COST action FP0703 – ECHOES

Expected Climate Change and Options for European Silviculture

COUNTRY REPORT

SLOVENIA

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Content

INTRODUCTION

Climate change is one of the main global environmental problems. In the context of climate change influence on the environment, forests could be observed from at least two different points of view. On one hand, the positive influences of forests and forest policy on the CO2 sequestration could be stressed out. Due to deforestation on the global level, forestry is characterised as one of the main emitters of CO_2, even greater than the transport. The forest cover of Europe has been enlarging in the last decades. The European Union stimulates the preservation of forest resources, the enlargement of forest area and the appropriate use of timber and wood products in order to intensify the positive effects of forests on the reduction of CO_2 concentration in the atmosphere. One the other hand, the influence of climate change on functioning and stability of forest ecosystem could be exposed. The consequences of climate change on forest stand development are numerous, diverse and of different intensity. Significant differences in climate change consequences and forest stand dynamics could be observed between countries; as a consequence different adaptation strategies of forest management were adopted. Slovenia is a country with a very diverse relief and a considerable heterogeneity of climate on a relatively small area; therefore predictions (scenarios) of climate change are quite uncertain. In the last 50 years, climate changes (average temperature, average precipitation etc.) in Slovenia have been observed to be higher than the European or global average (Kajfez-Bogataj *et al.*, 2008). This fact gives forests and forestry even greater importance in the process of mitigation of climate change consequences.

1. IMPACTS

1.1 OBSERVED IMPACTS

1.1.1 Observed climatic evolution

Observed climate change in Slovenia can be summarized to following (Kajfez-Bogataj *et al.*, 2003):

- Mean air temperature have increased 1.1 ± 0.6°C in the period 1951–2000; the increase is statistically significant ($p<0.05$).
- Trends of yearly amounts of precipitations on most areas in Slovenia are not statistically significant with some exceptions; e.g. in SE Slovenia (location: Kocevje) and in NW Slovenia (location: Ratece) significant decrease of precipitations was registered.
- Intensity of heavy rain is slowly increasing.
- In basins, there are fewer days with fog.
- Trend of solar radiation duration is increasing.

1.1.2 Impacts on ecosystem dynamics and functioning

1.1.2.1 Vegetation phenology

Spring phenological events are particularly sensitive to temperature and consequently suitable indicator to assess the impact of increased winter and spring temperatures on plant development. The 46-year series (1955–2000) of leaf unfolding in beech, common silver birch, large-leaved lime and horse-chestnut, and of flowering of common silver birch, dandelion, goat willow, hazel, snowdrop, black locust, common elder, common lilac and large-leaved lime were studied at eight selected observation points in Slovenia (Crepinsek and Kajfez-Bogataj, 2004). Phenological data were combined in an annual leaf unfolding index, early-spring flowering index and late-spring flowering index to determine the changes in the beginning of the growing season. There were significant differences in the trends of the different pheno-phases in spring. The mean linear trends (days per decade) ranged from –1.4 for leaf unfolding, –2.2 for late-spring flowering and –3.1 for early-spring flowering. This resulted in an earlier leaf unfolding of 6 days and an earlier flowering of 10–14 days. Observed changes (a 10-day shift to earlier spring) in the average beginning of the growing season corresponded well with changes in early-spring temperatures (February to April). The investigation showed that a warming of 1°C in early-spring promoted the beginning of the growing season by 4 days.

1.1.2.2 Insect phenology and distribution area

Sanitary felling on a larger scale were carried out from 1990 to 2001 and 7.2 million m^3 of wood was felled; 1.4 million (18.8 %) due to the phloemophagous insects. From 1999 to 2005 sanitary fellings were constantly increasing, at that time 5.5 million m^3 of wood was felled, 2.3 million m^3 or 40.7 % due to bark beetles. In the submediterranean region the damages due to leaf-chewers (defoliators) *(Tortrix viridana* and *Aleimma loeflingiana)* were increasing, in the period 1995-2005 also some the large scale defoliations happened. In 2004, which followed the exceptionally dry year 2003, the areal spreading of *Lymantria dispar* was noted. The stands of *Pinus nigra* were also affected (more than 60 %). The altitudinal enlargement of the areas of *Ips amitinus* was registered; it appeared on 1270 to 1500 m above sea level and caused outbreaks in the years 2003 and 2004. In the year 2005 the damages of *Taphrorychus bicolor* were noticed, in the year 2005 *Agrilus viridis* caused dying of young maple trees. Four exotic insect species *(Xyleborus germanus, Metcalfa pruinosa, Leptoglossus occidentalis* and *Dryocosmus kuriphilus)* appeared on forest trees (Jurc M., 2007).

There are several invasive species of fungi recorded lately in Slovenia:

- After the 2003 drought, oak charcoal disease broke out in the Karst region. It was caused by endophytic fungus *Biscogniauxia mediterranea* in Turkey oak (*Quercus cerris* L.). The emergence of this disease was related to extreme drought and very high temperatures. It is a serious problem in cork oak (*Quercus suber*) and Turkey oak in the Mediterranean area but it had never been detected further north than southern Tuscany. The appearance of this disease in Slovenia, approximately 350 km north-east of Tuscany, may indicate that the predicted climate change could lead to outbreaks of this disease further north (Jurc and Ogris, 2006).

- Ash dieback caused by *Chalara fraxinea* appeared in 2006 (Ogris *et al.*, 2009).

There are several existing fungi present in Slovenia that cause more intensive damages in last ten years: *Botryosphaeria dothidea*, *Armillaria* spp., *Nectria* spp., *Phytophthora* spp. (Jurc, 2007).

1.1.2.3 Global productivity

Kotar (2002) made an analysis of changes in forest site productivity in the beech forests (18 beech forest types with 5 replications) of Slovenia during the last decades. The results indicated the increase of site productivity: the site index (i.e. average top height at the age of 100 years) determined in relatively younger stands were higher than site index determined in relatively older stands in the same forest type. Changes of site productivity (measured by correlation coefficients r) were in 6 forest types statistically significant at a level $P<0.05$, in 8 forest types at a level $0.05<P<0.10$. The analysis showed that the height growth pattern has changed in the last decades. In 5 beech forest types the annual height increment has increased in the last or in the proceeding decade despite the fact that the average age of analysed stands was over 100 years. Factors influencing the increase of site productivity have not been studied in detail. However, increased site productivity does not necessarily cause higher volume growth; the factors causing increase of site productivity can cause deterioration in the health status of the trees.

