Adapting to climate change in Estonia: current state, impact assessment and adaptation measures

Summary of the BioClim project

December 2015

The **BioClim** project advised the compilation of the **Estonian national climate adaptation strategy and action plan** concerning 11 topics under two general themes: **natural environment** (I) and **bioeconomy** (II). Climate change impacts on biodiversity, terrestrial, freshwater and marine ecosystems (including their ecosystem services) will be mapped, as well as impacts on relevant bioeconomy sectors, e.g. agriculture, forestry and hunting, fishery, tourism and peat mining.

The project had three work packages. **WP1** defined **relevant sub-themes (i.e. priority themes for Estonia)** and maps the current situation, i.e. describes **problems**, **opportunities**, and **threats**, as well as **impacts of past weather events**. **Existing adaptation measures** are also analysed. The results are based on the analysis of existing scientific literature, (national) policies and legislation and info from different databases, as well as expert knowledge.

On the basis of pre-defined climate scenarios, **WP2** analysed **climate change impacts** and existing measures to adaptation on these priority themes**. Risks**, **vulnerabilities** and **climate change impacts** on the pre-defined topical areas and their sub-themes were assessed. **Recommendations** for future research are also given.

Finally, WP3 developed suggestions[1] for **adaptation measures** for the national adaptation strategy and action plan, considering **four time-periods**: until 2020; until 2030; 2021–2050; and 2051–2100.

We appreciate the **contribution from sectoral interest groups**, whose input has given a remarkable added value to the work at hand.

Below the **main results** from **each topical areas** (11) are presented from WP1, 2 and 3, and an **indicative cost prognosis** (up to 2030) on adaptation measures for the two general themes (I and II) is made.

[1] BioClim was advised by a steering committee http://www.klab.ee/kohanemine/en/strategy/steering-committee/, based on whose suggestions certain adaptation measures included in this document (background analysis) were excluded from the final strategy and action plan. Certain exlcuded measures concern the following topics: terrestrial and freshwater ecosystems, ecosystem services, agriculture, fishing, hunting and peat extraction.

I Natural environment

1. Biodiversity

Priority themes and current situation

The climate change may cause shifts in species' distribution areas. Especially endangered are species at their range boundaries. Changing climate may decrease the adaption ability and viability of species. The changes in species phenology alter interspecific relationships. Climate change can also increase the negative impact of invasive alien species on biodiversity, causing for example the establishment of new and altered impacts of existing invasive alien species. Due to shifts in species distribution areas and spread of invasive alien species, climate change can have negative impact on protected areas. Only few studies about impact of climate change on protected areas were found. Increase of extent of protected areas and their coherence is essential to the maintenance of biodiversity.

Impact assessment, recommendations for future research

Endangered and also common species are the most influenced by increasing temperature, climate extremes, duration and extent of sea ice cover and sea level rise. These named climate changes may alter species abundance and composition. Negative impacts are species decline, decreased reproductive success and genetic variability. Also changes in species phenology and mutual relationships can be expected. Positive aspect is that general species abundance can be considered as constant.

Invasive alien species are most influenced by increasing air and water temperature and also duration and extent of sea ice cover. Named climate changes may cause establishment of new invasive alien species, altered impact of existing invasive alien species and also current prevention methods may become ineffective.

Influences of climate change affect entire biodiversity and thereby the state, protection needs and goals of protected areas are altered. Protected areas are the most influenced by increasing temperature and rise in sea level. The most vulnerable are habitat specialists and it can be expected that some native species are going to become extinct. It is possible that in general the number of species will remain the same, but the species composition changes (i.e. some species disappear and some new arrive). Climate change causes destruction of some ecosystems or changes in ecosystem functioning.

We recommend subsequent research topics to enhance biodiversity studies in climate change frame:

- assembling current research results;
- studying species at their distribution margins;
- studying of invasive alien species;
- analysing the information of species distribution patterns (Atlas of the Estonian Flora etc);
- studying the intraspecific variation of species.

Adaptation measures

Development of the adaptation measures in biodiversity has been based on general nature conservation measures and actions that help to face climate change and have positive impact on social and economic sectors. There are three priority adaptation measures in biodiversity: 1) ensuring the favourable condition of species in changing climate conditions; 2) prevention, eradication and control of invasive alien species in changing climate conditions; 3) ensuring the favourable condition of habitats and diversity of ecosystems and organizing nature conservation management in changing climate conditions. There are 27 activities altogether intended for the implementation of these three measures (eleven, six and ten activities, respectively). The cost of the measures until 2030 is the following: the first measure 2 600 000, the second measure 8 300 000 and the third 1 610 000 euros, altogether 12 510 000 euros. Some activities, being important for general nature conservation purposes as well as for adaptation with climate change, are already implemented and funded and the cost of those activities has not been considered in this action plan.

