based on the IPCC SRES scenarios (Nakićenović et al, 2000; Carter et al, 2004). The large interval for cumulative CO_2 emissions in the A1 case corresponds to specific scenario types within this family. The IPCC A1 family contains a variant A1FI (prolonged use of fossil fuels), which results in very high cumulative emission levels, while no stabilisation of greenhouse gas concentrations is reached. The A1FI variant is not considered in any detail in the Global Markets scenario in FINADAPT. A1B (balanced use of fossil, renewable and nuclear energy) results in slowing down the growth of emissions and even in reduction of emission levels by the end of the 21st century, but no stabilisation of GHG concentrations is reached in the 21st century (so cumulative emissions are in the mid range). The A1T variant (strong progress in technology) on the other hand results in stabilisation of concentrations in the 21st century and hence much lower cumulative

emissions. The assertion is that at least up to 2050[10] the variants within the A1 family are economically the same. The differences across A1 variants are focused on R&D policy and in the various technology choices made (notably regarding the energy and transport system). Key demographic and economic figures for the Finnish scenarios are presented in Table 4.

Table 3. Demographic and economic trends in the global SRES scenarios. Source: Carter *et al*. 2004.

SRES scenarios	Annual growth rates	1990–2020	2020–2050	2050–2100	Cumulative CO_2 1990– 2100 (GtC)
A1 global	Population	1,16 %	0,41 %	0,45 %	1068 .. 2189
	GDP	3,32 %	3,99 %	2,17 %	
	GDP/capita	2,16 %	3,58 %	1,72 %	
A2 global	Population	1,47 %	1,07 %	0,58 %	1862
	GDP	2,26 %	2,34 %	2,20 %	
	GDP/capita	1,21 %	1,27 %	1,62 %	
B1 global	Population	1,21 %	0,45 %	-0,43 %	983
	GDP	3,13 %	3,19 %	1,78 %	
	GDP/capita	1,92 %	2,74 %	2,21 %	

Table 4. Demographic and economic trends in the FINADAPT scenarios. Source: VATT calculations (see also MMM, 2005)

SRES scenarios	Annual growth rates	1990-2020	2020-2050	2050-2100	index 2100 (1990=100)
Global markets (A1B or A1T in Finland)	population	0,28 %	-0,18 %	-0,33 %	86
	GDP	2,25 %	2,10 %	1,30 %	677
	GDP/capita	2,00 %	2,30 %	1,65 %	792
Retrenchment (A2 in Finland)	population	0,28 %	-0,18 %	-0,33 %	86
	GDP	1,65 %	1,05 %	1,00 %	368
	GDP/capita	1,40 %	1,20 %	1,35 %	424
Sustainability (B1 Finland)	population	0,28 %	-0,18 %	-0,33 %	86
	GDP	2,10 %	1,50 %	1,30 %	556
	GDP/capita	1,80 %	1,70 %	1,65 %	642

Population effects in Finland. When focusing on Finland, the main features of the SRES storylines remain the same. However, the population perspectives in Finland (and in most EU countries and Japan) are quite different than the global average. The population in Finland is forecast to reach its peak between 2025 and 2030 (Statistics Finland, 2002). The population in the employable age bracket (18-65) is expected to decrease from 2010 onwards. However, the number of actually employed people may stay stable for a longer time. In the event of additional employment measures being introduced, the employment rate might even rise somewhat in the next 10 to 15 years. Over the long run, this means that even though growth of GDP (Gross Domestic Product) per capita is projected to remain roughly the same as in the EU15 area, overall GDP growth will – sooner or later – drop to somewhere below that in some other Member States. However, a different situation would arise if an active policy on immigration was implemented, implying an annual net influx of 5.000 to 10.000 employable people over the next 30 years. However, in all scenarios considered here, the demographics in Finland remain unchanged, and *do not* include significant net immigration.

[10] Given the correlation between higher GHG concentrations and the risk of more dramatic climate changes this assumption becomes contestable when we get well beyond 2050.

At a more detailed regional scale, the distribution of the population may be different in the Sustainability (B1) scenario as compared to the Global Markets (A1) and Retrenchment (A2) scenarios. Such differences could not be taken into account in the current scenario investigations. Table 5 provides an impression of the baseline regional demographic dynamics in terms of occupied dwellings. The average household size in Finland diminishes by about 15% between 2000 and 2030, consequently the number of households and dwellings growths substantially even though the total population hardly grows.

Table 5. Percentage change in the number of occupied dwellings by region and type of settlement between 2000 and 2030 on the basis of simulations of the development of the occupied dwelling stock (KulMaKunta project).

	Urban	**Suburban**	**Countryside**	**TOTAL**
Coastal South	28 %	42 %	20 %	31 %
South	22 %	39 %	10 %	23 %
West	27 %	42 %	8 %	21 %
East	12 %	16 %	-4 %	7 %
Lapland	9 %	-	0 %	5 %
TOTAL	24 %	38 %	6 %	22 %

Coastal South: Uusimaa, Itä-Uusimaa, Varsinaissuomi, Kymmenlaakso
South: Satakunta, Pirkanmaa, Kanta-Häme, Päijät-Häme
West: Etelä-Pohjanmaa, Pohjanmaa, Keski-Pohjanmaa, Pohjois-Pohjanmaa
East: Kainuu, Pohjois-Karjala, Pohjois-Savo, Etelä-Karjala, Etelä-Savo

Employment. In all three scenarios it is assumed that people in the age bracket 65-70 will become employable to some extent (20% of the relevant population). However, whereas the fulfilment of current employment policy (a return to 75% of the employable population from the present 68%) is realised in the Global Markets and Sustainability scenarios, in the Retrenchment scenario it is not (Table 6). The age extension nevertheless only postpones the moment that an absolute reduction of the labour force begins, and causes economic growth to slow down (unless productivity increases can compensate for it). This assumption differs to some extent from the version published for the Adaptation Strategy (MMM, 2005) but this has only minor overall implications for the employment totals.

Table 6. FINADAPT scenarios for total Finnish employment (millions), 2000-2050. Source: VATT calculations (see also Perrels 2005)

Year	**Global markets (A1T)**	**Retrenchment (A2)**	**Sustainability (B1)**
2000	2,310	2,310	2,310
2005	2,370	2,370	2,370
2010	2,481	2,439	2,481
2015	2,502	2,412	2,502
2020	2,504	2,367	2,504
2030	2,374	2,244	2,374
2050	2,118	2,003	2,118

Trends in the Finnish economic structure and implications for productivity. Another aspect common to all fully developed EU member states, including Finland, is that future economic development will tend to concentrate ever more in the service sectors. The productivity increase in the service sectors in the past decades has been systematically lower than in industrial sectors. Therefore, in the absence of important productivity-augmenting service

innovations, the overall long term productivity trend will be downward in EU15. Yet, globalisation (prominent in the A1 and to a lesser extent the B1 families) can keep up export led growth in industry in the next few decades, whereas the larger stress on technology development and its global distribution is expected to provide better prospects for productivity improvements in the service sectors up to 2050.

Even though the B1 scenario family also supposes – in principle – a global free trade regime, the societal pressures for vigorous improvements in the sustainability of products, services and the living and working environment result in more conditions on trade, more steering elements in policies, and in a tendency to look for localized solutions. The consequence is that factor productivity growth is not as high as in the A1 scenario family. However, in the long run beyond 2050, the productivity growth in both scenarios converges under the assumption that the precautionary technical and social-economic strategy at both the global and Finnish level starts to pay off, e.g. in terms of considerably reduced damage costs from climate change and other environmental changes.

In the A2 (Retrenchment) scenario family, economic growth is lower for the reasons explained in section 2.4. In addition, the resulting less favourable situation for employment and the development of wage and pension levels tightens the manoeuvring space for the public budget. This results in a permanently significantly lower growth rate than in the other two scenario families. At the same time the environmental and economic risks of climate change increase considerably in this scenario.

A detailed breakdown of economic growth in Finland up to 2050 by sector is given for each scenario in Table 7. Scenarios have also been constructed for private consumption expenditure out to 2030 (Table 8), based on the following price assumptions:

- *Global Markets (A1T)* – This largely coincides with the KTM BaU scenarios up to 2020, though labour market policy is more active (20% of 65-70 age category employable). Transport prices increase much faster than the average inflation rate. Owing to changes in EU agricultural policies and textile policies, both textile and food prices fall behind average inflation up to 2015. The cost of housing increases slightly faster than at present up to 2010, after which it follows average inflation up to 2020, after 2020 price development falls somewhat behind average inflation as tensions in the housing market fade away.
- *Sustainability (B1)* – A Finnish derivation of SRES B1, which differs from Global Markets (A1) by exhibiting lower productivity growth due to sustainability criteria in trade and production. Labour market development is the same as in A1 (though with somewhat slower wage development). The stricter sustainability criteria imply less reduction in food, clothing and textile prices. There is also a unit-cost increase for housing due to more vigourous sustainable building policies, but this is partly compensated by diminished expansion of floor area. The latter aspect in turn attenuates other parts of the cost of living, the price scenario for housing remaining the same as in Global Markets (A1).
- *Retrenchment (A2)* – A Finnish derivation of SRES A2, which differ from the above two scenarios through lower productivity growth due to protectionist trade policies. Household incomes develop less favourably compared to the other two scenarios. Prices of foodstuffs, textiles and clothing also diminish less in this scenario, whilst the larger global population growth causes more tensions for the markets of these products after 2015.

Initially, the price level for transport does not increase as much as in A1 and B1, but for the same reason as mentioned for food and textiles, transport (fuel) prices start to increase markedly after 2015.

