COST FP0703 action – ECHOES

Expected Climate Change
and
Options for European Silviculture

COUNTRY REPORT

HUNGARY

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Content

Foreword

Hungary was not among the initial members of the COST action. Voluntary representatives from the Faculty of Forestry (University of West Hungary, Sopron) joined the Florence meeting and accepted the compiling of a country report. Very recently new representatives have been appointed from the Institute of Environment and Earth Sciences, where climate change impact research is concentrated, in the team of Prof. Csaba Mátyás.

Research and monitoring of climate change impacts on forest ecosystems are – as in other countries – carried out across numerous institutions and the adaptation and mitigation tasks are under the responsibility of the following bodies:

- Ministry of Agriculture and Rural Development, Dept. of Natural Resources: running of monitoring networks, forest inventories and data collection,
- Ministry of Environment: follow up of respective international agreements such as the Kyoto Protocol, developing National Strategies on adaptation and mitigation,
- Academy of Sciences: a presidential Committee on Climate Change is initiating cross-sectorial coordination of scientific and development activities in this field among research institutions, universities etc.

In the field of forestry, climate change impact research is mainly carried out by two institutions:

- **Faculty of Forestry** at the University of West Hungary (UWH), Sopron: most of the institutes are involved in various research activities, the Institute of Environment and Earth Sciences (IEES) being the main hub. The latter Institute is maintaining also a newly established **NEESPI Focus Center for Non-Boreal Eastern Europe**. This international center was created with the aim of climate impact assessment and mitigation in the whole continental southeast of Europe. It operates within the NEESPI framework (North Eurasian Earth Science Partnership), which has been initiated by the US agencies NASA and NOAA, as well as by the Academy of Science of Russia.
- The **Forest Research Institute** (ERTI) is mainly involved in carbon sequestration, growth studies, forest protection, ecologic and genetic research.

Other institutions involved in certain aspects of climate change and forest ecosystems research are the Ecological and Botanic Research Institute of the Academy of Science (ecology), and the University of Debrecen (physiology, ecology and carbon sequestration)

In addition, with the emerging awareness of climate impacts in forests, numerous state owned forest companies have started actions and support research activities.

In this report, some highlights of results and ongoing research activities are presented, with references to published results.

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Introduction: climatic and ecological challenges for continental SE Europe

Why does the whole of continental SE Europe need special attention?

Although issues of global change are in the focus of international research and politics, however mainstream research of well established networks, as well as European climate change policy consider the specific problems of continental Southeast Europe as low priority, marginal issues (EU White paper – 2009). It should be however taken into account that

- climatic forecasts for Southeast Europe show higher uncertainties, and processes are displaying trends different or even opposite to western or north European forecasts,
- There are extensive plains in the region which are situated in a broad climatic and ecological transition zone (ecotone) towards steppes and arid lands. The vulnerability of this region to climatic changes is high,
- the decline of vitality and stability of vegetation zones, especially forests, in this region may generate ecologically harmful processes (degradation, aridification, oxidation of organic carbon stored in ecosystems etc.),
- the region is densely populated, and plays an important role in food production and industry, at the same time the economical and social restructuring following the political transition has not reached a stabilization phase yet. These facts may enhance expected ecological and social consequences of changes considerably,
- most of the region has been under extensive land use for long historic periods, which renders potentially beneficial spontaneous processes of adaptation to changes dysfunctional. At the same time, this fact offers the possibility of applying planned, large-scale measures to support natural processes by human interference.

The above problems are common all over continental Southeast Europe, including Hungary. The whole region is experiencing a deep restructuring and transitory phase with partly negative social and economic changes (Mátyás 2009).

Changes in climate conditions in Hungary in the 20th century with respect to forest ecology

Annual precipitation sum decreased in the last 50 years in most part of Hungary. Significant decrease has occurred in the western part of the country (Figure 1). Temperatures have increased at the same time, but the trend is not uniform within the country. From point of view of forest ecosystems, the changes in the frequency of droughts are the most decisive for the stability, health and growth of forest tree populations and for the floristic, faunistic and genetic diversity of communities.

From among simple indices describing climate suitability for forest vegetation, Ellenberg’s climate quotient (EQ) is one of the most illustrative. For Hungary, the EQ value was calculated for climates at the beginning and the end of the 20th century. Value 24 of EQ represents the long-term optimum limit for beech in Central Europe (higher values are unfavourable). Figure 2 shows a remarkable shift which hits first of all the climatically more favourable Southwest of the country.

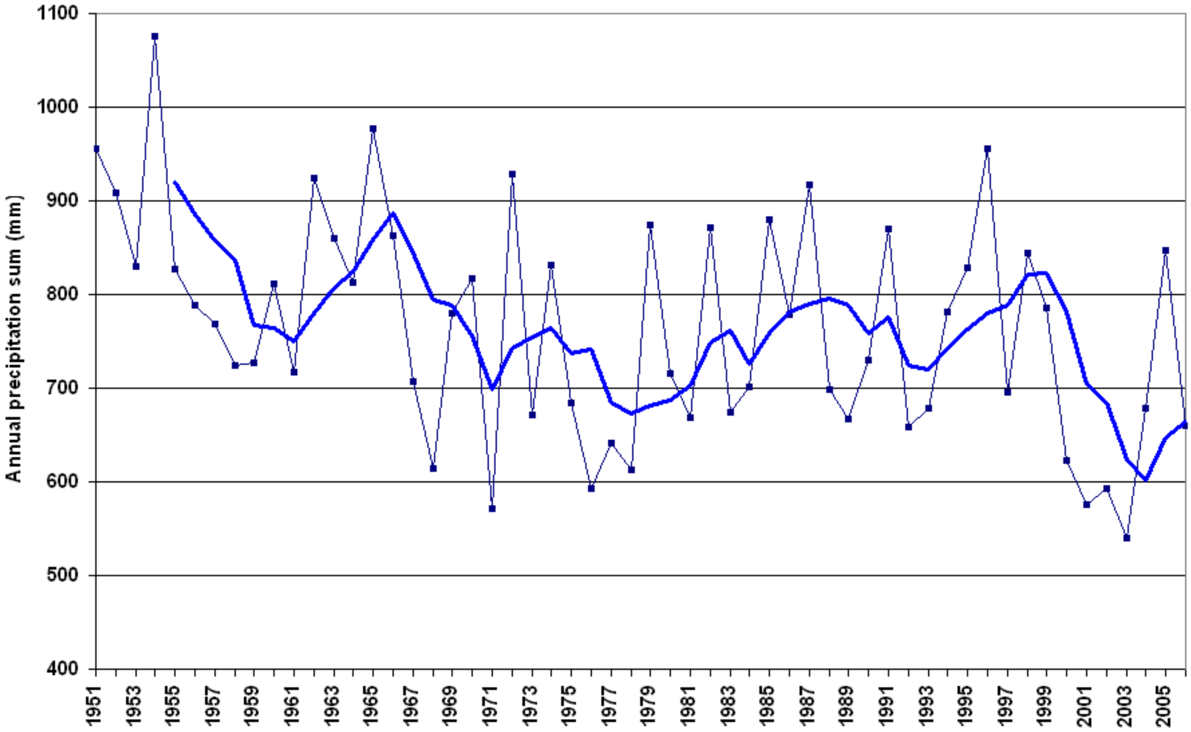

Figure 1. Annual precipitation sum at Szentgotthárd (West Hungary) from 1951 to 2006 (Source: Hungarian Meteorological Service)

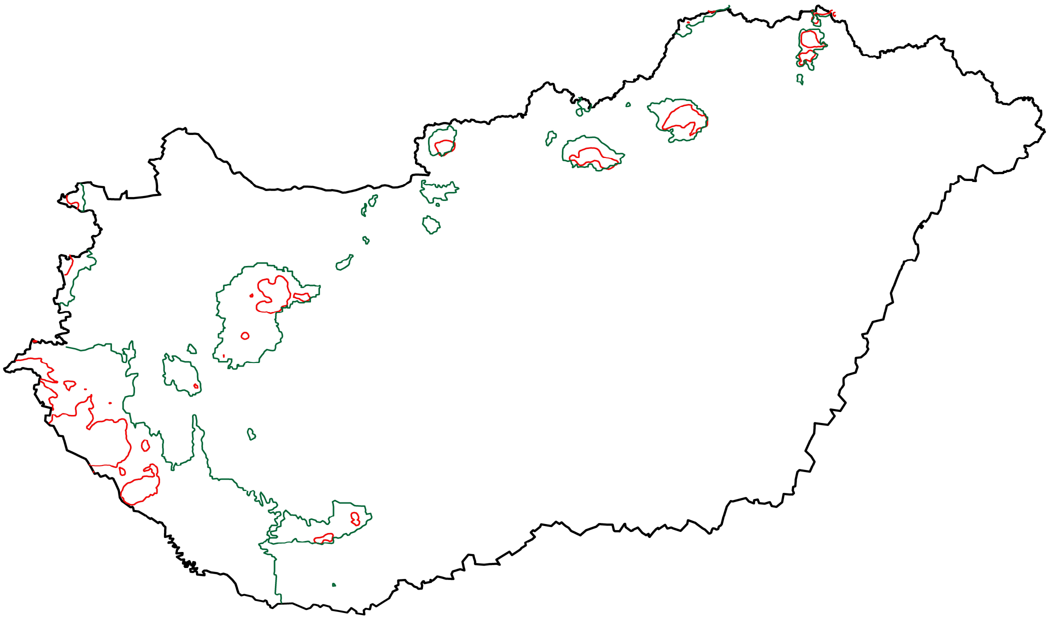

Figure 2. Change of climate favourable for beech in course of a century: shift of contour line 24 of Ellenberg's climate quotient (= long-term minimum for beech) for Hungary, in the average of the years 1901-1930 (green) and 1975-2004 (red) (design: Rasztovits, Móricz, 2009)

I. Impacts

I.1 Observed impacts

Forest damage trends

The recent decades have shown an increasing tendency of both biotic and abiotic damages. (Source: National Forest Service, Figures 3 to 7)

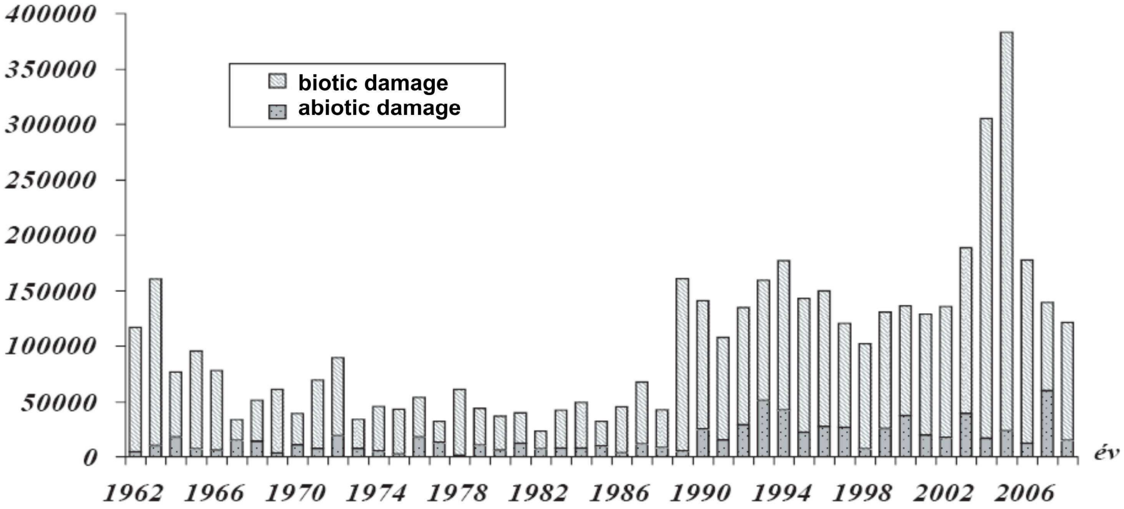

Figure 3. Reported biotic and abiotic damages (in hectares) in Hungary between 1962 and 2008

