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ECHOES
Expected Climate Change and Options for European Silviculture

Country Report
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Introduction

Climate change and its impacts on forest ecosystems with subsequent effect on forests management has been very urgent issue from scientific viewpoint and from socio-economic and political viewpoint as well. Low attention has been paid to the mentioned issue in Slovakia. In extreme cases the issue was undervalued, whereas in many cases this issue has been non-professionally confused with the issues of weather. We understand weather as an actual state and prognosis for following 10 days, while climatic conditions are being understood as a long-term regime of weather for the period at least 30 years.

Issues of possible impacts of climate change concern practically all, natural and socio-economic spheres. This fact has reflected also in forestry activities when at the ministerial Conference On Forest Protection in Europe held in Helsinki in 1993 a strategy H4 titled "Strategy of Long-Term Adaptation of Forests in Europe to Climate Change" was adopted. This strategy was signed also by Slovakia. The Fourth Ministerial Conference on Forest Protection held in April 2003 has adopted another resolution aimed at the problem of climate change under the title "Climate Change and Sustainable Forest Management in Europe" that has extended the framework of the Resolution H4 by the aspects of Kyoto Protocol, monitoring activities, support to research and incorporation of this issue into national forestry plans.

First debates on the effect of increasing greenhouse gases and possible climate change on forest ecosystems have appeared in forest research in Slovakia at the end of the 80s of the past century. But only implementation of the project "National Climate Programme of the Slovak Republic" that was launched in 1993 (as a continuation of "National Climate Programme of Czechoslovak Republic") has brought a significant movement forward. In the years 1993 – 1993 there were worked out in the framework of this programme, part forestry, 4 final reports and 4 expert reports. The first stage of solving this issue was finished by international workshop "Forest Ecosystems and Global Climate Change" that was held in Zvolen in February 1995. Another important stimulus for solving the mentioned issue on higher level what concerns the quality of research was participation in the project "US Country Studies". One of the results of this international programme was also preparation of a strategic study on the consequences of climate change for forests and forest management in Slovakia that was worked out as charged by the Ministry of Agriculture of the Slovak Republic. Besides great number of published works, which we have used and cited in our report, we must note also the most complex overview of recent knowledge on the issue of forest and global climate change in the monograph "Forests of Slovakia and Global Climate Change". Editors of this book MINĎÁŠ and ŠKVARENINA (2003) collected knowledge from 24 co-authors and all data were used later in the elaboration of the Fourth national report of Slovakia on climate change as well as the Report on progress in fulfilment of Kyoto Protocol commitments (2005). In the chapter 6 titled "Expected consequences of climate change, estimation of vulnerability and adaptation measures" there are described changes in climate in Slovakia in last years, scenarios of climate change in Slovakia, scenarios of possible changes in the distribution of daily values and extremes as well as issues of the impacts of climate change on forest ecosystems and forestry.

We followed up with our research the obtained knowledge and the results of foreign authors as well as the works of Slovakian authors (MINĎÁŠ, J., ŠKVARENINA, J, 1994, ČABOUN, V., 1994, MINĎÁŠ, J., LAPIN, M., ŠKVARENINA, J., 1996, ČABOUN, V., 1998, MINĎÁŠ, J., 1999, MINĎÁŠ, J., ŠKVARENINA, J., STŘELCOVÁ, K., PRIWITZER, T., 2000, MINĎÁŠ, J., ČABOUN, V., IŠTOŇA, J., PAVLENDA, P., PAVLENDOVÁ, H., PRIWITZER, T., VLADOVIČ, J., 2002, MINĎÁŠ, J., ŠKVARENINA, J., LAPIN, M., ČABOUN, V., VLADOVIČ, J.,

PRIWITZER, T., ZÚBRIK, M., MORAVČÍK, M., 2004, ČABOUN, V., ŠTEFANČÍK, I., HLÁSNY , T., KAMENSKÝ, M., TUČEKOVÁ, A., MORAVČÍK, M., JANKOVIČ, J., MINĎÁŠ, J. 2005, TAKÁČ, J., LAPIN, M., ŠPÁNIK, F., ČABOUN, V., ŠIŠKA, B., VALŠÍKOVÁ, M., ŠILHÁR, S., CHUDÝ, J., SOBOCKÁ, J., 2005).

In the years 2004-2005 we have solved the project of state programme of research and development titled "**Ongoing climate change and its impacts on the development of the country**". In the framework of this task we have solved subproject "Consequences of climate change on forests and forest ecosystems and adaptation measures, including silvicultural rules for forest management".

The aim of sector's project **"Impact of climate change on the forests in Slovakia"** (2003-2008) was to extend scientific knowledge on the impacts of global climate change on forest ecosystems, specify predictions of the development of forest ecosystems under the conditions of climate change, and based on them to work out a system of adaptation and mitigation measures for sustainable forest management and fulfilment of all required forest functions as well as for the needs of strategic decisions of the sector.

The project, which was the most complex research project, had four subprojects. Titles and objectives of four subprojects were as follows:

1. CONSEQUENCES OF CLIMATE CHANGE FOR FOREST ECOSYSTEMS

Extend scientific knowledge on the impacts of global climatic change on forest ecosystems, specify prognoses of the development of forest ecosystems under the conditions of climate change and based on them to work out a proposal of a system of adaptation and mitigation measures for sustainable forest management and fulfilment of all required forest functions (ecological, economic and social) as well as for the needs of strategic decisions of the sector

2. MONITORING OF BALANCE CHANGES OF CARBON IN FOREST ECOSYSTEMS

Create experimental basis for objective assessment of carbon balance in forest ecosystems, develop and verify national methodology for balancing emissions of greenhouse gases in the landscape and forests utilization, and propose a system of monitoring of balance changes in greenhouse gases for forest sector

3. STRATEGY OF FOREST PROTECTION AGAINST A COMPLEX OF INJURIOUS AGENTS UNDER THE CONDITIONS OF CLIMATE CHANGE

Specify methods of forest protection against injurious agents, to define preventive measures and develop strategy of integrated forest protection under the conditions of climate change

4. SPECIFICATION OF MEASURES FOLLOWING FROM KYOTO PROPOTOCOL IN FOREST SECTOR

Specify measures in relation to fulfilling commitments of Kyoto Protocol in forest management

At present (2008 - 2010) we have been dealing in the framework of the task "Study of ecology, structure and dynamics of forest ecosystems under changing natural conditions" with the issue of climatic changes as well as with other issues as impacts of climatic extremes on some components of forest ecosystems, impact of changing conditions of environment on the structure and diversity of herbs and tree species in forest ecosystems, assessment of the changes of biophysical and production parameters of forest ecosystems in relation to climatic factors.

We have been participating in the project CECILIA - Central and Eastern Europe Climate Change Impact and Vulnerability Assessment, which is aimed at use of climatic scenarios with detailed differentiation for target model territories and for the assessment of risks of climate change impacts on important sectors of human activities and natural ecosystems in some model areas.

1. Impacts

1.1 Observed impacts

Overview of Slovak forest sector

Total forest area in 2007 was 2,007 thousand hectares (ha) of which forest cropland formed 1,932.9 thousand hectares. At the same time, forest cover deducted from the area of forest land was estimated at around 41%. Slovak forests are known for their richly diverse species composition with beech being the dominant forest cover (31.2%) followed by spruce (25.9%) and oaks (13.4%). At present, management preferences focus on the establishment of more resistant, biodiversity rich mixed forest stands with greater ecological values. Split by main species groups reads as follows: coniferous forests 31%, broadleaved forests 50%, mixed forests 19%.

Tree species composition and forest origin

Forests in Slovakia are typically tree species rich and are dominated by beech (31.2%), spruce (25.9%) and oak spp. (13.4%). Table 1 indicates a gradual decrease in the area of coniferous forests (less resilient spruce in particular) in favour of broadleaved forests, which are positive with respect to long-term efforts to enhance stability and vitality of forest ecosystems.

Coppice currently covers an estimated 35,000 hectares – i.e. 1.82% of total forest cropland; its total area has fallen by 6.3 % since 1980.

Table 1 Main tree species and their groups

Species	1970	1980	1990	2000	2006	2007
	%					
Conifer	41.3	42.5	42.3	41.9	40.8	40.5
Broad-leaf	58.7	57.5	57.7	58.1	59.2	59.5
Spruce	26.0	26.4	27.3	26.8	26.1	25.9
Fir	6.2	5.8	5.0	4.3	4.0	4.0
Pine	6.7	7.5	7.0	7.5	7.2	7.1
Beech	30.1	29.5	29.8	30.3	31.2	31.2
Oak + Turkey oak	14.4	14.4	14.2	13.6	13.4	13.4
Hornbeam	6.2	5.7	5.6	5.7	5.7	5.8

Source: Compendium of Slovak Forestry Statistics 2008, NFC-IFRI Zvolen.
Prepared by: NFC-FRI Zvolen.

Slovak forests also harbour a number of naturalised tree species. With the exception of invasive black locust uncontrollably spreading to forest and non-forest land the area of these species remains largely stable.

Climatic conditions

What concerns geography Slovakia is a very diverse country. The arc of the Western Carpathians stretches in the west and north while vast lowlands dominate in its southern parts. Diversity of her natural conditions and physical landscape reflects also in local climatic conditions that vary considerably between its regions. Mountainous topography with highlands and mountains cover a large part of the country's surface. These topographic features form an estimated 60% of the country's area. Lowlands form the remaining 40%. The altitude ranges between 94 and 2,655m. In a broader European context, her territory belongs to a submontane to montane type of landscape.

From a climatic point of view, Slovakia belongs to a moderate climatic zone with a climate significantly influenced by both, altitude and topography as well. Its western part is more influenced by the Atlantic Ocean whereas its eastern regions are under the influence of continental climate. The average annual temperature in lowland regions varies between 9 – 10° C whilst highest mountain locations (> 2,500m) record a sub-zero average of -3.7° C.

The average temperature decreases by 0.5° C for every 100 m of altitude. As for the hours of daylight, southern regions experience an estimated 2,000 hours of daylight whereas in northwestern parts this figure is down to around 1,600 hours.

Average annual precipitation for the whole country is 743 mm – 65% of it evaporates, remaining 35% is runoff. Snow cover is not stable and there are many years, when regions at lower altitudes have not permanent snow cover at all.

