COST action FP0703 – ECHOES

Expected Climate Change and Options for European Silviculture

COUNTRY REPORT

Croatia

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Summary

Introduction

The Republic of Croatia became a party to the UN Framework Convention on Climate Change (UNFCCC) in 1996. As an economy in transition, it assumed the responsibilities under Annex I to the Convention. The Republic of Croatia signed the Kyoto Protocol in 1999. After its ratification by the Croatian Parliament, the Republic of Croatia will have to reduce greenhouse gas emissions by 5% in the first commitment period between 2008 and 2012 in relation to the base year. The First Croatian National Communication under the UN Framework Convention on Climate Change was submitted to the Convention Secretariat in 2002. Following the guidelines of the Convention Secretariat, this national communication comprised the consolidated second, third and fourth communication and covered the period from 1996 to 2003.

The total land area of the Republic of Croatia is 56,594km^2. The territorial waters and internal marine waters cover an area of 31,067 km^2. By its position Croatia belongs to the Central-European, Adriatic-Mediterranean and Pannonian-Danube basin group of countries. The total length of the land borders of the Republic of Croatia with the neighboring countries is 2,373 km. It borders with Slovenia (670 km) in the northwest, Hungary (355 km) in the north, Serbia (322 km) and Montenegro (25 km) in the northeast and southeast, and has the longest border with Bosnia and Herzegovina (1001 km). The national sea border is 948 km long and stretches along the outer edge of the territorial sea. It is followed by a protected ecological and fishing zone covering an area of 25,207 km2 and reaching the continental shelf border between Croatia and Italy. Three large geomorphological sections may be distinguished in Croatia: the Pannonian basin, the mountain range of the Dinarides and the Adriatic basin. Lowland areas up to 200 m above sea level account for 53%, the rolling hills up to 200-500 m for 26% and the highland and mountainous areas above 500 m for 21% of Croatia's land area. The highest mountain peak in Croatia is Dinara (1831 m). The karst area covering 54% of Croatia's territory represents relief specificity. Karst phenomena and forms have developed primarily in limestone on the mountainous and coastal zone of Croatia and also as an isolated phenomenon of the Sava and the Danube basin. Agricultural land covers an area of 55.6 % and forest 37% of Croatia's mainland area. Urbanized land used for housing, sport, infrastructure systems and economic and social activities accounts for 7.6% of the mainland. The total surface of Croatia's protected areas is 5,125 km2 (9.05 % of the mainland) and 283 km2 of the marine area. Pursuant to the 2005 Nature Protection Act they are classified into nine categories, among which there are 8 national parks and 10 nature parks.

Short descriptions of forests in Croatia

The Republic of Croatia is a medium-forested country. According to the 1996 data forests and forest land cover an area of 2,468,830 ha or 43.7%, with forests covering 37% of the country's mainland area. New Forest Management Plan for the area in the period from 2006 to 2015 is in the process of preparation. Details on forest and forest land areas will be provided by the National Forest Inventory (CRONF) late in 2008. 81% of forests and forest land are owned by the state and managed by Croatian Forests with the Directorate in Zagreb,
16 forest administrations and 171 forestry offices, while the remaining 19% are privately owned. In 1996 the total timber stock amounted to 324,256,137 m3 (Table 1) of which 85% account for the broadleaves and 15% for the deciduous trees. The total annual stock increment of all forests in Croatia amounted to 9,643,117 m3. The prescribed portion of timber stock intended for annual cutting is 4,934,199 m3 or 51.2% of the annual increment. The presence of landmines in forests is an important factor affecting forest management.

According to the 2004 estimate, the land suspected of mines and therefore excluded from the management covers an area of 181,762 ha or 9% of the total forest and forest land area. The Republic of Croatia lies at the crossroads of two large phytogeographical regions – the Euro-Siberian-North-American and the Mediterranean, which gives the country a great variety of ecosystems, habitat types, and plant and wildlife species. The former includes 45 forest communities of the lowland, hilly, highland, mountain and pre-mountain vegetation belt and the latter 17 thermophilous, evergreen and deciduous forest communities of the Mediterranean coastal and insular Croatia. Croatia's higher plants flora which includes pteridophytes and spermatophytes, comprises 5,347 species and subspecies, of which 326 are endemic. The Red List of Vascular Flora of Croatia mentions 420 taxa considered threatened or at risk of extinction.

Type		1986	1996
Common beech	*Fagus sylvatica* L.	105.297,612	118.197,958
Common oak	*Quercus robur* L.	41.598,258	44.980,967
Durmast oak	*Quercus peraea* (Matt.) Liebl.	27.971,54	32.386,239
Silver fir	*Abies alba* Mill.	34.360,233	30.475,088
Hornbeam	*Carpinus betulus* L.	23.043,099	24.892,301
Narrow-leaved ash	*Fraxinus angustifolia* Vahl.	9.336,373	10.280,248
Spruce	*Picea abies* (L.) H. Karst.	4.918,592	6.525,657
Holm oak	*Quercus ilex* L.	5.864,256	5.091,853
Pubescent oak	*Quercus pubescens* Willd.	5.662,204	4.317,504
Aleppo pine	*Pinus halepensis* Mill.	3.624,268	3.880,114
Other conifers		4.268,468	6.201,959
Other broadleaves		32.336,445	37.026,460
Evergreen underbrush, garigues and thickets (estimate)		2.361,660	3.299,460
TOTAL(m^3/ha)		**163**	**185**

Table 1: Timber stock (in m^3) of ten main tree species in 1986 and 1996
(Source: Forest Management Plan for the area of the Republic of Croatia, 1996-2005)

From the 14 total categories of European forests, 11 prevail in Croatia which makes it one of the countries with the largest biodiversity in Europe. The predominant forest types are:

- *Beech forest, and mountainous beech forest* - Central European submountainous and mountainous beech forest, Illyrian submountainous and mountainous beech forest).
- *Floodplain forest* – Riparian and fluvial
- *Mesophytic deciduous forest* – Pedunculate oak – hornbeam forest, Sessile oak – hornbeam forest, Ashwood and oak-ash forest
- *Thermophilous deciduous forest* – Downy oak forest, Chestnut forest

Less common are *Acidophylous oakwood and oak-birch forest, Alpine coniferous forest, Hemiboreal forest and nemoral coniferous and mixed broadleaved-coniferous forest, Broadleaved evergreen forest, Coniferous forests of the Mediterranean, Anatolian and Macronesian regions and forest plantations*.

The management of the state forests is performed according to the FSC (Forest Stewardship Council) regulations which incorporate ecological, social and economic standards.