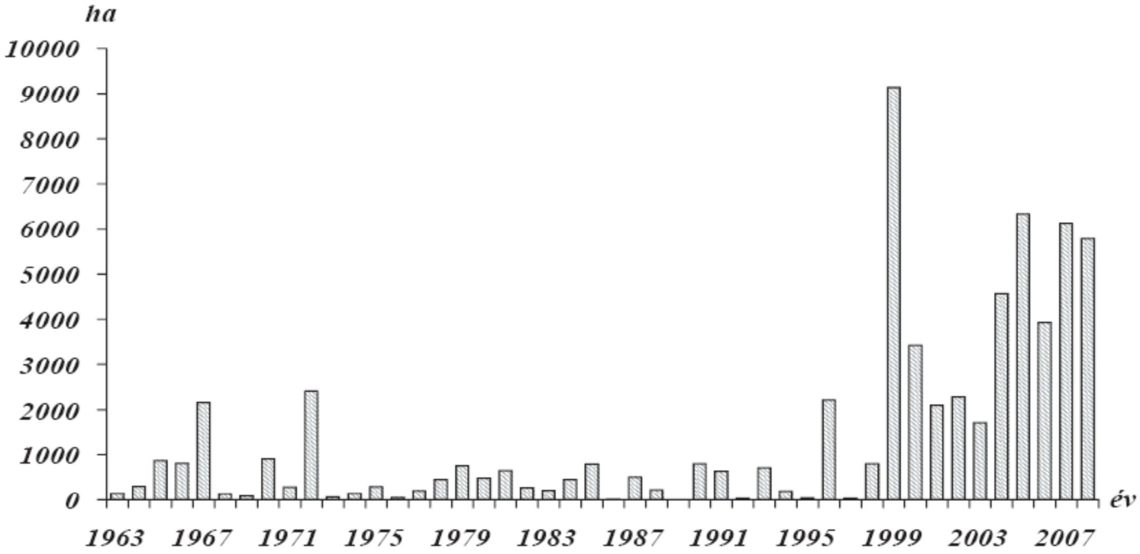

Figure 4. Reported damage (in hectares) caused by windfall and windbreak in Hungary between 1963 and 2008

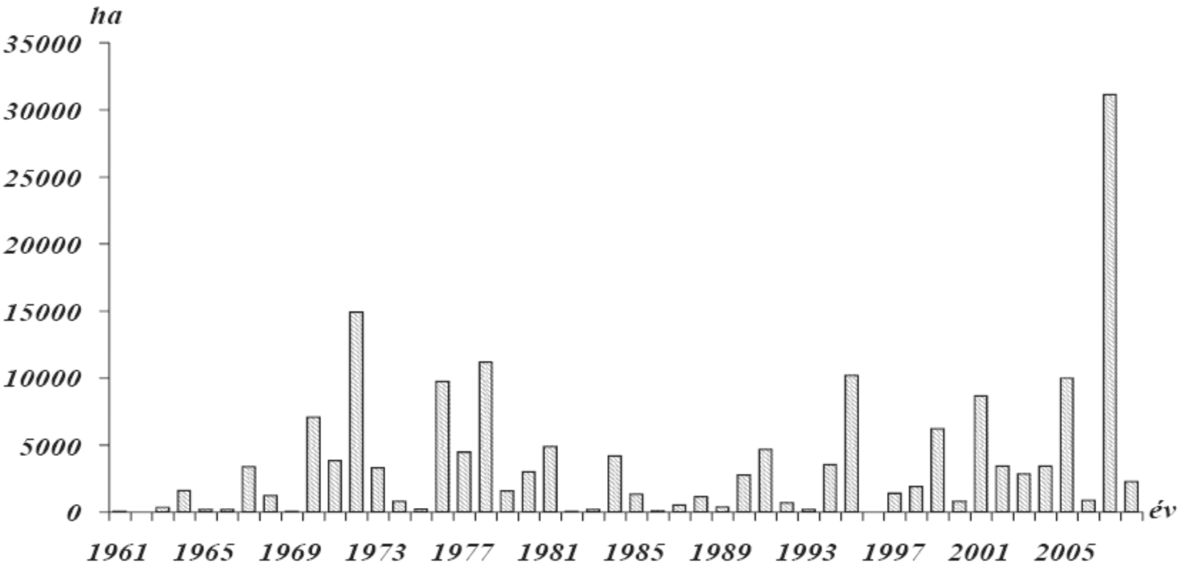

Figure 5. Reported damage (in hectares) caused by spring frost in Hungary between 1961 and 2008

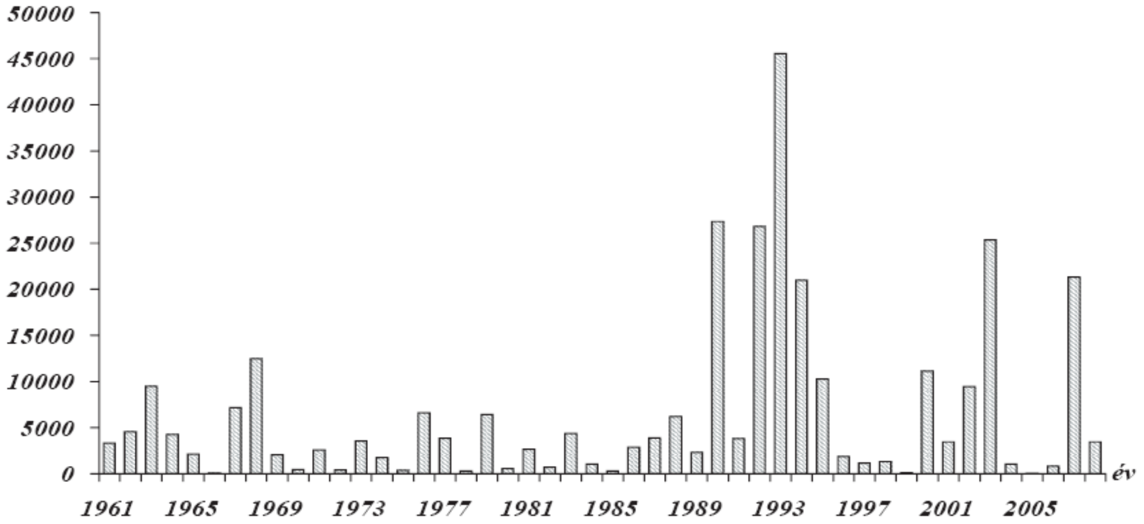

Figure 6. Reported drought damage (in hectares) in Hungary between 1961 and 2008

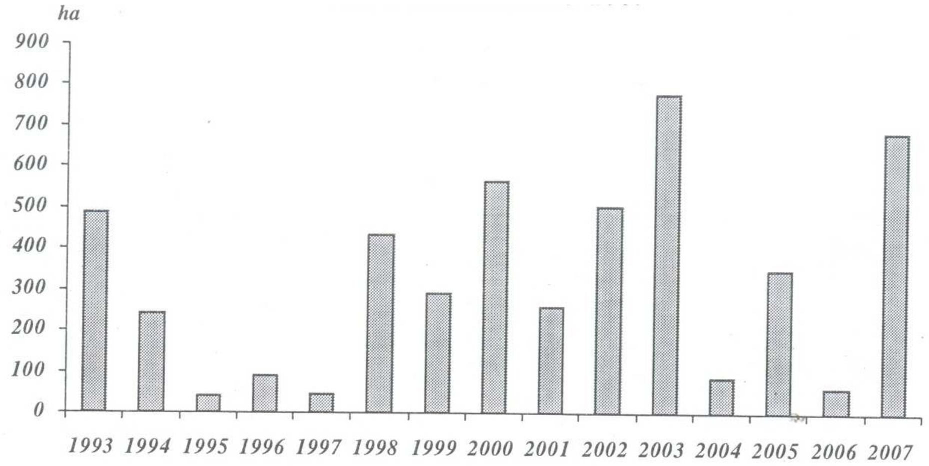

Figure 7. Reported fire damage (in hectares) in Hungary between 1993 and 2007

Drought and health decline

Drought has a major influence on health conditions on sessile oak and beech stands in Hungary. A single drought year does not have dramatic effects in sessile oak stands, but after 2-3 consecutive drought years the health status of trees show already obvious negative trends. The symptoms become apparent often only with 1-3 years delay.

In beech stands (particularly in the South-Transdanubian region) already one drought year can cause significant deterioration.

Very likely more frequent and more severe insect outbreaks will occur if the frequency and severity of droughty years will increase in the future. Either new or "forgotten" insect species can become more important. Outbreaks of some well known species will likely spread vertically, heavily influencing forest types not damaged earlier (i.e. gypsy moth in beech stands at higher altitudes). (Csóka et al, 2007).

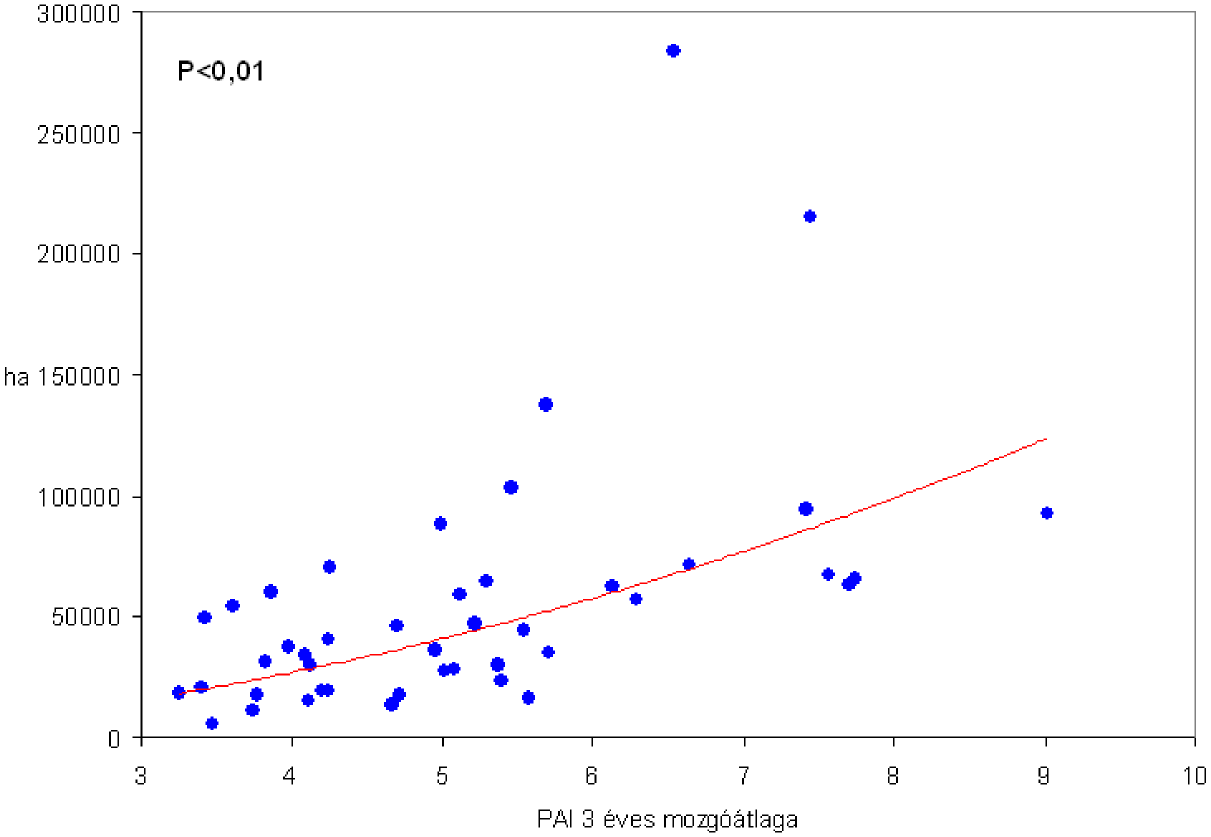

Figure 8. Correlation between 3 year moving averages of Pálfai's drought index (PAI) and the total insect damage in forests in hectares (Csóka et al. 2007)