In last decade, the territory of Slovakia has experienced a number of extreme weather events (prolonged droughts, flooding, violent wind storms), all of which had somewhat detrimental effect on forests.

Climate change and forests

In the past century, the territory of Slovakia was significantly warmer (the average annual temperature rose by 1.1° C, more substantially in winter) and drier (total annual precipitation dropped by 5.6%). Average centennial figures for particular regions show certain variableness in climatic parameters of southern Slovakia recording 10% decrease in the amount of precipitation. At the same time some northern and northeastern regions recorded precipitation increase by up to 3%.

Moreover, significant drop in relative air humidity (up to 5%) and snow cover duration was observed almost on the whole territory of the country. Other climatic variables (potential and actual evaporation rate, soil moisture, global radiation, radiation balance) also confirm gradual drying of the country with its southern regions being most severely hit as potential evapotranspiration grows and soil moisture falls. Values for solar radiation remained grossly unchanged in the period monitored.

In order to provide a qualified assessment of potential impacts of climate change on health and vitality of Slovak forests, a number of climatic models have been developed to determine climatic amplitudes of the natural distribution range of particular tree species in Slovakia as well as the amplitudes of their real distribution. The latter mentioned were derived from satellite imagery. The amplitudes were projected for future following regional climate change scenarios (2001). Subsequent comparison of the acquired data provided for the assessment of spatial shift of distribution ranges corresponding with natural and current distribution of particular forest tree species. The analysis was carried out for the following tree species: beech, oak, spruce, larch, fir, and pine. Its results clearly indicate that spruce in particular shows a marked divergence between its bioclimatic demands and its actual distribution.

Results of our analysis of phenological data from the period 1986 - 2000 refer to a considerable variability of the temporal duration of vegetation season in Slovakia, above all its opening part in early spring. We found a tendency of earlier beginning of early spring, spring and summer phenological events. On the contrary, later onset of autumn phenological phases was observed. Duration of the whole vegetation season from early spring to autumn prolonged in period 1986 – 2000 for one week. An increase in the biomass production of agricultural and forest plants could be supposed as a consequence of that.

Biological diversity and ecological stability of forests

Forests represent most complex terrestrial ecosystems on our planet and as such contribute significantly to the conservation of global biodiversity. Biodiversity can be defined as the variety and complexity of life on the Earth at all scales including species, ecosystem and genetic (morphological and physiological) levels. Ecological stability of forests is one of the main factors of sustainable development of forest sector since it underlies long-term delivery of multiple benefits and services provided by forests. At an ecosystem level, optimum biodiversity adjusted to local conditions is favoured over so-called maximum biodiversity. Modern forestry emphasises a need for achieving minimum biodiversity enhancing ecological stability of forests.

Forest health and vitality

Investigation of forest health and vitality is based on monitoring networks of the level II and I. At present, there are 112 permanent monitoring plots (PMP) in a 16×16 km grid (extensive level I monitoring) and 7 PMP established in selected forest ecosystems (intensive level II monitoring). Both monitoring levels constitute a part of the European network of monitoring plots. The European Forest Monitoring Programme (EFMP), aim of which is to provide credible data on the state of forests in Europe and qualified insight into underlying causes and impacts of ongoing changes in forests and other associated ecosystems, has so far been acceded by 39 European countries.

It is generally accepted that broadleaved tree species better resist unfavourable environmental conditions than coniferous species because of their foliage cycle. It is thus perhaps not surprising that hornbeam and beech are perceived as the least damaged tree species in Slovakia; on the other side of scale are coniferous species like fir, pine and spruce.

Figure 1 shows the trend in average defoliation of main species groups (coniferous, broadleaved) and total defoliation since the beginning of the monitoring period including outlook to 2012. Entered figures were computed using data from all monitoring plots and thus provide representative averages for the entire country. Notwithstanding to that, vitality and health of forest ecosystems can vary considerably depending on their location. The data indicate that in the 1987–1996 reporting period the combined value of defoliation for all tree species was 20–30%. In the past 11 years, however, average total defoliation has fallen under 25%. Most recent results of defoliation and forest damage assessment indicate very little changes in vitality and health of forests in recent years – experienced interannual variations have primarily been associated with weather and climate factors.

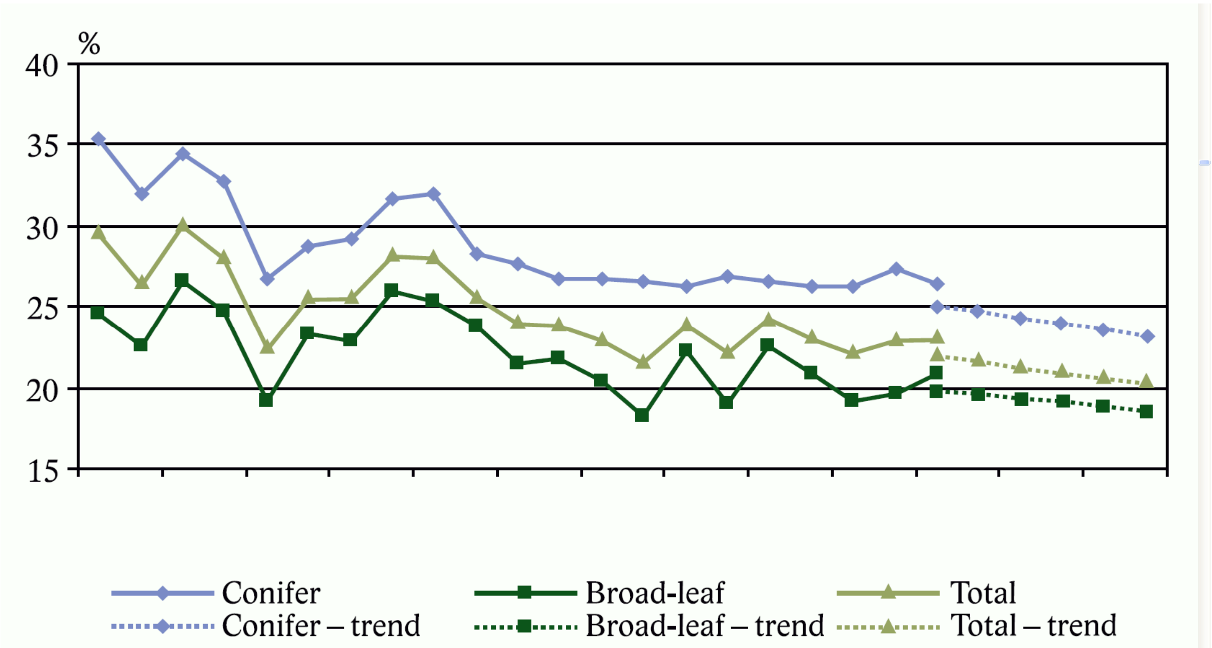

Figure 1 Trend in average defoliation of main species groups (coniferous, broadleaved) and total defoliation since the beginning of the monitoring period including outlook by 2012.

FOREST DISTURBANCES AND THEIR IMPACT

Volume of salvage felling is used in Slovak forest planning practice as an indicator best describing detrimental impact of injurious agents on forest health.

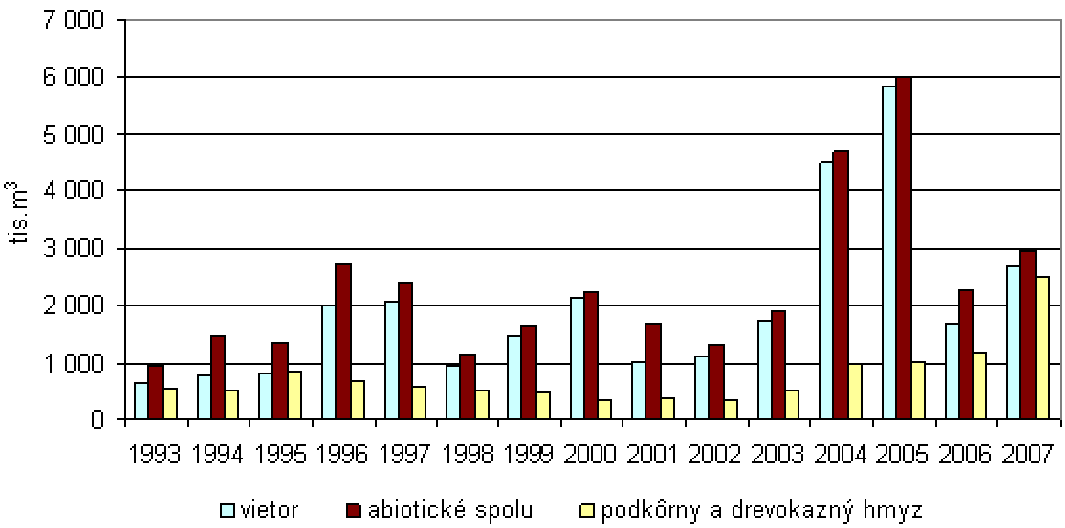

Figure 2 Forest damage by wind (blue), abiotic factors together (brown) and by insects (yellow)

Timber felling

Volume of felled timber interannually increased to 8,367 million m^3 – the second largest volume ever recorded in Slovakia, second only to 2005 10.2 million m3 of largely calamity timber from wind storm disaster in November 2004. The ongoing trend is projected to continue as current age structure of Slovak forests favours further growth in felling volumes.

The total volume of timber felled for example in 2007 reached 8,367.1 thousand m^3 which represented 9.9 thousand m^3 increase compared to 2006. The volume of salvage felling formed 56.2% of the total felling volume; in coniferous forests, this volume was almost 80%.

Recent felling volumes are due to abnormally high occurrence of annual salvage felling larger than a long-term sustainable level. Since 2000 the annual felling volume has on average been 16.7% above planned with maximum increase of 27.8% recorded in 2005–2007. Record volumes improve short-term forest revenues, yet compromise future felling potential of over exploited forests. High volume of salvage felling is linked to general decline in forest condition and largely disproportionate presence of unstable coniferous forests, spruce forests in particular.