2. Terrestrial ecosystems

Priority themes and current situation

Terrestrial ecosystems and climate change are inherently linked. Increasing temperature, precipitation and extreme weather events caused by climate change influence the structure and functions of forest ecosystems, altering forest growth, carbon accumulation, and thus the whole nutrient cycle. Changes in the hydrological regime and water table will affect wetlands greenhouse gas balance – carbon dioxide and nitrous oxide emissions generally increase and methane emissions decrease. Soil carbon sequestration in grass- and arable land is affected by increased temperature, plant growth, rainfall, but also by soil obesity, water regime, particle size distribution and concentration of carbonates. Different terrestrial ecosystems are essential for the provision of ecosystem services such as carbon sequestration, protection against floods

and soil erosion, and the regenerative and healthy ecosystems provide substantial protection against the effects of climate change. In order to assure sustainability of terrestrial ecosystems benefits and services in changing climate conditions, it is necessary to implement appropriate climate adaptation measures, which are currently missing in Estonia.

Impact assessment, recommendations for future research

Climate change accelerates carbon cycling in forest and increase biomass production along with the potential felling volumes, having a positive effect on economy. On the other hand, forest felling, especially clear-cutting endangers forest habitats and may lead to formation of bogs due to increased moisture conditions. Due to climate change winter temperatures will not drop below zero degrees, thus soil does not freeze, which hinders timber harvesting. Heavy logging machinery may damage unfrozen soil texture, causing soil compaction, which will deteriorate growth conditions, decrease soil fertility and carbon stocks, cause formation of waterlogged areas and increase soil emissions. Increasing frequency of drought will raise the danger of forest fires, increasing occurrence of storms will enhance storm damage in forests. Climate change may alter relationships between species and the proportion of different forest site types, thus having an impact on the overall functioning of forest ecosystem.

Different climatic factors such as increase in air temperature and precipitation will affect wetlands hydrological regime, seasonality, nutrients movement and greenhouse gas emissions. The role of wetlands in synchronizing water flows and level will increase. Also, wetlands are vulnerable to frequent alternation of freezing and thawing, and depletion of days with snow cover. Summer droughts inevitably reduce the water level and supply of wetlands and it has clear consequences on wetlands biota and water purifying properties. Global warming and changes in rainfall patterns will cause displacement in wetlands species composition, change the ratio of different kind of peat moss and increase the competitive advantage of shrubs. Changes in wetlands plant structure will affect the biota of wetlands, especially coastal wetlands plant and bird communities have an additional impact caused by storminess and extreme wind events.

Climate change may threaten the soil humus content and thus the overall soil fertility of Estonian soils. The soil fertility will be greatly influenced by future land use, especially in changes in land use. Higher temperatures will lead to prolonged growing season and thus to higher overall productivity. Higher temperatures will accelerate the decomposition rate of soil organic matter, and may therefore increase the CO_2 emission from soils. In semi-natural grasslands the higher temperatures will alter the community species' composition and/or species abundances. Increase in rainfall during winter and early spring will lead to larger flooding risk. Wind erosion may have serious impact on arable soils during early spring droughts. Water erosion may damage fallow lands in occasional strong storms and heavy rains.

In order to improve the assessment of risks, vulnerability and climate change impact on terrestrial ecosystems, the following research topics are recommended:

- the impact of climate change on carbon stocks (carbon balance), hydrological water regime, nutrients mobility and greenhouse gas emissions;
- the impact of climate change on different terrestrial ecosystems sity types, species diversity, and ecosystems functional and structural changes.

Adaptation measures

The aim of adaptation measures in the terrestrial ecosystems is to preserve ecosystems' good condition, functions and resources. Altogether there are 10 proposed measures that include 29 activities, many of which are targeted to expanding monitoring and research activities. The cost of the measures until 2030 is approximately 12 200 000€. The measures under the terrestrial ecosystems topic are closely linked to measures proposed under biodiversity, ecosystems services, forestry, agriculture and peat extraction, inter alia preservation of ecosystems functionality, habitats, biodiversity and soil fertility, and carrying out additional research in the field of greenhouse gas fluxes and carbon balance. The implementation of measures under terrestrial ecosystems is considered moderately complex as many of the proposed measures are already present in currently existing national strategies and development plans. 8 out of 10 measures are considered of high priority, these measures should be implemented in the near 5 years. However, all of the measures are expected to be long term measures (implemented until 2100), in order to achieve its goals.

3. Freshwater ecosystems

Priority themes and current situation

Changing climate will affect freshwater ecosystems mostly by changes in ice regime, ice-free period water temperature, water chemistry and biota. Climate change impacts on freshwaters are often difficult to distinguish from the impacts of human activity and further research is needed. When considering large lakes, Lake Peipsi is most vulnerable to changes in water temperature, Lake Võrtsjärv is strongly affected by water level fluctuations. The most serious threat to small lakes is eutrophication and climate change will affect these lakes in a type-specific manner. Shifts in the water column stratification and mixing patterns are predicted in small lakes. Due to increased water temperature, cyanobacterial blooms are more common in the future. Decrease in snow cover will lead to lower maximum water level and runoff in the watercourses compared to what is seen today. Summer minimum drain period will prolong and high water levels in the autumn can be seen more often. These changes will improve the ecological status of rivers in winter, but make it worse during the summer. Changes in the hydrological regime of watercourses will affect the transport of nutrients and other substances.