Table 7. FINADAPT scenarios for economic growth in Finland by sector, 2000-2050. Source: VATT calculations (see also MMM 2005)

Global markets	**Gross value added by sector**				**Annual growth rates by period**		
FIN - A1(T)	**2000**	**2005**	**2025**	**2050**	**%00-25**	**%00-50**	**%25-50**
Primary sector	4651	4866	5912	7589	0.96	0.98	1.00
Forest industry	8389	9167	13426	19344	1.90	1.69	1.47
Metal & electronics industry	14917	20912	33186	49702	3.25	2.44	1.63
Other industry	6827	7337	9853	13044	1.48	1.30	1.13
Energy sector	1739	1910	2782	4890	1.90	2.09	2.28
Transport sector	12099	14398	26307	61635	3.16	3.31	3.46
Commercial services	46995	52817	82999	158706	2.30	2.46	2.63
Public services	20469	21915	27849	36366	1.24	1.16	1.07
Total	**116085**	**133323**	**202313**	**351276**	**2.25**	**2.24**	**2.23**
Retrenchment	**Gross value added by sector**				**Annual growth rates by period**		
FIN – A2	**2000**	**2005**	**2025**	**2050**	**%00-25**	**%00-50**	**%25-50**
Primary sector	4651	4741	5160	6764	0.42	0.75	1.09
Forest industry	8389	9068	12502	16931	1.61	1.41	1.22
Metal & electronics industry	14917	19672	24666	24622	2.03	1.01	-0.01
Other industry	6827	7050	8000	8618	0.64	0.47	0.30
Energy sector	1739	1854	2372	3284	1.25	1.28	1.31
Transport sector	12099	13842	21208	36693	2.27	2.24	2.22
Commercial services	46995	51188	69930	109227	1.60	1.70	1.80
Public services	20469	21453	24787	28203	0.77	0.64	0.52
Total	**116085**	**128867**	**168624**	**234342**	**1.50**	**1.41**	**1.33**
Sustainability	**Gross value added by sector**				**Annual growth rates by period**		
FIN – B1	**2000**	**2005**	**2025**	**2050**	**%00-25**	**%00-50**	**%25-50**
Primary sector	4651	4862	5890	8095	0.95	1.11	1.28
Forest industry	8389	9127	13223	20844	1.84	1.84	1.84
Metal & electronics industry	14917	20678	31834	32451	3.08	1.57	0.08
Other industry	6827	7280	9438	11276	1.30	1.01	0.71
Energy sector	1739	1908	2770	4275	1.88	1.82	1.75
Transport sector	8364	9836	17379	31554	2.97	2.69	2.41
Commercial services	50729	57235	90443	160997	2.34	2.34	2.33
Public services	20469	21841	27242	34177	1.15	1.03	0.91
Total	**116085**	**132767**	**198219**	**303669**	**2.16**	**1.94**	**1.72**

3.3. How to learn from the scenarios

The scenarios presented above are typically meant as possible alternative futures indicating what would happen to Finland and what would be the climate change implications under those circumstances. The Retrenchment scenario represents a world in which we prefer not to end up. So, the principal questions attached to this alternative are: (1) what can Finland do to help to prevent the emergence of a world in Retrenchment and (2) what should be done to minimise damages to Finland in case this scenario materialises?

Table 8. FINADAPT scenarios for private consumption expenditures at macro level in Finland by category (2000–2030). Values were obtained by applying changes in average household characteristics (income, age, etc.) and retail price developments. Note that there are moderate aggregation errors when going from micro to macro. Source: KulMaKunta project.

	Aggregate household consumption (billion €)						
Global Markets (A1T)	**1998**	**2001**	**2005**	**2010**	**2015**	**2020**	**2030**
Food, beverages, restaurants	11.9	13.5	14.2	15.3	17.3	19.9	24.2
Clothing, footwear, accessories	2.5	2.8	3.2	3.0	3.8	4.5	5.5
Living (home, energy, interior)	19.3	18.4	21.1	25.6	28.6	32.7	36.6
Transport	3.5	4.0	4.6	5.3	6.2	7.1	8.9
Media	2.8	3.3	3.7	4.2	5.0	5.6	7.3
Leisure	2.1	2.4	2.8	3.2	3.6	3.8	4.5
Health and personal care	3.1	3.6	4.2	4.8	5.8	6.7	8.8
Tourism	1.0	1.2	1.5	1.8	2.2	2.5	3.4
Financial services	3.3	3.8	4.5	5.4	6.5	7.5	9.8
Cars	1.4	1.6	1.9	2.2	2.4	2.5	2.5
Electric appliances	0.6	0.7	0.8	0.9	0.9	1.0	1.1
Large leisure goods	0.6	0.6	0.7	0.8	0.9	1.1	1.3
Furniture, int.decor.	1.5	1.6	1.7	1.9	2.1	2.3	2.6
Total	**53.6**	**57.5**	**64.9**	**74.4**	**85.4**	**97.0**	**116.6**
	Aggregate household consumption (billion €)						
Retrenchment (A2)	**1998**	**2001**	**2005**	**2010**	**2015**	**2020**	**2030**
Food, beverages, restaurants	11.9	13.5	14.3	15.2	16.9	19.2	22.9
Clothing, footwear, accessories	2.5	2.8	3.2	3.2	3.7	4.1	4.7
Living (home, energy, interior)	19.3	18.4	21.0	25.0	27.8	29.9	29.4
Transport	3.5	4.0	4.6	5.3	6.0	6.5	7.4
Media	2.8	3.3	3.7	4.2	4.8	5.3	6.7
Leisure	2.1	2.4	2.8	3.1	3.4	3.4	3.5
Health and personal care	3.1	3.6	4.2	4.8	5.6	6.2	7.4
Tourism	1.0	1.2	1.5	1.8	2.1	2.2	2.6
Financial services	3.3	3.8	4.5	5.3	6.1	6.7	7.9
Cars	1.4	1.6	1.9	2.1	2.2	2.2	2.1
Electric appliances	0.6	0.7	0.8	0.8	0.9	0.9	1.0
Large leisure goods	0.6	0.6	0.7	0.8	0.9	1.0	1.0
Furniture, int.decor.	1.5	1.6	1.7	1.9	2.0	2.1	2.3
Total	**53.6**	**57.5**	**64.9**	**73.4**	**82.4**	**89.7**	**99.0**
	Aggregate household consumption (billion €)						
Sustainability (B1)	**1998**	**2001**	**2005**	**2010**	**2015**	**2020**	**2030**
Food, beverages, restaurants	11.9	13.5	14.3	15.4	17.5	19.8	24.4
Clothing, footwear, accessories	2.5	2.8	3.2	3.3	3.8	4.2	5.4
Living (home, energy, interior)	19.3	18.4	21.0	24.9	28.0	32.1	35.4
Transport	3.5	4.0	4.6	5.3	6.1	6.9	8.7
Media	2.8	3.3	3.7	4.3	5.0	5.6	7.3
Leisure	2.1	2.4	2.8	3.1	3.5	3.6	4.3
Health and personal care	3.1	3.6	4.2	4.8	5.7	6.6	8.6
Tourism	1.0	1.2	1.5	1.8	2.2	2.5	3.3
Financial services	3.3	3.8	4.5	5.4	6.4	7.4	9.6
Cars	1.4	1.6	1.9	2.2	2.3	2.5	2.5
Electric appliances	0.6	0.7	0.8	0.9	0.9	1.0	1.1
Large leisure goods	0.6	0.6	0.7	0.8	0.9	1.0	1.3
Furniture, int.decor.	1.5	1.6	1.7	1.9	2.1	2.2	2.6
Total	**53.6**	**57.5**	**64.9**	**74.0**	**84.5**	**95.5**	**114.4**

Figure 1 attempts to position the FINADAPT scenarios in relation to the dual policy goals of socio-economic and ecological sustainability. The broken lines indicate the notional frontiers to be crossed to achieve each of these goals. These frontiers indicate the areas in which the combination of technical, societal and economic solutions can lead to ecologically and socio-economically sustainable societies, respectively. The area delimited by both frontiers (shaded) is supposed to contain solutions that enable overall sustainability.

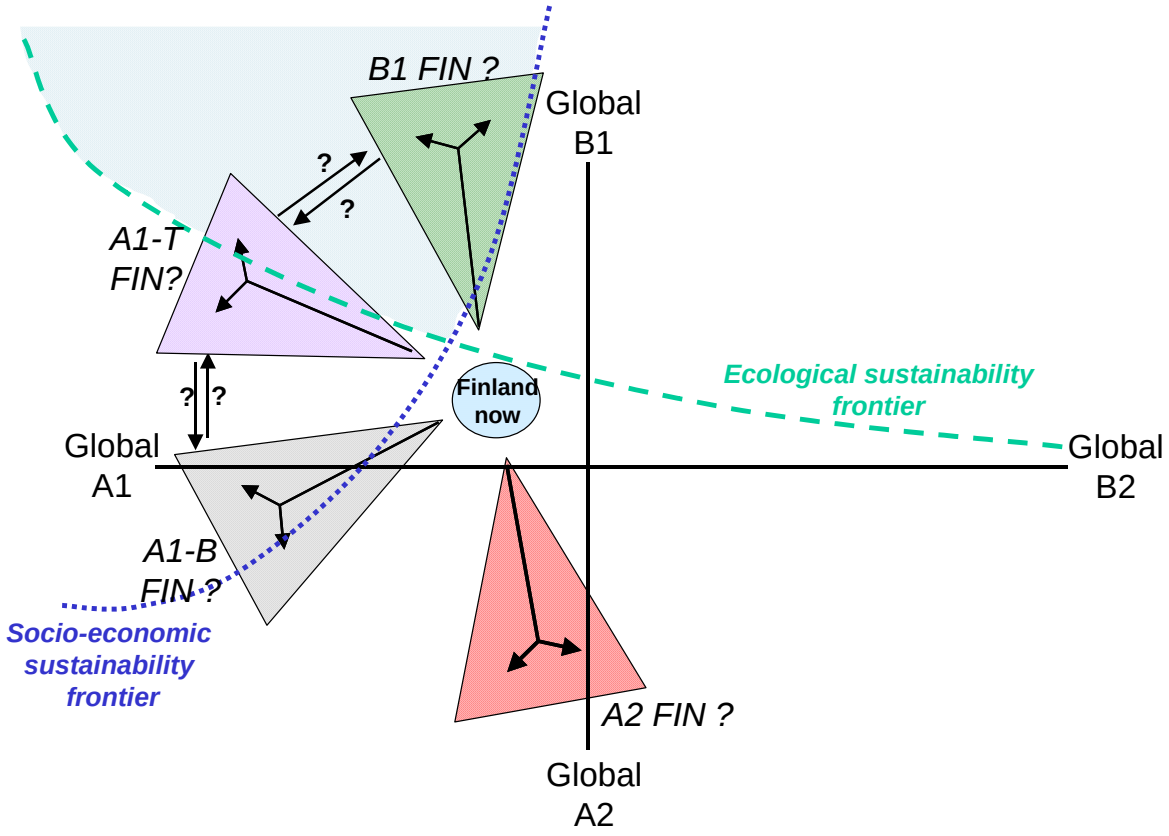


Figure 1. Approximate positions of the FINADAPT scenarios in relation to the present situation (Finland now) and to the dual policy goals of socio-economic and ecological sustainability (blue/grey shading above the broken lines). Scenarios are represented as triangles which are mapped onto the global SRES storylines described by Nakićenović et al. (2000). Arrows within triangles depict alternative pathways within a future world. Arrows between triangles represent possible similarities or transitions between aspects of the scenario worlds.