1.1.3 Disturbances and extreme events

In the period 1961–2004 eight extreme droughts happened, five of them in the last 20 years (Fig. 1). Increase of droughts recorded is noticeable but it is not statistically significant (Kajfez-Bogataj and Bergant, 2005). The most intense drought occurred in 2003.

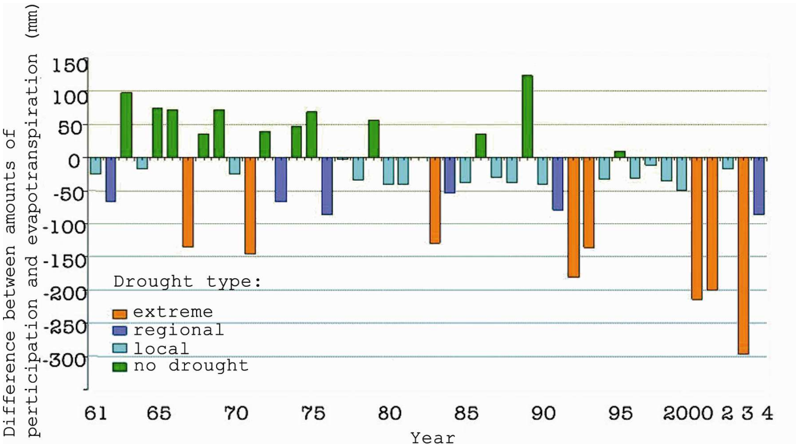

Figure 1: Droughts in Slovenia during 1961 to 2004. The intensity of drought is determined by the rate of water deficit in eight main agricultural areas in Slovenia (Matajc, 2002; Kajfez-Bogataj and Bergant, 2005; Susnik, 2006).

Slovenian Forestry Service (SFS) recorded several extreme weather events from 1965 to 2008 (Fig. 2 and Fig. 3). Larger events happened in following years (Ogris, 2006; SFS, 2009):

- windthrow: 1965, 1975, 1984, 1986, 2003–2006, 2008;
- snow breakage: 1961, 1972, 1981, 1996, 1999, 2007;
- sleet: 1975, 1980, 1984, 1997;
- insects: 1966, outbreaks 1984–1988, outbreaks 2003–2008 (peak 2005);
- diseases: increasing from 1980 to 1993, then steady;
- forest fire: 1971–1973, 1982, 1993, 1998, 2003.

Most serious disturbances in the period 1995-2008 were caused by insects (mostly spruce bark beetles), then by diseases of forest trees, and a little less by extreme weather events (wind, snow and sleet), other reasons (e.g. emissions) were les important. In last 20 years annual number of extreme events increased, but the changes are not statistically significant. Number and area of forest fire in 1995–2005 was lower than in 1963–1984.

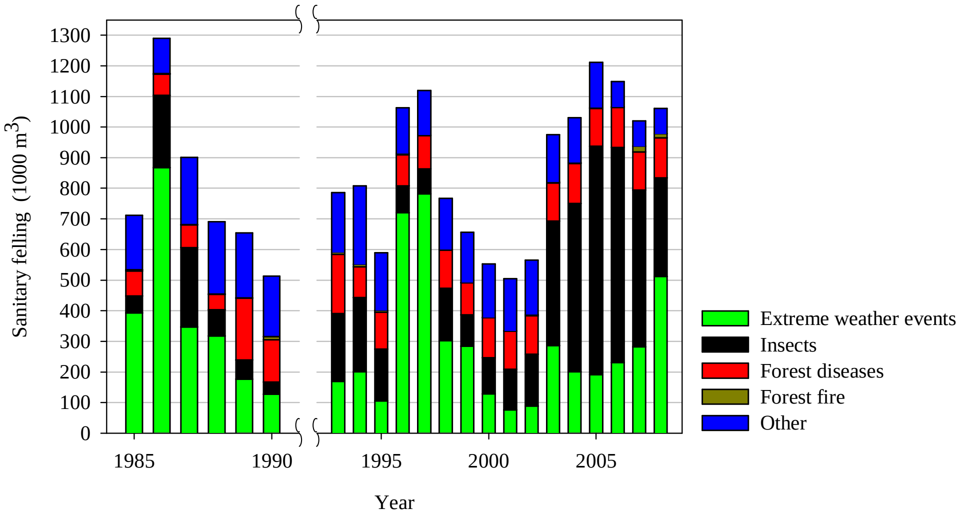

Figure 2: Sanitary felling in Slovenia (1000 m3) for the period 1985–2008 (SFS, 2009)

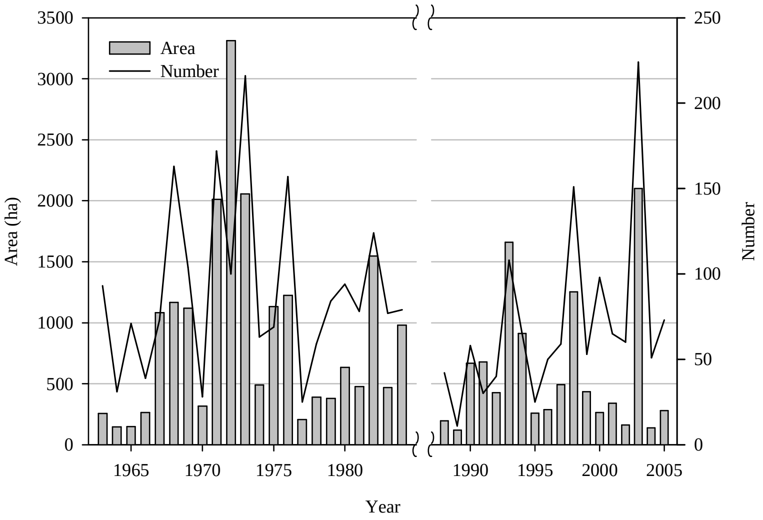

Figure 3: Area and number of forest fires in Slovenia in 1963–2005

1.2. *EXPECTED IMPACTS*

I.2.1. Expected climatic evolution

To estimate the future temperature and precipitation conditions in different regions of Slovenia by the end of 21st century, empirical downscaling was used to project the results of general circulation models (GCM) simulations with four different models (Bergant, 2007). Five locations were selected, representing four main climate types in Slovenia: moderate continental (two locations), subpannonian, alpine and submediterranean climate.