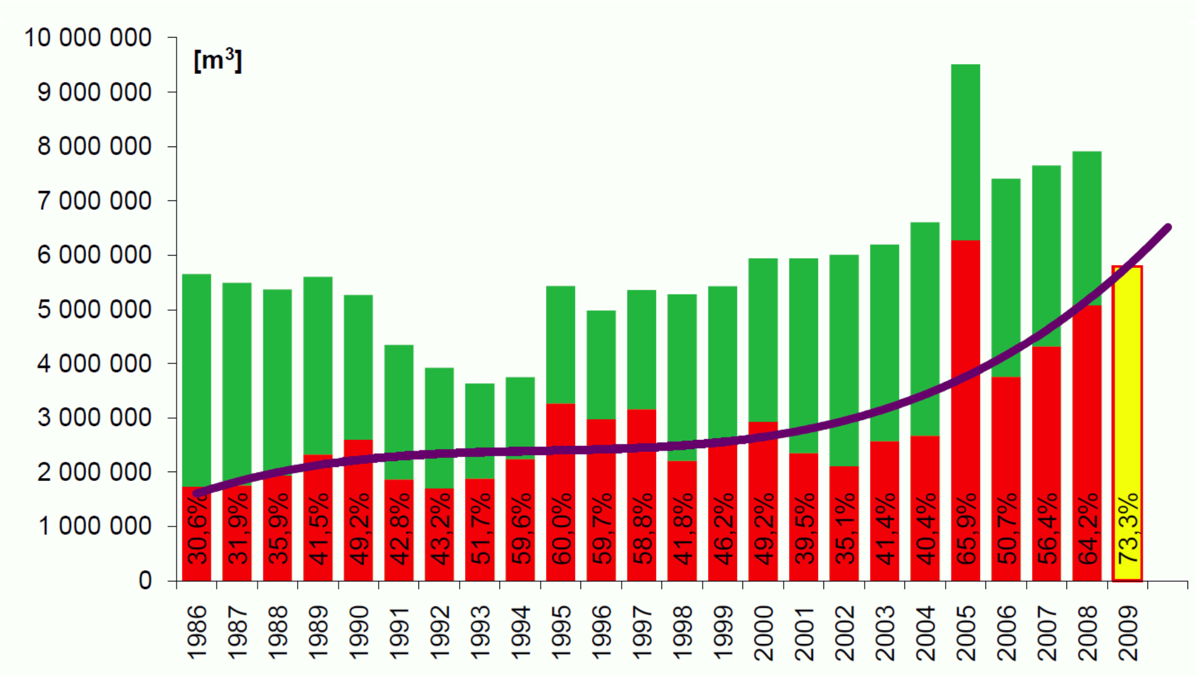

Figure 3 Trend of felling with prognosis by 2009; green - total felling, red – salvage felling

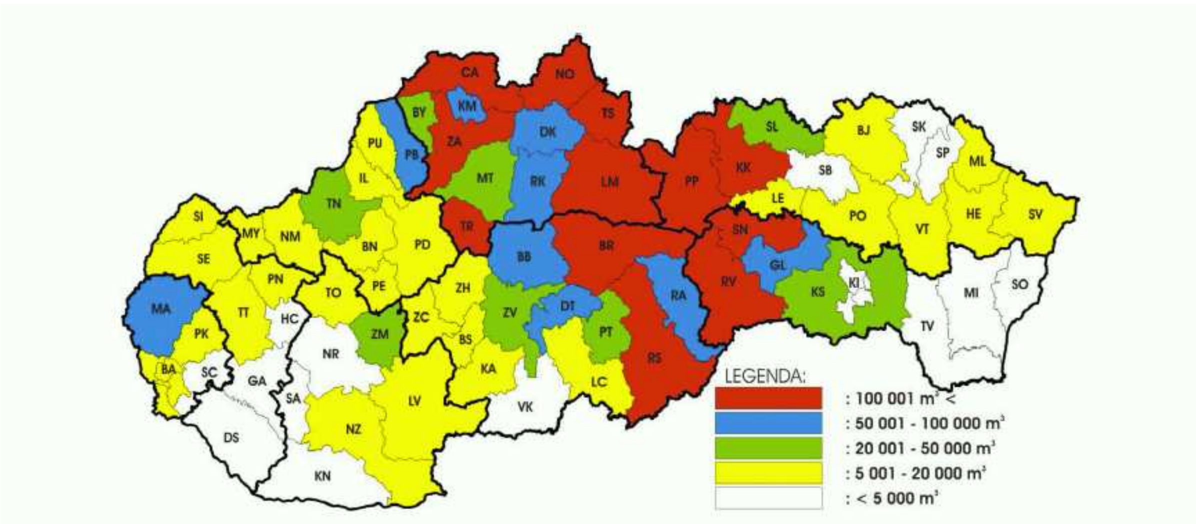

Figure 4 Volume of salvage felling in individual districts in 2008

Abiotic disturbance

Salvage felling due to mechanical damage of forests by wind, snow, rime and total is given in Table 2.

Table 2 Development of salvage felling (m^3 of timber) caused by mechanic abiotic factors

Year	Wind	Snow	Rime	Total
1997	1 815 592	51 245	64 857	1 931 694
1998	954 270	30 538	29 161	1 013 969
1999	1 472 253	43 456	6 611	1 522 320
2000	2 143 483	74 807	6 413	2 224 703
2001	933 670	31 242	466 743	1 431 655
2002	1 115 861	42 514	54 306	1 212 681
2003	1 607 474	16 004	20 338	1 643 816
2004	1 096 220	15 786	25 866	1 137 872
2005	5 177 337	33 059	3 931	5 214 327
2006	1 684 124	460 414	4 702	2 149 240
2007	1 943 505	92 973	4 084	2 040 562
2008	2 330 586	19 557	6 606	2 356 749

On 19 November 2004 Slovakia was hit by a storm wind. This storm caused extensive damage all over the country. Essential environmental, social and economic functions of forests and forestry are affected. The most severe wind throws have occurred in the High Tatra Mts. National Park (TANAP) and the Low Tatra region (Districts of Brezno, Banska Bystrica, Zvolen, and NAPANT), where large areas are under nature protection. The approximate estimate of the damage amounts to around five million m^3 of timber. 25% of the fallen timber is located on non-state property; the rest of the affected wood is under state property. In High Tatra Mts. National Park the fallen wood amounts to approximately 2.5 million m^3 on about 12000 ha, approximately 30% of the fallen wood is located in areas which are protected under highest level of protection (level five, Act 543/2004) thus no intervention is foreseen on these sites unless exceptions to the law are made.

Biotic disturbances

Bark beetles and woodborers

Temperature abnormal beginning of the vegetation period reported last year from many middle altitude regions of Slovakia favoured mass swarming of bark beetle species.

Populations‘ development was further accelerated by a high volume of removal pending calamitous timber left in most vulnerable spruce forests. The volume of not removed damaged timber came to an estimated 160 thousand m^3. Intensive swarming of European spruce bark beetle was also recorded in regions affected by November 2004 windstorm. Since the wind blown timber was no longer attractive for the beetle, it spread to surrounding standing stands causing considerable damage to hundreds of hectares of forests in protected areas (Tichá and Kôprova Valleys, Hrebienok, ridges of the Low Tatra Mts. and Slovenské rudohorie Mts.).

In 2008 the density of pest populations is estimated to increase largely because of large volumes of not removed timber from windstorm calamity and the scale of bark beetle spreading in 2007. The pest shows clear tendency to invade timberline altitudes where forests fulfil important a number of non-production functions. Concerns have thus been raised about the safety of foresters, hikers and visitors because of hazard posed by snags.

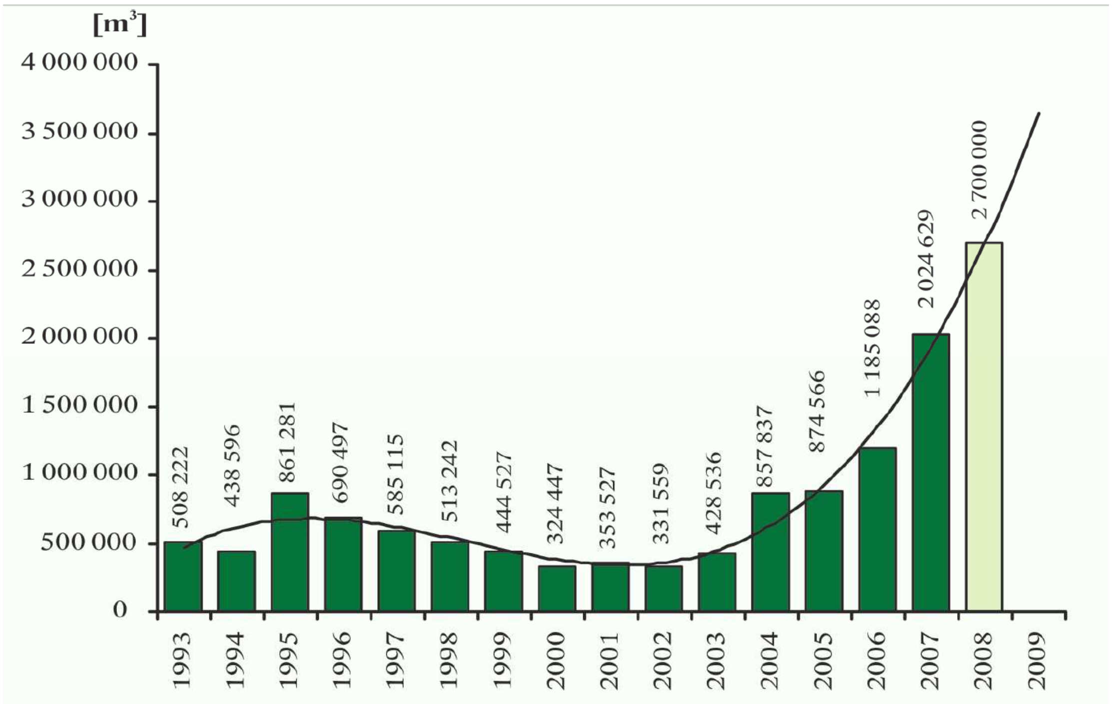

Figure 5 Volume of salvage timber felled due to bark beetle and woodborer damage including outlook for 2008.
Source: NFC-FRI Zvolen, 2008 (Form L 116).

Fungi pathogens and diseases

In 2007 most concerns were raised in connection with continuing decline of spruce forests associated with honey mushroom *Armillaria ostoyae*. The fungus development was enhanced greatly by weather development in 2006 and 2007.