The Retrenchment scenario is positioned outside both the socio-economic and ecological sustainability frontiers. The other two scenario alternatives, i.e., Global Markets and Sustainability, represent more desirable alternatives. In the Finnish context they may well contain many common solutions. This is indicated in Figure 1 by means of the arrows between the two strategy pathways (A1T-FIN and B1-FIN). From the current position ("Finland now") the reference direction in the near term is the Global Market scenario. However, with present trends this could alternatively indicate a development represented by A1-B (which may only fulfil social-economic sustainability) or the realisation of an A1-T scenario (which could enable overall sustainability). Therefore, the principal questions for the assessment of the Global Markets and Sustainability scenarios are: (1) what elements have A1T and B1 in common? (2) what elements in A1 seem to lead to an A1-B variant deviating away from the ecological sustainability frontier? (3) what elements in B1 may cause Finland to drift outside the social-economic sustainability frontier? and (4) what can Finland do to promote global developments conducive to the realisation of A1T and B1 scenarios?

4. FINADAPT climate scenarios

An introduction to the FINADAPT climate observations and scenarios is given in this section. For a more detailed description of the observational data set, see Venäläinen et al. (2005). The model-derived climate responses to the SRES A2 (Retrenchment) and B1 (Sustainability) scenarios are given more comprehensively in Ruosteenoja et al. (2005). Note that the projected climate changes under the B1 scenario are also used in this project as surrogates for the climate responses to the A1T scenario (Global Markets). Compared to the FINSKEN climate scenarios (Jylhä et al. 2004), a larger suite of climate variables is considered here, in reply to requests by FINADAPT partners. A slightly different baseline period is also used.

4.1. General remarks

The FINADAPT climate scenarios are primarily based on experiments performed with six coupled atmosphere-ocean general circulation models (AOGCMs; see Table 9). The experiments are downloadable from the IPCC Data Distribution Centre[11] and have also been employed in the FINSKEN project (Jylhä et al. 2004). AOGCMs are global models that are capable of providing time-dependent estimates of how climate in various regions of the globe responds to given changes in greenhouse gas and aerosol concentrations. Typically having a horizontal resolution of between 250 and 600 km, 10 to 20 vertical layers in the atmosphere and up to 30 layers in the oceans, AOGCMs provide an explicit description of coarse-scale processes of the climate system. Processes and mechanisms occurring at finer scales, such as those related to clouds and convective precipitation, need to be parameterized, and the details of these procedures vary from model to model. This is one source of uncertainty in projections of future climate. Uncertainty also arises from the fact that each climate change simulation comprises a combination of a climate change signal and random noise caused by the internal variability of the modelled climate. Because of differences in model formulation and the influence of noise, AOGCMs may simulate quite different responses to the same external forcing (Figure 2). It is therefore advisable to consider outputs from several AOGCMs rather than from one model alone.

Table 9. The coupled atmosphere-ocean general circulation models (AOGCMs) considered in the FINADAPT project. Column 4 shows simulated increases in global mean surface temperature (ΔT) from 1971-2000 to 2070-2099 for the Retrenchment (SRES A2 emissions) scenario.

Model acronym	Country of origin	Grid box size	Global ΔT (°C) by 2070-2099 (A2)
CGCM2[1]	Canada	3.8° x 3.8°	3.4
CSIRO-MK2[2]	Australia	3.2° x 5.6°	3.3
ECHAM4/OPYC3[3]	Germany	2.8° x 2.8°	3.1
GFDL-R30[4]	U.S.A	2.2° x 3.8°	2.9
HadCM3[5]	United Kingdom	2.5° x 3.8°	3.1
NCAR-PCM[6]	U.S.A.	2.8° x 2.8°	2.2

1 Canadian Centre for Climate Modelling and Analysis (Flato and Boer 2001); a millennial control simulation is available. 2 Australia's Commonwealth Scientific and Industrial Research Organisation (Gordon and O'Farrell 1997). 3 Max Planck Institute für Meteorologie (Roeckner *et al.* 1999); data from the ECHAM4 GSDIO experiment were used for the baseline period 1971-2000. 4 Geophysical Fluid Dynamics Laboratory (Delworth *et al.* 2002). 5 Hadley Centre for Climate Prediction and Research (Gordon *et al.* 2000, Pope *et al.* 2000); a millennial control simulation is available. 6 National Center for Atmospheric Research (Washington *et al.*. 2000); data from the NCAR-PCM historic run experiment were used for the baseline period 1971-2000.

[11] http://ipcc-ddc.cru.uea.ac.uk/dkrz/dkrz_index.html

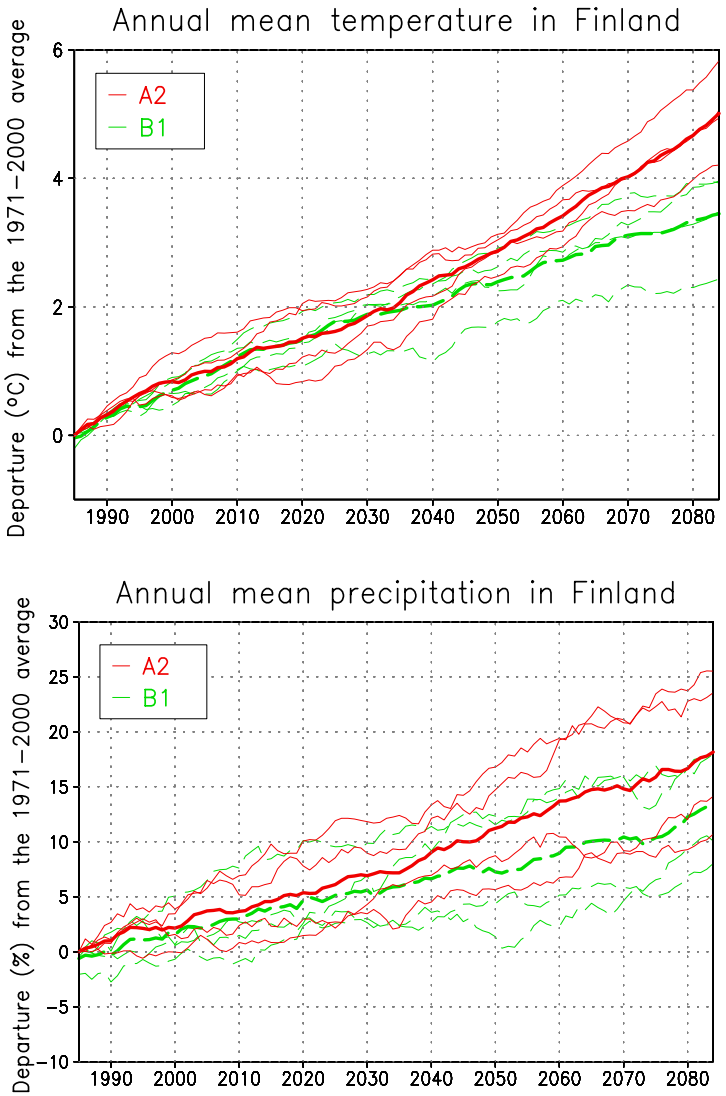


Figure 2. AOGCM-simulated annual mean surface air temperature (top) and precipitation (bottom) changes for Finland, relative to the 1971-2000 mean. Thin curves represent 30-year running means of the temperatures simulated by four models (HadCM3, ECHAM4/OPYC3, NCAR-PCM, CSIRO-Mk2) employing the A2 and B1 scenarios (in red and green, respectively). Thick curves depict the means of the four model simulations.

The AOGCM output employed here represents time-series of monthly means from which 30-year climatological mean changes can be calculated. The values of climate variables simulated by the models represent spatial averages over the grid boxes. On the other hand, some quantities, e.g., precipitation, tend to be very noisy on a grid box scale. These two factors complicate comparisons of simulations of the current climate with site-based observations. Thirdly, many variables, such as mean, maximum and minimum surface air temperature, are dependent, among other factors, on the land-sea distribution and topography, which are represented rather coarsely in AOGCMs. Consequently, differences in altitude between a measurement station and a grid-box average, as well as other station-specific characteristics like surrounding topography or proximity to heat sources (cities, water bodies), often result in discrepancies between the observed and simulated present-day climate. Moreover, models often have problems in accurately reproducing the observed large-scale atmospheric circulation which is largely responsible for the climate in Finland. To minimize

the influence of inaccuracies in modelling, it is customary to use present-day climate observations as baseline values and either add projected absolute changes to them or multiply them with simulated relative (percentage) changes, depending on the variable (the so-called "delta-change" method).

4.2. Observational data for 1971-2000

The observational FINADAPT data set giving the baseline for the climate scenarios is summarized in Box 2 and described in detail by Venäläinen et al. (2005). The project partners are also encouraged to visit the web sites of FMI[12], the European Climate Assessment & Dataset project ECA&D[13], the NORDKLIM Data Set[14] and to refer to Drebs et al. (2002) for observed climate statistics.

Box 2: FINADAPT observational data

Area: Finnish land area
Time interval: 1961-2000.

Variables and spatial resolution:

Observed daily data sets from five meteorological stations
(Helsinki-Vantaa, Jyväskylä, Kauhava, Kuopio-Siilinjärvi, Sodankylä):

- Precipitation
- Mean air temperature
- Minimum and maximum air temperature
- Lowest and highest relative humidity
- Lowest and highest wind speed
- Snow depth
- Global solar radiation
- Sunshine hours
- Soil temperature at 20 cm depth
- Potential evaporation (April to September)
- Growing season start, finish and length
- Effective temperature sum (ETS)
- Total precipitation during the thermal growing season

Observed daily data interpolated to a regular raster grid (10 km x 10 km):

- Mean temperature
- Precipitation

Data availability:

FINADAPT partners can request data from the Finnish Meteorological Institute

Reference: Venäläinen et al. (2005)

[12] http://www.fmi.fi/saa/tilastot.html
[13] http://eca.knmi.nl/
[14] http://www.smhi.se/hfa_coord/nordklim/

4.3. Scenarios for mean changes

The core variables for which scenarios of climatological mean changes have been developed are presented in the upper part of Table 10. Responses to the SRES A2 forcing scenario have been simulated with all AOGCMs[15], whilst few AOGCM simulations have been performed for the B1 scenario. By using the so-called pattern-scaling method[16], it is possible to approximate the climate response to the B1 scenario even when no AOGCM simulations have been conducted for this forcing. For projected near-term (1991-2020) changes[17], however, model differences and random noise are more influential than deviations among the forcing scenarios (see Figure 2). Consequently, pattern-scaling for selected variables is carried out for projections of the mid-term (2021-2050) and long-term changes (2071-2100) only (see section 4.3).

Table 10. Variables for which FINADAPT monthly mean climate scenarios have been constructed. The SRES scenarios analyzed for various time periods and the spatial representation of the data are indicated. Asterisks refers to pattern-scaling. Note that scenarios of mean changes in some variables cannot be developed based on all six AOGCMs (see numbered footnotes).