Diseases and pests leading to mass mortality

Out of the manifold impacts observed in the past, the oak wilt syndrome of the 1970s and 80s has to be highlighted. Originally identified as a disease caused by fungi earlier mainly saprophytic, and turning now virulent, it was later admitted that the primary reason triggering the pandemy was climatic. The total extent and damage of the dieback hitting sessile oak stands in the Northern Mountain Range and in Transdanubia may be assessed to damaging ca. 35% of all stands above the age of 40 years, amounting to a total damage of 2.5 million cu. m. (the total annual cut being 7 million cu. m.).

Basic trends in insect community changes are (with typical examples, Csoka et al, pers. comm.):

1. Species expanding area to North: *Gravitarmata margarotana, Eurytoma amygdale;*
2. Successful overwintering of naturally migrating termophilous species *Helicoverpa armigera;*
3. Successful establishment and spread of accidentally introduced species: *Obolodiplosis robiniae, Dryocosmus kurriphilus;*
4. Increasing damage trends: *Euproctis chrysorrhoea, Thaumetopoea processionea, Lymantria dispar;*
5. „New” pests (known species turning dangerous): *Agrilus viridis, Chrysomela cuprea;*
6. Changing phenology: a few Macrolepidoptera
7. Changing of hosts (see below)

As typical examples for **mass mortality following climatic extremes**, beech (*Fagus silvatica*) and Norway spruce (*Picea abies*) should be mentioned.

The mass mortality of beech in Hungary is the result of a typical damage-chain. The symptoms appear first on marginal sites, isolated stand margins and in opened-up stands. In mass mortality events observed in West Hungary, both insect species, such as the green jewel beetle (*Agrilus viridis*) or the beech bark beetle (*Taphrorychus bicolor*) and also some fungi (e.g. *Biscogniauxia nummularia*) play an important role. Further pest and pathogen species causing damages on beech are expected (Molnár & Lakatos 2008, Czucz, Galhidy, Mátyás 2009).

Mass mortality of Norway spruce (man-made) stands started in the early ’90s. The hot and dry summers, the decrease on winter precipitation were favourable for the main pests (bark beetles), which had up to three generations per year. The outbreak of *Ips typographus* and *Pityogenes chalcographus* resulted in a strong decrease of this tree species (1990: 1.4%, 2008: 0.7%) and a high volume of sanitary cuttings (approx. 800.000 cu. m. 1990-2008). Bark beetles (especially *Ips typographus*) attacked not only their main host (*Picea abies*), but also many other coniferous species of the genera *Picea, Pinus, Larix, Abies, Pseudotsuga* or even *Taxodium* and *Thujopsis* (Lakatos 2006, Lakatos & Kovács 2006).

Growth and increment

The climate change and the tree growth addresses two related issues. One is whether, and how, growth patterns of stand mean height have changed in Hungary in the last few decades, the other is whether this change could be attributed to increases in mean annual temperature. Changes in tree growth were investigated for beech (*Fagus silvatica*), sessile oak (*Quercus petraea*) and Turkey oak (*Quercus cerris*) by comparing stand mean height over age using data from the forest inventories of 1981 and 2001. Tree growth was found to have accelerated for each species, with Turkey oak showing the largest acceleration. In another analysis, stand mean height was related to elevation. Stand mean height was found to increase with decreasing elevation, i.e. with increasing mean annual temperature for each of the three species (Somogyi 2007). General inventory data therefore do not detect growth decline yet. However, for sessile oak stand mean height data since 1961 were analysed from permanent yield plots. There results show already a decrease in height in higher age classes (Figure 9).

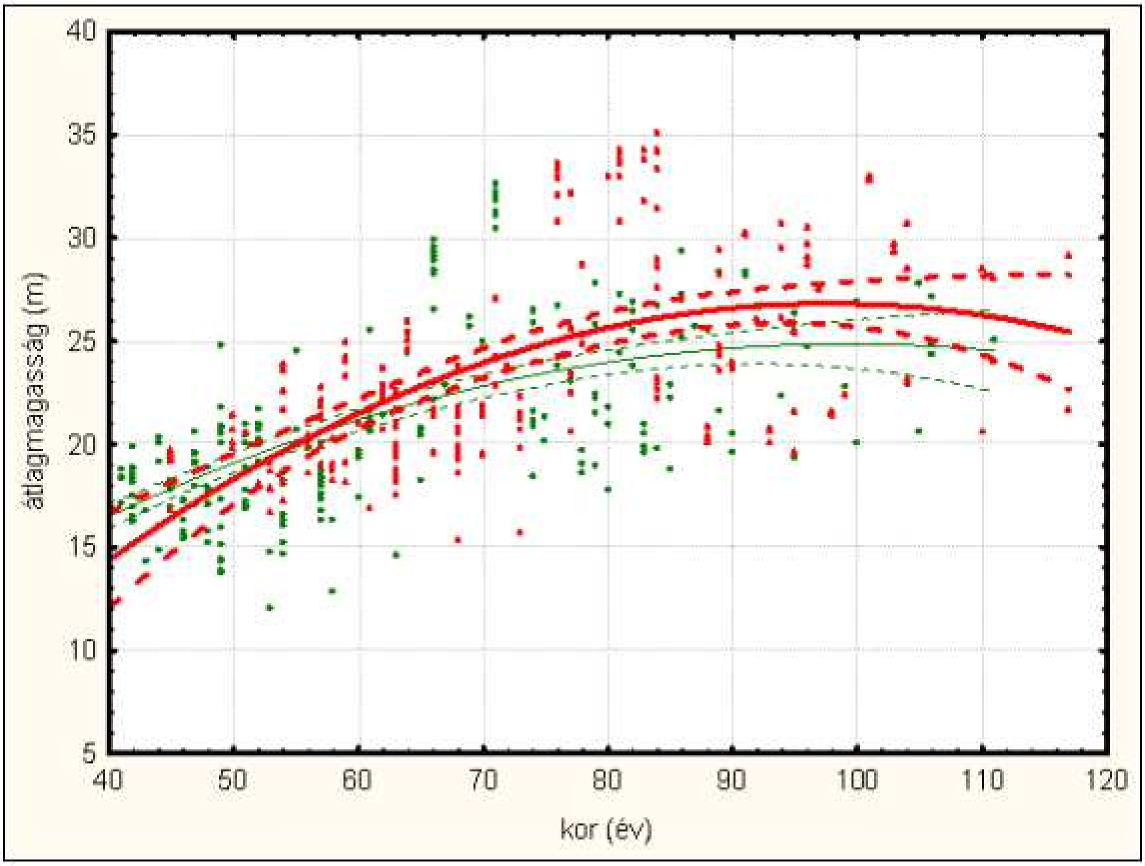

Figure 9. Mean height of sessile oak over age before 1990 (red, thick continuous line) and after 1990 (green, thin continuous line), together with confidence bands of 95% probability (dashed lines) (data of permanent yield plots, from Somogyi 2007).

Due to the multiple uncertainties in yield studies, simulation of growth trends are also evaluated in common garden experiments of tree geneticists. Such analyses are under way for beech (Mátyás 2009), and have been completed for Scots pine and also for spruce (Mátyás, Nagy, Ujváriné 2008). An example is presented for Scots pine (Figure 10).

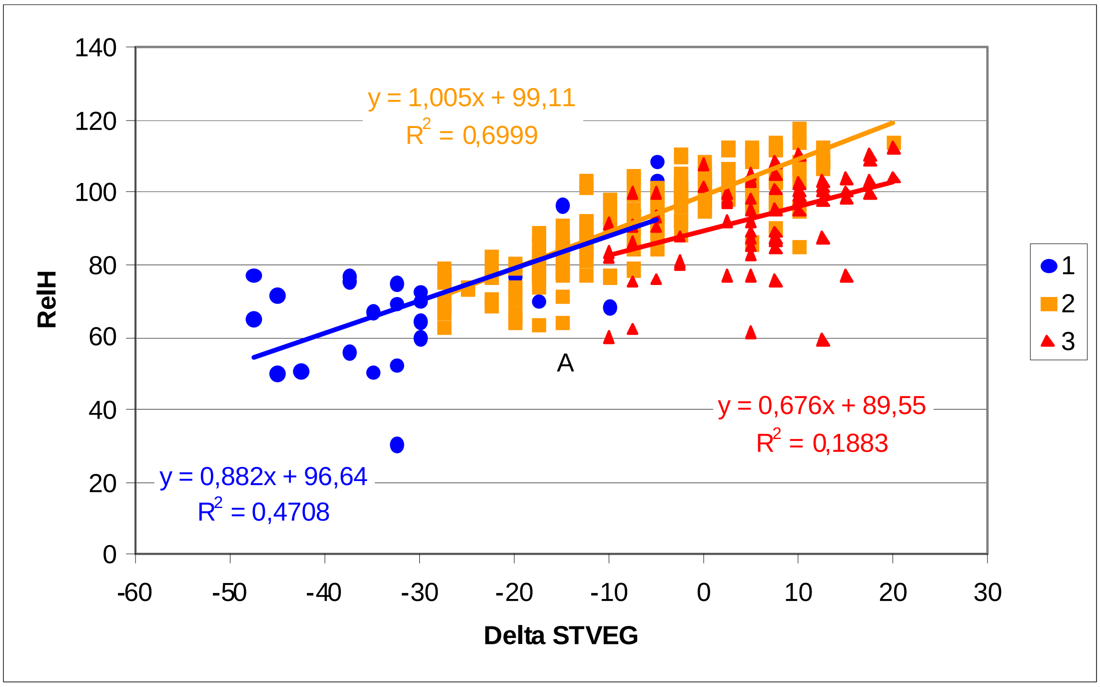

Figure 10. Linear regressions relative height vs. calculated change of temperature sum in common garden tests (delta STVEG) by groups of provenances (1: northern, 2: central, 3: southern group). It is visible that height growth performance declines with increasing temperatures (negative figures, to the left) in all investigated provenance groups (graph from Mátyás, Nagy, Ujváriné 2008)

Common garden data show the remarkable width of adaptability to even dramatic changes in thermal conditions, photoperiod and, to a less extent, in moisture supply. The results indicate, that *the responses of populations in different parts of the distributional range are divergent*, as different climatic factors exert their selection pressure. Accordingly, *the reaction of indigenous populations to changing conditions will be different* by climatic zones. In the northern-boreal zone, expected rise of temperature will lead to marked growth acceleration without any significant genetic change. In the temperate-maritime zone, growth will accelerate too, along with higher temperatures and increasing or at least unchanged rainfall.