1. Impacts

1.1.1. Climate profile of Croatia

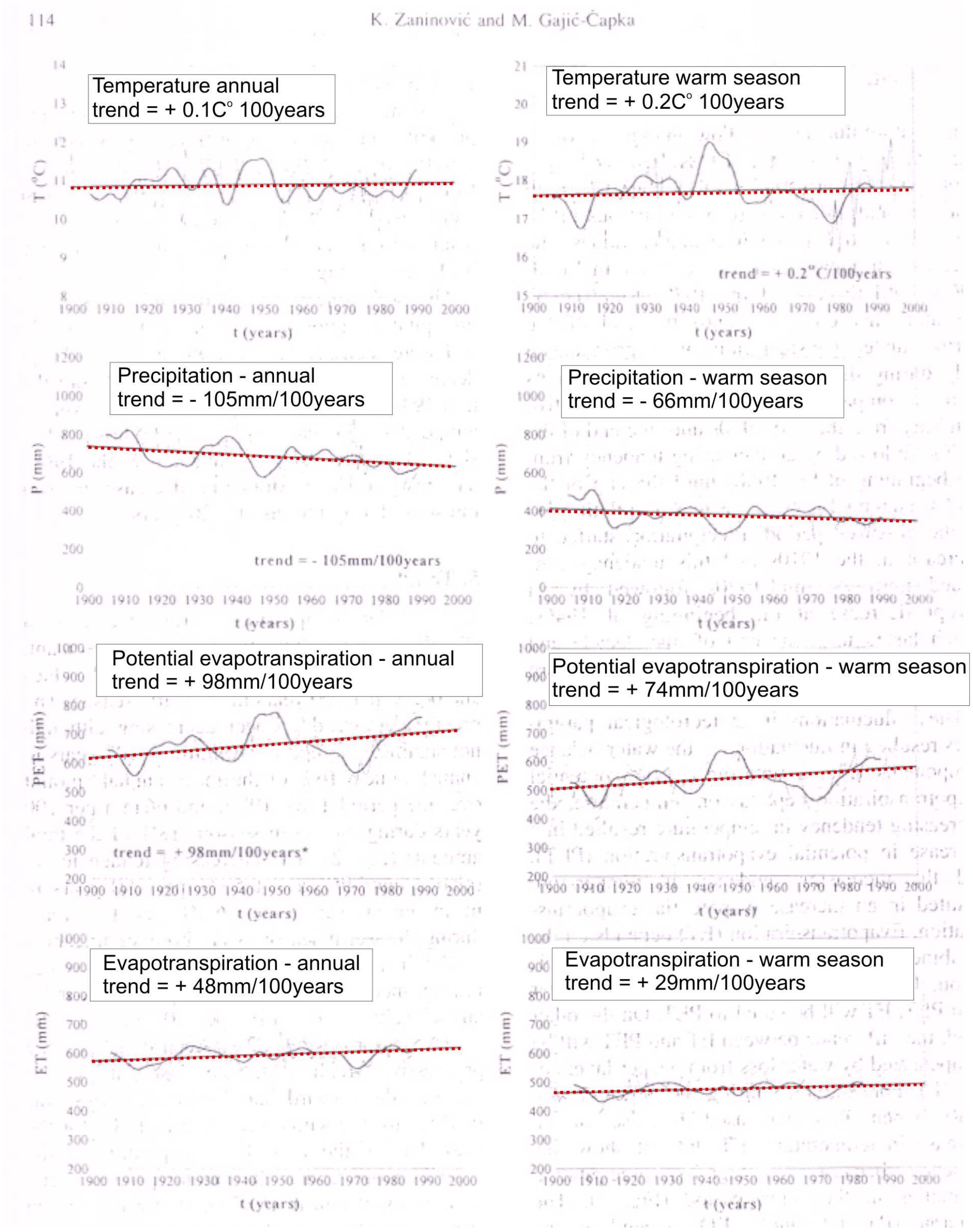
For the most part Croatia belongs to the moderately warm rainy climate, and only areas above an altitude of 1,200 m belong to humid snowy forest climate type. The mean annual air temperature in the lowland area is 10-12℃., in the highland 3-4℃ and in the coastal area 12-17℃. The absolute minimum air temperature measu red is -35.5℃ and the absolute maximum 42.8℃. The least precipitationin Croatia i s recorded in the open part of the central Adriatic (304 mm) and in eastern Slavonia and Baranja (Osijek, 650 mm). Central Croatia and the coastal zone have 800-1200 mm of precipitation per year. Most of the precipitation is recorded on the slopes and peaks of the coastal Dinarides, from Gorski Kotar (Risnjak, 1470 m) to the southern Velebit. The coastal zone from Dugi otok to Prevlaka is the fairest part of Croatia; the islands of the central and southern Adriatic (Hvar, Vis, Korčula) have some 2,700 hours of sunshine per year.

1.1.2. Observed climate change

The decade from 1991-2000 was the warmest recorded in the 20th century and in Croatia. The rise in mean annual temperature of air recorded between 1901 and 2004 was higher on the coast than on the mainland owing to summer and autumn temperatures. Among the seasonal temperatures in the mainland area of Croatia the highest rise was recorded in winter temperatures. The number of cold nights and cold days is decreasing, with a marked upward trend in the number of warm days and warm nights. During the 20th century annual amounts of precipitation felled throughout Croatia, which is in line with the long-term desiccation trend in the Mediterranean. The reduction in annual precipitation amounts is the result of the changed frequency of days with low rain intensity and a higher frequency of dry days. The fall in amount of precipitation is more marked in the northern Adriatic, on the Dalmatian islands and in eastern Slavonia than in the highlands and north-western part of Croatia. Due to the simultaneous presence of high temperatures and precipitation reaching a quarter of average mean values, the year 2003 was extremely warm in 80% and extremely dry in 90% of the area of Croatia (fig 1).

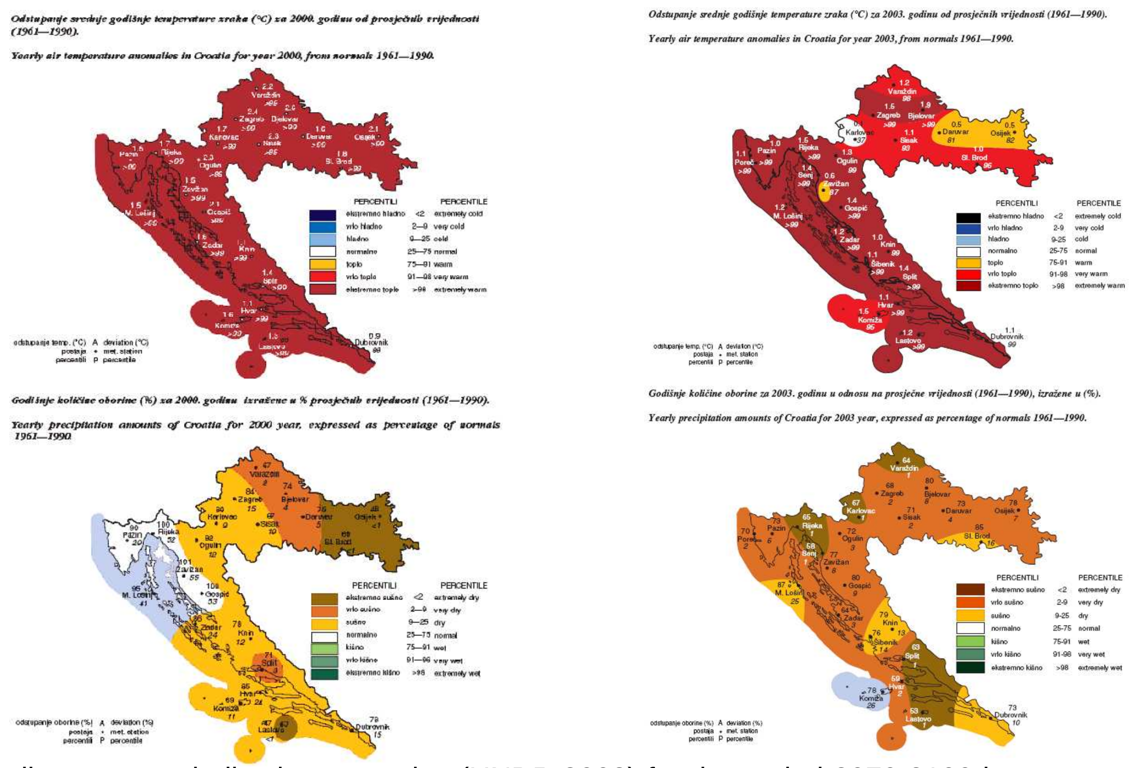
Climate changes caused alterations in evapotranspiration, soil humidity and water infiltration. Changes in the precipitation pattern had an effect on the size, time of occurrence, frequency and intensity of floods and droughts. Changes in the flood pattern in Croatia (Bonacci and Horvat 2003) are not so much seen in their size as in the time of their occurrence. Between 1961 and 1990 a downward trend of some 7 mm in the annual amount of precipitation in Croatia was observed. According to the 100 years measurments on meteorologic station Osijek in eastern Slavonia (Zaninović & Gajić -Čapka 2000) an increase in the annual temperature of 0.1^{o}C in 100 years and of 0.2^{o}C during the warm season is evident (fig 1). The evidence of descending 100 yearly pattern of precipitation, -105mm/100 years and -66/100 years in warm seasons, is even more significant. Respectively the loss of soil water (potential evapotranspiration) 98mm/100 years and 74mm/100 years proves that scenarios of water scarcity is very certain in the near future. Droughts and heat waves are intensifiing across the region, especially in last two decades where significant events appear in 1993, 2000 and most prominently in 2003. Climate changes and anthropogenic activities affected considerably the hydrological regime of open watercourses. The decrease in watercourse discharge will result in water shortages in summer. A shift from the glacial to the pluvial discharge regime has been observed on the Drava River (Hrvatske vode 2005). In highland zones of catchment areas intensified processes of water erosion will cause damage area on the flish base (central Istria, Kvarner littoral, Dalmatia).