Variable	1991-2020	2021-2050	2071-2100†	Spatial representation
Core data (monthly means)				
Temperature[1]	A2	A2, B1*	A2, B1*	Grid
Precipitation[1]	A2	A2, B1*	A2, B1*	Grid
Daily maximum temperature[2]	A2	A2, B1*	A2, B1*	Selected stations
Daily minimum temperature[2]	A2	A2, B1*	A2, B1*	Selected stations
Wind speed[2]	A2	A2	A2	Selected stations
Snow amount[3]	A2	A2	A2, B1*	Selected stations
Incident solar radiation[3]	A2	A2	A2, B1*	Selected stations
Soil moisture[3]	A2	A2	A2, B1*	Selected stations
Derived data (monthly means)				
Number of hot days[2]	A2	A2	A2, B1*	Selected stations
Number of frost days[2]	A2	A2	A2, B1*	Selected stations
Semi-quantitative data (seasonal means)				
Maximum 1-day precipitation[1]	A2	A2, B1*	A2, B1*	Selected stations
Number of snow cover days[3]			A2	Selected stations

† Some model-based scenarios are for the period 2070-2099

1 Scenarios based on CGCM2, CSIRO-MK2, ECHAM4/OPYC3, GFDL-R30, HadCM3 and NCAR-PCM.

2 Scenarios based on CGCM2, CSIRO-MK2 and HadCM3.

3 Scenarios based on CGCM2, CSIRO-MK2, GFDL-R30 and HadCM3.

Taking an average of all model-simulated changes for each forcing scenario alleviates the influences of random noise and deviations in model formulation. Projected maps of seasonal multi-model average long-term changes of surface air mean temperature and precipitation for the SRES A2 scenario, together with their inter-model standard deviations, are given in Figure 3 and Figure 4. Table 11 and Table 12 represent national-scale seasonal and annual climate change scenarios for Finland during the 21st century, given as six-model means. Standard deviations across the six model simulations are also shown. Comparison of the mean changes (signal) with the between-model standard deviations (noise) indicates a low signal-to-noise ratio in the climate change scenarios for the first decades of the 21st century, and further into the future in the case of summer precipitation. In contrast, higher signal-to-noise ratios signify AOGCM agreement on mid-term and long-term warming trends.

[15] But not for all variables, see Table 9.

[16] For an explanation of pattern-scaling, see Jylhä et al. (2004), p. 131.

[17] Also, to a lesser extent, for mid-term (2021-2050) changes.

Table 11. Projected seasonal and annual mean surface air temperature changes (°C) in Finland for three 30-year time periods, relative to the baseline period 1971–2000. Between-model standard deviations are shown in parentheses. Changes under the A2 (Retrenchment) scenario are derived from AOGCM outputs, those for the B1 (Sustainability) scenario are in most cases pattern-scaled. The AOGCMs used are shown in **Table 9**.

Period	**1991–2020**	**2021–2050**	**2070–2099**
Dec–Feb			
A2	1.1 (0.8)	2.6 (0.8)	6.5 (0.8)
B1		2.5 (0.7)	4.3 (1.1)
Mar–May			
A2	1.1 (0.6)	2.2 (0.9)	5.2 (1.5)
B1		1.9 (0.9)	3.4 (1.1)
Jun–Aug			
A2	0.6 (0.3)	1.5 (0.4)	3.6 (1.0)
B1		1.3 (0.3)	2.3 (0.8)
Sep–Nov			
A2	0.7 (0.5)	1.8 (0.5)	4.5 (0.9)
B1		1.6 (0.3)	2.7 (0.6)
Annual			
A2	0.9 (0.4)	2.0 (0.4)	5.0 (0.7)
B1		1.8 (0.4)	3.2 (0.7)

Table 12. As in **Table 11**, but for changes in precipitation (percent).

Time slice	**1991–2020**	**2021–2050**	**2070–2099**
Dec–Feb			
A2	4.7 (5.3)	9.7 (6.9)	22.3 (12.2)
B1		7.3 (7.0)	13.2 (8.3)
Mar–May			
A2	3.8 (4.2)	7.3 (7.3)	19.9 (9.7)
B1		7.6 (6.6)	12.7 (6.6)
Jun–Aug			
A2	1.9 (2.7)	4.1 (3.0)	3.8 (6.9)
B1		2.8 (4.0)	4.6 (5.4)
Sep–Nov			
A2	1.4 (2.8)	5.5 (3.4)	14.5 (6.5)
B1		5.1 (1.5)	10.4 (3.7)
Annual			
A2	2.7 (2.1)	6.4 (2.4)	14.2 (5.7)
B1		5.4 (2.7)	9.8 (4.1)

4.4. Scenarios for changes in climate variability and extremes

In order to offer information on possible changes in indices describing climate variability and extremes (see the lower part of Table 10), we have adopted two approaches. First, for indices requiring daily mean, maximum or minimum temperature data (T_i, i=mean, max or min), such as the number of frost days or hot days, the delta-change method is employed: we add the projected changes in 30-year mean monthly T_i to observational daily data of T_i and then compute the future indices. The resulting differences between the calculated future and observed current indices are consistent with the projected monthly, seasonal, annual mean changes. However, this approach does not account for possible changes in the shape of the frequency distributions of T_i.

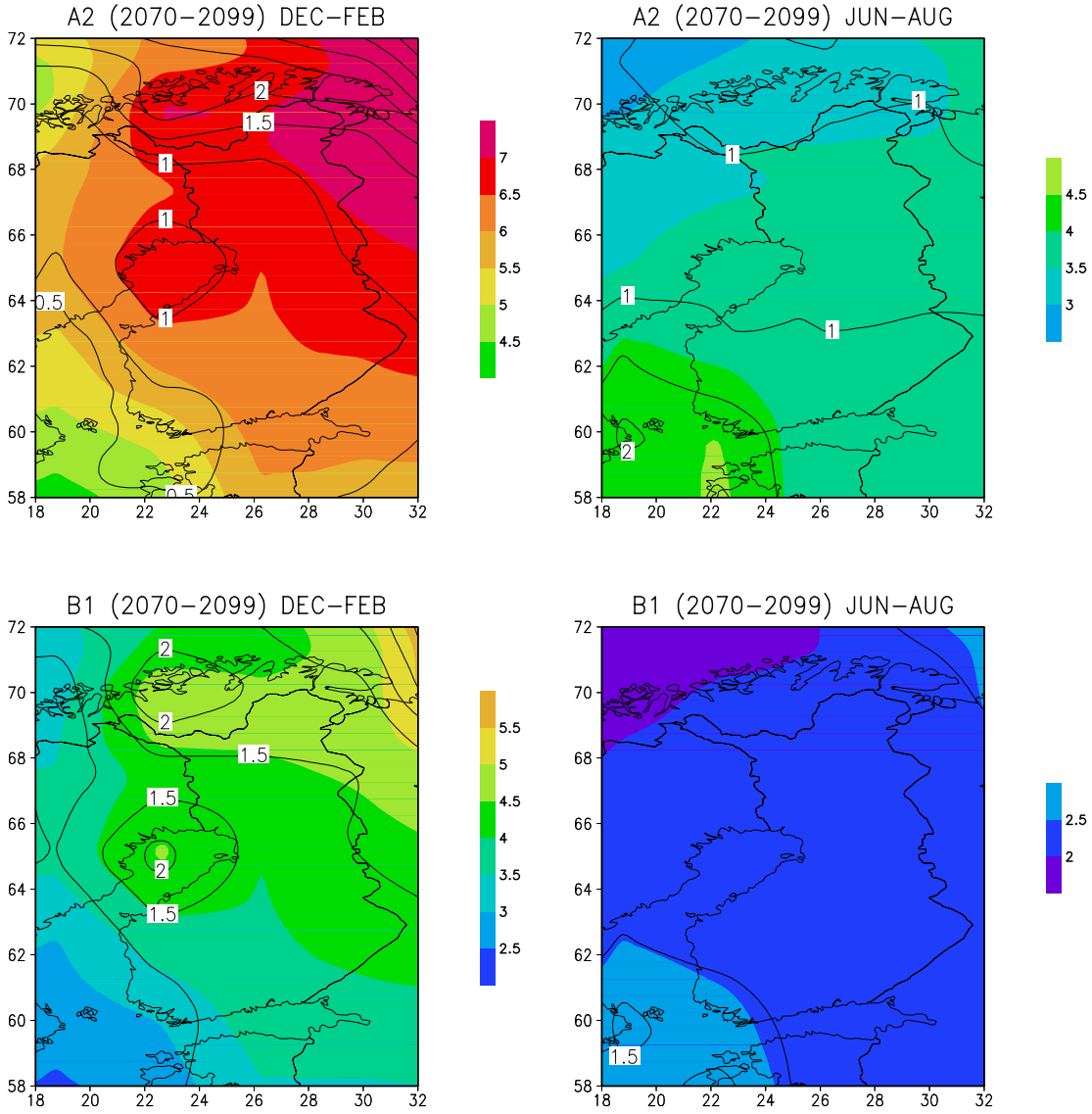


Figure 3. AOGCM-simulated changes (°C) in winter (Dec-Feb) and summer (Jun-Aug) mean surface air temperature in Finland for the A2 (upper panels) and B1 (lower panels) scenarios, computed as the difference between 2070-2099 and 1971-2000. Shading represents multi-model means from six AOGCMs (see **Table 9** for the models and the bars on the right-hand side of the figures for colour coding). Contours give inter-model standard deviations.

For indices related to daily precipitation or snow mass, such as the maximum 1-day precipitation amount (*R1d*) or the number of days with snow cover (*SCD*), the delta-change method is less applicable. This results from the zero-bounded nature of daily precipitation and snow mass. For *R1d*, for example, the method would result in exactly equal percentage (and absolute) changes as for mean precipitation. Instead of using the delta-change method, we utilize findings from the European Commission-funded PRUDENCE[18] project (Christensen et al. 2002). The project employed a number of regional climate models (RCMs) that "regionalised" or "dynamically downscaled" global simulations performed by a few AOGCMs (Table 13).