In the temperate-continental zone however, even relatively minor temperature increases, coupled with growing drought stress, will trigger loss of compatibility, higher susceptibility to diseases and increase of mortality – a selection of tolerant individuals. In semiarid climates at the lower forest limit mass mortality may lead to local extinctions and shift of distribution area northward, or upward in altitude.

In drought stress climates increment loss and higher frequency of diseases and pests will challenge the economy of forest operations and will put emphasis on maintenance of ecological functions and conservation of stability and of genetic resources (Mátyás, Nagy, Ujváriné 2008).

Succession

Species-dependent responses to climatic extremes trigger changes in both structure and composition of forest stands, i.e. succession (or rather degradation) is ongoing. This effect is often compensated by human (silvicultural) intervention and can be properly observed in undisturbed reserves only (Figure 11).

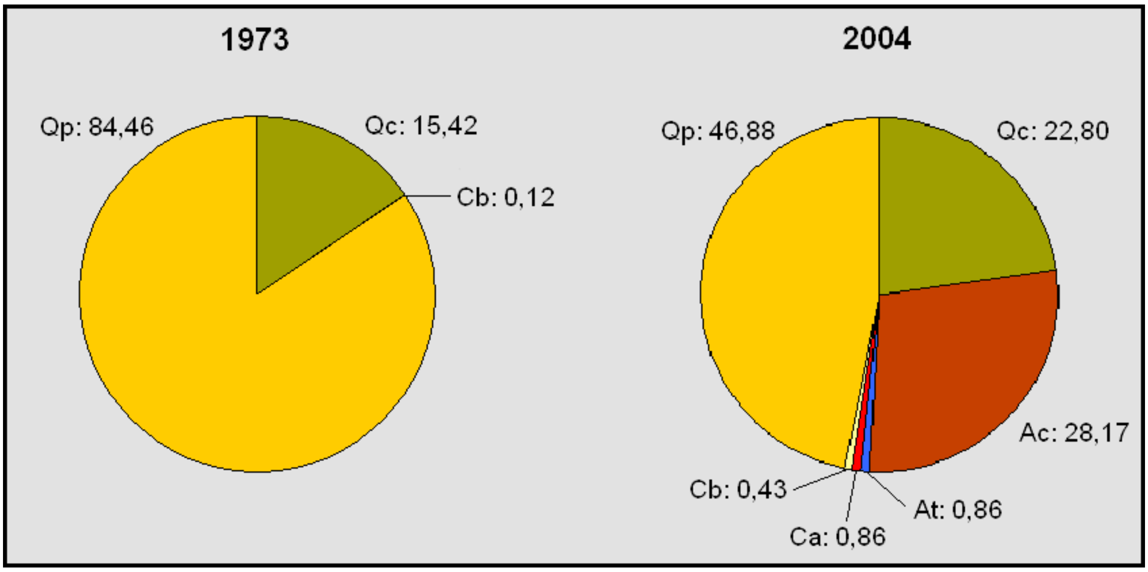

Figure 11. Effect of severity of climatic change on the species composition in the MAB reserve Síkfőkút, a Turkey and sessile oak mixed forest, indicating ongoing succession (Kotroczó et al. 2007)
Qp = Quercus petraea, Qc = Quercus cerris, Ac = Acer campestre,
At = Acer tataricum, Ca = Cerasus avium, Cb = Carpinus betulus

Water cycle

During the last century groundwater levels have been sinking significantly in the lowland of Hungary. Groundwater sinking has begun in the early 70s in the central part of the Hungarian Lowland. Main reason for the decreasing groundwater levels were the accumulating precipitation shortage, that reaches up to 1000mm until 1995. In the region of the central Great Plains groundwater level decreased almost six meters by the middle of the 90s (Figure 12). Groundwater levels have not recovered significantly since, in spite of longer rainy periods.

Figure 12. Groundwater level sinking in the central Great Plains (at Ladánybene) from 1951 to 2006 (Source: Szalai, 2006)

I.2 Expected impacts

Tolerance is the main trait at the xeric (aridity) limits

The presence of closed forests at the xeric limits are determined by the tolerance capacity of the dominant species (oaks and towards the East, also Scots pine). It is visible in Table 1 that *even the mildest expected scenario of climate change is similar in magnitude to a whole vegetation zone difference*; the temperature and precipitation change might trigger a complete destabilisation or shift of zones (Mátyás, Czimber 2000).

Table 1. Average temperature and precipitation data of zonal forest belts in the lowlands of the Carpathian Basin and the magnitude of expected changes (Mátyás, Czimber 2000)

	Annual precipitation (mm)	July temperature (^{o}C)
Beech zone	734 ± 65.2	19.1 ± 0.95
Hornbeam-oak zone	702 ± 70.3	20.0 ± 0.79
Turkey- sessile oak zone	616 ± 49.0	20.2 ± 0.70
Forest steppe zone	563 ± 49.0	21.5 ± 0.56
Average difference between zones	57	0.80
Expected mildest change scenario in the region (HADCM3 A1B)	±0	+1.8

Any prediction about the effects of future scenarios on stability and yield of low-elevation forests in this region requires information on the tolerance and adaptability of tree species involved.

Main studies on future impacts

Research projects on national level have been initiated already in 2001 to make projections about expected damages. Since then, support for financing such forest research has been increasing and the circle of partners has been steadily increasing. Beside national research projects on forests and climate change, a cooperative platform “Forests and Climate” is existing since 1996 in which universities, research organisations dealing with forest ecology and climatology exchange results (with a triennial publication).

There are both bilateral (Interreg) and multilateral projects on European level where Hungary is participating in assessing future impacts (EUROBEECH, COST 52, EVOLTREE).

Due to the peculiar situation of Hungary and based on antecedent research, the main focus of studies is concentrated in the following fields:

- Expected frequency and severity of extreme events (primarily droughts)
- Limits of tolerance and preconditions of mortality
- Genetic adaptation and its limitations
- Future of damages caused by pests and diseases

Extreme events

At the end of the 21st century summer mean temperature shows a strong increase based on the simulation results of the regional climate model REMO for the IPCC SRES emission scenarios B1, A1B, A2 (Gálos et al. 2007). For 2071-2100, the Gauss-curves representing the temperature distribution are flatter and wider than in the period 1961-90 (Figure 13). This means that not only the temperature means but also the probability of extreme warm events could be significantly higher. High temperatures intensify the impact of extreme dry conditions, which are also predicted to be more frequent in the future.

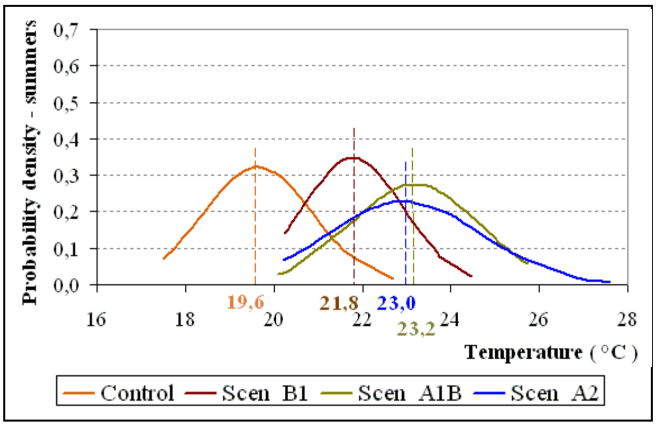

Figure 13. Probability distributions of summer mean temperatures in Hungary for the period 1961-90 (control) and for 2071-2100 (scenarios) (Gálos et al. 2007)

Declining vitality and mortality

This is the thematic area where research in Hungary is concentrated. The species with highest priority is beech, being the most sensitive to climatic extremes. The total area of the reported beech decline was 66 hectares in 2008.

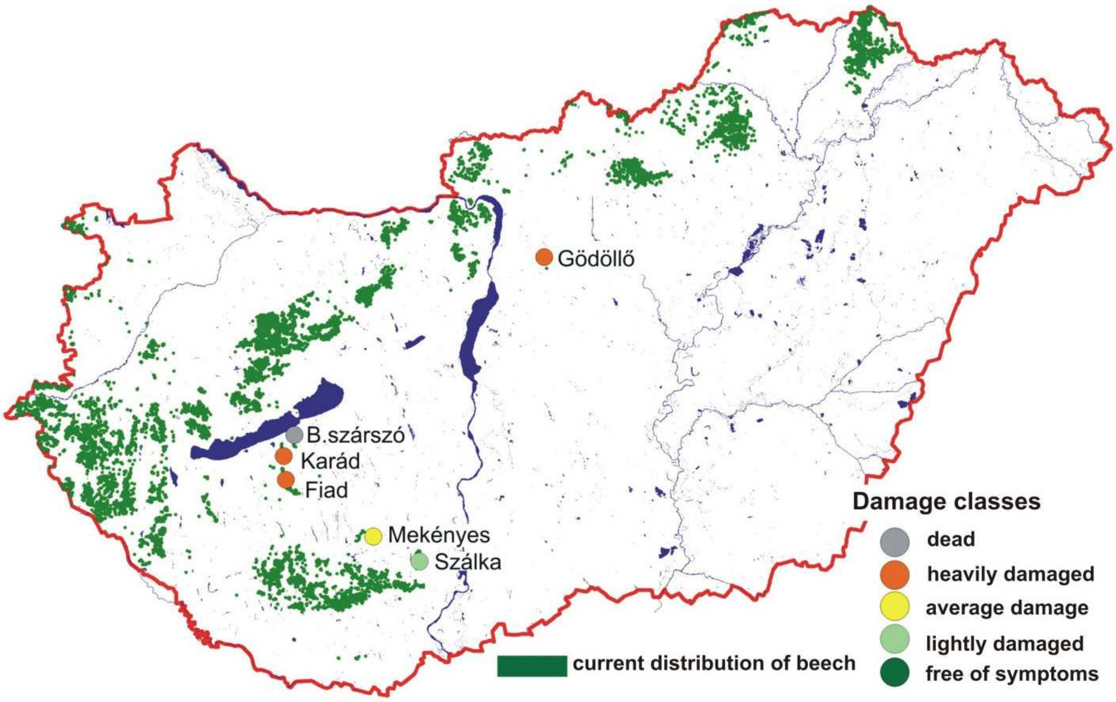

Figure 14. Beech decline observation points with the observed damage classes in 2005 (Berki et al. 2007)

Beech decline was reported from 129 hectares in 2002, 805 hectares in 2003 and 2860 hectares in 2004. Due to the rainy weather during summers of 2005 and 2006 the affected are decreased (833 hectares in 2005 and 193 hectares in 2006). (Hirka et al. 2008)

Genetic diversity change

Studies on beech and oak have found that extreme events strongly affect genetic diversity of forest stands. With increasing exposure, selection pressure increases and both allele numbers and heterozygosity decrease. The effect naturally depends on the gene site: the more important the site is for adaptation, the stronger the purifying selection (Figure 15). This phenomenon has to be taken into consideration in the future for reproductive material use as well as for gene conservation programs.