Fig 1. 100 years changes in temperature, precipitation and evapotranspiration in Eastern Croatia



Droughts and heat waves are intensifying across the region, especially in last two decades where significant events appear in 1993, 2000 and most prominently in 2003. (fig 2.)

Fig. 2. The excedance of temperature and precipitation in dry spells 2000 and 2003 in relation to base period (1961-1990)(www.meteo.hr)



According to some indicative scenarios (UNDP 2008) for the period 2070-2100 in respect to the base period (1961-1990), a possible increase of precipitation (16.5 mm) could be expected only during the winter season. The other seasons will encounter a decline of precipitation with a possible maximum of – 75.6 mm in summer. Also temperature rise during all seasons is expected with maximal amplitude of 4,6^{o}C during winter.

1.1.3. Expected climate change

Regarding predictions of future climate development, there are limited studies specifically covering Croatia although it has been included in a number of wider studies. For the period of the near future (2025) there seems to be only one study which includes Croatia, based on the scenario of low emissions growth (Coskun, Demir and Kilic 2008). This study predicts that average temperatures in Croatia in 2025 will have increased by maximum of 1° (winter, summer and autumn), while spring temperature will remain the same. No significant differences in precipitation are expected in most regions accept the maximum change of -2.5% along the coast in autumn. The mid-term study for period 2041-2070 based on global EH50M model (Branković, Patarčić and Srnec 2008) states that significant changes of climate in Croatia are noticeable in dependence of seasons:

- During the winter season, Northern Croatia will experience a warming of 2.5° while the rest of Croatia will warmer by between 2° and 2 .5℃. This will be more important for inland rather than coastal Croatia.
- During the springtime Croatia will be 1.5° warmer throughout the country and at sea. A drying trend is expected in southern and western Croatia during spring (-0.1 mm per day i.e. 9mm less for the season.
- In summer temperatures will increase by 3.5° in t he northern Adriatic and in other parts the temperature will increase between 3° and 3.5° C. There will be 9mm less rain per month in the east (27mm for the season). This represents a more than 10%

drop. In the rest of the country, there will be a drop of 0.2 mm/day in precipitation (18 mm less for the season)

- Autumn temperatures will increase by 2.5℃ mostly uniformly throughout Croatia. Precipitation levels will drop 27mm for the season in the south on the coast. Moving northward along the coast, the reduction will be 18 mm for the season. In the northern part of the country (including Istria and most of the eastern part of Croatia) the reductions will be 9mm for the season.

Fig 3. The comparative change in average seasonal temperatures for the periods 1961-1990 and 2041-2070.

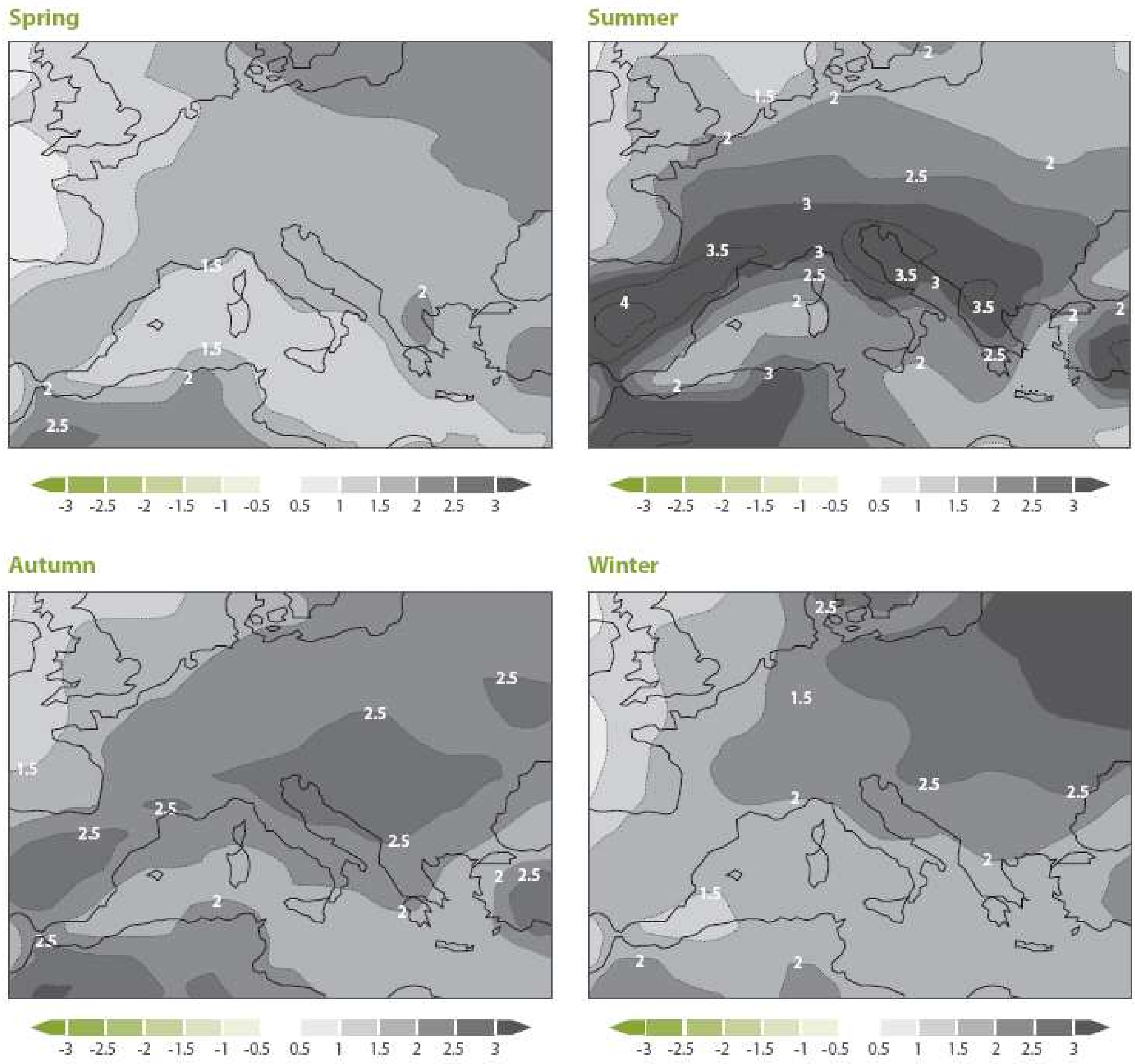


Fig 4. The comparative change in average seasonal precipitation for the periods 1961-1990 and 2041-2070.