Localised decline of oak woods was chiefly attributed to spreading of fungus-borne vascular diseases and *Armillaria* spp. induced by precipitation deficit and hot summer temperatures.

Reports from some regions of Slovakia (Považská Bystrica, Štós) indicated isolated decline of larch specimens damaged by early May frost. The decline was accompanied by severe defoliation and reduction in the volume of crown branches with root systems of dying and died trees showing honey mushroom Armillaria ostoyae infection.

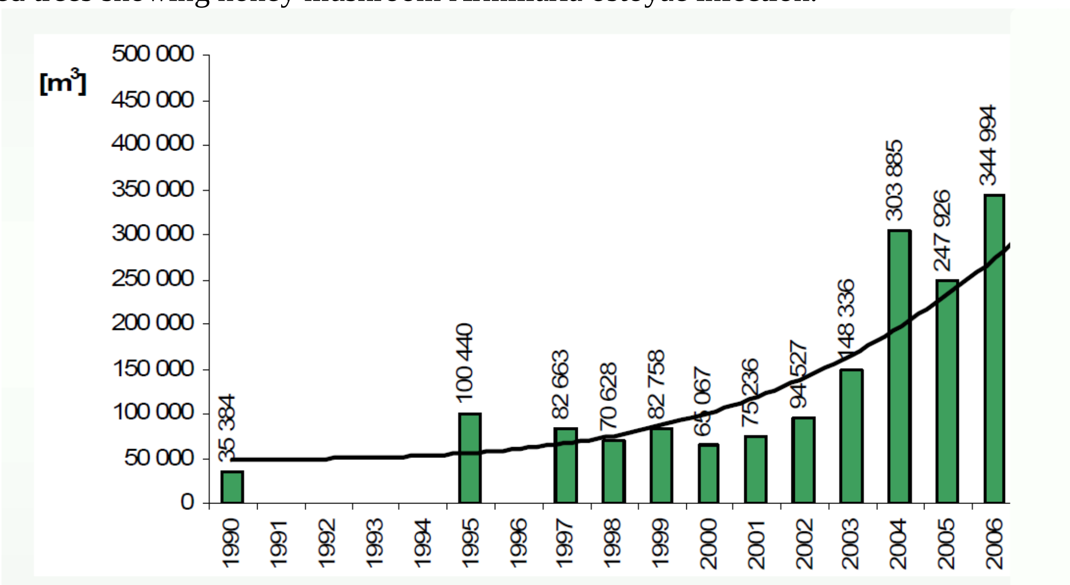

Figure 6 Volume of timber damaged by fungi pathogens and diseases

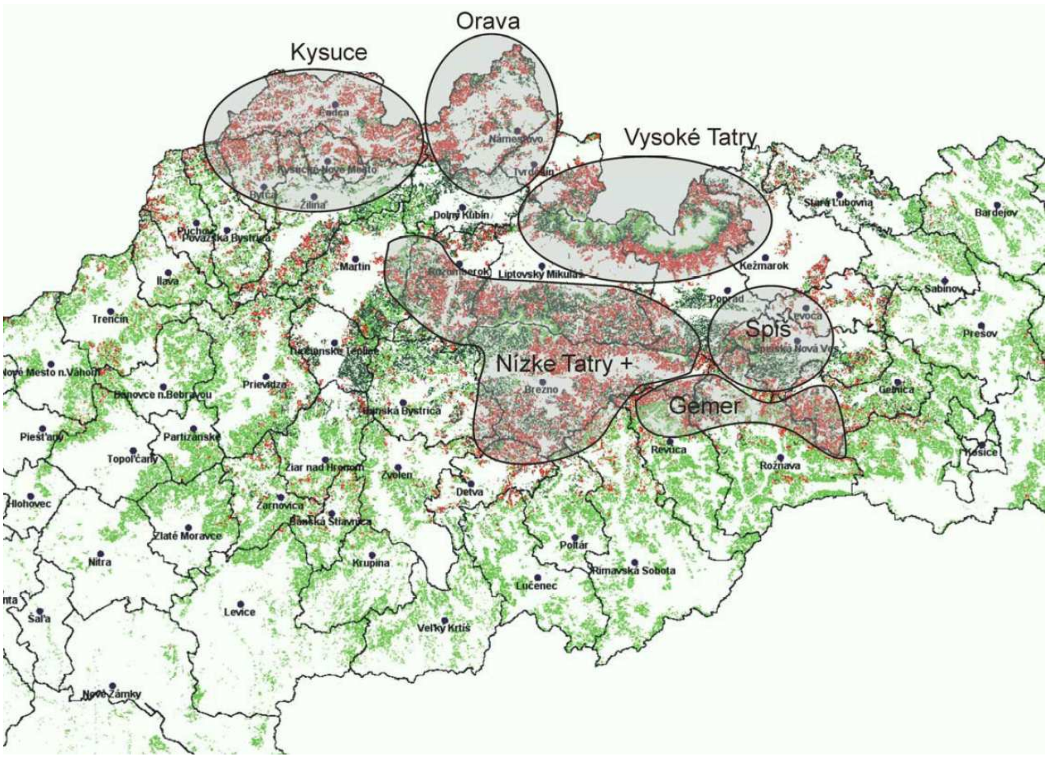

Figure 7 Critical regions in Slovakia - spruce dieback

Forest fires

In 2007, the Fire Appraisal Institute reported 463 forest fires – a twofold increase compared to 2006. The cost of fire-incurred forest damage was estimated at 158 million SKK, fortunately with no human casualties. The increase was chiefly attributed to mild winter conditions (snow shortage) and weather development in spring and summer months. The most serious fire broke out in state forests in the cadastre area of Staré Hory (state forest enterprise Slovenská Ľupča) on 15 April 2007. The fire destroyed 116 hectares of forest with direct costs estimated at 5.9 million SKK. The largest number of forest fires was reported from districts of Spišská Nová Ves (36), Poprad (35), Martin (19), and Kysucké Nové Mesto (18). The fires resulted from the following events: grass burning (122), illegal fires in wilderness (104), and manipulation with open fire (65).

Table 3 Number of forest fires, damage in mil. SKK and total area (ha) damaged by forest fires

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Number	366	254	662	535	1056	426	824	311	570	852	155	286	237	463
Damage	3.5	3.8	33.5	3.2	10.1	5.1	385.1	7.1	17.4	17.5	1.3	48.4	3.6	158.0
Area	-	-	-	-	-	557	904	305	595	1567	150	528	178	680

1.2 Expected impacts

Assessment of bioclimatic potential of the territory of Slovakia was performed on the basis of the frequency of the occurrence of chosen tree species. Real temperature and humidity amplitudes of respective tree species were determined by using a model of tree species composition in Slovakia being derived from satellite scenes. In the framework of monitoring climate change there were constructed climatic models referring to individual years for the period 1961-2005.

Analysis of the change of bioclimatic habitats of individual tree species due to climate change was carried out by classifying climatic models according to the amplitudes of former occurrence, in sense of potential and real occurrence of tree species on the territory of Slovakia, whereas a shift of tree species to the north, it means to higher altitudes, was evaluated. This analysis was done for beech, oak, spruce, larch, fir and pine.

Solving the task was based on construction of climatic models for Slovakia in form of raster maps and their analysis. The models were used for determination of climatic amplitudes of former distribution of individual tree species on the territory of Slovakia (reconstructed according to the work by BLATTNÝ AND ŠŤASTNÝ 1959 AND MINĎÁŠ 1999) as well as the amplitudes of their real distribution, which was derived from classified satellite scenes LANDSAT (BUCHA 1999). The amplitudes were projected for future in sense of regional scenarios of climate change being elaborated by LAPIN ET AL. (2001). In the outputs, which have been worked out from nine models of general circulation of the atmosphere (GCM) up to now in Slovakia, emphasis was put to the models CCM 2000 and GIS 1988. There was used a method of so-called statistic downscaling in regionalization of the outputs of GCM, it means modification of the outputs of global climatic models for respective points on the territory of Slovakia by means of statistical methods and using the sets of measured data. In final solution the scenario A1B was used the most.

For the construction of a model of precipitation and air temperature there was used method of kriging with external drift. For the comparison of the change in the structure and accuracy of final model with the approach without introducing supportive variable (altitude) there was used the method of original kriging. Outputs of the first mentioned method were used in practice. Outputs of both methods are illustrated in Fig. 8 and 9.

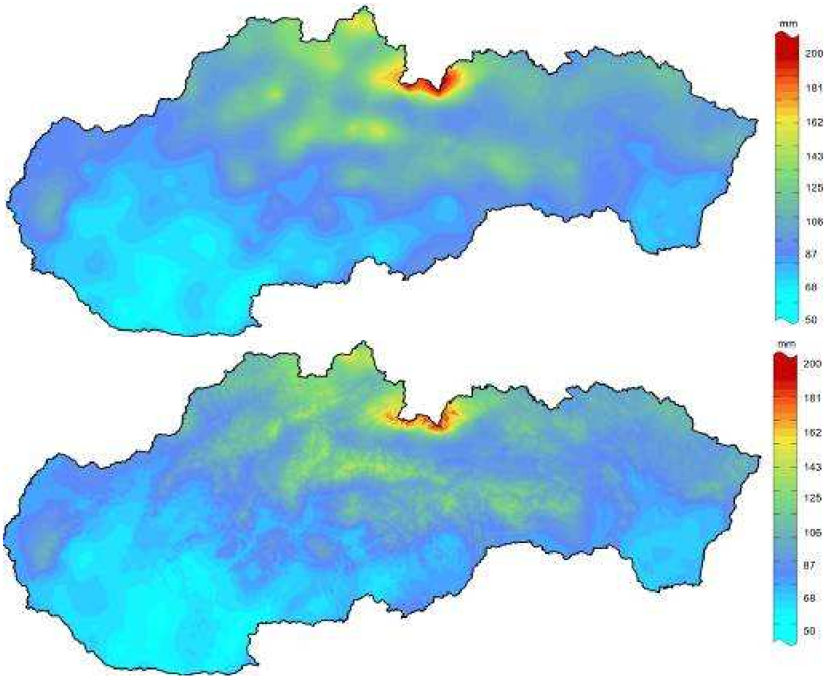

Fig. 8 Model of long-term average July precipitation totals derived by the method of ordinal kriging and kriging with external drift