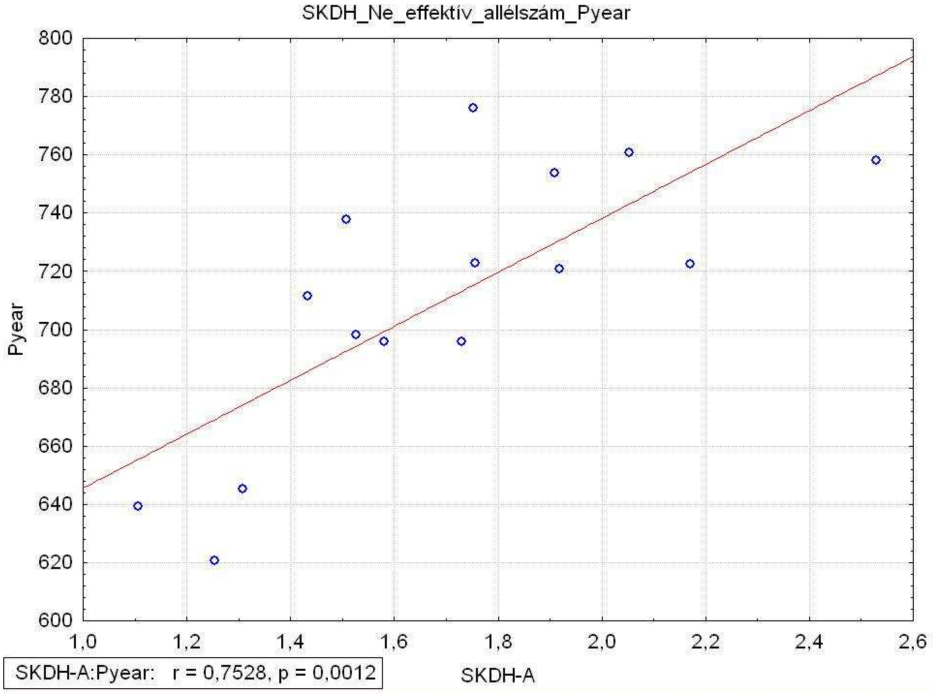

Figure 15. Selection effect of aridity on genetic diversity of sessile oak populations: annual precipitation vs. effective allelic number at gene locus SKDH-A (data by A. Borovics, 2009)

Carbon sequestration and climate change

The forestry aridity index (FAI) shows a causal relationship with the average yearly organic matter production (Führer 2007). (The smaller is the value of the FAI, the cooler and rainier is the climate.) The calculated FAI values show strong correlation with the carbon sequestration of the forest stand. The results may be utilised for forecasting productivity changes according to various scenarios. It is visible that carbon sequestration is declining with increasing aridity (Figure 16).

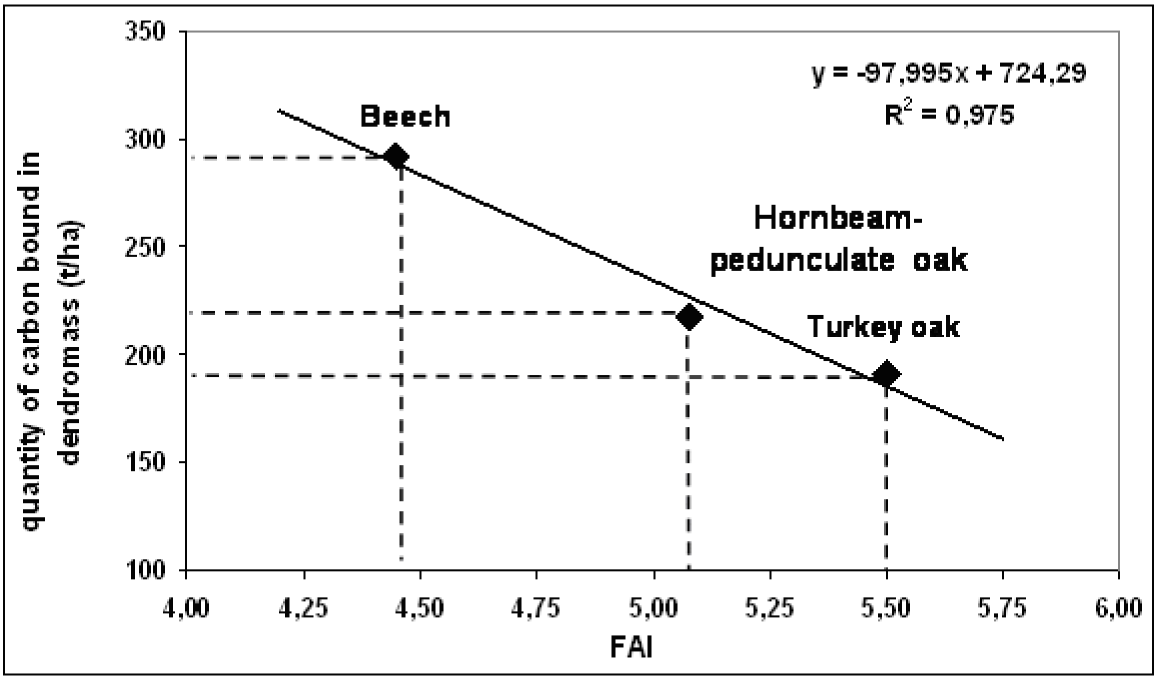

Figure 16. Correlation between aridity index (FAI) and the carbon stock stored in the dendromass of examined zonal forest types on optimal sites (Führer, 2009)

I.3 Impact monitoring

Additional monitoring networks and sample plots

In addition to level 1 and 2 of the European health monitoring, a growth and increment observation net (FNM) was attached to the 4 by 4 km grid in geometrically separated arrangement, where growth data have been measured since 1996 by the national forest inventory. The dendrometric data are taken in similar system on sample trees within a limited radius to minimise workload.

A drawback of the system is the missing reference to unit area. Therefore the comparability of this “FNM” network to general inventory data and to general trends is limited.

Especially regarding climate change effect monitoring, the grid system proved to be less informative in spite of relatively high density of points. It is the high site variability and a range of not excluded background noises which makes the network only limitedly useful for these studies. A more directed, although much more limited selection of larger plots for permanent observation will be methodically better.

Accordingly, such plots have been selected, including some ecological/climatological research sites where measurements are taken for a longer period already (e.g. MAB site Síkfőkút, ecological bases at Nyirjes, K-puszta, Sopron Hidegvíz valley, etc.).

New requirements for the monitoring network

Based on the above said, no additional requirements are raised for the health monitoring net.

Indicators presently used for climate change effect assessment

Growth and increment, health status, phenology, genetic diversity, species composition of dendroflora, insect community change.

I.4.Impact management

Detection of insect community change and pest/disease outbreaks, abiotic damages

A monitoring system for abiotic and biotic damages in forests is maintained in Hungary since 1960. It is operated on voluntary basis by the state forest companies' management units (forest districts). No specific forest fire reporting service is operated up to now.
In addition, a light trap system collects insect presence and density data since 1966 at 24 points across the country (Figure 17).

Figure 17. Locations of the Hungarian Forest Light Trap Network in 2008.

Monitoring of hydrological changes and of erosion

A system of groundwater wells is operated by the State Hydrological Service, the results of which are evaluated by forest experts as well. Specific forest hydrology and erosion monitoring bases are maintained by the Forest Research Institute and the Dept. of Geomatics at the Faculty of Forestry in Sopron. The national groundwater well network is shown in the Figure 18.

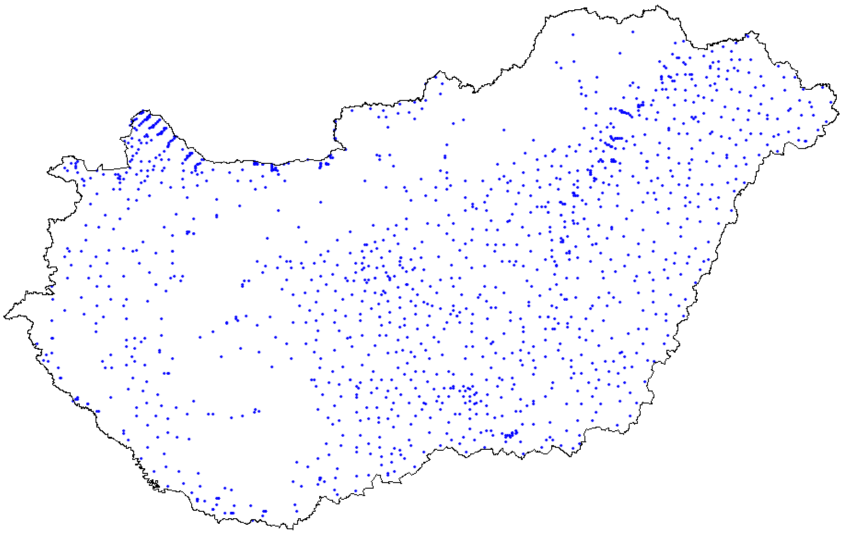

Figure 18. The national groundwater well network (Source: VITUKI)

Main foci of crisis management

As already mentioned in section 1.2., the main topics to be considered – due to the peculiar situation of Hungary – are the followings:

- Response to the expected change of frequency and severity of extreme events (primarily droughts);
- Monitoring the appearance of mortality and formulating pragmatic and locally applicable approaches;
- Appropriate strategies of dealing with locally developing damages caused by pests and diseases.

II. Adaptation

II.1. Vulnerability assessment

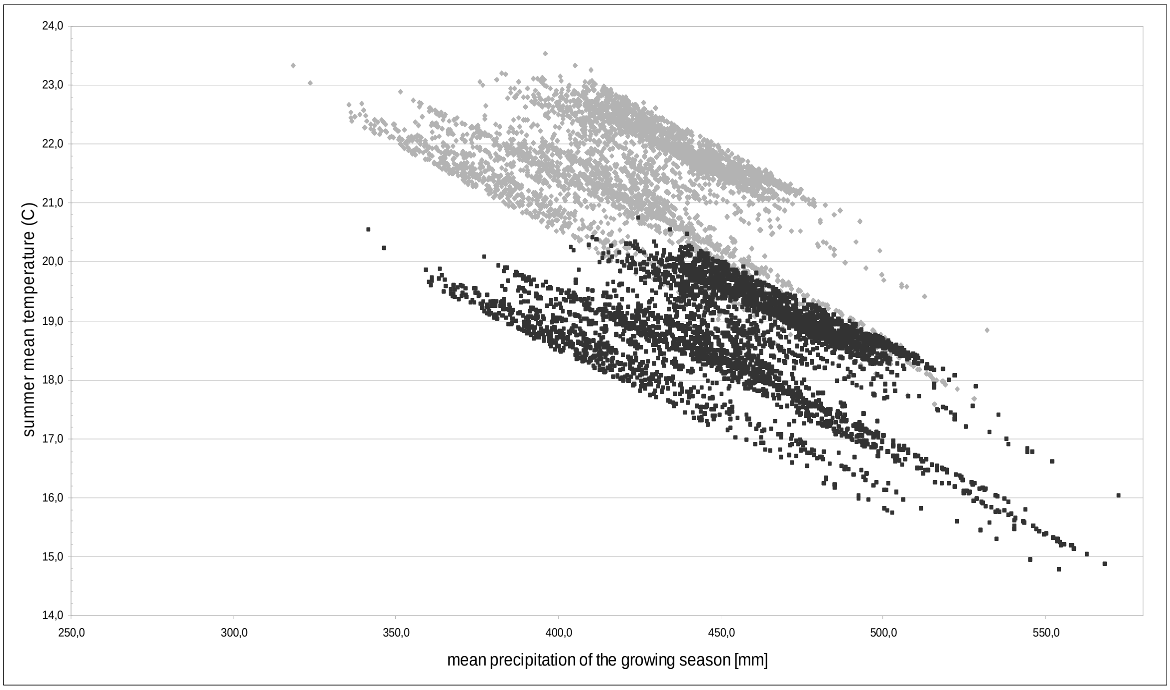

Figure 19. Climate parameters (mean precipitation of the growing season vs. mean summer temperature) of actual beech occurrences in Hungary (black) and parameters calculated with the Prudence climate model for 2050 (grey) (data by E. Rasztovics)

Contrary to general belief, the trend of raising temperatures and declining summer rainfall will not result in a mediterranisation in Hungary and the whole continental Southeast Europe because – compared to Mediterranean Europe - the regulating effect of the sea is weak and the predicted climate anomalies will be presumably stronger than the general trends calculated from hemispheric models. Even a relatively minor shift of temperature and precipitation parameters will affect profoundly the available climatic niche of dominant zonal species such as European beech (Fagus sylvatica), a climate-sensitive species. In Figure 19, the consequence of the predicted shift of the sensitive parameters summer heat and growing season rainfall is shown for Hungary: until the mid of the present century the climatic niche for the cultivation of the species will be reduced essentially[1].