[18] http://prudence.dmi.dk/

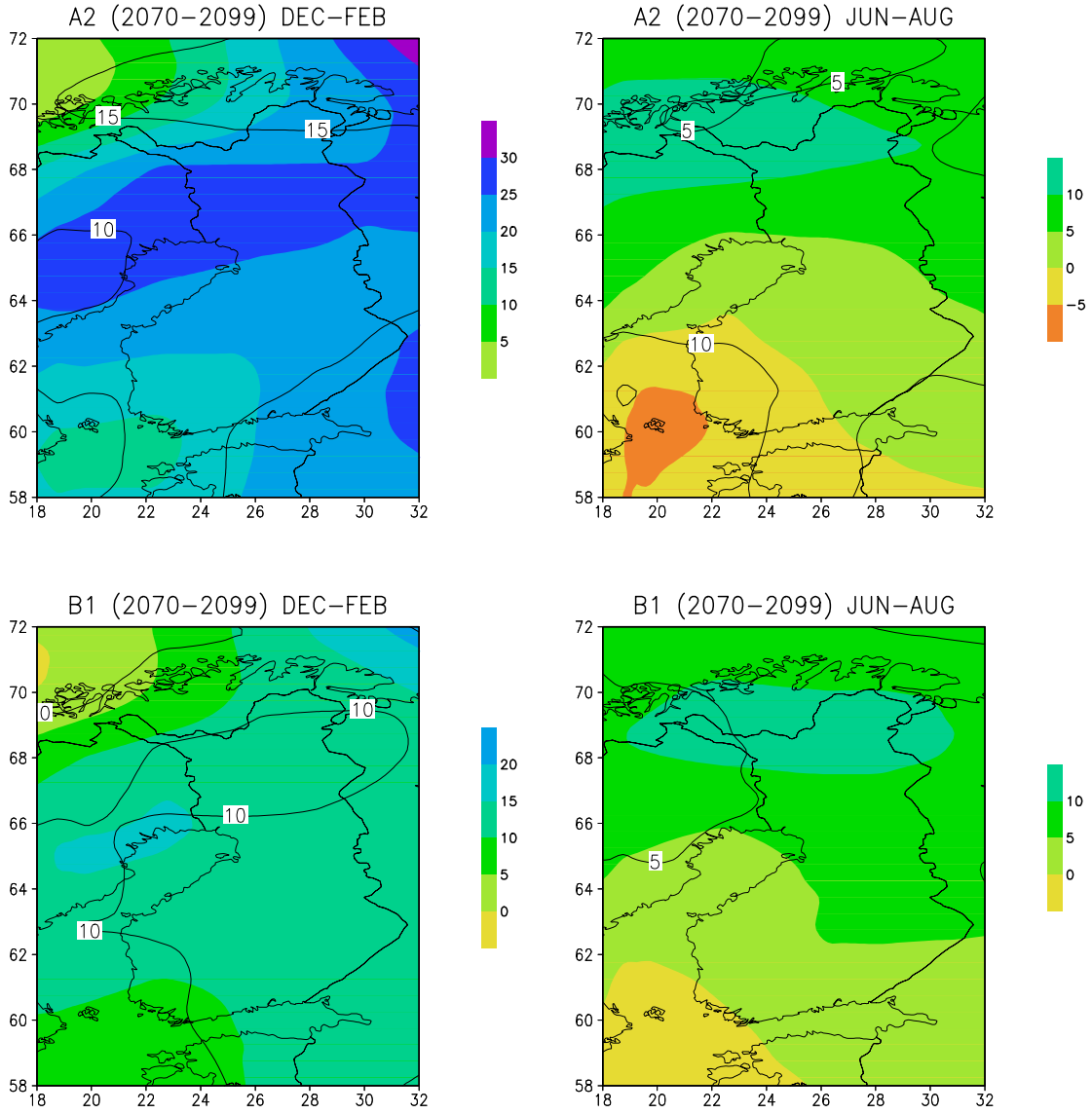


Figure 4. AOGCM-simulated changes (%) in winter (Dec-Feb) and summer (Jun-Aug) mean precipitation in Finland for the A2 (upper panels) and B1 (lower panels) scenarios, computed as the difference between 2070-2099 and 1971-2000. Shading represents multi-model means from six AOGCMs (see **Table 9** for the models and the bars on the right-hand side of the figures for colour coding). Contours give inter-model standard deviations.

Daily data from the RCM simulations are available for two time slices, 1961-1990 and 2071-2100. It was found that the projected domain-averaged mean changes in *R1d* and *SCD* were closely related to changes in average precipitation and mean snow mass, respectively (Beniston et al. 2005; Jylhä et al. 2005). As a rule of thumb, the projected percentage changes in the summer mean *R1d* in Finland may be approximated by adding a positive number smaller than about 15% to the corresponding percentage changes in mean precipitation (see Figure 5). In winter there is a tendency to slightly smaller increases in *R1d* than in mean precipitation. A simple method to produce approximate scenarios for *R1d* that are reconcilable with AOGCM-based projections of mean precipitation changes is hence to assess the former with the aid of the latter.

Table 13. Regional climate model experiments also considered in this project. For the acronyms of the driving GCMs in column 3 and the Baltic Sea modelling in column 4, see the footnotes. Column 5 shows the radiative forcing scenarios employed, together with the number of ensemble simulations (in parentheses). For more detailed information, see Déqué et al. (2005) with references.

Model acronym	Country of origin	Driving GCM	Baltic Sea forcing	SRES emissions scenarios
CHRM	Switzerland	H	HC	A2
CLM	Germany	H	HC	A2
HadRM3P	UK	HP	HC	A2 (3), B2
HadRM3H	UK	H	HC	A2
HIRHAM	Denmark	H	HC	A2 (3)
		E	RCO	A2, B2
RACMO2	Netherlands	H	HC	A2
RCAO	Sweden	H	RCO	A2, B2
		E	RCO	A2, B2
REMO	Germany	H	HC	A2

Acronyms in columns 4-5: H stands for the HadAM3H AGCM, HP for the HadAM3P AGCM, HC for the HadCM3 AOGCM, E for the ECHAM4/OPYC3 AOGCM, OPYC3 for the oceanic part of the corresponding AOGCM, and RCO for the oceanic part of the RCAO RCM.

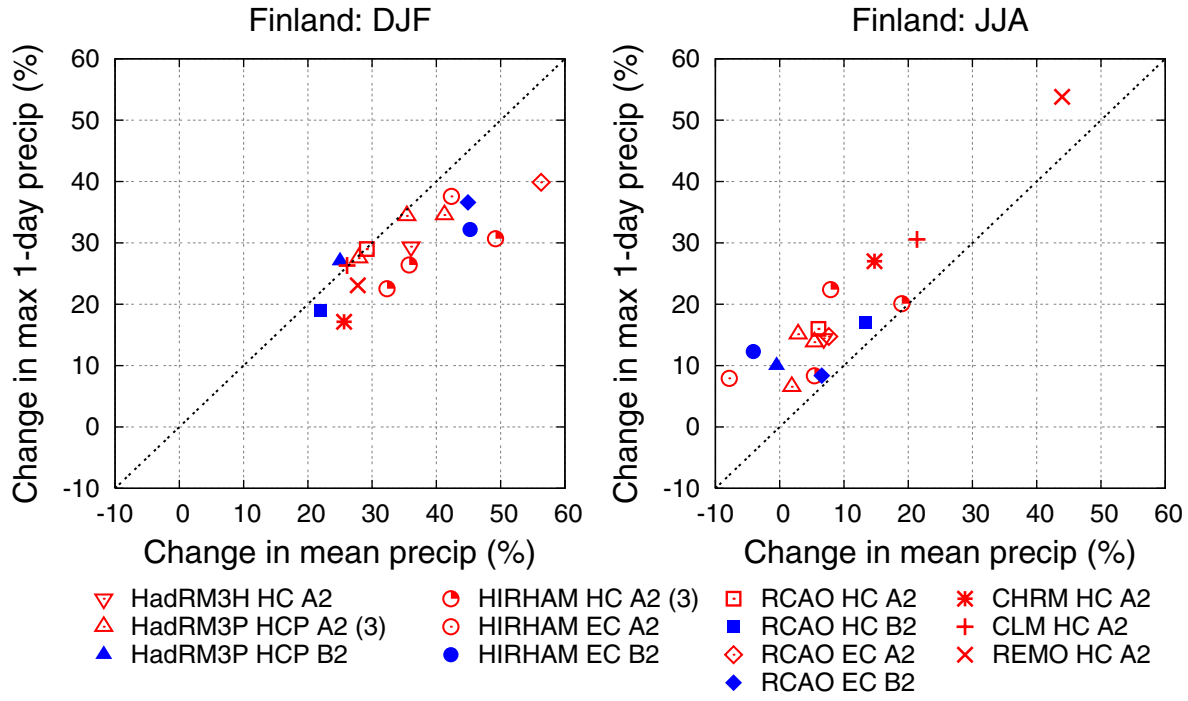


Figure 5. RCM-simulated area-averaged changes (%) in the 30-year means of the greatest 1-day precipitation total in winter (left) and summer (right) in Finland, relative to the baseline period 1961–1990, as a function of the seasonal mean precipitation changes. The legend indicates the regional climate model with codes indicating the driving GCM (H for HadAM3H, HP for HadAM3P, E for ECHAM4/OPYC), the SRES emissions scenario (A2 or B2), and the number (in parentheses) of ensemble simulations. See **Table 13** for details.

More caution is needed if using a comparable method to develop scenarios for the mean number of snow cover days. As suggested by Figure 6, the projected domain-averaged long-term (2071-2100) annual mean percentage decreases in *SCD* are smaller than those in mean snow water equivalent (*SWE*). Figure 6 also suggests that the relationship between changes in the two variables may be approximated by linear regression, if AOGCMs yield changes in

SWE that range from -45% to -75%. A very rough estimate for percentage changes in annual mean *SCD* can hence be obtained by adding a number equal to about 25-35% to the percentage changes in SWE. Percentage changes in the seasonal means of the two variables were also rather closely correlated, but for a fixed reduction in SWE, smaller changes in SCD may be expected in winter than in the transition seasons and annually. Outside the range considered, for smaller spatial and temporal averaging scales and for deviating time slices, however, nonlinear effects may be expected.

Both approaches, one for changes in the temperature-related indices and the other for changes in the precipitation- and snow-related indices, produce scenarios that are in harmony with the projected changes in monthly, seasonal and annual means. It is worth noting that the long-term (2071-2100) scenarios for index changes, relative to present-day (1971-2000) conditions, are compared in a subsequent paper by Ruosteenoja et al. (2005) with corresponding results from the PRUDENCE RCMs for the same future time span, but with respect to a slightly different baseline period, 1961-1990. This comparison supports the activities of those FINADAPT partners who have used simulations by PRUDENCE RCMs, e.g. the Rossby Centre model RCAO, in their investigations of future vulnerability to climate change and appropriate adaptation measures.