The results of projections (presented as estimated changes for the period 2061–2090 in comparison to the reference period 1961–1990) indicate the strongest warming in summer (3.5°C to 8°C) followed by winter (3.5°C to 7°C), spring (2.5°C to 6°C), and autumn (2.5°C to 4°C). No significant change in precipitation amount is expected in spring and autumn, while in summer a decrease in precipitation (down to –20%) and in winter an increase (up to +30%) is expected. Among the selected five locations some deviations with regards to the others can be found only in sites located in the submediterranean climate; the projections indicate for all seasons a weaker warming as in case of the other four locations (summer: 3.0°C to 5.5°C, winter: 2.5°C to 4°C, spring: 2.5°C to 4.5°C, autumn: 2°C to 4°C).

Droughts in summer could rise to cover 40 % of Slovenia in case of temperature rise by 2 °C and reduction of precipitation by 10 % (Fig. 5). In addition, the prediction model of sleet damages for three climate change scenarios (Ogris, 2007) showed that sleet damages will slowly decrease in all climate change scenarios.

The results of local climate change projections are affected by several factors (e.g. from the selection of emission scenario, GCM, downscaling method, predictor selection). Local climate change projections are related to a large degree of uncertainty, which should be respected when interpreting the results.

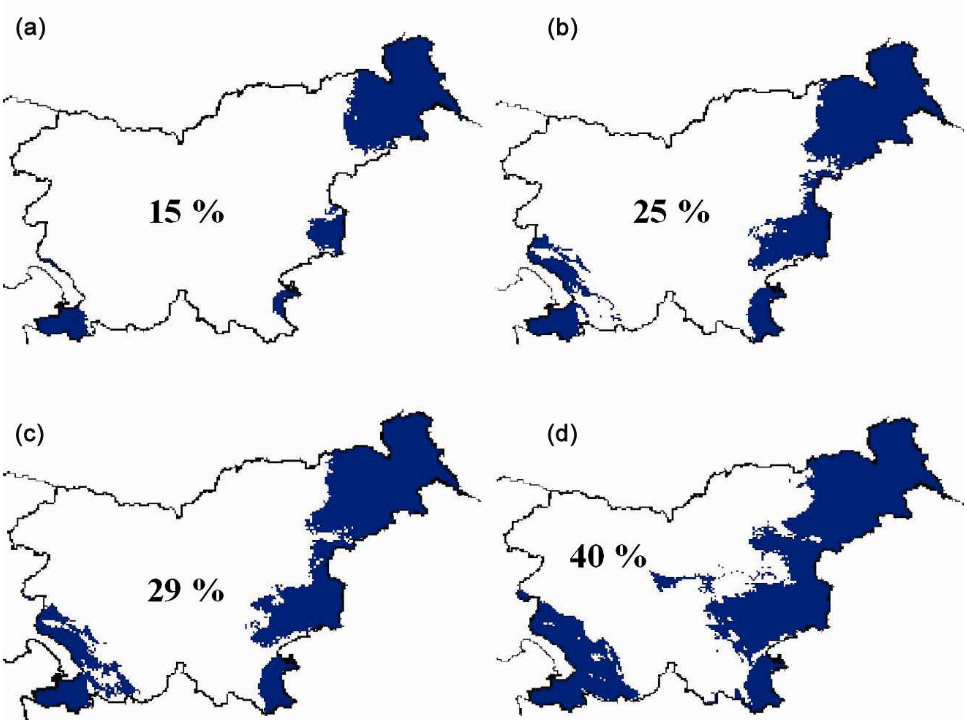

Figure 4: Spatial distribution of summer potential soil moisture deficit areas in Slovenia a) based on long term average data (1961–1990), b) in the case of an air temperature rise of 2 °C, c) in the case of a reduction in precipitation of 10 % and d) the combined effect of an air temperature rise of 2 °C and a reduction in precipitation of 10 % (Kajfež-Bogataj and Bergant, 2005).

1.2.2. Impacts on ecosystem dynamics and functioning

1.2.2.1 Vegetation distribution area

The simulation of vegetation changes to hypothetically changing in Slovenia has been performed in a GIS framework (Kutnar and Kobler, 2007); the potential climate change scenario is defined as a spatially uniform increase in the mean annual temperature of 2°C and decrease in the annual precipitation of 200 mm. The simulation indicated the geographic distribution of 13 forest types will be changed considerably: forest communities on 45 % of total area will be changed. The model indicated that the area of silver fir (*Abies alba* Mill.)-European beech (*Fagus sylvatica* L.) forests, and alpine beech forests will significantly decrease, while the area of sub-Mediterranean beech forests, thermophilous deciduous forests, and other beech forests will increase. In the alpine and pre-alpine regions, a significant part of current coniferous forests with predominant *Picea abies* and *Abies alba* might be converted to deciduous forests. Also spatial distribution of individual tree species is expected to be changed (e.g. Ogris and Jurc, 2007).

1.2.2.2 Insects, parasites, pathogens

We expect that that damages and consequently also sanitary felling due to climate changes will be more often and serious in forests where natural tree species combination had been changed, if compared to the forests with preserved “natural” tree species composition.

Model to predict sanitary felling of Norway spruce (*Picea abies*) due to spruce bark beetles (*Ips typographus*, *Pityogenes chalcographus*) in Slovenia (Ogris and Jurc, 2009) according to different climate change scenarios showed an increase in sanitary felling of Norway spruce due to spruce bark beetles, for all scenarios.

Similarly the model of *Eutypella parasitica* spread risk in Slovenia (Ogris *et al.*, 2007) showed increased spread risk (especially in NW part of Slovenia) for the scenario with average rise of temperature for 2 °C.

Biscogniauxia nummularia, a xylariaceous fungus that causes strip-canker and wood decay on European beech (*Fagus sylvatica* L.) is predicted as a possible harmful organism that could affect potential areal of European beech, in pessimistic scenario even on the larger area, especially in the Subpannonian and Submediterranean region of Slovenia. European beech stands are relatively stable. However, extreme weather conditions (especially with drought and heat) may cause serious damages; many of existent harmful factors could become more serious when considering susceptible beech bark.