Frequency changes of drought events have been analysed for the territory of Hungary using the REMO climate model of the Max Planck Institute of Meteorology (MPI), Hamburg (Gálos et al. 2008). The predicted frequency of drought years (precipitation decline exceeding 5% of the periodic mean) and of drought summers (precipitation decline exceeding 15% of the seasonal mean) are shown in Table 2. The anomalies are averages calculated for the territory of Hungary, related to the 1961–1990 period. The model indicates no frequency increases of drought events for the scenario A2, in the first half of the 21st century. Still, the temperatures will rise and precipitation decline will continuously progress. The average

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[1] Similar climatic shifts are proposed for Central and Northwest Europe as well. The difference lies in the fact that in Southeast Europe the lower end of the present distribution is identic with the distributional limit. At the xeric limit of closed forests, there is no natural tree species taking spontaneously the place of the ones retracting from their lost habitats

precipitation loss of drought summers may reach 30% (related to the predicted averages). It has to be pointed out that the data refer to average anomalies, and single drought events may be much more severe. It is highly remarkable in Table 2 that from 2050 onward, the REMO model defines every second summer as drought event: 24 summers out of 50 years (Mátyás et al. 2008, Gálos et al. 2008).

Table 2. Frequency of recent and predicted drought events for Hungary, according to scenario A2, calculated with MPI's REMO climate model (Gálos in: Mátyás et al. 2008)

Period	**Drought years**		
	number of years	mean of precipitation anomalies (%)	mean of temperature anomalies (○C)
1951–2000	17	–12.42	+0.39
2001–2050	9	–16.52	+1.24
2051–2100	21	–19.07	+3.75
	Drought summers		
	number of years	mean of precipitation anomalies (%)	mean of temperature anomalies (○C)
1951–2000	15	–28.02	+0.95
2001–2050	9	–29.21	+2.00
2051–2100	24	–34.98	+2.86

Critical in the zone of closed forest limit toward the woodlands/steppe region are the factors influenced by the terrestrial vegetation cover: surface albedo, carbon emission and sequestration, evapotranspiration, and the effect of changing hydrology. Land use change, afforestation, changes in forest policy (tree species preference change) also contribute to the changes in climate forcing.

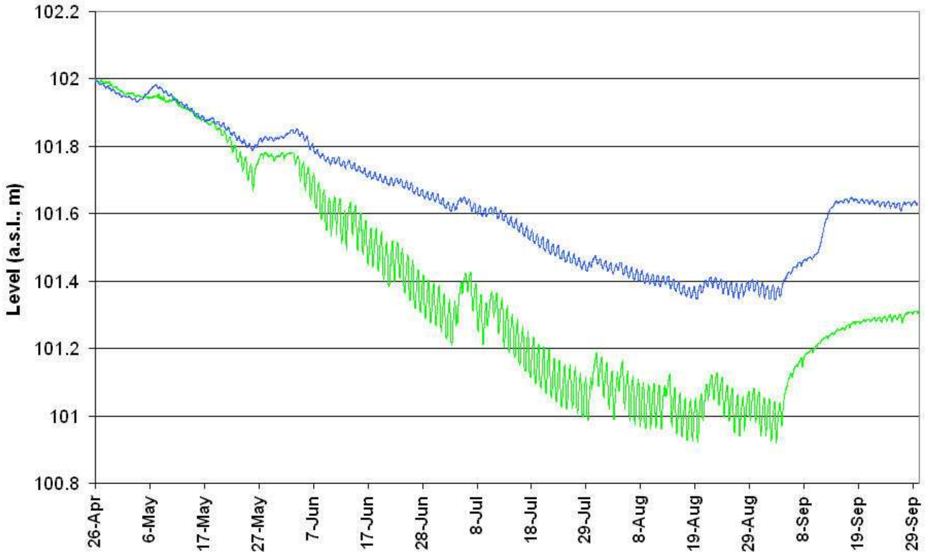


Figure 20. Pulse of the forest: daily soil water-table fluctuation due to evapotranspiration under a pedunculate oak (*Quercus robur*) forest stand (green) compared to a neighbouring agricultural fallow (blue) in East Hungary. At the experimental site (mean annual *P* = 505 mm, mean annual *T* = 9.7 °C), the difference in water table level under the forest, due to higher transpiration rate, was 320 mm at the end of the summer season, which amounts to 63% of the mean annual precipitation (data of summer 2007, collected by N. Móricz)

At the xeric limits, precipitation is the ecological factor at minimum. On the Hungarian Great Plain, the amount of additional transpiration of the forest cover (vs. grass vegetation) in the growing period may surpass 60 % of the mean annual rainfall, compared to agricultural surfaces (Figure 20). In certain areas, this gap may be partially substituted by lateral seeping of groundwater.

Vulnerabilty of main climate-dependent forest types has been investigated by modelling climate envelopes and by investigating the factors determining specifically the xeric (lower) limit of distribution (Table 3). All analyses support a drastic shift of present ranges.

Climate models predict for the country an area increase of forest steppe climate by more than 50% by the end of the century, which implies that open woodlands could potentially replace a significant part of present-day closed forests (Mátyás et al. 2008). Table 3 presents data for the two most important zonal species for 2050. The predicting power of these assessments has to be taken, however, with critics as neither the inherent uncertainty in climatic predictions, nor the constraints in climate stress response (see Czucz, Gálhidy, Mátyás 2009, Jump, Mátyás, Penuelas 2009) are taken into consideration: the climate niche shift may not necessarily lead to the total retraction of present ecosystems of the respective habitats (Jump et al. 2009).

Table 3. Expected changes of climatic conditions by 2050 and estimated area loss of present zonal beech (Δbeech) and sessile oak (Δsessile oak) ranges in Hungary - changes in summer/winter temperature (ΔTs/ΔTw, °C) and precipitation (ΔPs/ΔPw) according to 3 climate scenarios (data from Czucz, Galhidy, Mátyás 2009, analysis based on xeric limit determinants)

	HADCM3 A1B	**HADCM3 B1**	**CSMK3 A2**
ΔTs	**+ 3.3**	**+ 2.6**	**+ 1.8**
ΔTw	**+ 2.6**	**+ 2.3**	**+ 1.5**
ΔPs	**-10.9%**	**-12.4%**	**+ 0.4%**
ΔPw	**+ 9.4%**	**+ 3.5%**	**- 3.3%**
Δbeech	**94-99 %**	**97-99 %**	**56-96 %**
Δsessile oak	**97-100 %**	**90-100 %**	**82-96 %**

II.2. General adaptation strategy

General strategies

A *National Strategy for Climate Change* covering all sectors has been elaborated by the Ministry of Environment in 2008. This strategy paper covers also forestry issues.

In general it may be stated that the topics regarding agriculture and especially forestry play on national level a similarly subordinate role as on European level (EU White paper 2009). Strategic considerations are dominated by a generally urban/technocrat approach to adaptation and mitigation. A more balanced approach is characterising the initiative of the Academy of Sciences ("VAHAVA" report and followup). It needs further rising of awareness to get the concept accepted that the fate of biological systems has to be one of the central issues in adaptation strategies.

II.3. Forest adaptation measures

Policy level

The *National Agricultural Program* was accepted in 1997. This program declared that large scale afforestation should be continued in Hungary to reach 27% forest cover. In forestry, long-term strategies have been formulated in the *National Forestry Program* (2006). It is symptomatic that in the program climate change adaptation has not been thematically considered.

A new forest law entered into force at 1st, July, 2009 as XXXVII. Act of 2009, on forests, forest protection and forest management. In the new act there are signs of awareness of global warming: first function of the forest is considered to be the mitigation of climatic changes.

General list of adaptation measures in forestry

The list contains answers of the Ministry of Agriculture to the survey of EU 27 Member states to promote adaptation to climate change in forestry. It has been coordinated by the DG Agriculture and published as „Impacts of Climate Change on European Forests and Options for Adaptation AGRI-2007-G4-06", Report to the European Commission (EU Directorate-General for Agriculture and Rural Development, 2009).

Symbols: **O**: on-going measure
S: planned measure in short term
L: planned measure in long term
N: new idea

1. Regeneration, afforestation, nurseries and tree breeding

O Increased application of natural regeneration
O Increased application of selective cutting (only rarely used method in the past 50 years)
O More careful planning of stand conversions (change non native forest types to natural forest types)
O More careful selection of main species of regeneration during management planning considering possible local effects of climate change
L Decrease the number of seedlings in plantation forests

L Sowing could be more frequently used in artificial regenerations

L During the obligatory planning process not only site conditions also possible effects of climate change should be considered (more reliable weather scenarios and forestry guidelines on regional level are needed)

N Preference of native species against non native species in the subsidy system is reasonable, however possible effects of climate change should be better considered in the future as native species may not be sustainable in already marginal site conditions (in general, worsening of site conditions can be predicted due to climate change)

O Collection of drought tolerant species native in Hungary and introduction of non native species to dry sites

O Productivity of improved poplar clones on dry sites

O Research on possible application of fast growing natural tree species in energy plantations with special focus on dry sites

2. Tending and thinning

O In natural forest types tending and thinning less frequent, more room for natural processes, mixed stands, keep the forest canopy closed.