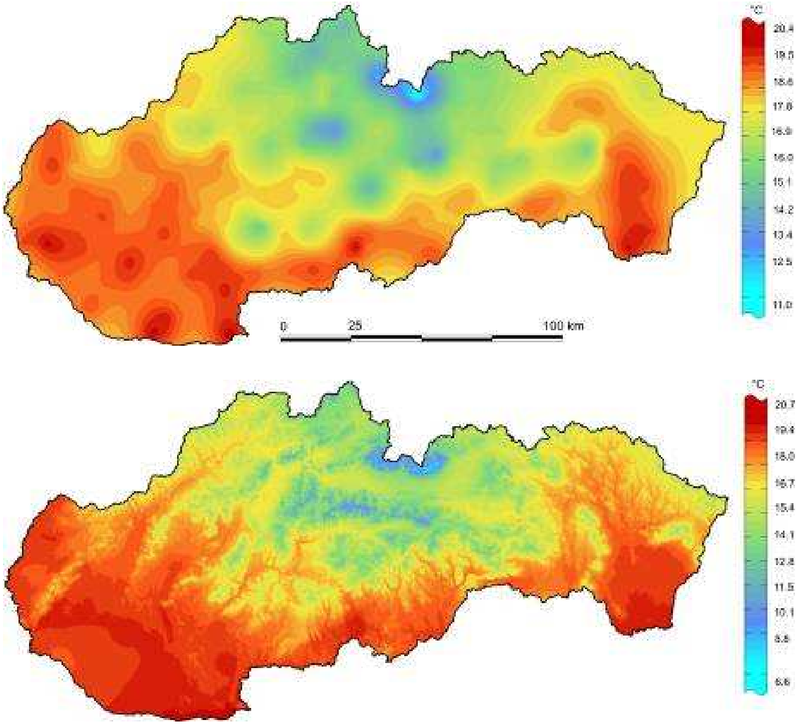

Fig. 9 Model of long-term average June and July air temperatures derived by the method of ordinal kriging and kriging with external drift

Climatic Water Balance (CWB) is the difference between the amount of precipitation and evapotranspiration. It is an important indicator of landscape humidity being used frequently in bioclimatology. In case of climatic water balance the obtained results show that the area with negative balance is situated in lowlands, valleys and it stretches up to the highest parts of submontane zone with exception of humid regions in northwestern part of Slovakia. In these regions we may expect a lack of moisture in summer. Area with positive balance and theoretically sufficient supplies of moisture is in fact almost all mountainous regions of Slovakia. The lowest altitude with positive balance is about 250 m. More detailed results were published in the work by HLÁSNY and BALÁŽ (2007) and HLÁSNY (2007).

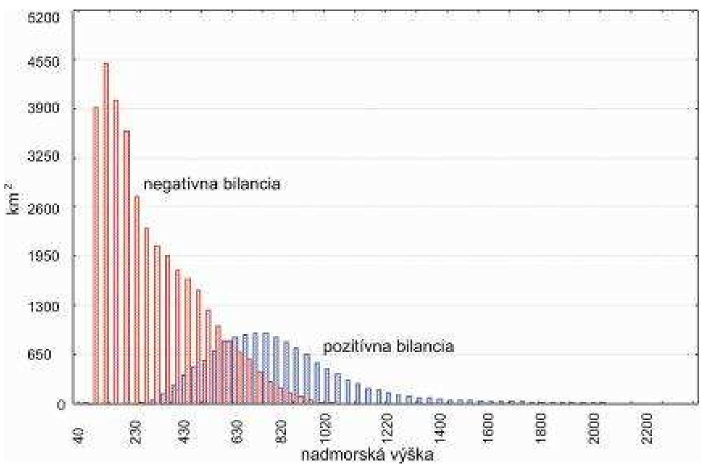

Fig. 10 Area of the territory of Slovakia with negative and positive climatic water balance in dependence on altitude (present climate)

Altitudinal zoning is obvious from the course of the values of water balance, but a significant overlapping of territories with positive and negative balance occurs here (Fig. 10). Regions at the highest altitudes with negative balance are situated above 1,000 m. They cover all lowlands and main valleys, and stretch to the highest parts of submontane zone with exception of humid regions in the northeastern part of Slovakia. There is a presupposition in this region that they will suffer from lack of moisture for the time of warm half year. Areas with positive water balance are situated almost exclusively in mountainous regions. The lowest locations with positive balance are at the altitude 250 m. Water balance during the months April-September on the territory of Slovakia for the period of normal (1951-1980) and for time horizons 2015 (2000-2030), 2030 (2015–2045), 2045 (2030–2060) 2060 (2045–2075) a 2075 (2060–2090) is illustrated in Fig. 11.

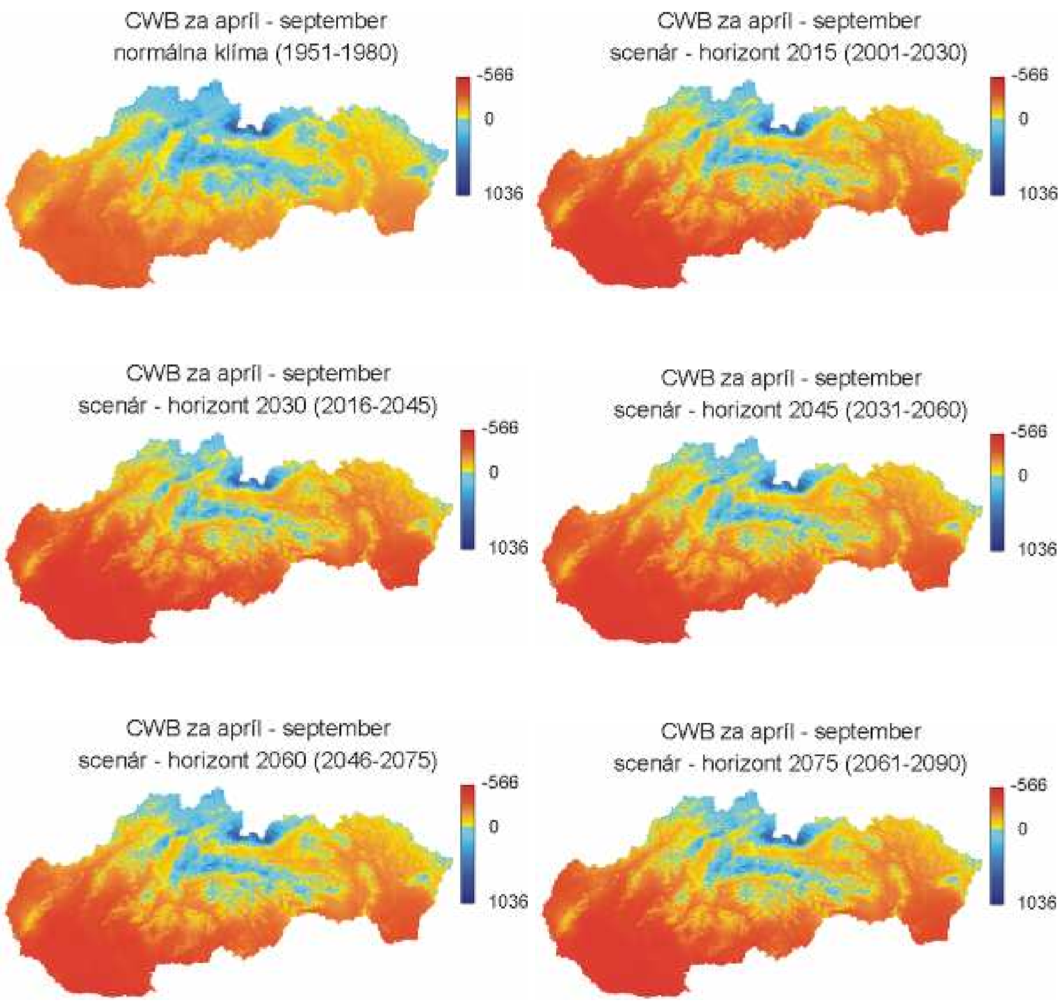

Fig. 11 Climatic water balance (CWB) for the period April - September in mm in Slovakia (averages for the period of 30 years) in the years 1951–1980 (normal climate) and for time horizons (2015, 2030, 2045, 2060 a 2075) of CCCM 2000 climatic scenario

We carried out also spatial analysis of the change in the territory with positive or negative water balance according to time horizons.

It follows from the analysis that present climate in comparison with normal (1951-1980) reflected negatively on the area larger by 5.8%. Negative trend will continue also in further period and by the year 2045 negative water balance will be on further 6.1% of the territory of Slovakia. Later this trend will stop and slight improvement will be recorded – by the year 2075 on the area of 0.2% of the territory.

Application of the functions of growth response in the maps of climatic factors was used for the determination of growth response of tree species to temperature and climatic water balance on the whole territory of Slovakia.

For the assessment of the impact of climate change on the growth, production and structure of forest stands there was used growth simulator SIBYLA, whereas there were constructed 9 representative stand models. The models cover all significant altitudinal vegetation zones and five main tree species as spruce, fir, pine, beech and oak. Classification system of ecological stability was used for the determination of the change in ecological stability and vitality of tree species.

More detailed methodologies were published in the final report of the project ČABOUN ET AL. 2008 and in the works by HLÁSNY and BALÁŽ (2007), HLÁSNY (2007), FABRIKA (2006), ČABOUN (2002).

Prognosis of the development of climate change and its impact on main tree species comes out from current distribution of tree species with regard to current climatic conditions (2007) for main tree species (beech, oak, spruce, fir, larch and pine), from short-term prognosis of the change of climatic conditions by the year 2045 for the given tree species and from long-term prognosis of changes in climatic conditions by the year 2075 for the given tree species. For illustration we present synthesis of results on expected development of oak, beech and spruce, the last one as the most attacked, growing in respective altitudinal vegetation zones according to growth response, climatic water balance and the frequency of occurrence and growth simulations in tables (Tab. 4 – 6).