There are several opportunistic pathogens that are predicted to cause more intense and broader damages to forests in Slovenia (Jurc D., 2007):

- *Botryosphaeria dothidea*, causing hop hornbeam (*Ostrya carpinifolia*) dieback in Slovenia (Jurc *et al.*, 2006); the fungus is generalist and can cause bark necrosis and cankers on several woody plants, e.g. *Alnus, Fraxinus, Betula, Catalpa, Ulmus, Juniperus, Tilia, Juglans, Pinus, Metasequia, Viburnum*, etc.
- Honey fungus (*Armillaria* spp.) can cause slow dieback of several woody plants that are under stress; the most pathogenic are *A. mellea* and *A. ostoyae* but also other should not be underestimated (e.g. *A. gallica, A. cepistipes, A. borealis, A. tabescens*).
- *Nectria* spp. There are several *Nectria* species that could increase the extent and severity of forest damage, e.g. *N. cinnabarina, N. galligena, N. ditissima, N. fuckeliana*.
- Fungi from the genus *Phytophthora* could represent serious danger to forest due to introduction of new species and/or their fast evolution and breeding among species

1.3 IMPACT MONITORING

1.3.1 Usual monitoring system/network

On the national level there are several monitoring systems important for impact monitoring, e.g.:

- Slovenian Forest Service gathers data for the entire forest area in Slovenia in the frame of forest management planning (SFS, 2009). Monitoring is designed on 4 levels: (1) Permanent sampling plots (500 m2 each, usual network 250 x 250 m), (2) sub-compartments, (3) forest stands and (4) forest function units.
- Monitoring of devaluation and impacts of forests has been carried out in the frame of international program for cooperation (ICP-Forests) which is preformed since 1985. Program of Intensive monitoring of forest ecosystems in Slovenia started in 2004 in the frame of EU program Forest Focus (Mavsar *et al*., 2004), then continued under the support of Ministry for Agriculture, Forestry and Food.
- The Phytosanitary administration of Republic Slovenia (FURS) was established as a part of The Ministry for Agriculture, Forestry and Food. It has administrative and legislative functions, conducts the coordination of plant protection, organizes international cooperation and gives professional advice. FURS develops methods for forest damage registration, determination of harmful organisms and forest pests’ inventories.

1.3.2 Specific monitoring system/network

There are numerous monitoring systems of forest ecosystems, orienting e.g. to estimations of biomass and carbon assessment (Hocevar *et al*., 2005; Krajnc *et al*. 2006), MCPFE criteria and indicators (Hocevar *et al*., 2006), land use change (Hocevar *et al*., 2004).

I.4 IMPACT MANAGEMENT

In Slovenia, Forest Management Plans (FMP) are mandatory for all forests regardless to their ownership (see also Chapters 2.3.1 and 2.3.2). FMP for Forest Management Unit (approx. 5000 ha of forest area) is made every 10 years. Adaptive forest management planning is adopted countrywide, therefore changes, which happened in the 10-years long period in forests, some also because of climate change, are considered when renewing the FMP and they crucially affect the planning of forest management goals and measures and future forest management in general.

When larger extreme events happen (large windthrow, snow breakage, sleet breakage etc.), the Sanitation Plan has to be made, usually by the professionals at Slovenia Forest Service. All participants, which have been impaired because of the extreme event (forest owners, local municipality people, forest operation companies, broader public etc.), have to be considered and included in the Sanitation Plan. The Sanitation Plan has to estimate the largeness of the extreme event (damaged area and amount of damaged timber in forests), prescribe the organization of sanitation of damaged timber, and prescribe future forest protection measures and measures of renewal of damaged area. If forest management goals in the broader area of the extreme event are changed due to damages made by it, FMP has to be renewed and new forest management goals and measures have to be prescribed.

In the sub-Mediterranean region of Slovenia, where the highest risk of forest fires is present, a map of cleared strips used to control a fire (public and forest roads, maintain of cleared strips, water resources etc.) was published by the Ministry of Defence, Administration for Civil Protection and Disaster Relief to help fire fighters to more easily navigate in the dense sub-Mediterranean termophilous forests.

2 ADAPTATION

2.1 *VULNERABILITY OF FORESTS AND FORESTRY*

Slovenia is topographically and climatologically diverse country, therefore many different forest types could be found. They differentiate in the vulnerability to climate change. Consequently, the amount and distribution of damages are expected to be different among forest types.