S Labour intensive tending methods for careful maintenance resulting more diverse stand structure

S Maintenance of forest edges

L More intensive tending and first thinning to reduce the number of remaining trees in not natural forests types, especially in plantation forests

3. Harvesting

O Increase application of natural regeneration and selective cutting, decrease clear cutting methods

O Proper technology for better protection of soil, regeneration and remaining trees (e.g. use of forwarders instead of skidders, improvement of transportation, road system)

4. Management planning

O Planning of management regime, regeneration and thinnings locally considers site conditions and possible effects of climate change. Forest managers and environmental authorities are also consulted prior to the final decisions

N Local conditions and climate change scenarios are considered on subcompartment level in planning, but due to the lack of reliable climate change scenarios and approved guidelines there is no particular guidance in relation to climate change. They should be elaborated in the future on the basis of the research results

5. Infrastructure and transport

L Improvement of water management infrastructure, especially for retention of water

L Maintenance and increase the density of forest roads

N Improvement of erosion control due to higher frequency of weather extremes

6. Forest protection against biotic and abiotic factors

O Continuation of national forest condition monitoring including monitoring of damages

S Subsidies for protection against pests and diseases and restoration of damaged areas

L Develop and apply forest management methods ensuring higher stability of strands against pests, diseases and abiotic damages

L Extension of national forest condition monitoring to specific climate change indicators

N Research on possible outbreaks of pests and pathogens in dry and warmer climatic conditions

O Improved forest fire information system and regionalization of fire endangered areas

O Modify management practice to improve the stability of stands. (Natural regeneration, mixed stands, selective cutting – uneven aged stands, less conifers – more native broadleaves, forest edges.)

O Subsidies for protection against forest fires and restoration of damaged (abiotic damages) areas

S New fire prevention plans on national, regional and management level, forest fire prevention campaigns, education of forest managers to fire prevention and mitigation

6. Protective function of forests

O The primary functions – especially protective functions of forest sub-compartments are defined in the forest management plans and in the National Forest Database. In case of weather extremes require some extension of the protective forests, it can be done during management planning. No special guidelines have been developed yet

7. Protected forests

O Where possible natural regeneration is applied, area of selective cutting is increasing

N Nature conservation authorities proposed selective cutting in all protected forests (with native species), prior to decision ecological and economic consequences have to be clarified

8. Research and monitoring

L Extension of national forest condition monitoring to specific climate change indicators

N Additional research to clarify climate change effects on forestry (ecology, economy, cross sector) better, adaptation measures and operational guidelines have to be developed

9. Training, education and communication

S Forest fire prevention campaigns, education of forest managers to fire prevention and mitigation

N Based on the scientific findings and practical experiences better communication to foresters, forest owners and to the society to improve knowledge on climate change effects on forests and possible/recommended/implemented adaptation measures

10. National and regional level adaptation options (risk management and policy)

O National Climate Change Strategy approved by the Parliament in 2008. Development of implementation is going on

11. Other suggestions for adaptation options

O/N Water management strategy in Hungary is changing slowly. I the past the fast drainage of floods and high level of excess surface waters from the Carpathian basin was the principle of water management following the primacy of human safety and agriculture production. Lowland forestry has always been in favour of retaining the waters. Climate change effects seem to support the forestry approach. Plans to retain more water in the country are on the table and actions especially along the Tisza River are going on.

Emerging specific initiatives in Hungarian forestry

Accumulating new and convincing research results on climate change effects have strongly contributed to a growing awareness in the forestry community.

Nature-close technologies

Forest companies directly confronted to climate change effects such as large-scale mortality, diseases and pests cooperate now with research teams to find appropriate answers to these challenges. These initiatives are parallel with the spreading trend to apply *nature-close technologies* in silviculture (Pro Silva movement). Much of the program is serving also the aims of climate adaptation as well (maintenance of closed forest cover, natural regeneration, increasing species diversity and creating more structured forest stands etc.).

Microclimate-saving regeneration cuts

A specificity of Hungary is the combating of drought effects in forests. The species most exposed to extreme droughts is beech. A method to naturally regenerate beech by considering orientation to insolation, to keep suitable microclimate, has been developed (Török 2007).

***G*enetic considerations**

On much of the Hungarian forest cover artificial regeneration methods will be still applied in the future because of ecological and economical considerations. This implies the stronger application of directed genetic interventions first of all through utilising reviewed directives for reproductive material. It is the result of recent genetic analyses (Mátyás 2007, EVOLTREE 2009) that

- genetic response to climatic changes is strongly species-specific
- generally, response depends on the ecological distance from the limits of tolerance
- populations exposed to extreme climate stress need special consideration both in risk management and conservation

II.4. Research studies

Major findings

Ongoing research programs deal on a very broad thematic basis with climate change effects on forest ecosystems. Results are published, besides of periodicals, in the triennial “Forests and Climate” volumes (recent ones are Mátyás, Vig 2004 and 2007). Some major findings may be summarised as follows:

- specific climatic challenges for the continental part of SE Europe justify specific approaches,
- xeric forest and species limit conditions need very specific responses and risk management, extreme events (drought) playing a decisive role
- genetic background of climate change response is verified,
- out of hereditary traits phenotypic plasticity, and persistence make simple climate envelope studies questionable,
- differences between ecological zones are much smaller than the magnitude of expected climatic changes, therefore shift of ecological zones has far-reaching consequences,
- the shift of ecological zones strongly influences the carbon balance both in the dendromass and in the forest soils
- climate shifts trigger changes of insect communities, gradation and disease prospects,
- the future of disease and pest damages remains difficult to forecast due to unforeseeable changes of behaviour and immigration of unknown agents,
- competition conditions have already changed in forest ecosystems and transformation of ecosystems is under way,
- human interference (management) is indispensable due to the speed of expected changes,
- the modelling of future response needs a stronger consideration of human input.

Objectives of current research studies

Beyond generally acknowledged themes, and the continuation of the above listed items, the Hungarian climate effects on forest research is characterized by

- emphasis on hydrological and drought studies
- a strong genetic component in evaluating response to changes
- practice-oriented, complex approach in formulating silvicultural risk management guidelines
- climatic drivers of carbon sequestration of forest zones, in detail:
  estimating the carbon stock of the Hungarian forests,
  estimating the annual carbon balance of the biomass in Hungarian forests,
  estimating the change of the C pool in forest soils,
  and evaluating the status of forests as C source or sink according to Kyoto Protocol Art. 3.3., based on the Hungarian Forest Inventory and on the research work of the Forest Research Institute
- carbon balance of wood and wood-based products on national level

III. Mitigation

Forest management according to operational plans implies that forest cover changes caused by climatic shifts may and will be canalised: e.g. instead of spontaneous loss of forest cover the artificial planting of an exotic species may be envisaged. Artificial regeneration together with forest protection measures may effectively buffer the spontaneous effects of climatic shifts – needless to say, only until the ecologically-genetically set limits. Consequently, the impacts of forest policy and management, intensity of forest harvesting, timber utilisation etc. have to be considered in forecasts.

All this has an input also on the carbon sink function of the forest vegetation. Primeval forests may be regarded as carbon neutral. The extraction of timber for industrial purposes creates new sinks in the human infrastructure which might last sometimes for centuries. Life cycle analysis (LCA) techniques will help to elucidate its importance for the carbon.

III.1. Carbon accounts

National Greenhouse Gas Inventory

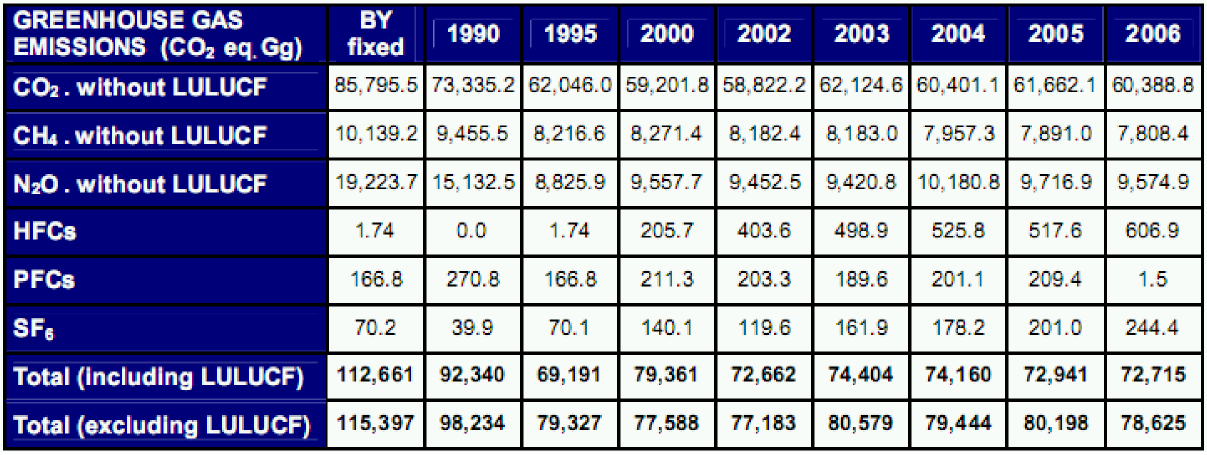
Pursuant to the United Nations Framework Convention on Climate Change (UNFCCC), Hungary, as Party of the Convention, has been preparing annual inventories of greenhouse gas emissions using the IPCC methodology since 1994. In accordance with the Kyoto Protocol, the following direct greenhouse gases are taken into account: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The GHG inventory is compiled by the Hungarian Meteorological Service, based on a mandate of the Minister of Environment and Water.

Summary of National Emissions and Removal Related Trends

In 2006, total emissions of greenhouse gases in Hungary, were 78.6 million tonnes carbon dioxide equivalents (excluding the Land Use, Land-Use Change and Forestry (LULUCF) sector). With less than 8 tonnes, the Hungarian per capita emissions are below the European average. By ratifying the Kyoto Protocol, Hungary has committed herself to reducing its GHG emissions by 6%. At present emissions are 32% lower than in the reference year (average of 1985-87). There is no significant trend in the emissions of the last 10 years, they fluctuate around 79 million tonnes.

The most important greenhouse gas by far is carbon dioxide accounting for 77% of total GHG emissions. The main source of CO_2 emissions is burning of fossil fuels for energy purposes, including transport. CO_2 emissions decreased by 30% since the middle of the 80's (Table 4).

Table 4. Greenhouse gas emissions (CO_2 eq. Gt) BY=average of 1985-87 (1995 for F-gases) as fixed in 2007. (Source: Hungarian Meteorological Service 2008)



GREENHOUSE GAS EMISSIONS (CO_2 eq. Gg)	BY fixed	1990	1995	2000	2002	2003	2004	2005	2006
CO_2 . without LULUCF	85,795.5	73,335.2	62,046.0	59,201.8	58,822.2	62,124.6	60,401.1	61,662.1	60,388.8
CH_4 . without LULUCF	10,139.2	9,455.5	8,216.6	8,271.4	8,182.4	8,183.0	7,957.3	7,891.0	7,808.4
N_2O . without LULUCF	19,223.7	15,132.5	8,825.9	9,557.7	9,452.5	9,420.8	10,180.8	9,716.9	9,574.9
HFCs	1.74	0.0	1.74	205.7	403.6	498.9	525.8	517.6	606.9
PFCs	166.8	270.8	166.8	211.3	203.3	189.6	201.1	209.4	1.5
SF_6	70.2	39.9	70.1	140.1	119.6	161.9	178.2	201.0	244.4
Total (including LULUCF)	112,661	92,340	69,191	79,361	72,662	74,404	74,160	72,941	72,715
Total (excluding LULUCF)	115,397	98,234	79,327	77,588	77,183	80,579	79,444	80,198	78,625

Overview of Source and Sink Category Emission Estimates and Trends

By far, the biggest emitting sector was the Energy sector contributing 76% to the total GHG emission in 2006. Agriculture was the second largest sector with 11% while emissions from Industrial Processes (with Solvent and other product use) accounted for 8% and the waste sector contributed 5%. Compared to the base year, emissions were significantly reduced in the Energy, Agriculture, Industry and Solvent sectors. In contrast, the emissions in Waste sector are increasing. In the Land Use, Land-Use Change and Forestry (LULUCF) sector removals (negative value) show fluctuating behaviour.