Tab. 4 Synthesis of the results on expected development of oak trees growing in respective altitudinal vegetation zones according to growth response, climatic water balance (CWB), occurrence frequency and growth simulations

Oaks

AVZ	Growth response	CWB	Change of range	Growth simulations
1st	Suitable conditions for growth of xerophilous oaks Conditions for forest communities of "Balkan type"	Slightly limited conditions for growth of our oaks Invasion of oak xerothermic forests	Change of range is not expected with regard to global climate change	Ok production has been decreasing significantly
2nd	Suitable or substantially not changed conditions for growth of oaks	Suitable conditions for growth of oaks	Slight increase of range with regard to GKZ	Production of oak woods has been slightly, insignificantly decreasing
3rd	Suitable conditions for growth of oaks	Suitable and improving conditions for growth of oaks	Oak expansion on 20% of the area of avz	Production not changed
4th	Improving conditions for growth of oaks	Improving conditions for growth of oaks	Creating of conditions for oak communities	Not tested
5th	Creating of conditions for growth of oaks	Creating of conditions for growth of oaks	Minimal changes	Not tested
6th	Currently unsuitable conditions	Improving conditions for growth of oaks	Minimal or none changes of current state	Not tested
7th	Unsuitable conditions	Unsuitable conditions	Without change	Not tested

8th	Unsuitable conditions	Unsuitable conditions	Without occurrence	Not tested

Tab. 5 Synthesis of the results on expected development of beech trees growing in respective altitudinal vegetation zones according to growth response, climatic water balance (CWB), occurrence frequency and growth simulations

Beech

AVZ	**Growth response**	**CWB**	**Change of range**	**Growth simulations**
1st	Negative growth response for 56% of beech trees	Fast deterioration of conditions for beech growth	Endangered occurrence of beech on 90% of range area	Not tested
2nd	Deteriorating conditions for beech growth but not greatly	Deteriorating conditions for beech growth	Deteriorated conditions for beech in almost 60% of occurrence	Significant reduction of increment
3rd	Slightly worsened conditions	Slightly worsened conditions with regard to lack of moisture	Slight reduction	Significant reduction of beech increment by 20%
4th	Conditions suitable but deteriorating for the growth of beech	Deteriorating conditions suitable for development of mixed communities of beech and valuable broadleaved species	Deterioration of conditions for beech in 35% of the area of avz	Significant reduction of beech increment by 17%
5th	Conditions suitable and improving for the growth of beech	Conditions suitable for beech	Beech expansion to the detriment of spruce	Production and proportion of beech not changed
6th	Markedly improving conditions for beech	Conditions suitable for beech	Slight expansion of beech	Statistically insignificant changes
7th	Creation of conditions for beech	Gradual quick creation of conditions for beech	Expansion of beech to the 7th avz	Not tested
8th	Conditions unsuitable for beech	Conditions unsuitable for beech	Not changed	Not tested

Tab. 6 Synthesis of the results on expected development of spruce trees growing in respective altitudinal vegetation zones according to growth response, climatic water balance (CWB), occurrence frequency and growth simulations

Spruce

AVZ	**Growth response**	**CWB**	**Change of range**	**Growth simulations**
1st	Absence of conditions for spruce occurrence	Disappearing of communities with spruce	Loss of conditions for spruce occurrence	Not tested
2nd	Absence of conditions for spruce occurrence	Unsuitable conditions for spruce occurrence	Loss of conditions for spruce occurrence	Not tested
3rd	Absence of conditions for spruce occurrence	Absence of conditions for spruce occurrence	Unsuitable conditions for spruce occurrence	Not tested
4th	Limited conditions for spruce reflected in its health condition and vitality	Limited conditions due to lack of moisture	Deterioration of conditions for spruce almost on 80% of the area of avz	Not tested
5th	Increasing problems with spruce cultivation	Deteriorating conditions for spruce Competitive pressure of	Deterioration of conditions for spruce on 50% of the area of avz	Significant drop of production

		beech and fir		
6th	Only slightly changing conditions for spruce	Improving conditions for spruce	Birch changes not supposed	Significant drop of production in monocultures by 22%, in admixtures no problems
7th	Substantial improvement of conditions for spruce growth	Sufficient precipitation for spruce growth	Spruce expansion, improvement of conditions in whole avz	Significant increase of spruce production by 7%
8th	Creation of conditions for spruce growth	Creation of conditions for spruce growth	Shift of timberline	Not tested

1.3 Impact monitoring

In the framework of solving the task **"Impact of climate change on the forests in Slovakia"** there was worked out also implementation output "Proposal of a system of monitoring the consequences of climate change for the needs of decision making in forest sector". In most of countries with developed forestry a system of repeated selective monitoring – national inventories has been used in forest sector. In past they were aimed at finding the growing stock and assess trends of main mensurational and stand indicators. Such monitoring was sometimes connected with other monitoring (not repeated), the most frequently with inventory of forest soils or sites.

There have existed various kinds of detections aimed at forest management but they have not been related to the same time level. Mainly due to practical reasons of work organization it was a cycle of detections in certain spatial units (areas) performed in different time.

A new impulse for monitoring certain parameters in forests arising in connection with the need to monitor the effect of polluted air on forests was establishment of the programme ICP Forest, which has defined for the first time on European level common harmonized system with defined selective design, parameters, methods of their determination and assessment. This kind of monitoring is called not quite properly monitoring of forest health condition. More specific would be is "monitoring of forests and environmental interactions" (what is full title of the scheme Forest Focus) as obtaining data on various factors (anthropogenic as well as natural) and analysis of their effects on forest ecosystems and assessment of the dynamics of parameters characterizing the environment and their effect on processes going on in forest ecosystems is a main part of the monitoring.

ICP Forest monitoring (and subsequently monitoring as a part of Forest Focus scheme) has two basic components – extensive large scale monitoring in regular network of 16x16 km (level I) and intensive monitoring (level II). Though in the beginning of the programme the scale of detected parameters was relatively narrow and it was aimed at symptoms of damage (health condition, vitality), gradually the programme has developed into an integrated system with a vast set of obtained parameters, which may be used for the assessment of processes in forest ecosystems and the development of forests in broader environmental interactions.

At present a trend of developing European system of forest monitoring has been apparent in Europe with the aim of the most possible detailed methodically harmonized detection and assessment of data on forests for various purposes (impact of climate change on forests, change in biodiversity, supplies and capture of carbon in forest ecosystems, production, etc. It follows from several documents including Forest Action Plan of the EU.

Recently existing systems of forest monitoring and detection of forest condition are good basis for finalization of the whole system. Preconditions of the whole system functionality are as follows:

- Adoption of decisions on whole concept of obtaining, processing and utilization of information on forests whereas the system of monitoring the consequences of climate change consequences for forests would be an integral part of the system,
- Complementing the set of plots with detailed detection (especially the plots of intensive monitoring) by new plots (mainly in lower locations) and extension of monitoring by measurements and assessment of further parameters directly related with climate change
- Closer information interlinking of two basic components of current monitoring system – monitoring of the level I (ICP Forest Network) and National Inventory of Forests

1.4 Impact management

In the framework of the results of the task “Impact of climate change on the forests in Slovakia” **there was worked out also an implementation output** “Proposal of the strategy, adaptation and mitigation measures from the viewpoint of climate change impact on the forest ecosystems in Slovakia”. **Measures given in this document must be elaborated to the level of local conditions in framework of forest management plans, which will affect directly forest management in Slovakia.**
Existing real threat of the consequences of climate change for the forests of Slovakia requires in sufficient advance to adopt measures for mitigation of the consequences also with regard to long-term character of reproduction in forest management.

Presuppositions of adaptation strategy

- Complex reworking of the principles and methods of present typology with the aim of respecting time changes of the environment’s conditions in long-term outlook (rotation) and applying the principles in forest management planning
- Creation of legislative-economic conditions for fulfilling the principles of functionally integrated forest management regardless ownership’s relations
- Consistent application of silvicultural principles aimed at close to nature structure of forests on the basis of increasing ecosystem, species and genetic diversity being based on natural regeneration of forest stands

Proposal of concrete measures of adaptation strategy in forest management for time horizons 2007, 2045 and 2075 are presented in the mentioned implementation output. With regard to great extent of newly obtained knowledge all new data are summarized in tables and related measures.

Prognosis is based on the synthesis of results of the analysis of classes of conditions suitability, which were determined for individual tree species on the basis of the frequency of present occurrence and growth responses of respective tree species in respective altitudinal vegetation zones, as well as on the basis of the results of growth simulation by means of raster simulator SIBYLA, analysis of the impacts of climate change on production, ecological stability, vitality of tree species and the structure of stands using the models of climate change for chosen tree species.

Evidential value of the obtained results is somewhat reduced for non-autochthonous tree species in the given region and for the tree species with low frequency of occurrence, for example for larch in lower altitudinal vegetation zones.

Area where tree species, for which we give **necessary measures**, are growing, there are marked tree species growing at present, or growing according to the scenarios of climate change under the conditions being unsuitable for them.

For tree species growing under the conditions limiting their growth and existence we present the category **– suitable measures**. For tree species growing under suitable conditions, it means optimal ones, we do not propose any measures and the category is named as **unnecessary measures** (it means from the viewpoint of expected climatic change).

We must note that we state in the tables suitability of conditions for the growth and development of tree species but we do not consider extreme weather events, which are expected at increased rate, and which will affect as abiotic injurious agents. They are mainly wind, storm, and in lower locations (especially the 1^{st} – 3^{rd} altitudinal vegetation zones) drought as well.

Basic characteristics of altitudinal vegetation zones are given in following table:

Tab. 7 Distribution of forests according to altitudinal vegetation zones and their characteristics

Altitudinal vegetation zone		Altitude (m)	Total annual precipitation (mm)	Vegetation period (days)	Average annual temperature (^{o}C)	Area	
						(ha)	(%)
1	Ok	Within 300	600 and less	180	8.5 and more	140 373	7.27
2	Beech-Oak	200 – 500	600 – 700	165 – 180	6.0 – 8.5	265 332	13.74
3	Oak-Beech	300 – 700	700 – 800	150 – 165	5.5 – 7.5	457 063	23.66
4	Beech	400 – 800	800 – 900	130 – 160	5.0 – 7.0	401 346	20.78
5	Fir-Beech	500 – 1000	900 – 1050	110 – 130	4.5 – 6.5	419 371	21.71
6	Spruce-Beech-Fir	900 – 1300	1000 – 1300	90 – 120	3.5 – 5.0	186 434	9.65
7	Spruce	1250 – 1550	1100 – 1600	70 – 100	2.0 – 4.0	41 141	2.13
8	Dwarf pine	1500 and more	1500 and more	60 and less	2.5 and less	20 585	1.06
Total stand area:						***1 931 645***	***100***

Source: Summary information on forest condition in SR 2006

Average climatic characteristics (temperature and water balance) for the period 1951-1980 were used as comparison level for the assessment of the impact of global climate change on current distribution of tree species on the territory of Slovakia in relation to chosen climatic characteristics.