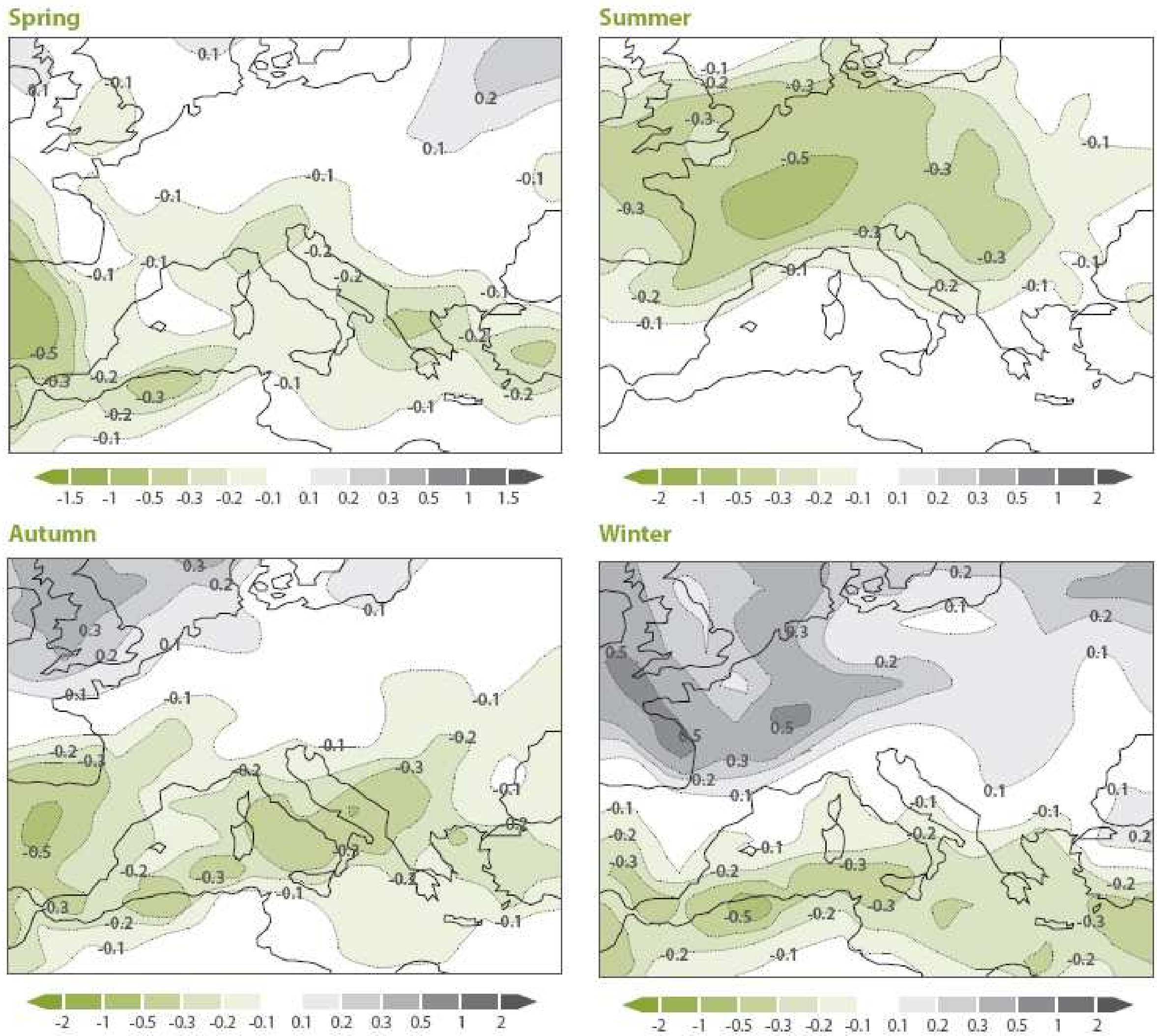
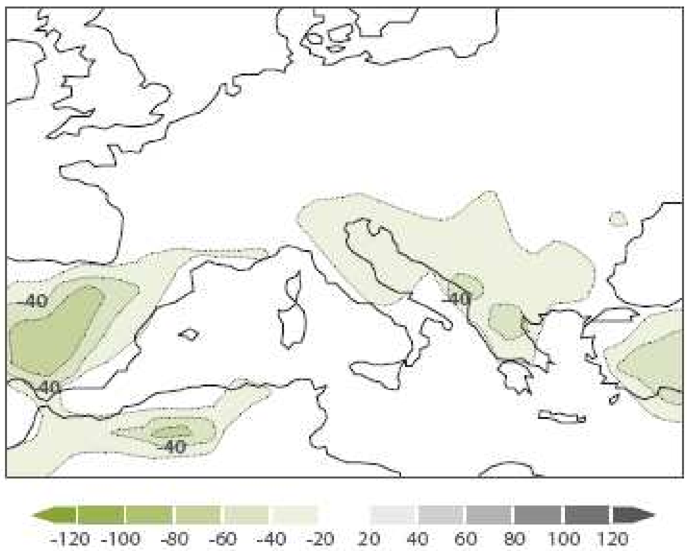


Fig 5. The changes in spring soil moisture for the periods 1961-1990 and 2041-2070.



According to some indicative scenarios (UNDP 2008) for the period 2070-2100 in respect to base period (1961-1990), a possible increase of precipitation (16.5 mm) could be expected only in the winter season. The other seasons will encounter a decline of precipitation with possible maximum of – 75.6 mm in summer. Also, a temperature rise during all seasons is expected with maximal amplitude of 4.6^{o}C during winter.

The averaged results from a number of models for the period 2080-2100 give the following suppositions of particular importance:

- The summer temperatures on the coast are expected to rise significantly. This could severely impact the levels of comfort for tourists as well as the water needs for forests in those regions.

- Summer average temperatures in the Pannonian Plain are also expected to rise.

- Winter average temperatures in the mountains are expected to be above freezing which may have a significant impact on snow formation.

- Precipitation levels are expected to drop significantly, especially during the summer around Croatia. This could have significant impacts on agriculture, forestry and hydro-electrical power production.

1.1.4.. Recorded dieback of main tree species in Croatian forests

The records of historic extreme events which cause significant forest decline of the main tree species in Croatia (Quercus robur, Abies alba, Fagus silvatica) exist for time period from the beginning of the last century and are important to keep in sight of footprints regarding climate change progression.

European beech

The first evidence of dieback of beech forests reaches down to the mid 20th century and are more regional in nature (Prpić et al. 2003). The summer storm of 1940 in Gorski Kotar (north-western part of Croatian mountain region) caused extensive damage when it overthrew and broke almost all trees in large areas. Extensive dieback of beech forests on Učka Mountain (Istrian peninsula) occurred in 1952 where about 5000 m^2 of fuelwood was obtained from dead standing trees. The reasons of dieback were the simultaneous effect of climatic, biotic factors and anthropogenic silvicultural treatments. Consequently, the initial reason for beech dieback of such an extent is accentuated strong anthropogenic influence or silviculuture treatments of that time. The treatments were severe: gaps were made, resulting in soil water deficiency, bark sun scorch, physiological weakening and tree dieback and decline of beech stands over large areas. At that time, from biotic factors, the population of beech jewel beetle (*Agrilus viridis* L.) rose both in Europe and in Croatia inflicting serious damages on beaches. This is typical secondary pest, whose larvae live under the bark in the cambial zone, which died and dried out from overheating.

Today in relation to the main tree species in Croatia, the health status of the beech is relatively satisfactory with the percentage of damaged trees being between 4 and 10%. It should be pointed out that all species except beech have numerous defoliators which periodically significantly reduce the leaf area, so the future condition of the beech in Croatia will depend mostly on the environmental condition related to climate change.