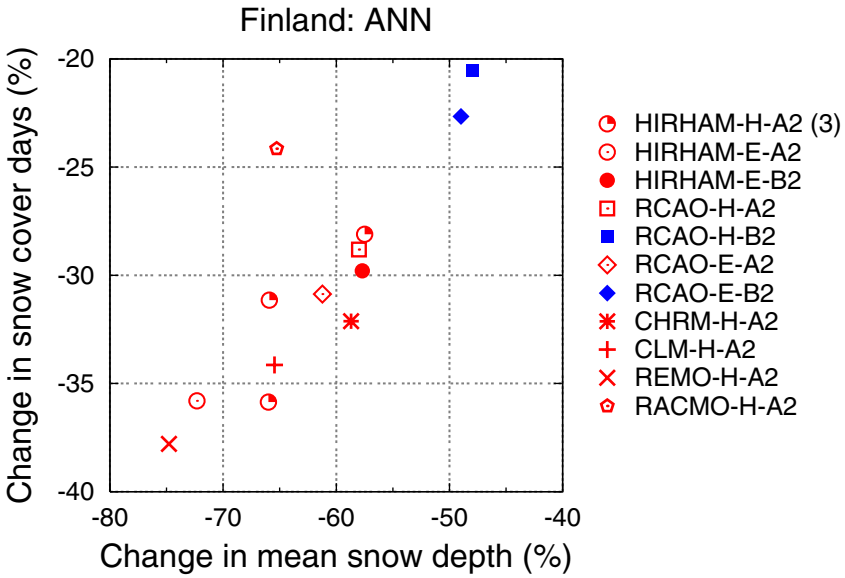


Figure 6. RCM-simulated changes (%) in the annual mean number of days with snow cover as a function of changes in the average liquid water equivalent of snow for the period 2071-2100, relative to the baseline period 1961-1990. For explanation of the legend, see **Figure 5**.

5. FINADAPT scenarios of atmospheric carbon dioxide concentration

Atmospheric carbon dioxide (CO_2) concentration rose steadily during the 20th century and that trend is continuing in the 21st century. Apart from its role as a major greenhouse gas, CO_2 is also very important for the growth and productivity of plants and aquatic organisms. For this reason, some ecological studies require information on projected CO_2 concentration.

Projections of future climate are closely related to CO_2 concentrations, so it is important that scenarios of CO_2 are consistent with the climate scenarios adopted in FINADAPT. Since these are based on the SRES scenarios, we can make use of the estimates of future concentrations presented in the IPCC Third Assessment Report based on the Bern-CC model. These are summarised in Table 14. There are large uncertainties in projections of CO_2 concentration for a given emissions scenario, related to uncertainties in the carbon cycle.

Table 14. Projected atmospheric carbon dioxide concentrations (ppm) based on the Bern-CC model that are consistent with the SRES-derived FINADAPT scenarios. Values in parentheses bound uncertainties due to assumptions about ocean uptake, heterotrophic respiration and CO_2 fertilization (Sources: Prentice et al., 2001; Keeling and Whorf, 2005).

Year	Global Markets (A1T)	Retrenchment (A2)	Sustainability (B1)
2000	**367**	**367**	**367**
2004	**377**	**377**	**377**
2010	**386** (381-393)	**386** (381-393)	**386** (381-392)
2020	**410** (400-427)	**414** (404-431)	**410** (400-426)
2030	**435** (419-467)	**444** (428-477)	**432** (417-463)
2040	**466** (442-514)	**481** (459-533)	**457** (436-503)
2050	**496** (464-562)	**522** (492-597)	**482** (455-544)
2060	**523** (483-610)	**568** (529-670)	**503** (470-584)
2070	**545** (496-653)	**620** (569-753)	**518** (479-617)
2080	**563** (505-689)	**682** (617-848)	**530** (485-645)
2090	**572** (508-717)	**754** (671-957)	**538** (487-666)
2100	**575** (506-735)	**836** (735-1080)	**540** (486-681)

6. FINADAPT nitrogen deposition scenarios

Spatially explicit scenarios of NO_x deposition for Finland for 5-year intervals were produced for each of the SRES scenarios in the FINSKEN project (Syri et al., 2004), drawing on some earlier work at European scale in the AIR-CLIM project (Mayerhofer et al., 2002). Examples taken from the FINSKEN web site[19] are shown in Figure 7.

Emissions of ammonia (NH_3) also contribute a notable proportion of N-deposition, and these are not accounted for in either the FINSKEN or the AIR-CLIM scenarios. Discussions have been initiated with RIVM in the Netherlands to obtain European estimates of ammonia nitrogen, in connection to an ongoing EU Integrated Project, and these will subsequently need to be downscaled to Finland.

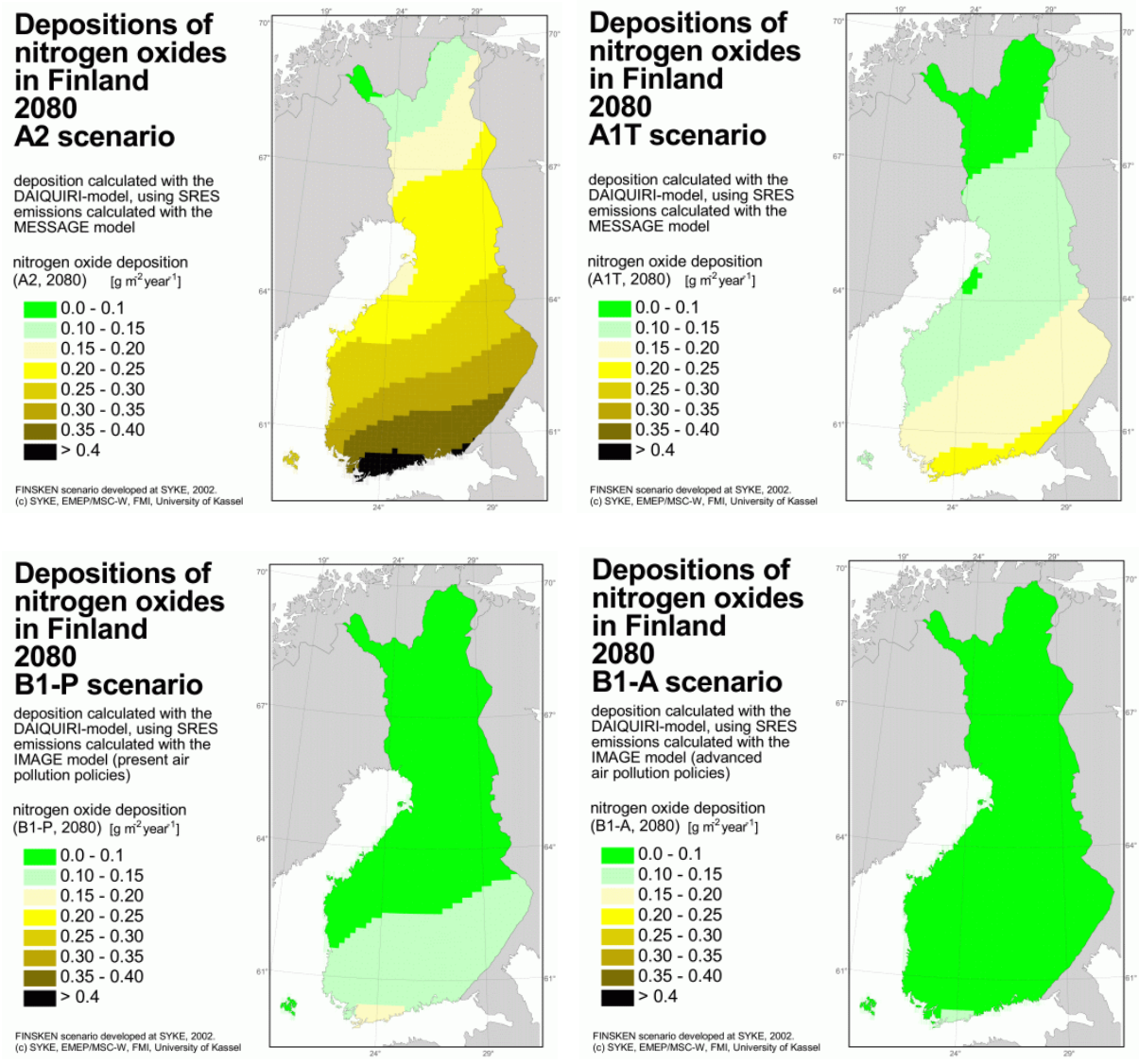


Figure 7. Deposition of nitrogen oxides (NO_x) in Finland by 2080 under the four SRES-based emissions scenarios closest to the FINADAPT scenarios: A2, A1T, B1-P (present-day air pollution policies), B1-A (advanced air pollution policies) [19]. For explanation, see Syri et al. (2004).

[19] http://www.finessi.info/finsken/sce/

7. FINADAPT land use change scenarios

7.1. Background

The land use change scenarios provided for FINADAPT are those developed for the ATEAM (Advanced Terrestrial Ecosystem Analysis and Modelling) project (Schröter et al., 2005) funded by the Fifth Framework Programme of the European Commission (Project No. EVK2-2000-0007). Here we provide a short description of the methodology, underlying assumptions, baseline data and availability of the ATEAM scenarios as well as a comparison of the scenario outcomes for Finland.

The ATEAM land use change scenarios were constructed to support analyses of the vulnerability of ecosystem services for Europe (EU15, Norway and Sweden – Rounsevell et al., 2005b). They are quantitative, spatially explicit and alternative scenarios of future land use in Europe. The methodology is based on a qualitative interpretation of the SRES storylines for the European region, an estimation of the aggregate totals of land use change using various land use change models and the allocation of these aggregate quantities in space using spatially explicit rules. The scenarios were constructed for a 10' x 10' grid over Europe.

The baseline year is 2000. Land use scenarios were constructed for three time slices (2020, 2050 and 2080) and for the following land use/land cover classes: urban, cropland, grassland, and bioenergy crops, forest, protected areas.

7.2. Approach

The approach adopted for the ATEAM land use change scenarios is based on a framework proposed by Giupponi and Rosato (2002). The approach recognises 3 levels in the derivation of land use scenarios that move from qualitative descriptions of global socio-economic storylines to quantitative projections of regional land use.

The 3 levels are:

- level 1 – global driving forces
- level 2 – European sector driving forces
- level 3 – regionally specific values of land use change

The global driving forces are based on the scenario storylines described in the SRES report (Nakićenović et al., 2000). The level 2 analyses translate the global driving forces into sector-specific driving forces for Europe and each land use type. This was done by extending the SRES narrative storylines to the European region based on an understanding of the land use driving forces important for Europe. Also knowledge of past and present European and national policies and regional trends for some of the land uses (forestry, protected areas) were used. An important aspect of the level 2 qualitative descriptions was to provide a check of internal consistency between each of the land use sectors and storylines.

In the level 3 analyses, changes in land use areas for each land use type were estimated. Estimations of trends in global trade were provided by the IMAGE 2.2. model (IMAGE Team, 2001). The baseline for the land use scenarios was derived from the PELCOM (Pan-European Land Cover Monitoring) 1 km resolution land cover data set (Müncher et al., 2000) combined with REGIO statistical data at the NUTS2 level (Eurostat, 2000).