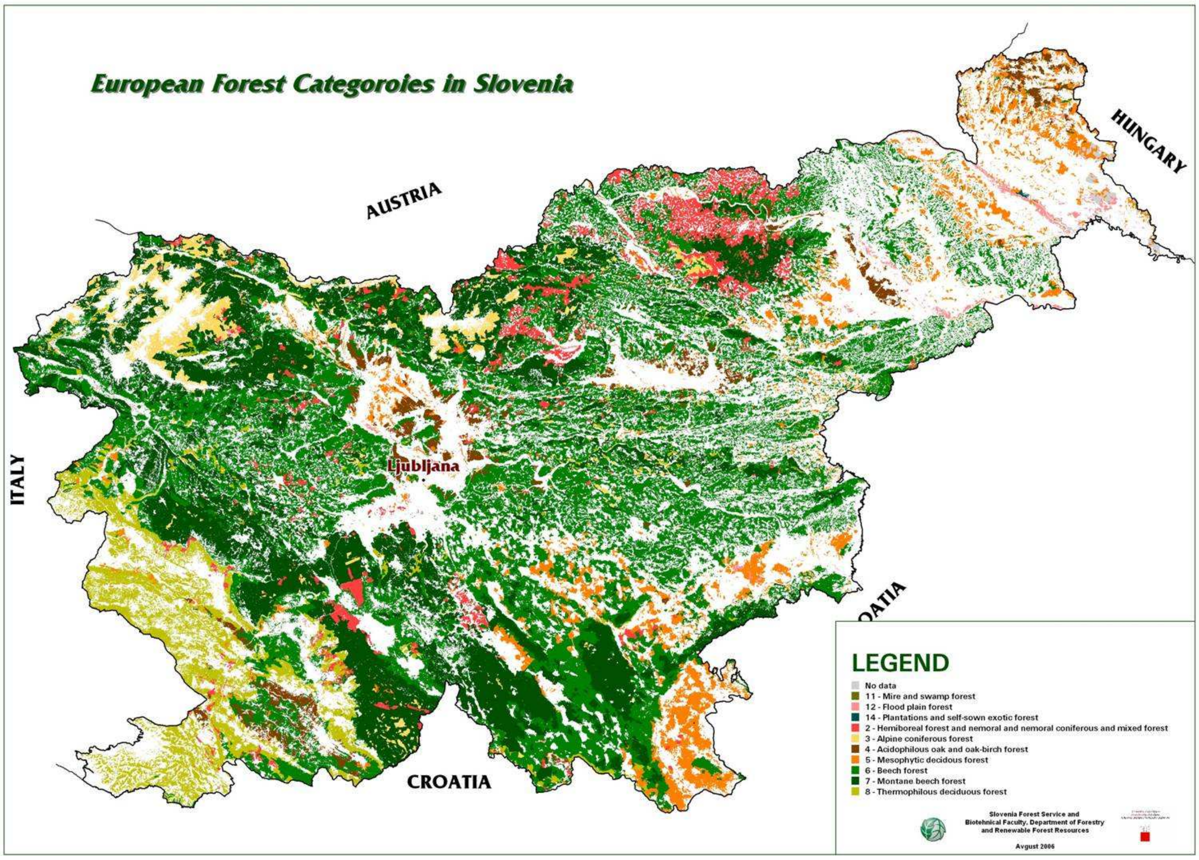

Figure 5: Forest types in Slovenia (Boncina *et al*., 2006)

A significant part of whole forest area is characterized by a altered natural tree species composition (> 30 % of non-site adapted tree species) because of past forest management. These forest stands are known to be more vulnerable to impacts caused by climate change. According to Kajfez-Bogataj *et al*. (2003) deciduous and mixed submountainous and mountainous forests (i.e. Central European submontane beech forest, Illyrian submontane beech forests) are the less vulnerable forest types, while pure stands with only one tree species (i.e. pure spruce forest) and forests on extreme site conditions supposed to be the most vulnerable. Forest stands with larger share of coniferous will be the most damaged, especially Norway spruce and silver fir dominated forests. Also silver fir-European beech forest type (Illyrian montane beech forests) is supposed to be highly vulnerable, especially in lower altitudes, i.e. 400-800 m a.s.l. (Robic, 1999).

Forests the sub-Mediterranean region, dominated by black pine and termophilous deciduous tree species are the most vulnerable to forest fires. However, due to climate change increased vulnerability of forests to forest fires is expected up to the lower montane altitude belt, in termophilous decidous forests in the sub-Mediterrenian region, and in lower south- or west-exposed hilly parts of Slovenia.

Table 1: Main possible disturbance agents in forest types (vulnerability adapted after Robic, 1999 and Kajfez-Bogataj *et al*., 2003)

Forest type	**Vulnerability due to climate change**	**Main agents of disturbance**
2.3 Nemoral spruce forest	vulnerable	bark beetle attacks
2.4 Nemoral Black pine forest	vulnerable	bark beetle attacks
3.1 Subalpine larch-arolla pine and dwarf pine forest	less vulnerable	windthrows, snow breaks
3.2 Spruce and mixed spruce-silver fir forest	very vulnerable	windthrows, snow breaks, bark beetle attacks
3.3 Alpine Scots pine and Black pine forest	less vulnerable	insects and pathogens
4.1 Acidophilus oakwood	less vulnerable	
5.1 Pedunculate oak-hornbeam	very vulnerable	drought; oak declination (draining)
5.2 Sessile oak-hornbeam forests	very vulnerable	oak declination
5.8 Ravine and slope forest	less vulnerable	
6.4 Central European submontane beech forest	less vulnerable	
6.6 Illyrian submontane beech forests	less vulnerable	
7.4 Illyrian montane beech forests	vulnerable	browsing; decrease of proportion of silver fir
8.8 Other termophilous decidous forest	very vulnerable	forest fires and pathogens

2.2 GENERAL ADAPTATION STRATEGY OR POLICY

A general adaptation strategy entitled Adaptation strategy of agriculture and forestry in Slovenia to climate change (Kajfez-Bogataj *et al*., 2008) was elaborated by a group of scientists and professional workers. The strategy consists of five main sections of measures: 1) strengthening the efficiency of adaptation of agriculture and forestry to climate change (i.e. restoration and management of integral, qualitative, and open-accessed information system on influences of climate change to agriculture and forestry; extension of activities of Slovenia Forest Service and Service for Reporting, Diagnosis, and Prognosis related to climate change); 2) education, awareness, and advice (i.e. giving advice to forest owners by employees of Slovenia Forest Service); 3) maintenance and acquisition of knowledge on climate change and adaptation to them (i.e. research of possible impacts of climate change to forest ecosystem; research of adaptation of forest management to changed conditions); 4) measures on agricultural and forestry policy and modification of existent regulation (i.e. stimulation of complementary activities regarding forestry on private farms; stimulation of forestry practice which are favourable for mitigation and adaption to climate change); 5) strengthening international cooperation and partnership in adaptation of agriculture and forestry to climate change, especially in the EU.

2.3 FOREST ADAPTATION MEASURES

2.3.1 Political level

Forest cover in Slovenia is already as high as 60.3 % (Ministry of agriculture…, 2008). Programme of Forest Development was declared already in 1996; following international and European commitments National Forest Programme (NGP, 2008) was additionally enacted in 2008. One of the main objectives of NGP is sustainable forest, wildlife, and landscape management based on ecosystem approach considering its biodiversity, ecological, economical, and sociological functions. Climate change is considered as one of the important issues and several goals and measures were defined to adopt forest management to climate change.

Adaptive forest management is used countrywide. Selection of silvicultural system is flexible and measures are chosen to be optimal for specific conditions. Clear-cutting system is not allowed since 1949. Forest area is divided into 14 forest regions and 233 forest management units. Forest planning is a key tool to consider social, environmental and economic conditions. It is mandatory in the whole forest area. Forest monitoring as well the assessment and evaluation of changes in forest ecosystems and their environment are an important part of planning and adaptive forest management. Such approach enables forest management to adapt constantly to changing environmental conditions. Forest planning is organized at different spatial scale (regions, forest management units, stand level); it is carried out by Slovenia Forest Service.

2.3.2 Management level

Close-to-nature forest management has been used since the 1960s (i.e. Diaci, 2006). Three silvicultural systems are mainly used and combine when practicing forest management: small-scale irregular shelterwood, group and single-stem selection ("plenter") and the combination of different systems, i.e. "free style silviculture". Irregular shelterwood system is used on larger areas than group and single-stem selection systems (plenterwald). All mentioned silvicultural systems create mainly patchy horizontal forest structure with stands of mixed tree species composition and uneven-aged vertical structure.