Impact assessment, recommendations for future research

Freshwaters are the most affected by the predicted increase in temperature and precipitation, the shorter winter period, especially decrease in ice and snow cover thickness. Stronger winds and extreme weather events will impact large lakes more frequently.

Due to the increase in temperature there will be more algal blooms, the oxygen conditions will worsen, environmental conditions will be more suitable for southern foreign and invasive species. The mixing type and increase in strength and duration of summer stratification can occur. This leads to an expansion of the oxygen-depleted zone and increased pollution from bottom sediments. The rise of temperature and increased rainfall will increase the leaching of nutrients and carbon from the catchment area.

The positive effect of the climate change is the smoother hydrologic regime of water bodies, higher water levels, and higher discharges due to the increasing precipitation. Also the oxygen conditions during the winter time will improve. Rising water temperature in summer will be positive for recreational activities, if not limited by the decrease of water quality.

Predicted changes in climate will oppose the efforts done to reduce the effects of nonpoint and point sources of pollution, achieving a 'good' status of water bodies, and will intensify the eutrophication process. Lakes will emit more greenhouse gases, which may make it difficult to meet the emissions limitation goals, and provide positive feedback for further climate change.

The following research topics are recommended to increase the precision of impact, risk and vulnerability assessment of climate change on freshwater ecosystems:

- research to distinguish the impacts of eutrophication and the impacts of climate change;
- monitoring and modelling of possible effects on cycling of substances, hydrological and stratification regime, and on emission of greenhouse gases;
- to assemble and to analyse the information on the effects to the freshwater habitats, composition of species, and functional/structural changes of ecosystems;
- to reduce possible socio-economic impacts and poisonings, it is important to develop fast and reliable monitoring methods & early warning system to detect harmful algal blooms.

Adaptation measures

The aim of the adaptation measures for freshwater ecosystems is to minimize the negative impacts of climate changes to achieve and preserve a good status of freshwater ecosystems and to ensure the availability of ecosystem services at least on the current levels. Five measures with in total nine activities are proposed. Their total cost up to 2030 is estimated to be EUR 4 250 000. All measures have the highest priority, and their implementation should start as soon as possible. At first the modelling should be carried out to predict more accurately internal and external loads and possible changes in stratification of water bodies. These results should be included in the preparation of the new round Water Management Plans (Measure 1). Climate sensitive indicators should be included to the monitoring schemes of water bodies, climate change hotspots should be mapped and greenhouse gas emission measuring carried out (Measures 2 and 4). These data can be analysed only in the presence of a sufficient length of time series. Problems related to algal blooms and alien species will become more topical, and it is necessary to increase the readiness to address these risks (Measures 3 and 5).

4. Marine ecosystems, incl. the Baltic Sea

Priority themes and current situation

Eutrophication is one of the most important environmental issues in the Baltic Sea. Eutrophication along with climate change poses a significant threat for benthic communities and is a direct driver of decreasing marine biodiversity. More frequent disturbances and drifts in seawater circulation, temperature and salinity regime directly affect marine ecosystem stability. Increased water temperature enhances primary production which results in increased eutrophication rate and gradually higher establishment of invasive species. In reality, there is a significant lack of information on marine environment changes in relation to climate change. There is a need to improve the resistance capacity to direct physical stressors and reduce anthropogenic pressures in order for the marine ecosystems to adapt to changing climate conditions.

Impact assessment, recommendations for future research

Climate scenarios predict the increase in temperature and precipitation, and extreme weather events, which lead to changes in multiple directions. Changes like intensification of eutrophication, increase of southern non-indigenous species and decline of keystone species will affect marine biodiversity and stability in a negative direction. In addition climate change leads to regime shifts in food webs dynamics, longer vegetation period, and higher primary and secondary production, where impact directions for marine processes and general functioning are unknown. Decreasing salinity and mechanical disturbances by storms will influence communities' species composition and marine biodiversity. Several processes occur in interaction of different factors, like water acidification, and the effect on the functioning of the Baltic Sea is yet to be determined in a long scale.

Considering current knowledge and gaps in it, there is a need to experimentally examine separately and interactively the effect of different factors (extreme weather events, increase in temperature, decrease in salinity) to marine ecosystem and also to eutrophication and food web functioning. Moreover, there is a need for assessments of the impact and impact range caused by non-native species and their relative importance in native species food base.