To describe the competition between different land uses over geographic space, a simple land use competition hierarchy was used. This reflected the following order of precedence: protected areas>urban>agriculture>biofuels>commercial (unprotected) forests>not actively managed. Thus, an expansion in a "higher order" land use type at a given location, will cause a land use that is lower in the order to contract in extent at the same location.

7.3. Storylines

The translation of the global SRES driving forces to the European scale was undertaken at two levels: 1) an interpretation of cross cutting drivers that are relevant to the socio-economic background, and 2) identification of specific drivers that influence each land use type. The interpretations were based on an understanding of the land use drivers that are important for Europe, using also knowledge of past and present European and national policies. For some land use types, it was also necessary to identify distinct regional trends in driving forces based on county groups. In addition to qualitative data sets, some quantitative data, such as population and GDP, were used. The cross cutting drivers for the SRES scenarios that are compatible with the three FINADAPT scenarios are shown in Table 15.

7.4. Methodology for each land use type

7.4.1. Urban land use

An urban land use model was used for the development of the urban land use scenarios (Reginster and Rounsevell, 2005). The model included a demand module and a spatial allocation module. Two main driving forces for urban land use change were identified as: population and economic development. Urban demand estimates were calculated using an empirical-statistical model with population and GDP as the independent variables. Four other variables were used as pattern drivers: accessibility of the transport network, severity of restrictions due to land use planning, the relative attractiveness of small, medium, and large cities, and competition with other land uses.

7.4.2. Agricultural land use including bioenergy crops

The driving forces of agricultural land use change were identified as: world demand and supply, market intervention (through agricultural policy), rural development policy, environmental policy pressure, impact of EU enlargement, resource competition, the role of the WTO, and climate change through its effect on agricultural productivity.

Scenarios of changes of agricultural land use (food crops, grassland and energy crops) were estimated using a combination of simple supply-demand model at the European scale and scenario specific spatial allocation rules (Rounsevell et al., 2005a). The basic idea behind the estimations was that agricultural land use areas would increase if demand increases, but areas would decline if productivity also increases – meeting the same demand requires less land. These changes are further modified by policy and economic assumptions within the scenarios and the regional effects of climate change. Climate change is assumed not to affect the overall balance of supply and demand, but to influence the relative capacity of different locations to supply agricultural goods. Biofuels were allocated after sufficient land had been allocated to food production using potential distributions determined for each bioenergy crop species.

Table 15. Summary of cross cutting drivers for ATEAM land use scenarios at the European scale. Only scenarios that map onto the FINADAPT scenarios are shown.

Driver	Narrative description
A1 Europe (*FINADAPT Global Markets*)	
Economy	Very rapid economic growth and convergence between regions. European income inequalities eradicated. Material consumption and increases in income/capital lead to increased use of natural resources
Population	European fertility rates reach 1.7 with a slight increase in population to 2050 and then decrease
Technology	High investments in technology and high rates of innovation
Institutions and government	Governments are weak with a strong commitment to market based solutions. International co-operation. Stable political and social climate, with good health care and education. Self-sufficiency not an issue; free trade emphasised.
Rural development	Focus on centres and international connections, rural development not a focus area. Increased affluence has "spill-over" effects on rural and remote areas.
Recreation, tourism	Increase in recreation areas close to urban centres, wilderness areas less attractive, increase in beach resorts and locations with built facilities rather than eco-tourism
Spatial planning	Convergence of planning policy and less restrictions
EU enlargement	Proceeds rapidly
A2 Europe (*FINADAPT Retrenchment*)	
Economy	Moderate GDP growth; slower than A1. Economic development is regionally-oriented and uneven. The income gap between developed and developing countries does not narrow.
Population	European fertility rates reach 2.1 resulting in a steady increase in the population.
Technology	Slower than in A1 and more heterogeneous. Technology transfer and diffusion slower.
Institutions and government	Self-reliance of regions, less mobility of people, ideas and capital. Social and political institutions diversify. Central national governments weak, "markets first" approach. A more protectionist Europe compared to the present which could mean a stronger EU.
Rural development	Rural development results as a by-product of the stress on regional self-reliance.
Recreation, tourism	Tourism decreases, but recreation increases with population increases. Demand for near urban recreation areas increases, but areas distant to centres are also used for recreation by a dispersed population. Built facilities are valued, wilderness areas less popular.
Spatial planning	Heterogeneity of planning policy
EU enlargement	Stops or proceeds very slowly
B1 Europe (*FINADAPT Sustainability*)	
Economy	A convergent world with global solutions to economic, social and environmental sustainability. Progress toward international and national income equality. Affluent with moderate GDP growth rates.
Population	European fertility rates reach 1.7 with slight population increase by 2050 then a decrease.
Technology	Rapid technologial change
Institutions and government	Central governments strong with a high level of regulation. International institutions and cooperation central.
Rural development	Rural development a key issue; equitable income distribution and development a priority
Recreation, tourism	Tourism decreases, but recreation increases, both near to urban centres and in remote areas
Spatial planning	Homogenous, restrictive policies with high level of regulation
EU enlargement	Proceeds at a moderate rate

7.4.3. Forest land use

The driving forces of forest land use at the European level were identified as: economic (GDP, wood product demand), population (growth, density, rural population), institutions (government, participation, self-sufficiency, decision-making, rural development), technology (change, forest management), land use (intensity, other land use types, recreation and tourism), life style, environment (biodiversity, protection management), energy (wood based, biofuels), wood production, species distribution.

Scenarios of forest land use change were estimated for five country groups based on the assumption that forest policies are one of the major factors affecting forest land use change in Europe (Kankaanpää and Carter, 2004). In the ATEAM land use hierarchy, forest land use was treated as a residual. The forest land use scenarios therefore acted as a consistency and reliability check for the overall ATEAM land use scenarios. Trends in forestry and forests of today were assumed to continue into the future until 2020. The changed circumstances described in the storylines were taken into consideration from 2020. Percentage changes in the forest area, and the location of those forests, were estimated from an interpretation of trends described in the literature and the IMAGE 2.2 forest product demand figures.

7.4.4. Protected areas

Protected areas were considered a designation rather than a land use type because most protected areas enclose agricultural, forest and semi-natural landscapes. The main drivers for protected areas were considred to be European and national policy for nature conservation, agriculture, forestry and spatial planning policy, and demand for green recreation and tourism.

An assumption was made that for all scenarios 20% of the area of Europe will become designated as protected by 2080. The assumption was based on a judgement made from past and present increases in protected areas coverage in Europe. It was assumed that the same target for different scenarios would be reached for different reasons – the economic scenarios require areas for recreation whereas the environmental scenarios require areas designated for conservation purposes. The location of the designated areas varied, however, substantially between different scenarios.

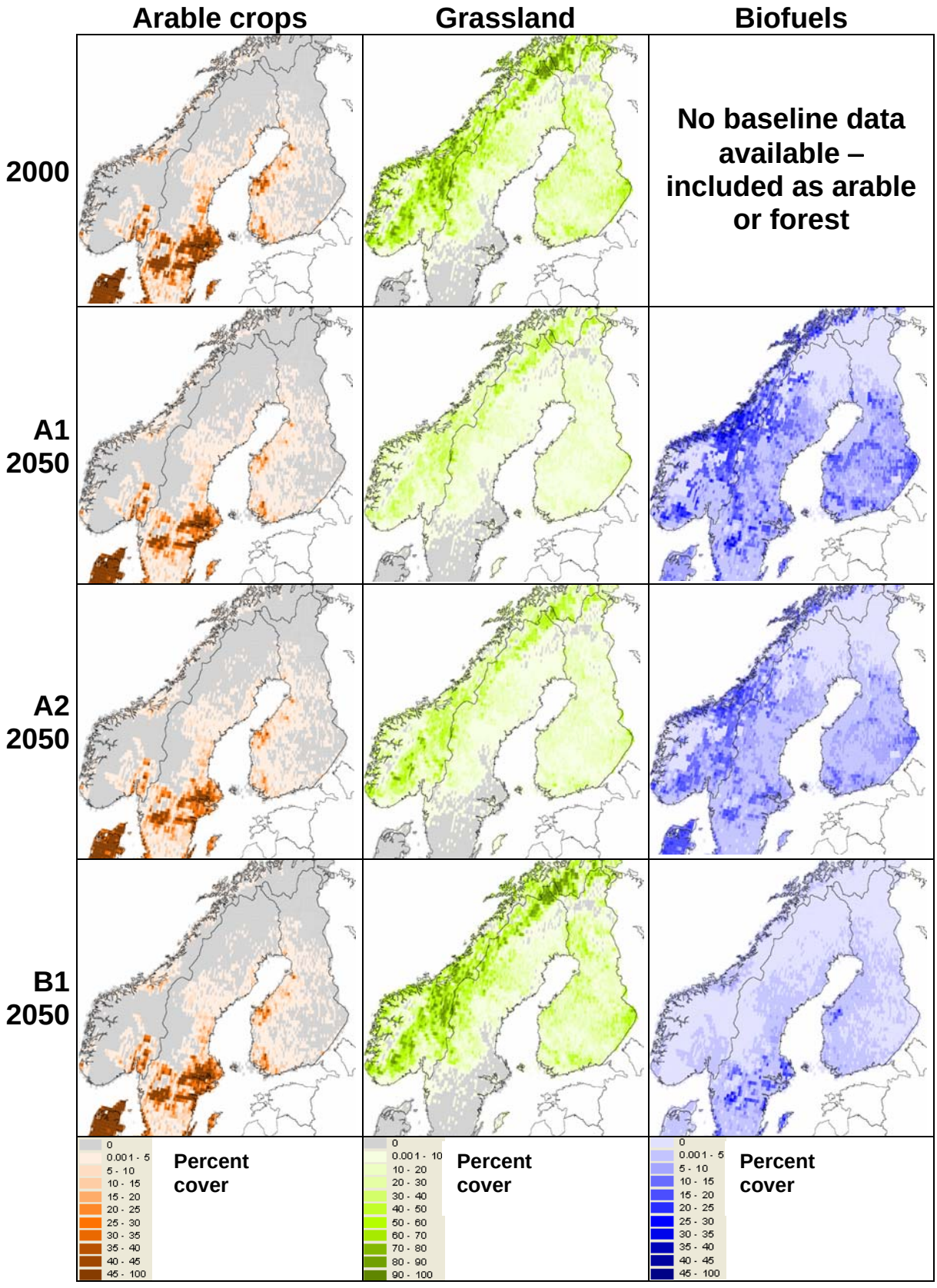
7.5. Characteristics of the FINADAPT land use scenarios for Finland

In this section we provide a brief illustration of the types of land use changes described by the ATEAM scenarios for Finland. As examples, areas of arable, grassland and biofuels by 2050 for the three SRES scenarios that map onto the FINADAPT scenarios are compared to baseline conditions (2000) for the Nordic region in Figure 8.