Natural regeneration is carried out on approx. 90 % of total forest area promoting site and environment adapted tree species. However, some small areas are artificially reforested (SFS, 2009), especially in sites damaged by natural disturbances (windthrows, forest fires etc.) and sites with soil erosion, avalanche and landslide risk. In the case of planting, promotion of site adapted tree species of local provenances is considered. Planting of Norway spruce has decreased (36 % of all planted seedlings in 2008; SFS, 2009); spruce has not been planted in lower altitudes on dryer sites of sub-Mediterranean and sub-Pannonian region of Slovenia for more than a decade (Diaci, 2007).

Natural tree species composition is promoted when thinning young and middle-aged forest stands. In secondary conifer stands (mainly Norway spruce stands), adaptable deciduous tree species should be promoted (Diaci, 2007) to support stability and biodiversity of forests. Mechanically and biologically labile forest stands - usually monocultures and forest stands with significantly changed natural tree species composition - should be converted into mixed, more uneven-sized forest stands.

The woody biomass has been accumulating in the last decades, consequently the average growing stock of forests stands has increased in the last years: from 193 m^3/ha in 1990 to more than 300 m^3/ha in 2008 (NGP, 2008; SFS, 2009).

New harvesting technologies (mechanized harvesting with harvesters and forwarders) have been introduced into Slovenian forests in the last decade; some of them are of great use in cases of large disturbances. However, ecologically sound harvest technologies and organizational forms are requested.

System for production, control and use of seed of most suitable (local) provenances and (autochthonous) tree species are in progress according to the Act of Forest reproductive Material. The registration of seed stands of all important tree species has been introduced ensuring sufficient amount of seed and plants.

Table 2: Forest adaptation measures in different forest types in Slovenia

Forest type	**Measure**
2. Hemiboreal forest and nemoral coniferous and mixed broadleaved-coniferous forest *Picea abies*, *Abies alba*, *Pinus sylvestris* combined objective/ multi-purpose forestry timber, carbon sequestration, maintainance of biodiversity, provision of drinking water, game management/hunting	1.1.5. Restoration of natural vegetation (current potential natural vegetation) 1.3.1. Using natural regeneration for the main forest tree species 1.5.3. promotion of small-scale regeneration methods (gaps, irregular shelterwood systems, group selection systems)
2. Hemiboreal forest and nemoral coniferous and mixed broadleaved-coniferous forest *Pinus nigra*, *Picea abies*, *Ostrya carpinifolia*, *Quercus* spp. combined objective/ multi-purpose forestry timber, fuelwood, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against soil erosion, game management/hunting	1.1.5. Restoration of natural vegetation (current potential natural vegetation) 1.3.1. Using natural regeneration for the main forest tree species 5.1.5. design and promote fire-smart management at management unit level/ landscape level
3. Alpine coniferous forest *Picea abies*, *Fagus sylvatica*, *Abies alba* combined objective/ multi-purpose forestry timber, berries, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against soil erosion, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species 1.5.3. promotion of small-scale regeneration methods (gaps, irregular shelterwood systems, group selection systems)
3. Alpine coniferous forest *Pinus sylvestris*, *Pinus nigra* close to nature forestry (C2N) berries, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against rockfall, protection against soil	1.3.1. Using natural regeneration for the main forest tree species

erosion, game management/hunting	
3. Alpine coniferous forest *Larix decidua*, *Picea abies* unmanaged/ nature reserve maintainance of biodiversity, provision of drinking water, protection against avalanches, protection against rockfall, protection against soil erosion, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species
4. Acidophilos oak and oak-birch forest close to nature forestry (C2N) timber, fuelwood, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against rockfall, protection against soil erosion, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species
5. Mesophytic deciduous forest close to nature forestry (C2N) timber, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against avalanches, protection against rockfall, protection against soil erosion, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species
5. Mesophytic deciduous forest *Quercus robur*, *Alnus* ssp., *Populus* ssp., *Salix* spp., *Carpinus betulus* combined objective/ multi-purpose forestry timber, fuelwood, carbon sequestration, maintainance of biodiversity, provision of drinking water, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species
5. Mesophytic deciduous forest *Quercus petraea*, *Fagus sylvatica*, *Picea abies* combined objective/ multi-purpose forestry timber, fuelwood, carbon sequestration, maintainance of biodiversity, provision of drinking water, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species
6. Beech forest *Fagus sylvatica*, *Picea abies*, *Carpinus Betulus* combined objective/ multi-purpose forestry timber, fuelwood, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against soil erosion, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species
6. Beech forest *Fagus sylvatica*, *Picea abies*, *Quercus* spp. combined objective/ multi-purpose forestry timber, fuelwood, berries, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against soil erosion, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species
7. Mountainous beech forest *Fagus sylvatica*, *Picea abies*, *Abies alba* close to nature forestry (C2N) timber, fuelwood, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against rockfall, protection	1.3.1. Using natural regeneration for the main forest tree species 1.5.3. promotion of small-scale regeneration methods (gaps,

against soil erosion, game management/hunting	irregular shelterwood systems, group selection systems)
8. Thermophilous deciduous forest *Acer* spp., *Alnus* ssp., *Populus* ssp., *Salix* spp., *Quercus* spp. combined objective/ multi-purpose forestry timber, fuelwood, carbon sequestration, maintainance of biodiversity, provision of drinking water, protection against rockfall, protection against soil erosion, game management/hunting	1.3.1. Using natural regeneration for the main forest tree species
Various forest types (unspecific)	2.1.2. Tending forest stands in a way that they are as close to the potential natural forest structure as possible 3.1.7. promote close-to-nature silviculture

3 MITIGATION

3.1 CARBON ACCOUNTS

GHG emissions and removals from land use, land use change and forestry (LULUCF) are presented by six main land categories required by IPCC (2003): A) forest land, B) cropland, C) grassland, D) wetlands, E) settlements, and F) other land. Sector LULUCF is estimated to be a net sink since 1998, amounting in 2007 to some -10.9 Mt CO_2 equivalents. CO_2 emissions and removals occur as a result of land use changes and mainly from accumulation of carbon in forest land remaining forest land. Net sink in this sector was 10.9 Mt CO_2 eqv. in 2007 what represents nearly 50 % of Slovenian total emissions.