There are given characteristics of altitudinal vegetation zones, distribution and proportions of main tree species, prognosis of the development of climate change and its impact on main tree species as well as proposal of measures for mitigation of negative impacts of climate change on respective tree species according to altitudinal zones. We pay attention to the changes in tree species composition and to the measures carried out in regeneration and tending of stands differentially according to growth phases.

Regarding regeneration we must include among “necessary measures” for all altitudinal zones verification of suitability of currently valid forestry legislation, which enables transfer of planting stock also by one altitudinal zone lower. It means that for example planting stock cultivated from seed source at the altitude 790 m can be planted out on the site with the altitude 410 m. Such transfer may be unsuitable with regard to an increase of average temperatures due to global climate change.

Principles of tending in last growth stage of a stand with dbh 20 cm are not given as it is impossible to increase ecological stability of forest stands by preventive silvicultural measures. For such case it is generally valid that undamaged stands must be fluently prepared for natural regeneration. Damage must be understood as a signal for the implementation of changes in the structure of stands, mainly in tree species composition in accordance with the principles given for stands regeneration. This is necessary measure already.

2. Adaptation

2.1 Vulnerability of forests and forestry

In the framework of solving the impacts of climate change on the forests of Slovakia we have considered three time horizons, namely the year 2007, 2045 and 2075. We worked out for the mentioned time horizons "Proposal of the strategy, adaptation and mitigation measures from the viewpoint of the impacts of climatic changes on forest ecosystems of Slovakia. The given measures are worked out for 6 tree species (spruce, fir, pine, beech, oak and larch), whose proportions are dominant in Slovakian forests.

In predicting the development of forests for the given time horizons there was taken into account a synthesis of results, which have followed from the analysis of conditions suitability being determined for respective tree species on the basis of the frequency of current occurrence and growth responses of tree species in respective altitudinal vegetation zones. The results of growth simulation obtained by means of growth simulator SIBYLA, analysis of the impacts of climatic changes on production ecological stability, vitality of tree species and the structure of stands were also used altogether with the models of climate change for chosen tree species.

2.2 Adaptation strategy and policy

In the years 2004-2005 we solved the task of state programme of research and development with the title "Ongoing climate change and its impacts on the development of the country". In the framework of this task we have solved partial task "Consequences of climate change for the forests and forest ecosystems and adaptation measures including silvicultural principles of the management of forests".

In the framework of branch project under the title "Impact of climate change on the forests of Slovakia" (2003-2008) there was worked out an independent implementation output "Proposal of the strategy, adaptation and mitigation measures from the viewpoint of the impacts of climate change on forest ecosystems in Slovakia".

Despite there were worked out several proposals, the adaptation strategy has not been approved separately yet. In the conditions of Slovakia **adaptation strategy presupposes following:**

- Complex reworking of the principles and methods of present typology with the aim of respecting time changes of the environment's conditions in long-term outlook (rotation) and applying the principles in forest management planning
- Creation of legislative-economic conditions for fulfilling the principles of functionally integrated forest management regardless ownership's relations
- Consistent application of silvicultural principles aimed at close to nature structure of forests on the basis of the increase of ecosystem, species and genetic diversity being based on natural regeneration of forest stands

We can state that in close future it will be necessary to work out for the forests of Slovakia an adaptation strategy and to apply it in legislation, or to elaborate measures that would eliminate the impacts of global climate change on forests. Moreover, this requirement is being mentioned also in the "*OPINION of the European Economic and Social Committee on The role of forests and the forest-based sector in meeting the EU climate commitments (Kallio 2009)*".

2.3. Forest adaptation measures

For better adaptation of forests to changed conditions as a result of the impact of global climate change there were worked out measures aimed at mitigation of the impact. These measures were summarized in the already mentioned output "Proposal of strategy, adaptation and mitigation measures from the viewpoint of climate change impacts on forest ecosystems in Slovakia". Coming out from the expected impacts of climate change there were worked out **necessary measures** that refer to tree species growing in the conditions being currently unsuitable for them or that will be unsuitable according to the scenarios of climate change in future.

For tree species growing in the conditions limiting their growth and existence **suitable measures** were defined. For tree species growing in the suitable conditions, it means optimal and appropriate conditions, there were not proposed any measures. Thus this category is named as **unnecessary measures** (from the viewpoint of expected climate change).

It must be noted that these measures are presented in tables for respective tree species (spruce, fir, pine, beech, oak and larch) according to respective altitudinal vegetation zone. Extreme weather events are not considered, though they are expected increasingly more and they will affect as abiotic injurious agents. They are particularly wind, storm, and in lower locations also drought (mainly in the 1st up to the 3rd altitudinal zone).

Based on the prognosis of the development of climate change and its impact on the given main tree species there was elaborated a *"Proposal of measures for mitigation of negative impact of climate change on tree species"*, which comprised following:

<u>Changes in tree species composition</u>

- Optimal regeneration tree species composition must be chosen in order to increase ecological stability of new forest stands
- To prefer tree species whose ecological requirements correspond with the most probable character of changed climatic conditions and tree species with broad ecological amplitude
- In general, it is recommended to increase the proportion of pioneer, mostly more drought-resistant tree species as of birch, aspen, grey poplar, Scots pine, Austrian pine as well as tree species with continental distribution as for example European larch, of warm-loving tree species (oak, hornbeam, linden) and some exotic tree species (Douglas fir, grand fir, locust, red oak and walnut).

<u>Principles of forests regeneration</u>

- Special attention should be paid to proper choice of tree species in connection with suitable forms of admixture of regenerated or established stands, choice of planting stock, its physiological quality during planting, way of planting with the use of non-

traditional procedures and methods (use of hydro absorbents – binders of water, ecological microbiological conditioners)
- Agrotechnical terms, technological procedures with subsequent care of cultures and their protection should be observed
- Genetic variability of planting stock for reforestation is extremely important as particularly it is carrying a capability of population to adapt to changing conditions

Principles of forests tending

Based on recent knowledge on the issue of the climate change impact on forest stands we may state that for developing of a strategy of the management of forests it will be crucial to determine those regions (stand types) that seems to be decisive from the viewpoint of expected changes. Most dramatic changes of bioclimatic conditions may be expected in lowland regions as well as mountainous locations. Having on mind these changes we have worked out adaptation measures for the mentioned areas.

Silvicultural measures in lowland forests

Silvicultural measures in areas with beech as dominant tree species

Objectives of silvicultural measures in relation to expected climate change in the stands with beech dominance might be characterized as follows:

- Preservation of two or more-layer structure of stands, eventually cluster or group of admixed tree species (fir, sycamore maple, spruce, oak)
- To apply in not mixed beech woods as a phytotechnical procedure crown thinning with positive selection in order to form sufficiently large, regular and symmetric crowns, whereas treatments are performed also in subdominant level with aim to influence ecological conditions of subdominant components
- To support in mixed stands with spruce and fir (on suitable sites) two-three layer (selection) structure to reach that spruce and fir is in the level of dominant trees, or in general level, and beech in the level of subdominant trees
- To apply selection thinning in stands with averaged heights and in one-layer stands
- To perform stands regeneration by group small-scale shelterwood felling, in group with shorter rotation or early final felling
- As the strategy for beech cultivation we can recommend cultivation of multi-layer stands with small-scale silvicultural system, and group shelterwood regeneration

Silvicultural measures in areas with insufficient static stability of forest stands

Occurrence of spruce will be related mainly with the 7th altitudinal vegetation zone. Spruce occurrence in lower altitudinal zones will be connected with a certain risk of damage by abiotic and biotic injurious agents, mainly in the 4th and 5th altitudinal vegetation zone. Spruce has good preconditions in the 6th altitudinal zone on suitable sites to form ecologically stable mixed stands with a high production whereas admixed tree species would fir and beech (sycamore maple). What concerns adaptation measures following principles can be recommended.

- Cultivation of stands composed of various tree species where greater ecological plasticity can be expected
- Formation of stable forest stands with appropriate stand structure with simultaneous securing of required functional forest effects
- Aim silvicultural treatments to reach differentiated diameter and height structure or the structure of close to nature forest
- Some form of selective system of small-scale form of shelterwood system may be considered but only on condition there exist serious biological and ecological difficulties for applying silvicultural systems being close to nature ones
- Most effective tools to reach and maintain the structure of stable selection forest are selection thinning and selection felling
- Silvicultural treatments are aimed at the change of homogenous structure with the support of admixed tree species and locally tending treatments of various intensity in order to form tree groups that later will be independent regeneration cells
- In treatments to apply positive selection on the level being aimed at strongest individuals with longer crowns, which will form so-called trees of stand skeleton also in small pole stage up to last growth stage of a stand with dbh 20 cm
- Similarly in mixed stands it is desirable to apply urovnovy positive selection aimed at mature individuals of admixed tree species (larch, Swiss stone pine, service tree) and to create by treatments presuppositions for formation of differentiated vertical structure
- In stands with changed structure (larger areas of more or less even aged stands) that prevail in Slovakia it is necessary to support cluster structure through silvicultural treatments, particularly by creating forms of irregularly dense biogroups

In general, we can recommend as adaptation measures being taken in the framework of the management of forest aimed at minimizing the risks in relation with the consequences of climate change for forests following ones:

- To reduce as most as possible one-layer, even aged stands and related clear-felling system, which creates a forest with low accumulation of biomass and carbon whereas in spruce monocultures also a risk of lowered stability against wind as an accompanying factor of climatic changes occurs as well
- Regardless ownership's relations close to nature management of forests should prevail in future with its locally typical characteristics and high resistance potential
- To adapt in advance close to nature commercial forests to climate changes resulting from global warming, for example by increasing the proportion of oak, pine mainly in the 1st up to the 3rd altitudinal zone
- In forests of the 1st up to the 4th altitudinal zone shelterwood system should prevail in future with higher proportion of small-scale form of this silvicultural system. Stands where the silvicultural system of long-term two-layer stands has been applied should

have a certain proportion as well. They would be two-layer stands of sun-loving and shade-loving broadleaved tree species, two-layer stands of sun-loving coniferous tree species (pine and larch) and shade-loving broadleaved tree species (beech)

- In general assessment of mountainous forests their state is being considered unsatisfactory (calamities, air pollutants, game, inappropriate regeneration procedures, and others). Applying close to nature silvicultural systems, it means small-scale shelterwood system and both forms of selection system, would be an effective way for the future
- To prefer in planning tree species composition of the stands in marginal altitudinal vegetation zones to prefer selected suitable tree species from locations in lower altitudinal zones

2.4. Research studies on forest adaptation

There have not been worked out research studies yet in Slovakia that would deal specially with adaptation measures. Such studies were always a part of studies being aimed at the impacts of climate change on the forests in Slovakia, it means including adaptation and mitigation measures as a part of the studies.
At present we have been solving in the framework of the task titled "Study of ecology, structure and dynamics of forest ecosystems under changing natural conditions" issues of climatic changes, but issues of forest adaptation and of the effect of implemented adaptation measures on forests have been neglected.