7.5.1. Agriculture

On the European scale, the scenarios present a large decline in the surface area of agricultural land use (especially grassland) for the A1 and A2 scenarios. The decline is caused primarily by the relatively low increases in demand and the far-reaching assumptions about the role of technological development. The surplus areas could be taken up by urban expansion, recreational areas, forest land and bioenergy production. A comparison of the direction of land use change for the different scenarios and land use types shows that agricultural land uses decreases in all scenarios, whereas urban and forested lands always increase. Also amongst the different land use types, agricultural land uses consistently change by the largest amount across all scenarios (Rounsevell et al. 2005a).

Figure 8. Percentage cover per 10' x 10' grid cell in 2000, and estimated for 2050 assuming a climate change described by the HadCM3 model, for arable crops, grassland and biofuels under the A1 (Global Markets), A2 (Retrenchment) and B1 (Sustainability) scenarios. Source: ATEAM project, http://www.pik-potsdam.de/ateam/



Declines for agricultural areas are less in the B1 scenario. The assumption is that there are policy mechanisms that seek to limit crop productivity. In Finland, grassland areas decrease in A1 and A2, but increase in B1. Arable area decreases in all the scenarios, most in A1.

The scenario results also suggest that crop production is not sensitive to alternative patterns of climate change given by different climate models at the European scale, whereas at the regional scale it can be more sensitive.

7.5.2. Biofuels

The area of biofuel land use increases in all the scenarios at the European level. The increase is greatest in the A scenarios. In Finland, biofuel areas increase most in A1 and least in B1. There is an increase in grassland areas estimated in B1, so there might not be as much agricultural surplus areas left for biofuels as in some other regions of Europe.

7.5.3. Urban

All the scenarios show small increases in urban areas at the European scale. The quantity of change in urban areas is similar between the scenarios, but the spatial patterns are different reflecting alternative urbanisation processes.(Rounsevell et al. 2005b). In Finland the population changes are relatively minor, and changes in urban area are small.

7.5.4. Forest

The forest area in the overall land use scenario increase in all the scenarios (A, B) at the European scale. The increase is larger in the B1 scenario and modest in the A scenarios. For Finland, the forest area increases in the A scenarios, but remains stable or even decreases in the B1 scenario, in line with interpretations of the driving factors affecting major forested countries of Europe (Kankaanpää and Carter, 2004). The change could be a result of an increase in unmanaged forests or in the protected areas.

8. Concluding remarks

The storylines and scenarios outlined in this document are representations of how environmental and socio-economic conditions may change in Finland during the 21st century. They have been developed:

1. to offer alternative, internally-consistent quantifications of future changes in Finland that are consistent with established storylines of global development;
2. to represent some of the key uncertainties in projections of future global change;
3. to provide contextual information for project researchers examining the vulnerability and adaptive capacity of natural systems and human activities to climate change in Finland;
4. to reconcile changes over different time horizons, including ongoing trends, short-term policy projections, medium-term policy targets as well as longer-term developments; and
5. to account, where possible, for geographical variations in future changes.

Researchers in FINADAPT have conducted an evaluation of past studies of climate change impacts and adaptation in a number of different sectors. These studies relied on a variety of scenarios describing future conditions. The FINADAPT storylines and scenarios provide a basis for interpreting that work in the light of the most up-to-date projections. In some FINADAPT studies quantitative scenarios have been applied directly in modelling future impacts and adaptation capacity. The scenarios and their underlying storylines also offer a consistent framework for conducting a dialogue with key stakeholders concerning alternative options for adapting to a future changing climate in Finland.

These scenarios are already being adopted, selectively, by researchers in FINADAPT. They are also available for any other prospective users. Needless to say, many aspects of the scenario development process can be improved and/or extended. New research will be required for addressing topics that have a critical bearing on future adaptive capacity but for which there is little information at present. These include scenarios of technological development (for example, in plant breeding, new construction materials, vaccines), of regional land use change (accounting for human decision making in response to environmental and economic forces operating at different scales), of lifestyle choices (which will strongly influence the demand for and use of natural resources), and of the relationships between national trends and external forces such as world trade, international migration and environmental changes occurring beyond Finland's borders.

Above all, scenarios have to be credible, so that target stakeholder groups can readily identify with them, as well as being relevant for addressing the key questions facing researchers and policy makers alike. For this reason, future scenario development work needs to embrace a wider constituency than simply the research community alone.

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Abstract	A set of three scenarios of environmental and socio-economic conditions in Finland during the 21st century is presented. The scenarios were developed to provide a contextual framework for research into adaptation to climate change in the FINADAPT project. They have similarities to the IPCC SRES global scenarios, but they also differ from SRES because they are national in scope and they account for climate policy. The scenarios are labelled: Global Markets, assuming low greenhouse gas levels, high economic growth with rapid technological development (related to SRES A1T); Sustainability, assuming low greenhouse gas levels, sustainability goals with slower economic growth than Global Markets and rapid technological development (related to SRES B1); and Retrenchment, assuming high global greenhouse gas emissions, a world in blocs with unbalanced wealth, rapid population growth and obstacles to technological proliferation and trade (related to SRES A2). The scenarios span four time frames (climatological averaging periods in brackets): present-day (1971–2000), near-term (1991–2020), mid-term (2021–2050), and long-term (2071–2100), and the requirements for adaptation are then treated as if they apply in 2005 (present-day), 2020, 2050 and 2100. Quantitative scenario information on socio-economic development, climate, CO_2 concentration, nitrogen deposition and land use change has been provided, with detailed data available from the FINADAPT web site or from relevant partner institutes.		
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Tiivistelmä	Raportissa esitellään kolmen skenaarion sarja Suomen ympäristön ja sosioekonomisen kehityksen muutoksista tällä vuosisadalla. Skenaariot ovat olleet viitekehyksenä ilmastonmuutoksen sopeutumisen tutkimukselle FINADAPT-hankkeessa. Skenaarioilla on yhteneväisyyksiä hallitustenvälisen ilmastonmuutospaneelin (IPCC) nk. SRES-skenaarioiden kanssa. FINADAPT-skenaariot kuitenkin eroavat SRES-skenaarioista siinä, että ne ovat kansallisella tasolla ja ilmastopolitiikan vaikutus otetaan niissä huomioon. Skenaariot on nimetty seuraavasti: Globaalit markkinat, jossa oletuksena ovat matalat kasvihuonekaasupäästöt ja korkea taloudellinen kasvu yhdistettynä nopeaan teknologiseen kehitykseen (liittyy SRESin A1T-skenaarioon); Kestävyys, jossa oletuksena ovat matalat kasvihuonekaasupäästöt, kestävän kehityksen tavoitteet sekä hitaampi taloudellinen kasvu kuin Globaalit markkinat-skenaariossa (littyy SRESin B1-skenaarioon); ja Taantuva, jossa oletuksena ovat korkeat maailmanlaajuiset kasvihuonekaasujen päästöt, eriytynyt maailma ja epätasainen varallisuuden jakautuminen, nopea väestönkasvu sekä esteitä teknologian ja kaupan kasvulle (liittyy SRESin A2-skenaarioon). Skenaariot kattavat neljä ajanjaksoa (suluissa ilmastollinen vertailujakso): nykyhetki (1971–2000), lähitulevaisuus (1991–2020), keskipitkä aikaväli (2021–2050), ja pitkä aikaväli (2071–2100). Ilmastonmuutokseen sopeutumisen vaatimukset käsitellään siten kuin ne koskevat vuotta 2005 (nykyhetki), 2020, 2050 ja 2100. Skenaariot sisältävät kvantitatiivista tietoa sosio-ekonomisesta kehityksesta, ilmastosta, CO_2-pitoisuudesta, typen laskeumasta sekä maankäytön muutoksista. Yksityiskohtaista tietoa on saatavilla FINADAPT-hankkeen verkkosivuilta sekä hankkeeseen osallistuvista tutkimuslaitoksista.		
Asiasanat	ilmastonmuutokset, sopeutuminen, Suomi, skenaariot, ilmastopolitiikka, hiilidioksidi, sosioekonomiset tekijät, typpilaskeumat, maankäytön muutokset		
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This report presents a set of three scenarios of environmental and socio-economic changes in Finland during the 21st century. They were prepared to support research into adaptation to climate change in Finland in the FINADAPT project. The scenarios have some similarities with the global IPCC SRES scenarios, but they also differ from SRES because they are national in scope and they account for climate policy. Two scenarios describe alternative worlds with pathways towards stabilisation of greenhouse gas emissions; the third describes a world with rapidly increasing emissions. Scenarios span four time frames: present-day (1971–2000), near-term (1991–2020), mid-term (2021–2050), and long-term (2071–2100). Quantitative information on socio-economic development, climate, CO_2 concentration, nitrogen deposition and land use change is provided, with detailed data available from the FINADAPT web site or from relevant partner institutes.

Tässä raportissa esitetään kolmen eri skenaarion sarja Suomen ympäristön ja sosio-ekonomisen kehityksen muutoksista tällä vuosisadalla. Skenaariot kehitettiin FINADAPT-hankkeessa käytettäviksi ilmastonmuutokseen sopeutumisen tutkimuksessa. Skenaarioilla on yhteneväisyyksiä Hallitustenvälisen ilmastopaneelin (IPCC) kehittämien maailmanlaajuisten SRES-skenaarioiden kanssa. FINADAPT-skenaariot kuitenkin eroavat SRES-skenaarioista siinä, että ne ovat kansallisella tasolla ja niissä otetaan huomioon ilmastopolitiikan vaikutus. Kaksi skenaarioista kuvaa maailmoja, joissa kasvihuonekaasujen päästöt vakiintuvat; kolmannen skenaarion kuvaamassa maailmassa päästöt kasvavat nopeasti. Skenaariot kattavat neljä ajanjaksoa: nykyhetki (1971–2000), lähitulevaisuus (1991–2020), keskipitkä aikaväli (2021–2050) ja pitkä aikaväli (2071–2100). Skenaariot sisältävät kvantitatiivista tietoa sosio-ekonomisesta kehityksestä, ilmastosta, hiilidioksin pitoisuudesta, typpilaskeumasta sekä maankäytön muutoksista. Yksityiskohtaisempaa tietoa on saatavilla FINADAPT-hankkeen verkkosivuilta tai hankkeeseen osallistuvista tutkimuslaitoksista.

This report is also available at the FINADAPT Web site:
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