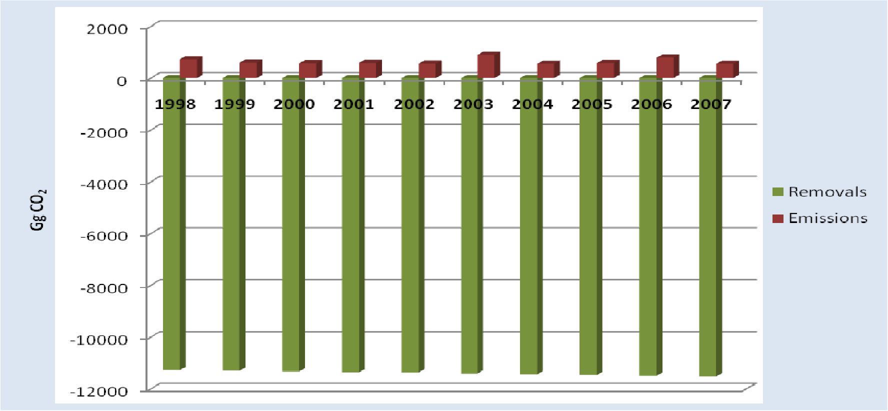

Figure 6: LULUCF sector emissions and removals from 1998 to 2007

Categories forest land remaining forest land and cropland remaining cropland were net CO_2 sink, whereas the other sub-categories were net sources of CO_2 emissions. However, total emissions arising from the other categories represent 5-8 % of removals from forest land and cropland together.

CO_2 emissions removals from living biomass (above and below ground), dead organic matter, soils and non CO_2 greenhouse gas, from forest remaining forest and land converted to forest have been recalculated. Net carbon stocks change by land converted to forest land, for living biomass, dead organic matter, soils and Non greenhouse gas, is included in the assessment of carbon stocks change.

With regard to forest land the annual net CO_2 removal in the analysed period 1998–2007 was 10,942.00-11,374.00 Gg CO_2. For this calculation new data from two successive national forestry inventories were taken into consideration.

The reported CO_2 emissions from forest soils have to be considered with high uncertainty whereas dead organic matter in general have a small influence on the net CO_2 balance of sector (about 650 Gg CO_2).

For the reported period 1998-2007 the total annual net removals (biomass, soils and dead wood) from land use changes to forest were around 75 Gg CO_2 per year.

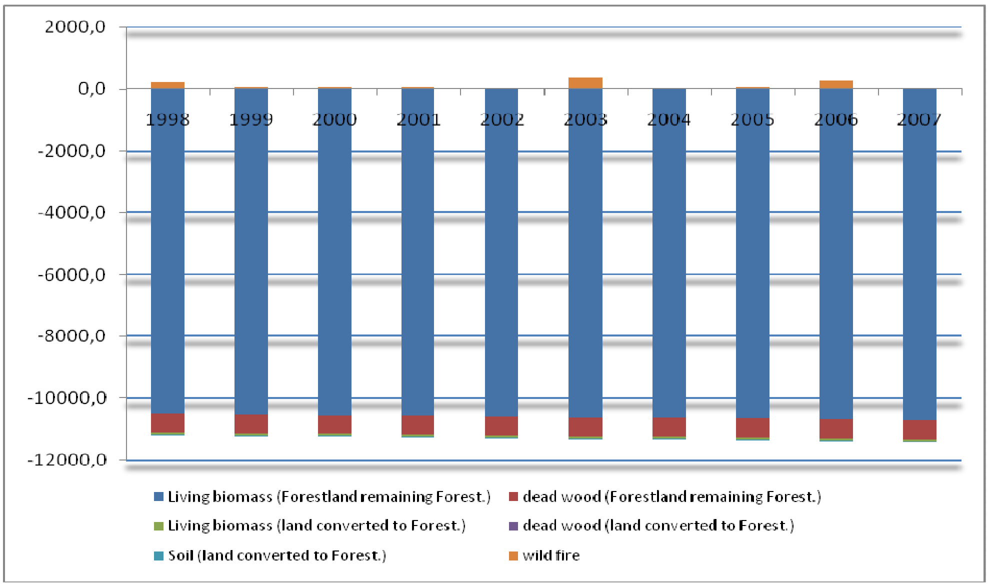

Figure 7: Emissions and removals from forestland by carbon pools (from 1998 to 2007)

The Republic of Slovenia is as a party to the convention obligated to make annual GHG emission inventories and to report them. The analysis of CO_2 stored in roundwood was prepared on the basis of analysis of roundwood and wood wastes flows and wood balance for Slovenia (Krajnc in Piškur 2006). In Slovenia the production of roundwood in reference year was, according to data from wood balance, from 2.5 to 3.1 million $m^{3,}$ which means that the total amount of CO_2 bounded in roundwood from the Slovenian forests was somewhere between 2.2 and 2.8. The majority of roundwood was used for further processing in Slovenia (67 %), 26 % was used for energy purposes and 7 % was exported.

According to the data from roundwood and wood wastes balance, 3,252,000 m^3 of roundwood and additional 476,000 t of wood wastes were used in Slovenia in the year 2004. If the efficiency factors for the primary wood processing (production of sawnwood, veneer sheets, particle boards, fibreboards, wood pulp and other industrial roundwood) are taken into account the amounts of primary wood products in Slovenia are estimated then we can calculate the CO_2 stored in these products. Our estimation is that 1.46 M t CO_2 was stored in primary wood products in 2004. We have to point out that this is not an estimation of CO_2 in all wood products used in Slovenia, but is only estimation of CO_2, stored in products produced in that year. There are different methods to estimate accumulation of

CO_2 in wood products. At wood products however, it is necessary to consider their different lifetime, which claims long term series of data on production, use and disposal of wood products on the state level.

Wood is also important as an energy source. According to the wood balance data, households used more than 1.068.000 m3 of round wood and larger biomass systems additional 275.000 t of wood wastes in the reference year. Our presumption was that wood biomass is a substitution for heating oil. According to our calculation we saved more than 1 M t of CO_2 emissions by using wood biomass, which represents approximately 5 % of all emissions of CO_2 in Slovenia in that year.