Adaptation measures

The aim of adaptation measures designed for the marine environment is to ensure good marine environmental status by 2030. The overall evaluation takes into account ecological state as well as chemical indicators. The evaluation will be conducted via assessing the separate and interactive effects of short and long-term changes of climate indicators on the marine environment. The field of marine environment consists of 9 measures through which 19 different actions will be undertaken that will aid to adapt to changing climate as well as to ensure the quality and biodiversity of the marine environment. The estimated cost for adopting planed measures and required actions is 2 054 000 EUR. All the measures are ready to be implemented whereas the delivery of results may take more than 5 years. Several adaptation measures require long-term monitoring or extensive research input which means that their implementation will be an ongoing process throughout the present century. 2 measures with uttermost importance have been identified for the marine environment and these require implementation within the next 5 years: 1) measure 4.1: minimisation of eutrophication caused by climate change; 2) measure 4.6: minimisation of risks caused by non-native invasive species to native species and to ensure long-term sustainability of ecosystems.

5. Ecosystem services

Priority themes and current situation

We have quite a good theoretical understanding of different potential effects of climate change on different ecosystem services, but there is little data on the actual effects of past extreme weather events. There is plenty of data about various supporting services in Estonia, but the data about the status and scope of regulating and cultural services is insufficient. Climate change adaptation measures are not applied in Estonia, although some measures in place contribute also to better adaptation.

Impact assessment, recommendations for future research

Extreme weather events have the greatest impact on ecosystem services during the first two time periods (until 2030). Several climate risks will be expressed by the end of periods of 2050 and 2100, which affect negatively and to a smaller extent positively many of the provisioning, regulating and cultural services that the ecosystems provide. Freshwater and marine ecosystems and their services are expected to be affected the most severely while the terrestrial ecosystems will be affected to a lesser extent.

Future research should concentrate on gathering statistical and functional data on provisioning, regulating and cultural services of the ecosystems and learn more about the probable effects of various climate risks on these services.

Adaptation measures

27 measures and 45 activities with a total cost of 13,9 million euros have been developed to adapt ecosystem services to climate change in the period of 2017–2030.

About half of the measures (14) have been designed to for maintaining the volume and quality of water related ecosystem services (maintaining water regime, water purification, fish, seafood, drinking and irrigation water, fishing, water tourism, etc.). This comes rather naturally, since the freshwater, marine, forest, wetland, meadow and soil ecosystems have an important role in water management and neutralising the emissions and depositions.

Regulative measures dominate among the adaptation measures in ecosystem services: 14 measures involve regulative action to consider climate risks in sectoral policies. Mostly the regulative changes anticipate careful planning and use of natural resources (such fishing quota, forest felling volumes, game hunting volumes) or ensuring conservation of them (such as conserving spooning grounds of fish). Second important group of measures is information sharing and increasing awareness of climate change risks on ecosystem services among general public but also among specific target groups (foresters, fishermen, tourism developers, etc). Also some investments are planned to increase security and awareness of people about climate risks, since the term “ecosystem services” is rather new to the general public. Also surveys and research are important components of the programme of measures of adapting ecosystem services to climate change, since there is an urgent need to develop the classification of all socio-economically important ecosystem services similar to the classification of ecosystem services of freshwater and marine ecosystems currently in development. Also, there is common need for all ecosystems to have a methodology to calculate their carbon balance. Climate change adaptation measures need to be taken into account also in county and comprehensive plans.

II Bioeconomy

6. Agriculture

Priority themes and current situation

The vegetation period has recently been showing signs of prolongation – spring has been arriving earlier and the harvest can take place at a later date, although it can be difficult due to excessive moisture. Repeated freeze-thaw cycles worsen the overwintering of the cover crops. The risk of snow mold is growing. The cultivation of silage corn and winter rape has been increasing due to the longer growing season, with some new crops (e.g. peas or broad bean) introduced in crop rotation practice. Higher temperatures, increased precipitation and reduced snow cover promote traditional practices of animal husbandry. Higher incidence of drought can complicate the production of livestock due to the shortage of feed. Higher ambient temperature creates preconditions for increasing pollutant emissions from manure handling. Climate change may cause more storms resulting in power cuts, whereas failures of electric automation equipment may potentially be of fatal consequences. For various reasons, 25–30% of bee colonies perish annually. In the light of global warming, more and more plants, farm animals and people are expected to be directly or indirectly threatened by the potential spread of pests and pathogens as well as their arthropod vectors. Increasingly more infections and vector species associated with warmer climates have been found in areas where they previously did not exist.

Impact assessment, recommendations for future research

Above all, Estonian agriculture is affected by rising average temperatures and thermal variability. Other major abiotic drivers of climatic challenges are predicted increase in atmospheric CO2, changes in precipitation and exposure to extreme weather and climatic events. Possible weather-related gains may also be driven mostly by temperature in various agricultural sectors. However, certain benefits may be encountered because of the increasing CO2 concentration, which affects plant physiology, severe drought periods in spring, which may suppress the breeding of blood sucking insects and reducing amount of UV-radiation in northern high-latitude areas, which would increase the efficiency and competitiveness of microbial pesticides for biocontrol. Many challenges inherent to plant production would affect also animal husbandry primarily via forage and roughage biomass.