Silver fir

In comparison to beech, the decline of the silver fir in Croatia was much more significant (Prpić et al. 2001). The first decline of the silver spruce was recorded in 1900 and in 1930 in the Lika region. In Gorski Kotar, spruce dieback was locally registered in 1950, and was spread over the whole area until 1967. Fir dieback intensified also in the Pannonic part of the country, particulary in the Pannonic highlands. The conclusion of related research of that time regarding spruce decline emphasised climate change, especially warming and a decrease of soil moisture in the sites. The unfavourable environmental conditions were beneficiary for the fir needle mining moth (*Argyrestia fundella* F.R.) gradation. The dry period began in 1935 and the warmest decade, 1943-1952, is considered to have been the incubation period of pest gradation. Also the results of established research shows that firs with considerable crown damage had a much smaller number of active root tips than healthy trees, while uptake was much lower in healthy than in damaged trees (Prpić 1975).

Systematic monitoring of crown condition began in 1987, based on 4x4 km network of experimental plots. The first data on fir crown condition revealed severe fir damage of 39.8%, and only 27.8% of healthy ones. By 1999 the health status of fir forests in Gorski Kotar deteriorated considerably; there were as much as just 4% of healthy trees compared to average fir damage of 14.3% in the entire range of Croatia. A substantial increase in fir damage even larger in scope during the period from 1987 to 1993 was marked by the existence of drier and warmer climatic oscillations. As a result of unfavourable regional climatic conditions, the health status of the silver fir is nowadays much more deteriorated than in rest of the Europe.

Common oak

Records of oak dieback and causes which have contributed to the continuous decline of the species which has a most important role in Croatian forestry have its origins in the 19th century (Prpić 1996). During the period of 1800 – 1900 almost all of the virgin oak forests were exploited from Croatian lowlands because of requirements of the oak wood in the European market of that time. Over 100 000 ha of oak forests were cut during that period. The removal of forest areas of such intensity had significant consequences in later environmental conditions in lowlands, namely, changes in local climate and hydrologic conditions. The removal of forests, changes of hydrologic components in surrounding watersheds resulted in increased discharges of water and increased waterlogging in the remaining forest complexes. Changes in the soil moisture status of that time made site conditions suitable for water tolerant forest species as white willow, field ash and black alder. The forest management of that time insisted on the removal of all of the introduced species and as a result the ecologically unstable, monodominant forests of the common oak remains with low tolerance predisposition for stress events in the future. The first records of common oak dieback date from 1878 and are related to an increased population of gypsy moth (*Lymantria dispar)* and from 1909, when mildew (*Microsphaera alphitoides*) was observed in this region for the first time. The dieback of oaks occurred periodically from that time on. The extensive dieback in whole area of lowland forests occurred during the period 1909-1925 during which the total mass of wood affected by decay was 1731000 m^3. There were three catastrophic episodes during that period: 1909-1910, 1910-1914 and 1915-1920. From 1930 further on the total extinction of Common elm (*Ulmus minor*) happened due to the Dutch elm disease (*Ceratocystis ulmi*) which additionally caused disturbances in oak forest stands. Massive diebacks reoccurred after WW2 due to the more intensive droughts during the period of vegetation. Also in the 20th century, strong impacts in the ground and surface water by intensive hydro-technical activities such as river canalizations, flood protection dikes, hydro power plants and internal forest drainage changed natural conditions of lowland forests. Hydro meliorative activities together with other abiotic and biotic factors as factorial complex caused a permanent increase of oak decline until the present. The recent dry spells in 2000 and 2003 caused significant expansion of the quantity and spatial extent of oak dieback in Croatia.

1.2. Expected impacts

1.2.1. Predicted Vegetation distribution

One of predicted consequences of climate change is a change in the spatial distribution of forest vegetation cover, the possible disappearance of particular forest species and forest types or the appearance of introduced ones. Predictions of future vegetation distribution in relation to climate change scenarios are relatively scarce and simple. In the National report of climate change one simple empirical model was built which predicts the future distribution of forest cover taking into account extrapolation from linear climatic trends for nine major forest types (Antonić et al. 2000). The change of vegetation cover in year 2030 was shown in fig 6. and it predicts that:

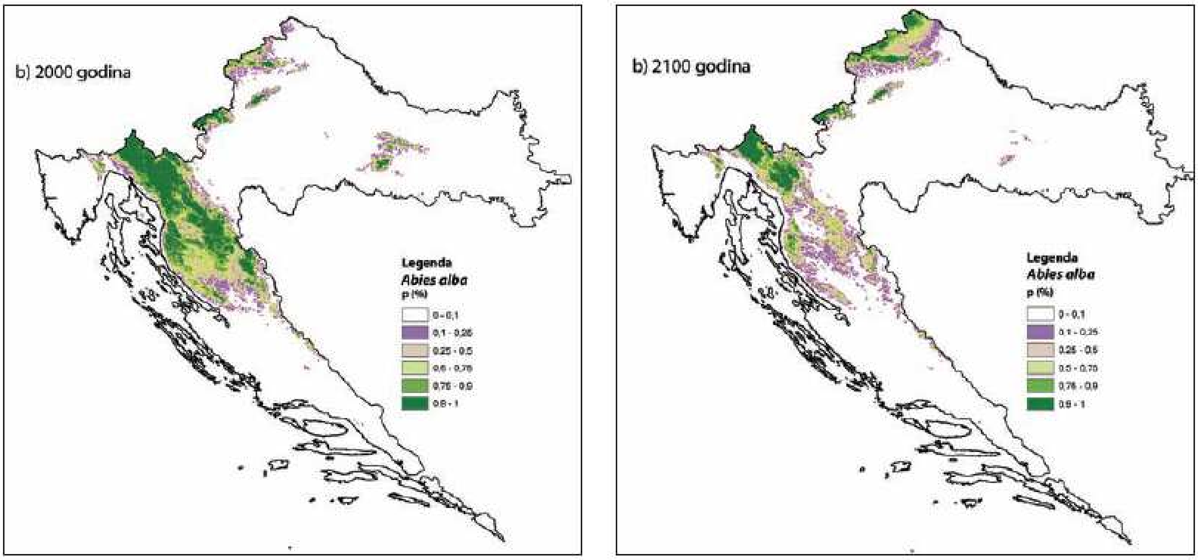
1. The spreading of the area of lowland forest types which is relatively uncertain as the effect of climate on the hydrological regime (droughts) is not included in the model.
2. The very certain reduction of the area of fir-beech forest in mountaneous region of Gorski Kotar.
3. The spreading of broadleaved decidous Submediteranean forests (*Quercus pubescens*)
4. The reduction of the area of Mediterranean evergreen broadleaved forests (*Quercus ilex*)

Fig 6. Current distribution of main forest types in Croatia and predicted vegetation distribution in 2030

Group	Forest type	Main species
	Lowland broadleaved deciduous forests and floodplains	Quercus robur
	Sub mountainous broadleaved deciduous forests	Quercus petrea
	Mountainous broadleaved deciduous forests	Fagus silvatica
	Mountainous mixed broadleaved coniferous forests	Abies alba, Fagus silvatica
	Sub alpine mixed broadleaved coniferous forests	Fagus silvatica, Pinus mugo
	Alpine broadleaved thermopile forests	Fagus silvatica
	Mediterranean broadleaved decidous forests	Quercus pubescens
	Mediterranean broadleaved evergreen forests	Quercus ilex
	Mediterranean coniferous forests	Pinus halepensis

The newer local study (Anić et al 2009) based on the CCM3 *(Climate Change Model)* scenario with a double increase of GHG until the period of 2100 shows the extinction of silver fir from the largest part of its natural habitat (fig. 7).