3.2 FORESTRY AS A SOURCE OF BIOENERGY

Slovenia is a country with a high forest coverage and traditional use of wood for heating and cooking. Wood biomass was and still is an important source of energy for rural population, especially for forest owners. According to results from population census in 2002 around 30 % of apartments in Slovenia are still heated with wood as only, primary or secondary fuel. According to latest research, households consume more than 1.068,000 m^3 of roundwood equivalent (37 % of annual felling in Slovenian forests) per year for heating purposes. Wood for heating is coming mainly from private forests. If we take in to account that mainly broadleaves are used for heating purposes, we can calculate that households are substituting more that 263.527,000 l of heating oil with wood biomass per year. And they are saving more than 0.74 Mt of CO2 emissions per year because using wood instead of heating oil. They are saving also 176 million €, this money is not spend for fossil fuels but it stays in the regions and in the country. Biomass is not used only in households, but also in other sectors, but data about amount of biomass use are weak. According to our estimations at least 300,000 t of wood is used in larger biomass plants (Fig. 8). We save around 5 % of total CO2 emissions in Slovenia with biomass (substitution of fossil fuels) use per year (Piskur and Krajnc, 2007).

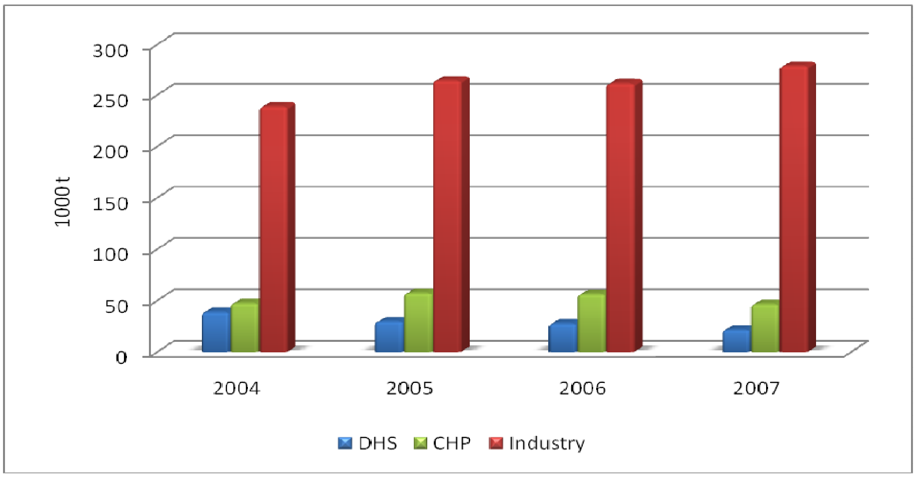

Figure 8: Use of wood biomass in larger biomass plants

A system of subsidies and advantageous credits was set up more than 5 years ago. The results are: modern technologies for biomass used in individual houses, many modern micro systems and some new modern district heating systems. The interest for subsidies for biomass heating system in households has grown fast in last 6 years, which is reflected in number of subsidies given at Ministry for environment and spatial planning (Fig. 9).

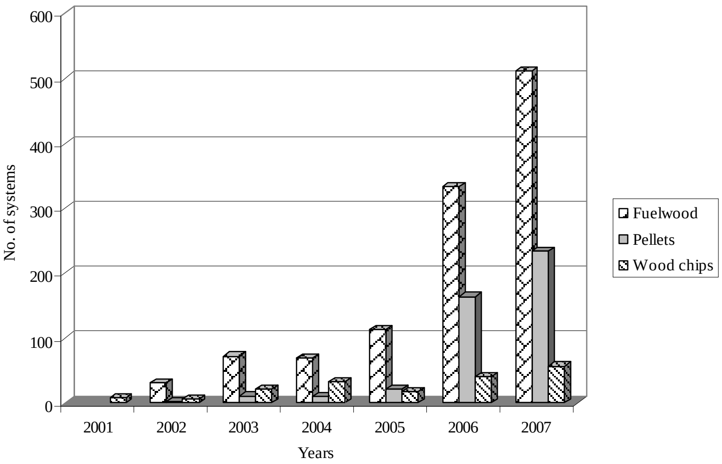

Figure 9: Number of subsidies given at Ministry for environment and spatial planning to households

Wood biomass sector is fast developing sector in Slovenia. To support development and implementation of modern technologies for biomass preparation, production and use national action plan is needed. Long-term goals and perspectives are given in *Resolution on the National Energy Programme (under revision)*. Short-term and concrete goals for wood biomass development in Slovenia should be setup in *National wood biomass action plan* - like it is stated in Commission decision (2009/548/EC).

3.3 PROCESSES, INSTRUMENTS AND STRATEGIES

Main documents dealing with mitigation is Action plan for lowering GHG emissions till 2012. Program was ratified by government in 2006 and revised in 2009. The main aim of this document is to set up the list of actions which has to be taken to reach the Kyoto goals in Slovenia.

Resolution on National Forest Programme (2008) also stresses out the importance of forests as sink of CO_2.(see chapter 6.3.2: Forests and climate change). Sink of CO_2 in the forests can be reached by accumulation of carbon in growing stock and by maintaining forest land. Additionally, in National Forest Programme use of wood as material and renewable energy source is promoted. In last few years

Slovenian government ratified a package of instruments and strategies to promote use of wood biomass as renewable source of energy.

3.4 RESEARCH STUDIES ON MITIGATION

Ministry of the Environment and Spatial Planning is financing the research project to assure accurate data for reporting and accounting under the framework of UNFCCC and KP. Research activities are carried out mainly by Slovenian forestry institute.

CONCLUSION

Climate changes are generally accepted to be reality. In the last decades, a rise of average temperature and a change in annual distribution of precipitation have been observed. However, opinions about their influences and impacts, especially on forests and forestry, are somewhat different – from overestimation to considerable underestimation. These discrepancies could be a consequence of insufficient knowledge on the impacts of climate change on forest ecosystem. Climate changes are usually presented with models which are more or less accurate. The models are often presented as a linear relation, which is in most cases not true. Usually a lot of important and relevant independent variables (factors) are not included in the model or at least in the modeling procedure. Models are often based upon presumptions, which are more or less probable. Therefore it is difficult to generalize the results. Modeling should not be treated rigid and ultimate, but as a tool which could give you a useful piece of information to develop ideas on future development of a definite phenomenon.

According to observed climate change, some changes in forest ecosystems could be expected in the next decades and centuries. Therefore, adaptive management approach is and is going to be of great importance in forestry - even greater if compared to some other branches (i.e. agriculture). The future development of climate, soil, forest stands etc. is very hard to predict with a significant certainty. Therefore, the basic ideas of adaptive management should be promoted: i) to monitor states of forests in (adjusted) time periods; ii) to pursue changes in structure, composition, functioning of forest ecosystem; iii) to adapt forest management goals and forest management measures to new circumstances. Such concept could be useful also in the field of forest policy.

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