Most significant impacts of climate change may become disturbances and shocks due by abiotic but also biotic processes. On the other hand, the complex of weather events could end up leading to the introduction of a new, alien environmental status which is extraneous to the agricultural production. Crop failure due to climatic factors can vary locally depending on the soil conditions, but generally vulnerability of the agricultural producers arises on account of lower economic competitiveness.

Climate as well as agro-ecosystem is driven by dynamic behaviour of complex causal relationships, with consequences of each individual force and their synergy or interaction. In order to enhance protection against manifestation of climate variability, efforts shall be made towards developing methods to target uncertainties in the measurements and scientific processes and considering combined effects of multiple factors. Further insights shall be provided, engaging interdisciplinary research, to support new findings with a substantial body of scientific evidence, particularly by:

- modelling shifts in agro-climate;
- geo-modelling disaster risks for agriculture;
- studying changes in soil carbon content and humus balance;
- monitoring emerging animal diseases and zoonoses, incl. fish and bee parasitoses and plant pests and diseases;
- studying the effect of abiotic and biotic stress factors in metabolism and development of plants, arthropods and other animals;
- investigating the dynamics of changes in the cascade of multitrophic relationships;
- conducting studies to assess the effects of climatic drivers on developing and maintenance of resistance and virulence;
- developing innovative farming technologies for crop production and animal husbandry etc.

Adaptation measures

In order to manage the agricultural risks, a priority action plan of 30 actions were developed within a set of 4 economic, 2 regulatory, 3 planning, 3 research, 2 informational and 2 investment measures. Due to the increasing variability of weather conditions, revision of the legal framework is needed, in particular establishing relationships between the regulations and the climate change, to ensure the flexibility of the provisions and rapid response, availability of the necessary resources (incl. contingency plans, crisis management fund). Companies must have the possibility to increase the diversification of production necessary to promote adaptability, maximize added value and support for marketing and export. More attention is

required for larger scale, more structured trans-regional measures: to optimize the regional structure of cultivation, create regional programmes of plant protection, fertilization and soil and hydrological systems, utilize manure (especially the excess of autumn and winter periods) and plant waste as resources for renewable energy and to restore the soil fertility etc. In addition, the renovation of the infrastructure e.g. the drainage systems may include the investments to support irrigation or the establishment of a bilateral regulatory systems. In order to promote correct behaviour of the undertakings, the optimal measure complex must be commercially acceptable.

The policy-driven processes of adaptation require state investments and decision support. Cohesive system of controls and regulations is needed to settle the claims due agricultural emergencies (epidemies, eradication measures, wildlife and weather damage). National plan would be required to integrate meteorological and other available complex data of surveillances and surveys, research and network of volunteers into efficient data processing system and to generate the agroecological prediction models for operational support as well as avoid environmental damages and disturbances to the highest possible extent. Centralised early warning system shall be developed to provide the stakeholders with timely alarms, emergency action rules and direct instructions. A novel package of environmental protection regulations shall be developed, including the additional measures for sustainable agriculture, soil- and water protection, re-evaluation of manure and waste management, support development and maintenance of green infrastructure etc. Last but not least, supporting agricultural substructures are to be maintained: breeding more resilient varieties of longer vegetation, securing the forage sources for honeybees, developing educational and research institutions and improve competence in climate change. Solutions which are satisfactory to all interested parties are yet to be developed to establish the agricultural insurance system.

7. Forestry

Priority themes and current situation

In the Estonian forestry development plan for 2020 the climate change impacts and mitigation is concerned. The proportions of tree species and balance between coniferous and deciduous will change. One advantage is possible increase in forest biomass productivity, but there are many disadvantages. The risk of wind damages will increase. The risk of forests pests and pathogens will increase. The reduced period of frozen ground makes timber harvesting more difficult. More precipitation means more investment into forest roads and ditches. The quality of timber may reduce.

Impact assessment, recommendations for future research

The most important climate factors that based on the prognosis will affect forestry are increasing temperature and precipitation. Strong negative impact can be caused by more frequent extreme weather events (drought, extremely low winter temperatures, storms). Forest industry will face difficulties with timber transport out from forests due to decreasing period with frozen soil in winter. Economically the largest effect will be caused by the need for additional costs for tending forest roads and ditches. Among fellings, the amount of sanitary felling will increase. The share of deciduous tree species will probably increase in forests. Positive effect is expected from increasing timber increment although such trend might not persist for the whole century. Forest health could worsen due to new invasive pathogens.

The further studies are required to assess different felling methods from the perspective of climate change. Economic calculations about maintenance cost of forest roads and drainage systems are needed. Monitoring of invasive pathogens and their influence must continue and ability for their early detection and precautionary measures must be elaborated.