Fig 7. Current and predicted distribution of silver fir in Croatia



Slika 3. Prostorna distribucija ekološke niše (potencijalnog staništa) obične jele dobivena logističkim regresijskim modelom: a) stanje u razdoblju 1990 – 2000. godine, b) predviđanje za razdoblje 2000 – 2100. godine

Figure 3 The spatial distribution of ecological niche of silver fir obtained with logical regression model: a) for the period 1990 – 2000, b) predicting for the period 2000 – 2100

2. Adaptation

The Republic of Croatia is, according to the United Nations Frame Convention on Climate Change, obliged to produce periodic national communication which presents the main source of information regarding GHG emissions, projected impact and adaptation to CC. The first national communication was published in 2001, and afterwards joined second, third and fourth in 2006 covering the period 1996-2003. In 2008 a more comprehensive National Human Development Report was produced by the UNDP (United Nations Development Programme) concerning the challenge of climate change. The report emphasised overall a picture of climate change issues in Croatia in particular:

1. What do we know about the changing climate, what are the popular perceptions and level of public interest in climate change and what are the expected changes of climate in Croatia in terms of changes in temperature, precipitation and other factors.
2. How would climate change affect in Croatia concerning current and potential future vulnerability of key Croatian economic sectors to climate and possible positive impacts that may result from climate change. The ability to adapt to climate impacts is also discussed.
3. What can Croatia do to change the climate - assessing the cost of reducing emissions and the institutional capacity of Croatia to mitigate its own effect on climate change.

Impacts as well as the general level of adaptive capacity were examined for sectors of tourism, coastal resources especially related to sea-level rise, health, fresh-water resources, agriculture, fisheries and mariculture.

2.1. General adaptation strategy and policy

Up to the present there is no existing forest adaptation strategy in Croatia. Close to nature forest management has long been a tradition in Croatian forestry. Following close to natural management objective through long-term period and coping with various emerging impacts (forest decline, pests, loss of biodiversity…) some adaptation measures, which could also be related to climate change, were indirectly incorporated to maintain sustainability of forests. Recently, there were increasing research initiatives that emphasize the testing of behaviour of European and local provenances of the main tree species in Croatia (Common oak, silver fir and common beech). Together with in situ conservation or selection, according to the phenotype characteristic of most prominent forest stands of the main species, ex situ gene conservation which incorporates provenance tests, clone archives and family tests were established.

2.2. Forest adaptation measures

2.2.1. Close to nature forestry

The general lines of Croatian forest policy are represented in the Forestry Act (2005) which regulates management, protection and use of forests and forest land as natural heritage with the aim of sustaining biodiversity and the principles of sustainability, social responsibility and ecologic acceptability. The articles that define the criteria of sustainability concerning climate change are:

1. The role of forest management is maintaining and improvement of forest health, vitality and their contribution to global carbon cycle, improvement of biodiversity,

forest productive capacity, protection functions of soils and water and other socio-economic functions.
2. The responsible forest organizations have to: maintain natural forest composition and support native species
3. Artificial establishment of new stands and recovery of degradated forest should take account of adaptation to particular site characteristics and management objectives provide advantage to native species and local provenances.
4. In the forests threatened by forest dieback and natural accidents, observance should be established with the aim of determining the negative processes
5. Tendering and harvesting should be performed so as to avoid permanent damage of ecosystems and also measures should be applied to maintain and improvef biodiversity.

A more detailed operational level is provided by "Regulation of forest management" which defines all procedures needed to accomplish the general objectives of the Forestry Act. Regarding forest decline there is regulation that all forest areas greater than 0.1 ha, where stand composition is devastated and fragmentary, should be reforested by appropriate tree species.

According to this regulation the lower boundary of rotation period for the main tree species are:

Tree species	**High forests**	**Coppices**
Quercus robur, Q. ilex	140 years	40 years
Quercus petraea, Q. pubescens	120 years	40 years
Fagus sylvatica, Acer sp.	100 years	40 years
Q. cerris, Fraxinus sp., Common hornbeam, Ulmus sp.	80 years	40 years
Cherry	60 years	30 years
Tilia sp.,	50 years	20 years
Softwood broadleaved species	40 years	20 years
Native Populus sp., Salix sp.	30 years	20 years
Maqui		30 years
Abies alba	100 years	
Picea abies, P. nigra, P. sylvestris, P. strobus, P. halepensis, P. maritima	80 years	
Larix sp., Pseudotsuga menziessi	60 years	

Currently, there are emerging discussions about shortening the rotation period of the common oak due to the intensive decline and stand structural disturbances in the last decade.

Forests and forest services in Croatia are managed and structured at different levels of organization (from top to bottom):

2.2.2. Gene conservation

At present, there are two main types of gene conservation which are applied in Croatia in situ and ex situ (Kajba et al. 2006, Gračan et al. 2006). Through in situ conservation, genetic diversity within the population is preserved by selection of the highest quality stands according to phenotype inside particular seed zones or regions. Seeds or selected reproductive material gathered from these types of populations are used for further regeneration within the zone or region. At the moment there are 303 selected seed stands in

Croatia of conifers, social broadleaved species and noble hardwood species with a total area of 17 612 ha. (table 1).

Table 1. Conservation of forest genetic resources by *in situ* method

Species	Type	No.	Total area (ha)
Conifers			
Abies alba	PSS/ISS	14	418
Larix decidua	PSS	1	15
Picea abies	PSS	13	280
Pinus brutia	PSS	3	21
Pinus halepensis	PSS/ISS	5	185
Pinus nigra	PSS/ISS	15	302
Pinus nigra ssp. *dalmatica*	PSS	1	57
Pinus nigra ssp. *laricio*	PSS	2	29
Pinus pinaster	PSS	4	50
Pinus pinea	PSS/ISS	3	9
Pinus sylvestris	PSS	5	69
Taxodium distichum	PSS	1	1
Subtotal	PSS/ISS	76	1 436
Social Broadleaved species			
Fagus sylvatica	PSS/ISS	25	1. 603
Quercus ilex	PSS	3	85
Quercus petraea	PSS/ISS	35	2. 044
Quercus pubescens	PSS/ISS	3	129
Quercus robur	PSS/ISS	106	10. 094
Quercus robur var. *tardissima*	PSS	5	99
Subtotal	PSS/ISS	180	14 054
Noble Hardwoods species			
Acer pseudoplatanus	PSS	1	22
Alnus glutinosa	PSS/ISS	4	50
Carpinus betulus	PSS/ISS	4	132
Castanea sativa	PSS	1	23
Fraxinus angustifolia	PSS/ISS	25	1.603
Fraxinus excelsior	PSS	1	22
Juglans nigra	PSS/ISS	3	56
Tilia tomentosa	PSS	2	42
Tilia platyphyllos	PSS	3	172
Ulmus minor	PSS	3	GS
Subtotal		47	2 122
Total		303	17 612

PSS = seed stands
ISS = selected seed stands
GS = group of trees

By ex situ conservation, forest species are conserved independently from their natural habitats. The ex situ method is performed through provenance tests, seed clone plantations, half breeds test and clone archives. By this method of conservation it was established about 50 various trials with total area of 114.85 ha. The most important trials comprise main tree species in Croatia such as common oak, European beech (Jazbec et al. 2007) and silver spruce.

3. Mitigation

Mitigation is an anthropogenic intervention to reduce the anthropogenic forcing of the climate system. It includes strategies to reduce greenhouse gas sources and emissions and to enhance greenhouse gas sinks (IPCC 2007).

The Kyoto Protocol, which builds upon the UN Framework Convention on Climate Change (UNFCCC), commits industrial economies and economies in transition to reduce their collective emissions in 2008–2012 to five percent below the levels of 1990 (IPCC 2007). Also, all Parties of the Convention are obliged to implement into their policies national programmes containing measures to mitigate climate change by addressing sources and removals by sinks. Furthermore, they have to promote processes that control, reduce or prevent emissions of GHGs in relevant sectors, e.g. energy, transport, industry, agriculture, forestry and waste management and promote sustainable management, conservation and enhancement of sinks and reservoirs, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems.