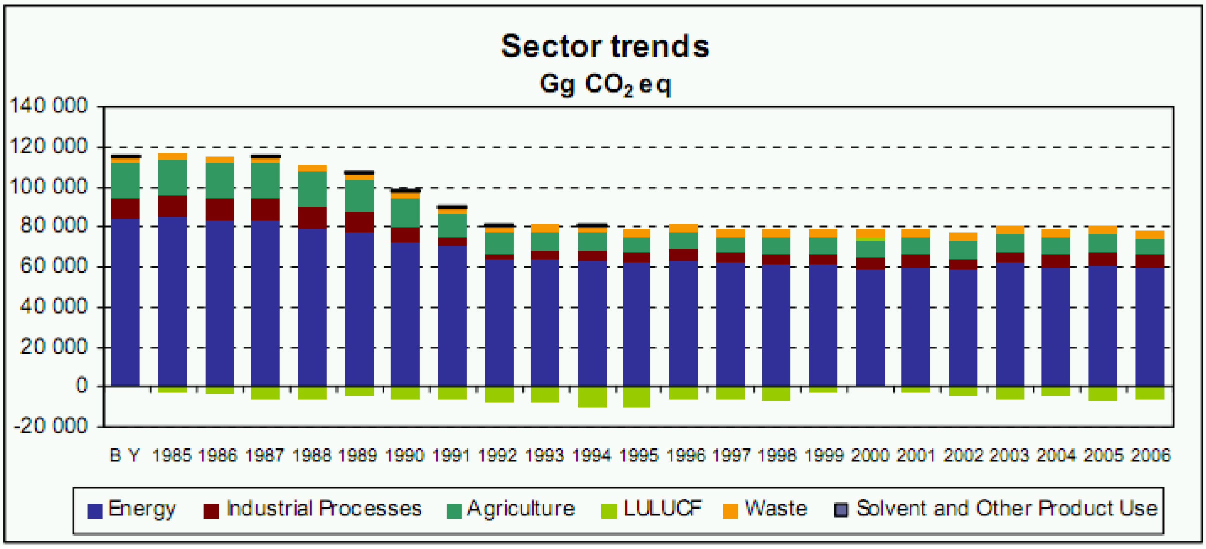


Figure 21. Change in greenhouse gas emissions from base year (1985-2006) Note: BY=average of 1985-87 but 1995 for F-gases (Source: Hungarian Meteorological Service 2008)

In the Energy sector, carbon dioxide from fossil fuels is the largest item among greenhouse gas emissions. Its contribution is 94.5% to sectoral emission, followed by CH_4 with 4.1% and by N_2O with 1.4%, in 2006. Among fuels, gases have the highest proportion (47.0%), liquids have less, and solids have the lowest, but the latter still represents 22.2% of the sectoral CO_2 emissions. Due to the changes in the fuel-structure in the '90s the most important source in the refernce period, solid fuel, have been replaced by natural gas, decreasing the total emission. The most important subsector of the energy sector is Energy Industries with a proportion of 32.3%. The most dynamically increasing category is Transport. The contribution of agriculture to total emissions decreased over the period 1985-2006 from 15.0% to its present share.

The Land Use, Land-Use Change and Forestry (LULUCF) sector was a net sink of carbon in most of the years and a net source of emissions in 2000. This result is determined largely by Forest Land, which is a major carbon sink. The Cropland living biomass is usually a net sink of carbon but can be a net source of emission in some years due to reduction of orchard and vineyard areas. Soil disturbance generates steadily decreasing removals of CO_2, as a consequence of reduction of agricultural land and afforestation of croplands. The complex dynamics of the land use and land-use changes leads to fluctuating trend in the LULUCF sector. In 2006, the net removal was -5.9 million tonnes. (Source: Hungarian Meteorological Service 2008)

III.2. Bioenergy issues

The 2003/30/EU guideline for bio fuels proposes for Hungary the use of 5.75% bio-fuel for 2010 and 10% in 2020 of the total fuel consumption. Electricity produced by renewable sources should reach 3.6% in 2010. In 2020, 13% of the total energy consumption should derive from renewable sources in Hungary.

The government Strategy of Renewable Energy Sources (2148/2008) defines the main target to reach a rate of energy produced from renewables of 186,3 PJ by the year of 2020, of which:

- electricity: 79,6 PJ
- heating: 87,1 PJ
- biofuels: 19,6 PJ.

The total biomass stock of Hungary is 350-360 million tons. 105-110 million tons of primary biomass is renewing annually and is mostly utilised. The primary and secondary agricultural products contribute to the yearly renewable biomass resources with 57-58 million tons and the forests supply 9 million tons.

Table 5. Comparison of the biomass potential and the present biomass demand

Biomass source	Biomass supply and demand	
	Present biomass demand, PJ	Available biomass potential, PJ
Forest	27,5	8,3
Arable land	146,3	50,2
Waste	5,5	87,0
Total	179,3	145,5

The majority of renewable energy is derived from biomass and mostly from wood. Renewable resources provide approximately 3-3.5% of Hungary's energy consumption (Figure 22). Biomass energy is only used for direct heat presently.

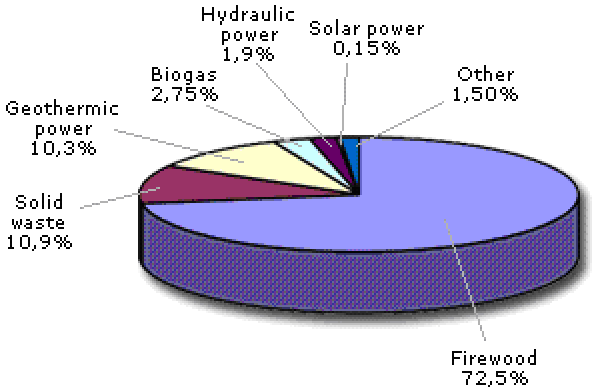


Figure 22. The share of utilisation of renewable energy sources in Hungary in percentages (1999-2003).

Although 70% of that comes from the utilisation of biomass, its level of utilisation is low compared to the available amounts, even for timber (Figure 22). Actually the total harvest is about 7 million gross cu.m per year which is much below the total allowable cut (Figure 23).

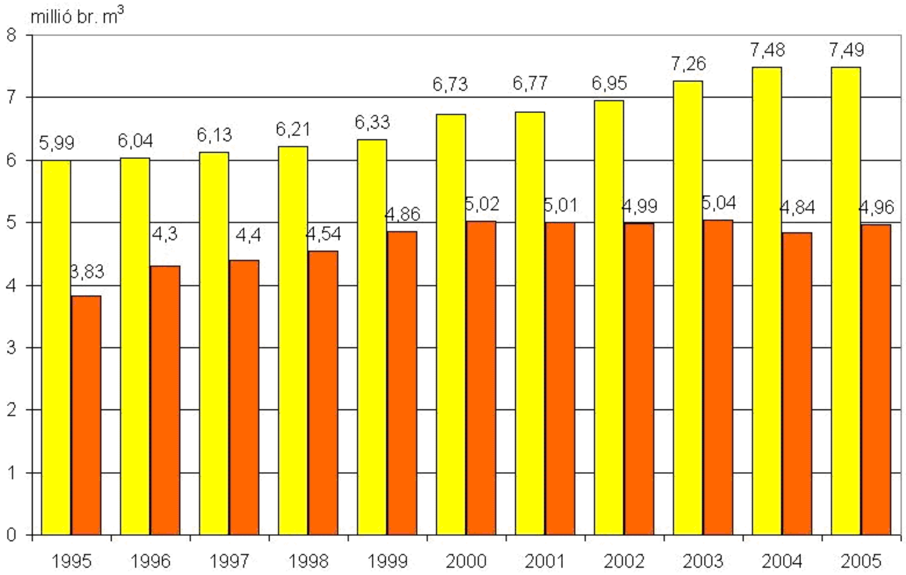


Figure 23. Final cut volumes 1995-2005: potential (yellow) and actual (red).

As in most European countries, in the previous decades the domestic firewood consumption was used for heating of private homes. Between 1970-1980 an important part of domestic energy policy was to establish natural gas pipelines in rural areas to provide to the population heavily subsidized natural gas. Due to the energy crisis and a significant increase of the price of the natural gas, local consumption of firewood started to grow once again (Figure 24). On the other hand, some large scale power plants which previously used brown coal were transformed into biomass heating.

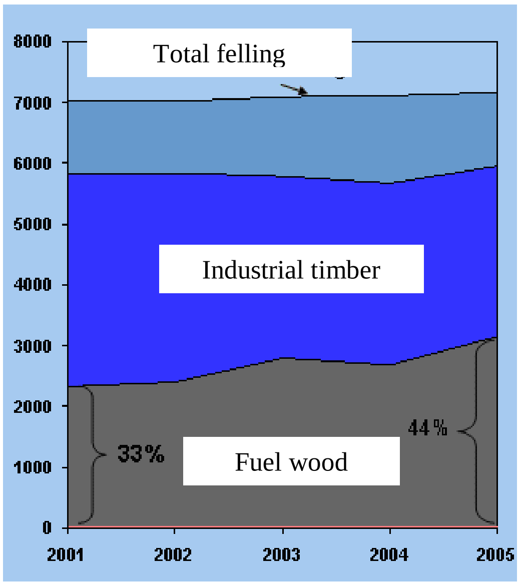


Figure 24. Annual felling (in 1000 m3).

Table 6. Role of renewable sources in energy production 2003-2005 (GWh) (Source: Magyar Energia Hivatal)

Source	2003	2004	2005
Power plants			
Borsodi	71	247	278
Tiszapalkonya	15	77	229
Pécs	0	129	344
Bakony V,VI.	0	13	60
Bakony VII	3	189	201
Mátra	1	14	445
other powerplants	6	8	11
Biomass total	**97**	**677**	**1568**
wind	4	5	9
water	23	42	50
Total renewable	124	724	1627

The large share of wood in the renewables is quite controversial. Currently green electricity is heavily subsidized by the state with 10 HUF/kWh (= 4 eurocents/kWh). In the big power pants the average energy efficiency is around 30%. Concentrated production means large transportation costs and industrial scale timber heating is regarded by many as a waste of valuable raw material. Future trend of biomass fuel utilisation should target the establishment of small and medium sized power plants closer to consumers.

Agricultural biomass utilisation for fuel

In 2006 there was a plan for building 20 bio-ethanol factories in 4 years. The total planned capacity was 5.9 million ton of corn and maize which could yield 2 billions litre of bio ethanol. These plans have not been realized in the majority, partly because of the unbalanced maize yield and the economic crises.

At present there are only 3 bio-ethanol factories in operation which are also producing spirituous liquors (Table 7).

Table 7. Bio-ethanol factories and the produced bio-ethanol and alcohol (t per year).

Bio-ethanol factory	Location	Produced bio-ethanol, alcohol and E85 (t)
Etanol-Line Kft.	Vácszentlászló	7 300
Hungrana Kft.	Szabadegyháza	13.500
Szeszgyár és Finomító Kft.	Győr	25.000

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