Adaptation measures

The aim of adaptation measures is to guarantee economically and ecologically sustainable forestry, forest management and forest utilisation. Totally five measures are planned and the Ministry of the Environment will be responsible for their implementation. The specificity of forestry measures is the long period of time required for their implementation and evaluation of the outcomes of measures due to the slow growth of forests. It is presumed that new principles are added in the legislation and standards. Forestry measures are all of the highest priority. Main measures are focusing on studies that support new regulations, investments, plans and innovation. More precise ecologically and economically justified planning of fellings is required as well as analysis of intensity and seasonality of maintenance fellings and other types of fellings in the changing climate. Silvicultural methods that ensure the preservation of forests' ecological value must be elaborated for forest felling and regeneration. In order to adapt with climate change, innovative technologies must be applied for timber processing to reduce damage on forest soil, the respective measure is also directed to the maintenance of forest roads and drainage systems. For successful forest regeneration, it is necessary to establish geographic progeny trials and carry out forest genetic studies to breed and select new progenies that are more resistant in future climate conditions and pathogens. Continuous monitoring of forest pathogens on permanent sample plots is required as well as monitoring and testing of imported biological material. Epidemiology and dispersal strategies of new pathogens must be investigated. It is essential to model the impact of pathogens and evaluate root rot damage in connection to wood quality and timber increment in forests.

The total cost of forestry measures is 6 million euros, in addition to this the cost of maintenance of forest roads and drainage network.

8. Fishery

Priority themes and current situation

The impact of climate change on fishery (commercial and recreational fishing) could be reflected mainly through the impact on fish stocks. Different components of climate change (e.g. changes in salinity, water level and temperature, extreme weather events, ice conditions) may strongly influence the most important and less resilient exploited fish populations abundance and stocks in the Baltic Sea and inland waters. Changes in population abundances may be opposite for cold-adapted (vendace, Peipsi whitefish, burbot, lake smelt) and warm-adapted species (e.g. cyprinids, pikeperch). Fish community structure in shallow lakes and rivers may be very vulnerable to water temperature increases, especially temperature extremes (heat waves) in combination with eutrophication that can led to strong cyanobacterial blooms, night time hypoxia and fish kills. Shortening the ice-cover period will decrease risk of winter fish kills in shallow lakes but will influence most strongly autumn/winter-spawning fish like vendace, whitefish and burbot. Warming has contributed also to the spread of invasive species, new parasites and diseases of fish.

Impact assessment, recommendations for future research

Fisheries are based on utilisation of the natural fish populations and therefore this branch of economy can be severely influenced by the climate change. Predicted changes such as increasing water temperatures, increased precipitation, shorter duration of ice-cover, higher frequency of extreme climate events etc. may impact both the list of fish species, and also relative abundance of fishes. Most likely, climate change will have opposite impact to cold-water species (e.g. salmonids, vendace, whitefish, burbot, smelt) and to warm-water species (e.g. cyprinids and pikeperch). While small changes in water temperature will have its effect in long run, short-term occurrence of extreme events (such as heatwaves, or large salt water inflows to the Baltic Sea) may have drastic and deep impact on fish fauna in relatively short period. Temperature effects on fish are most visible through its impact to fish reproduction– unfavourable conditions during the short critical spawning period usually result in weak year-classes. However, it is impossible to predict the detailed effects of climate change to fish fauna in distant future due to the opposed influence of different factors (e.g. increased precipitation decreases salinity of the Baltic Sea, but more frequent stormy periods and higher water level may increase inflow of salt water from the Kattegat). In order to facilitate the prognostication, more detailed and complex ichthyology and fisheries data collection is needed. Moreover, analyse of the ichthyologic data should be integrated more tightly with monitoring of other biota and climate data. Finally, while commercial landings are registered in detail, the information concerning recreational catches is still very scarce and needs to be improved.

Adaptation measures

Eight adaptation measures, with cumulative cost of 30.8 M € were planned in order to ensure sustainability of fish populations and both recreational and commercial fisheries. To minimize the effect of climate changes to fisheries these measures should be put forward as soon as possible, albeit the effect of those measures can be evident after several years. The main objective of proposed adaptation measures is to shift the regime of the use of fish stocks in order to maintain sustainable populations with healthy structure. The management measures are aimed at optimization of legal size limits, restoration and conservation of spawning and nursery areas, establishment of temporal and areal fishing restrictions and adapting allowable landings to the state of fish populations. Minimization of factors that have negative influence on fish (e.g. anthropogenic eutrophication, pollution) has also high priority. However, while vital in order to maintain healthy fish stocks, this measure is one of the most resource consuming. Also, more efficient utilization of caught fish and reduction of illegal landings are also proposed as measures to alleviate the anthropogenic pressure on decreasing fish stocks. To ensure that people depending on fisheries could retain their current welfare and standards of living, measures (e.g. promotion of tourism, developing of fish farming) should assure their employment in these areas. However, while the application of these measures should be mainly based on scientific knowledge (e.g. precise stock size assessments), current the shortage of such data should be also be decisively addressed. This promotes the acute need for studies to determine how do the factors that influence the size and development of fish populations interact with climatic variations. Moreover, also reliable monitoring system for recreational fisheries has to be developed to allow for competent assessment on the use of Estonian fish stocks.