The fulfilment of international obligations in relation to climate change mitigation and adaptation, in the first place the Kyoto Protocol, but also other EU and UN obligations related to specific mitigation and adaptation issues, oblige Croatia to endeavour to enhance carbon sequestration if possible or preserve carbon sequestration and C pools. Besides other activities, Croatia should also decrease carbon emissions through specific activities in forest based sector such as wood substitution, forest biomass substitution, avoided land use change and reducing the risks of wildfires.

3.1. Carbon accounts

3.1.1. Kyoto Protocol and Croatian position

As a result of specific circumstances related to the defensive war in Croatia and the Kyoto negotiations, the initiation of Croatian activities regarding climate change mitigation in legislative and political terms but also the implementation into practice has been delayed in relation to some other European countries.

Even though Croatia signed Kyoto Protocol and joined global mitigation efforts on 11th March 1999 as the 78th country which signed the treaty, it did not ratify it until the 27th of April 2007 after long and hard negotiations to have an equal position as other European countries. Following the principles of the Convention which state that parties to the convention would protect the climate system on the principles of equality and in relation to their different responsibilities and opportunities, the set goal of reducing the greenhouse gas emissions by 5 % in the period from 2008-2012 in relation to 1990 was not realistic for Croatia. The estimated GHG emissions for base year 1990 was rather low, 31.6 Mt CO2 eq, so this would have meant that about 31.12 million tonnes of carbon dioxide would be allowed for Croatia per year. Unfortunately, in the time of negotiations in Kyoto, the Croatian Government did not have at its disposal complete data on GHG emissions, the energy situation with development plans in the whole county or information about economically efficient possibilities of reducing GHG emissions. In the period just before Kyoto, from 1990–1995, emissions were reduced in Croatia for 45% due to the specific situation of defensive war which resulted with a general reduction of economical activities and energy consumption in the country. Also, one of the reasons for such low GHG emissions was the fact that Croatia until 1991 had settled 22.0 % of its electric energy demand from other Yugoslav republics energy sources, based on specific contracts regarding electrical energy investment and delivery, the power lease in thermal power plants because Yugoslavia was a single energy market.

Therefore, Croatia was not able to negotiate on the real quote of emission reduction which would be in harmony with its uniqueness and possibilities. Since these limitations would have meant for Croatia to go back in an economic sense to the development status of the year 1974, it would significantly slow down its industrial recovery which was very important for one transitional country in the after war period. Even though Croatia is a transitional country the *Article 4.6* of UNFCCC could not be applied as it has been in the cases of other transitional countries. Hence, Croatia applied for appreciation of specificity in the calculation GHG emission level in 1990 according to UNFCCC and Kyoto Protocol on the 7^{th} Conference of Parties (COP 7) in Marrakech 2001. After a long negotiation procedure the 'Croatian request' was finally approved on the 12^{th} Conference of Parties in Nairobi 2006. According to decision 7 of the conference in Nairobi, Croatia was allowed to add 3.5 Mt CO_2 equivalents to its 1990 level of GHG emissions not controlled by the Montreal Protocol for the purpose of establishing the level of emissions for the base year for implementation of its commitments under Article 4, paragraph 2, of the UNFCCC. Therefore, through these negotiations the Government had achieved success and increased allowed limitation of emissions to 34.62 million tonnes of carbon dioxide per year.

The total contribution of Croatia to the emission of greenhouse gases is especially small when net emissions are taken into account, because more than half of Croatian GHG emissions are absorbed into the total wood increment (sink of CO_2 into forests amounts 976 kt CO_2, which is 15 % of total sink in 1990). Even though Croatia has among EU countries and countries in transition the lowest emissions (6.6 tonnes of CO_2 eq per capita in 2000 in relation to average amount of CO_2 in transitional countries which is 13.7 tonnes) and new limitations for Croatia have been set, there will still be a need for implementation of mitigation activities in Croatia since the economy and industry develops rather quickly. Fulfilling these Kyoto Protocol obligations for Croatia also depends on political stability in the region and the admittance of Croatia into European Union.

3.1.2. Croatian carbon account

Forests in Croatia cover about 42 % of the terrestrial part of the country and the estimated current annual increment of state forests is around 10.5 mill m^3. These facts indicate how much forests and forestry in Croatia are participating in climate change mitigation processes. On the other hand, the climate mitigation and carbon sequestration function of forests is not yet well incorporated in the Croatian forest sector.

The reporting of GHG emission in Croatia is conducted by the company Ekonerg. The company gets forestry data from the government enterprise 'Croatian forests Ltd.' which manages state forests, and from the Forest Extension Service, a specialized public institution for conducting matters in part of public authorities, improving management of forests and woodlands in private forests. Calculated GHG emissions data are sent to UNFCCC and are published in the Croatian National Inventory Reports (NIR).

The IPCC methodology (IPCC 2003) has been used in NIR for the calculation of CO_2 emissions and removals from AFOLU sector (ex LULUCF). GHG inventory for the land-use category Forest Land Remaining Forest land (FF) was reported using Tier 1 method. In Tier 1 method GHG inventory in FF is estimated only for aboveground and belowground biomass. Other carbon pools are not taken into consideration.

Since the new *Forest Management Area Plan* (FMAP) became available in 2006, it was possible to make new calculations necessary for the estimation of CO_2 removals in the first commitment period and compare the results with corresponding values in NIR. Detailed results and description of the calculation procedure used in the pilot study are given in the final report of the pilot study by Joanneum Research. At present, it can be stated that the calculations in the pilot study were made using, when possible, species specific BEFs from the literature (ranging from 1.05 to 1.40). This approach is in line with Tier 2 methodology of the IPCC GPG for the living biomass. Due to problems in obtaining data, dead organic matter and soil pools were not estimated. Net annual removal of C (preliminary results) in units of Mt CO_2eq/yr was calculated by subtracting the expected loss of wood (thinning and harvesting) from the reported estimate of the increment (Marjanović et al. 2007).

Table 2. Estimated net annual removal of carbon in Croatian forests for the first commitment period 2008-2012 (in units of Mt CO_2 eq/yr) – preliminary results from the pilot study.

	Total for the first commitment period (2008-2012)	Annual within the first commitment period (2008 - 2012)
	Mt CO_2 eq/yr	Mt CO_2 eq/yr
Increment (I)	88.85	17.77
Loss (L)	40.79	8.16
Net removal (NR=I-L)	48.06	9.61
Forest fires (best to worst case scenario)	0.40 to 8.60	0.08 to 1.72
Net removal with forest fires (NR-fire)	47.66 to 39.46	9.52 to 7.89

Source: Marjanović et al. 2007

It is important to note the following: there is a gap between the net removal that has been reported in NIR for 2004 (16.32 Mt CO_2eq/yr.) and the expected net removal that is calculated here (9.61 Mt CO_2eq/yr). In addition, expected loss due to future forest fires would need to be included as well (our estimates range from 0.08 to 1.72 MtCO_2eq/yr) reducing the value of expected net removal to 9.52 to 7.89 MtCO_2eq/yr.

There are several reasons for the difference in the estimated net removal. The main reason lies in values of BEFs (single BEF of 1.9 used in NIR is 36-81% greater than BEFs used in the pilot study). Other reasons involve, for example, methodological issues in calculations made within FMAP because it does not contain data on biomass and increment of stands younger than 20 years nor biomass of trees of less than 10cm in DBH (Marjanović et al. 2007).