3. Mitigation

Measures aimed at elimination of negative effects being caused particularly by climate change (mitigation measures) have not been applied in greater extent in Slovakia up to now. First proposals of mitigation measures have been recently implemented rather on theoretical level than on practical one, whereas they have dealt mainly with the analysis of the climate change impact on forest management. Measures aimed at mitigation of the consequences of climate change can be divided into general and specific measures.

The first category comprises all measures related with enhancing biological and genetic diversity, with forest management close to nature and the principles of sustainable forest management. Their implementation has been more or less generally valid, and they should be taken into account regardless uncertainty of climatic changes predictions.

The second category comprises specific measures aimed at respective aspects of expected impact of climate change on forests (forests with inappropriate tree species composition and structure, forests entering the stage of regeneration, afforestation of non-forest areas) (Minďáš, Škvarenina 2003). The measures of the second category have either evidently low efficiency (change in tree species composition, change of silvicultural system, longer rotation and some others) or the changes have been carrying out only on minimal area. Thus for example 800 – 1000 hectares per year are deforested permanently in Slovakia as a result of the change in forest land use for other purpose than growing forest (construction of roads or other infrastructure).

Possible alternatives being under consideration are silvicultural measures. It is possible to carry out two basic silvicultural measures in the conditions of Slovakia. They are as follows:

Afforestation of fallow lands,

Strengthening of the adaptation potential of present and future forests to the changes of the environment,

In relation with climate change it is possible to set some new objectives of forest management in Slovakia:

To reach the greatest possible carbon sequestration in forest ecosystems, knowing that accumulation of biomass and carbon in soil is greatest in healthy stands of high age and full stocking, uncovering of soil connected with accelerated decomposition of litter, humus and dead wood has not occurred

To reach the greatest possible stands resistance against a broad spectrum of injurious agents,

To reach the highest possible carbon accumulation in products from wood – it is interlinked with serviceable life of wood products that is highest for furniture or building wood and lowest for wood for energy purpose

A special objective, which may be in conflict with the objectives mentioned above, is utilization of wood as a renewable source of energy to reduce utilization of fossil fuels. Such use in fact does not respect some objectives given above (smaller immediate real volume of accumulated carbon, short serviceable life of products) but on the other side it has also some advantages (quick carbon accumulation, energy production).

3.1 Carbon accounts

Kyoto Protocol and position of the Slovak Republic

The framework Convention on Climate Change (UN FCCC) - the basic international legal instrument to protect global climate was adopted at the UN Conference on the Environment and Sustainable Development in Rio de Janeiro in 1992. In the Slovak Republic, the Convention came into force on November 23, 1994. The Slovak Republic accepted all the commitments of the Convention, including reduction of the greenhouse gas emissions by 2000 to the 1990 level. One of the commitments, resulting from the Convention, is to provide greenhouse gas emission inventory regularly.

The Kyoto Protocol, adopted by consensus at the third session of the Conference of the Parties (COP-3) in Kyoto, December 1997, enforced the international responsibility for the climate change. The Slovak Republic agreed to reduce base year level of all six GHG emissions by 8% during period 2008–2012. In the context of joining of the Slovak Republic the European Union (May 1, 2004), raised new requirements for legislative implementation in the field of air protection.

A reduction commitment for the SR for the 2008–2012 period is defined in the Annex B to the Kyoto Protocol as a five-multiple of 92% of total national greenhouse gas emissions in 1990 (reduction commitment -8%). The strategy of meeting the Kyoto Protocol commitments in the Slovak Republic reduces a total quantity for the Kyoto period by further 5%.

The National Focal Point (NFP) at the Department of Air Protection of the Ministry of Environment SR is the key expert and legal guarantor for the achievement of commitments and requirements under the UNFCCC and Kyoto Protocol. Ministry of Environment has established on the 1st October 2008 new Department on Climate, Energy and Renewable Energy Sources. This unit serves as the national focal point to the UNFCCC as well as supervisor for the professional activities of OE connected with this Convention and with the Kyoto Protocol.

The Slovak Republic has selected as threshold values for the forest definition for reporting under Article 3.3 (ARD activities: afforestation, reforestation and deforestation) the following: forest land includes land with minimum tree crown cover of 20% for trees capable to reach minimum height of 5 m in situ. The minimum area for forest is 0.3 ha. Temporarily unstocked forest lands are included (forest regeneration areas). For linear formations, a minimum width of 20 m is being applied. The selected threshold values are consistent with the values used in the report to the Food and Agriculture Organisation of the United Nations (the GFRA 2005), National Forest Inventory, and MCPFE criteria and indicators of sustainable forest management. The Slovak Republic has decided not to use any activities under Article 3.4 (forest management, cropland management, grazing land management and revegetation) for meetings its commitment under the first commitment period of the Kyoto Protocol.

3.2 Slovak carbon account

The Slovak Hydrometeorological Institute, Department of Emission, is the organization authorized by the Ministry of the Environment as a chief coordinator of the National Inventory System under the Kyoto Protocol to monitor and report all activities as related to the annual inventory of GHG emissions and sinks and projections.

Two experts charged, one from the National Forest Centre and the other from The Slovak Hydrometeorological Institute, compile inventory of GHG in the Forest and Land Use sector. Experts have been charged by Slovak Ministry of Environment. Experts use relevant methodological procedures according to recommendations and methodological guidelines from UN FCCC secretariat (www.unfccc.de) and IPCC (www.ipcc.ch).

Forest and land use sector covers wide set of biological and technical processes of the country that affect balance of GHG emissions. This sector deals with basic greenhouse gas (GHG) CO_2. Particular balance categories are bound to all relevant processes concerning changes in carbon stocks in all five carbon pools for reporting purposes (above ground biomass, below ground biomass, litter, deadwood and soil carbon), as they was defined in conclusions of the Conference of Parties in Marrakesh (Marrakesh Accords). This balance is based on the definition of basic kinds of land use: forest land, grassland (meadows and pastures), cropland (land being used for production of food and other technical products), wetland, settlements and other land (e.g. parent rock of mountains, stone-pits etc.) and their temporal changes as well. From the viewpoint of the significance of carbon balance first three land use types are most important because they have been used on more than 90% of Slovakia territory. From the point of view of GHG balance these processes concern only balance of the carbon dioxide (CO_2). According to actual results of the GHG emissions balance in this sector a main source of emissions captures are forests (forest management)) – wood production and cropland conversion to forest land.

Table: GHG emissions results for Slovak forest sector in Gg of CO_2 (http://unfccc.int). Negative emissions correspond to sequestration.

Year	1990	1995	2000	2005	2006
Gg CO_2	- 4 436	- 4 388	- 4 301	- 159	- 2 555

There is the significant decrease of CO_2 emission (table x) against the base year (1990) about approximately 1881 Gg it means the decrease by about more then 42 % within LULUCF sector. The reason of significant difference between 2005 and other years was the natural catastrophe in the large part of forest in the end of 2004 in the High Tatra Mts., when the huge parts of forest were destroyed.

The Slovak experts annually update new information and activity data with the corresponding statistical information from the Statistical Office of the SR and other national statistics.

3.3 Forestry as a source of bio-energy

Political processes, tools and strategies for mitigation

The National Forest Programme of the Slovak Republic can be considered as main strategic document of mitigation policy in Slovak forestry sector. The Government of SR approved the document and it was discussed and noted by the National Council of SR in 2007. In the year 2008, the national forestry programme will be worked out in detail through the indicative action plan for the period of 2009–2011.

One of 18 NFP priorities, the priority number 4, is directly focused to mitigation consequences of climate change and to support adaptation of forests to impacts of climate change and stated following:

Forest ecosystems can absorb carbon dioxide and store it in soil and vegetation and affect so the process and the extent of climate change. In the global scale the deforestation is responsible for approximately 20% of total carbon dioxide emissions. The EU Forest Strategy mentions that mitigation of climate change can be most easily achieved via increasing existing reserves of carbon in forest ecosystems and by providing support to the use of biomass and wood products. By implementing proper forestry adaptation and mitigation measures in the area of carbon storage the forest management can considerably contribute to meeting the Kyoto Protocol commitments.

Completing the research and development project „Impact of climate change on forests of Slovakia“ in 2007 should create basic methodology and procedures for forest management under conditions of climate change. This project was aimed mainly at following issues:

Consequences of climate change on forest ecosystems,

Monitoring of changes in carbon balance in forest ecosystems,

Strategy of forest protection against injurious agents under conditions of climate change, measures resulted from the Kyoto Protocol for the forestry sector.

One of the outcomes of this project is absence of regional scenarios of climate development and scenarios of expected impacts on forest ecosystems.

The priority 4 presents following framework objectives:

• Increase of the carbon store in forest ecosystems through forestry measures (maintenance, replacement of carbon),

• Adaptation of the forest structure to expected climate change consequences through implementation of adaptation measures,

• Creation of conditions for application of nature-friendly and economically effective silviculture (Moravčík et al. 2007)

Slovakia has not been planning to use the Clean Development Mechanism or Joint Implementation as tools for mitigation in future.

3.4 Research studies on mitigation

Research projects have not been solved in Slovakia as well as studies dealing with mitigation measures have not been worked out. They were always a part of the projects aimed at studying the impact of climate change on the forests in Slovakia including mitigation measures.

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