9. Hunting

Priority themes and current situation

Climate change will presumably cause changes in the species composition and diversity of Estonian fauna. Predictably new southerly species may expand northwards to Estonia. It will become necessary to intensify hunting of some species and take measures to protect the diminishing native game species. The state may impose new responsibilities on hunters, while the goals of hunting may have to be changed as well. Changes will have to be communicated to the society and the attitude towards game management and hunters has to be worked on. Some diseases and parasites associated with wild animals may be major risk factors for humans and pet animals. One important impact of climate warming is the influence on moose population and other herbivores. Damage to forests and related agricultural crops may increase. This will create a need for the establishment of complicated and costly damage compensation mechanisms.

Impact assessment, recommendations for future research

Climate warming definitely influences game animal populations but its impact is largely overshadowed by that of human activity. In all probability climate change will directly endanger (up to the point of total disappearance from Estonian territory) only a very few narrowly adapted species. The prevalent majority of Estonian game animal species are widely distributed and climate warming may directly or indirectly – e.g. by changing food base – influence their living conditions and population dynamics.

Estonian game animal populations are directly influenced by the following climate phenomena: mean summer and winter air temperatures, and the duration and average depth of snow cover. Living conditions, above all the food base of game animals, can be indirectly influenced by changes in the species composition and biomass of the habitat, as well as by extreme weather conditions such as storms and protracted droughts.

In the near future it would be necessary to identify the game species most vulnerable to climate change and devise protective measures. It is needed to look for ways for preventing the invasion of unwanted species. It is of great importance to study the public opinion in order to find out the attitude of different stakeholders towards hunting and other game management activities. It will be essential to develop new game inventory methods that would be independent of the existence and duration of snow cover.

Adaptation measures

In the field of game management, all measures for adapting to climate change are interconnected and contribute to the main goal, which is economically and ecologically sustainable game management and hunting as an important part of it. In the field of game management and hunting, all measures for adapting to a changing climate have a high priority.

There are four important measures that need to be taken to ensure that Estonian game animal populations will remain stable in the changing climatic conditions. Responding to climate change entails taking timely action by reorganizing hunting, introducing protective measures for species considered at risk and keeping off invasive species that are alien to Estonian wildlife. When alien species arrive, hunting periods and hunting methods need to be imposed for them. Effective game management requires reliable data on game population numbers, as well as on parasites and diseases associated with them. Considering that hunting serves as a primary means of regulating game management related conflicts, it is necessary to ensure that hunting is viewed as a socially acceptable activity. This entails maintaining a tolerant attitude in society towards hunting, both as a volunteer recreational activity and a service to society by preserving the optimal wildlife numbers. It is necessary to implement new methods of game population monitoring, as the ones currently used depend on the presence of snow cover.

Given that with the climate warming the impact of endo- and ectoparasites on game population is likely to increase, in the future game monitoring must also include the monitoring of parasitoses.

All measures for adapting to climate risks must be included in the new Game Management Development Strategy. The overall cost of measures is 320,000 Euros and the agency responsible for implementing them is the Ministry of the Environment in collaboration with the Estonian Hunters' Society.

10. Tourism

Priority themes and current situation

Climate change has the main impact to internal tourists and tourists from neighbouring countries who can plan their vacation according to weather conditions. Using the Tourism Climate Index we see an increase in the frequency of months where the TCI is more suitable in North West Europe than in the Mediterranean. Specifically in relation to increasing TCI-s, Estonia could see a change in tourism flows across several tourism seasons with an increase in total tourism numbers. Increasing TCI-s in "shoulder" months might change seasonality of tourism demand and offer tourists the possibilities of taking vacations over a wider number of months. Tourism visits may increase in the spring and autumn seasons, especially to rural (inland) areas, with consequent impacts to the natural environment: on animal breeding behaviour during vulnerable periods; trampling of sites with low carrying capacity or higher maintenance costs of site protective infrastructure, e.g. walkways; higher visitor numbers at sensitive sites such as animal viewing platforms and hides. 5–12% of CO2 emission is caused by tourism sector, of which 75% by tourism transport and 20% by accommodation services. The greenhouse gas emission from tourism sector will increase by 130% from 2005 to 2035 according to prognosis.

Impact assessment, recommendations for future research

The impact of climate change on tourism in Estonia will be dependent on many interacting factors, physical, social, economic and political. Climate change will affect tourism in source and destination countries. Behaviour patterns of tourists are changing. Warmer and longer summers increase tourism flow to North- and North-West-Europe. Warmer water bodies may increase interest in water-based tourism though increased rainfall leading to greater agricultural land runoff may risk increased algal blooms in seas and lakes. Warmer winters may lead to poorer snow reduction in snow fall/increased milder periods could lead to shorter winter tourism season & reduction of winter-sports and events. Warmer winters may impact on ice sports and winter fishing, fewer occasions when ice roads can open to islands. Rising sea levels may impact on sea tourism through problems with harbour infrastructure and yacht tourism. It is predicted that weather patterns (with increased storm and rainfall events) may become more unsettled that arises need for more indoor facilities.