3.2 Political processes, instruments and strategies for mitigation

The Ministry of Environmental Protection, Physical Planning and Construction is in charge of matters related to the UN's Framework Convention on Climate Change (UNFCCC) and international negotiations under the Convention. *The Ministry* recently announced that the completion of *Strategy* and *Action Plan for Climate change mitigation* in Croatia is in the final stage. With those documents the *Ministry* will provide economically efficient measures for climate change mitigation and cost estimation for the implementation of these measures. Also, the Croatian Government adopted two legislative measures at the end of 2008 by which it has set the position of Croatia in relation to Protocol in the first commitment period and in the period just after its completion. Those are the *Directive on the implementation of the Kyoto Protocol flexible mechanisms* and *the Directive on emission quotes of GHG-s and the trade of emission units* (N.N. no. 142/08). The first Directive regulates the ways of implementation of Protocol flexible mechanisms, with respect to project activities of clean development mechanisms (CDM), joint implementation projects on the territory of Croatia and neighbouring territory, and the international trade of GHG emissions (IET). The means of implementation of flexible Protocol mechanisms is determined and supervised by the Conference of parties to the UNFCCC which serves as a convention of the Protocol parties (COP/MOP). Articles 13. to 24. of the Directive determine the implementation of JI project activities on the territory of Croatia. Under the term project activity it is considered the implementation of mechanisms of joint projects with respect to clean development mechanisms approved by one or more UNFCCC Annex I parties. In the Directive also states that implementation of joint projects mechanisms on the territory of Croatia is to be entered into force on 1st of January 2013 because the *Plan of protection and improvement of air quality* of Croatia did not foresee that Croatia would be host of JI project activities for the period from 2008 to 2011 (N.N. br. 61/08).

Delayed ratification of the Protocol is the main reason for the sort-term delay in inclusion of Croatia into emission credit market. Regarding the fact that “Croatian forests Ltd.” have not installed industrial facilities or heating plants on fossil fuel with input power more than 20 MW, they will not be capable to gain emission permits by which they could trade. The remaining possibility for the inclusion of Croatia in carbon credit trade is through JI projects which according to the Directive on implementation of flexible Kyoto Protocol mechanism are not possible before 2013, and in an operational sense they probably will not be able to start before 2016. On the other hand, there is possibility that “Croatian forests Ltd.” are going to be requested to present additional information on the increment and wood stock for stands in the first age class and degraded forests. In the next two years it is possible also that relevant institutions will be forced to present information on separate parts of forest ecosystems such as “death organic matter” and “soil organic matter”. This means that it will be necessary to present information on total carbon balance which includes live and dead biomass components and organic matter (carbon) in soil.

3.3 Forestry as a source of bio-energy

In addition to reducing GHG emissions, the use of wood for energy has the effect of increasing self-sufficiency in energy production, promoting good silvicultural practices, and improving the employment situation. The target of the European Union is to increase the share of renewable energy consumption to 12% by 2010. Progress has been made, but the 12% target will not be met (EC 2007, EC 2004 a, b). Nevertheless, in the Commission’s roadmap, the target is 20 % of energy consumption by 2020. In regards to the increased use of biomass, the EU´s Biomass Action Plan suggests that the use of biomass should increase by 80 Mtoe by the year 2010 (EC 2005). The target share of biologically based fuels for transport is 5.75% by 2010 as compared to 10% by 2020 in the Commission’s road map (EC 2007). These targets call for increased production of biomass on the EU´s own territory, but evidently a large part of the biomass will have to be imported. (Lunnan *et al* 2008)

Today in Croatia about 10 % of family homes use heating plants (more than 140 000 houses in more than 10 cities, which makes about 1/3 of population of Croatia) and those are mostly fossil fuel plants (gas, oil). Some of heating plants in Croatia are at the end of their life span which is 20 to 25 years and therefore investments should be made in building new plants which could use biomass and not only fossil fuels. “Croatian Forests Ltd.” initiated activities on pilot projects «energy from biomass» in 2002 under the motto «16 administration-branch offices – 16 heat plants on forest biomass», but only two of them have been completed until now. The first heating plant on biomass fuel was built in 1995 (1 MW) in Ogulin, and the second in Gospić in the year 2005. These two plants are the only ones in Croatia which use biomass. The annual production of pellets in Croatia is 150,000-200,000 tonnes, and brickets 25,000-30,000 tonnes. From these figures it is evident that biomass production in Croatia is in its early stage. But the *National energetic strategy* was re-evaluated and completed in 2007. According to the *Strategy* the minimal share of renewable energy sources in the total energy consumption until 2010 should be 5.8%. In 2007 a daughter company of the public corporation for managing state forests in Croatia called “*Forest Biomas”* was established with the aim of grouping and supporting the projects based on forest biomass (Sitas 2008).

Forests and forest lands in Croatia cover about 47% of land area and only 50 % of expected increment is used. Every four minutes in Croatia 1 m^3 of wood grows. But, Croatia imports about 50 % of fossil fuels (Dundovic, official web page of Croatian Forest Society).

Forest bio energy utilisation is closely related to issues of pronounced political importance such as energy policies and the international processes for sustainable development, especially climate change and sustainable forest management (Lunnan *et all* 2008). There are no subsidies for energy production in Croatia yet, but there should be since an increase in biomass production is planned in the *Strategy*.

Forest fires pose a great threat to climate change mitigation since they release carbon dioxide into the atmosphere and reduce carbon pools. For Croatia, forest fires pose a great threat especially on the karst area. The only possible way that the risks of fires could be significantly reduced, besides monitoring, is if those forests would become economically efficient, for example through biomass substitution which is important in mitigation. Therefore, this could be great mitigation possibility for Croatia.

3.4 Research studies on mitigation

Within the framework of the European Union project CADSES "Carbon-Pro" and with the help of "Croatian Forests Ltd." a station for continuous monitoring of forest carbon and energy fluxes was been put into operation on 21st of September 2007. Acquired data enabled Croatian scientists to better understand the processes, causes and effects that environmental factors have on Pedunculate oak stands and lowland forests in general. The station is the first of its kind in Croatia and in the wider South-European Region and as such has already become a valuable source of new data. At the station a wide range of meteorological and ecological variables is continuously measured and recorded. The fluxes of CO_2, sensible and latent heat are estimated using eddy covariance method (Marjanović et al 2008).

In the frame of the Short Term Scientific Mission (STSM) of this COST action a young phD student Martina Tijardović investigated the Potentials of forests and forest products to mitigate climate change as a case study between Finland and Croatia. As a result of STSM she presented a draft version of the report which includes short overview on the state of Finland's and Croatian forests in relation to their potentials for mitigating climate change and the potential of their forest products for mitigation with special regard to substitution effects. A brief overview is given on the related current and planned activities in Finland and Croatia. There are significant differences in the related past and present research activities, legislation, implementation, natural conditions and limitations for mitigation between these two countries so this report aims at providing information for every country in particular.

Other projects which address climate mitigation in Croatia are:

- Doctoral thesis of dr. sc. Elvis Paladinić, "Estimation of ability of forest stands for carbon storage in the scope of Kyoto Protocol commitments"
- Energy Institute Hrvoje Požar, Implementing legislation for renewable energy sources and congeneration in Croatia (duration 2005 – 2006)
- Energy Institute Hrvoje Požar, Overwiev of potentials and market prospect of renewable energy, industrial co-generation and district heating systems in Croatia (duration 2005)
- Energy Institute Hrvoje Požar, BIOEN in the scope of National Energy Programs (duration 1997 – 2003)
- Energy Institute Hrvoje Požar, Renewable energy development in the West Balkan Region (duration 2005 – 2006)
- IEA Bioenergy task 29 – Socioeconomic drivers in implementing bioenergy projects (duration 2003 – 2005).

Other publications in Croatia are mostly related with biomass production and fossil fuel substitution (e. g. Perić et al 2006, Perić et al 2003, Topić et al 2005, Kulišić et al 2007 a b, Kulišić and Tadić 2002, Kulišić and White 2008, Kulišić and Paar 2008 a b, Domac et al 2006).

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