For more reliable prognoses tourists behavioural patterns considering socio-economical aspects and climate change should be studied. For defining preparedness of adaptation of tourism sector with climate change impacts, a study of tourism entrepreneurs and other stakeholders should be conducted.

Adaptation measures

The aim of measures designed for the tourism is to achieve awareness of tourism sector about climate change adaptation and capacity for their implementation by year 2030. To ensure the objective the competence centre will be established, which creates prerequisites for the proposed 7 measures to implement 33 activities in total for 3.345 million euros by 2030. The energy efficiency requirements would be also designed during next 5 years. The rest of the measures will be implemented in period 2021-2030 because they need the input of studies, expert assessments or decisions of the respective form. The measure of the biggest impact in tourism subject is diversification of tourism products and services and creating investment opportunities for case of bad weather conditions in winter and for attracting summer tourists, incl. development of water based tourism.

11.Peat extraction

Priority themes and current situation

In the course of analyses peat mining was divided into following sub-themes: greenhouse gas emissions (GHG) from peat extraction sites; relevant policy documents; impact on peat extraction capacity; technologies for peat mining; and after-use of peat extraction areas.

Based on peat mining capacities (area and volume), resource analyses and policy documents, there are possibilities to increase extraction activities. On the other hand, there could be possible constraints related to high GHG emissions and dependence upon weather conditions. In order to minimize these influences, possibilities for wet mining and use of wet peat are analysed although it is not used much in practice.

Analysing weather conditions (period June-August, 1992–2013) relevance to peat mining capacity, there has been significant influence on extreme precipitation rates, e.g. in 1998 peat extraction volumes decreased drastically. On state level medium correlation between precipitation, temperature and mining capacity was determined, but on a county level this could be significantly different. Based on Finnish research, increasing precipitation and soil moisture could be accompanied with significant accretion of GHG emission from mining areas.

Impact assessment, recommendations for future research

Main negative impact due to climate change (higher medium air temperature) is increase of peat mineralization and inherent CO_2 emission from peat extraction areas. Positive impact from climate change is related to longer extraction period which increases efficiency of peat mining and could lead to bigger annual outputs of peat. If use of peat remains at the current level, total area needed for extraction will be smaller and this could also limit net CO_2 emissions and other environmental impacts. Additional environmental taxes have unknown or neutral effect – on one hand it increases costs for entrepreneurs (including investments into new technologies), on the other hand provides circumstances for reduction of environmental impact (e.g. use of wet mining technology could lead to reduction of peat extraction areas and related total CO_2 emissions). The main challenge is related to development and use of wet mining technologies, research on carbon balance and impact on water environment in changing climate circumstances, monitoring the effectiveness of after-use options of peat extraction areas, implementation of CO_2 taxes to peat mining and use and its impact.

Adaptation measures

Peat mining consists of four measures with nine activities with total costs of 520 000 EUR. Priority measure is establishment of conditions for optimal and climate adaptive after-use of abandoned peat extraction areas which includes relevant monitoring actions and inclusion of output in practice, including relevant amendments in legislation. Priority-wise follow measures to decrease dependence on weather conditions, also to minimize peat loss and CO_2 emissions – these include research on use and development of wet mining and peat technologies. Also, complex research to adapt changing environmental conditions – updating requirements for fire prevention, after-use methodologies, water protection etc. The forth measure is evaluation of greenhouse gas emissions related to climate change which is also bases for regulating environmental taxes.

III Indicative cost prognosis of adaptation measures

The adaptation measures of **natural environment** (the first general theme of BioClim) are estimated to cost around 45 million euros. 30% of these estimated costs should be done already before 2021 and 70% in the period 2021-2030. The largest cost category is foreseen for different studies (around 20 million euros), as there is a lot of uncertainty regarding climate change effects in natural environment. Investments in this area cost around 11 million euros and different economic measures cost about 10 million euros. There are also a lot of informative, regulative and planning measures foreseen in the general theme of natural environment, but their cost is not so high. Most of the adaptation measures in this area belong to the jurisdiction of the Ministry of the Environment.

In the theme of **bioeconomy** (general theme II), the adaptation measures cost 58 million euros in the period of 2017-2030, of which 46% of costs should be spent before 2021 and 54% in 2021–2030. The biggest costs are related to investments (24 million euros), studies (around 17 million euros) and economic measures (13.5 million euros). Most of the adaptation measures belong to the jurisdiction of the Ministry of the Environment, forming about 77% of the cost in bioeconomy), but there is quite remarkable amount of measures also in the jurisdiction of the Ministry of Agriculture (around 10 million euros).

In total, the cost of adaptation measures worked out in BioClim project, is 103.2 million euros in the period 2017–2030, which is divided quite evenly between two general themes of natural environment and bioeconomy. 40% of the costs (41 million euros) should be spent already before 2021 and 62 million euros in the period 2021–2030.