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DISTAT-Forest Ecology & Geomatics LAB

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Introduction

In Italy most of the climate change projects and climatological research programs were focused to agrosystems and health area. For this reason the majority of the climatological studies were carried out on the basis of rural or urban meteorological stations. And consequentially a relatively few information are available to evaluate climate change impacts on forests ecosystems.
Moreover most of the climate change and agrometeorology studies were carried out on Mediterranean scale or regional scale while applications at national level are relatively less frequent.

Concerning climatological studies applied in the Mediterranean area, in the last decades some meteorological and agrometeorological indexes related to temperatures and precipitations showed significant temporal trends. Which have direct impact on climatic system, climate variability and, potentially, on vegetation.
For example, a significant positive trend in sea surface temperature (Figure 1, Figure 3) in late summer and at the beginning of autumn leads to a more frequent flooding event; more dry spells (increased especially during the winter) heighten drought stress risks for vegetation (Marcus Lindner, 2009) and forest fires (IPCC, 2007;Miller, 2007; Sirca et al., 2007; Balshi et al., 2008; Camia et al., 2008; Good et al., 2008; Krawchuk et al 2008; Arca et al., 2009); more cloudiness in springtime decreased the number of frost days compromising dormancy.
Moreover, higher yield variability and reduction in suitable areas of traditional forest species are expected due to the increase of extreme events and seasonal shift.
Altogether these phenomena modify the phenology, photosynthetic efficiency, productivity and, at long time scale, composition and spatial distribution of forest ecosystems.

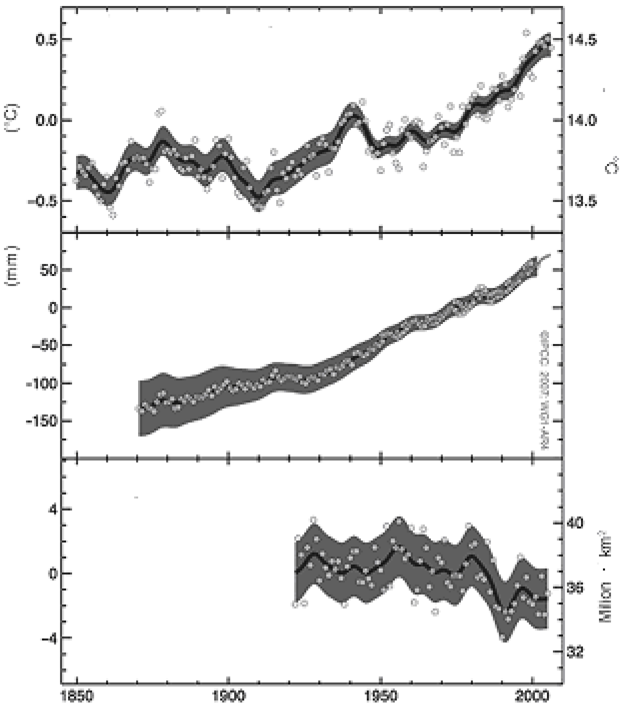


Figure 1: Sea temperature, global mean temperature and snow cover variations in the north hemisphere (source IPCC, 2007a).On x-axis is reported the period in years, on left y-axis of the central and down figures the differences of the period considered with the WMO period of reference (1961-1990), expressed in mm.

Altogether these phenomena modify the phenology (**Table 1**, Table 2), photosynthetic efficiency, productivity and, at long time scale, composition and spatial distribution of forest ecosystems (Walther GR, 2005, Ahas et al. 2002).

Location	Period	Change in growing season (days)	Number of species	Reference
Germany	1951–1996	+6.6	4	Menzel et al. (2001)
Switzerland	1951–2000	+13.3	13	Defila & Clot (2001)
Cardedau field station (NE Spain)	1952–2000	+32.6 ± 2.23	24	Penuelas et al. (2002)
Japan	1953–2000	+12	1	Matsumoto et al. (2003)
Europe (International Phenological Gardens)	1959–1993/96	+10.8	16	Menzel & Fabian (1999); Menzel (2000)
Northern latitudes	1981–1991	+8 ± 3	NDVI* data	Myneni et al. (1997)
Vegetated areas north of 45 °N	1981–1994	+12	NDVI* data	Shabanov et al. (2002)
Eurasia	1981–1999	+18 ± 4	NDVI* data	Zhou et al. (2001)
North America	1981–1999	+12 ± 5	NDVI* data	Zhou et al. (2001)

*NDVI = Normalised Difference Vegetation Index

Table 1: Change in the growing season based on phenological monitoring series (Walther GR, 2005)

Parameter	Period	Linear trend	Reference
Spring data			
Plant Phenology			
Trees in Europe (IPG)	1959–1993	–0.20 day/year	Menzel and Fabian 1999
Trees in North and Central Europe (IPG)	1959–1993	–0.31 day/year	Menzel and Fabian 1999
Trees in Germany (IPG)	1959–1993	–0.31 day/year	Menzel and Fabian 1999
May shoot of Norway spruce in Germany	1951–1996	–0.10 day/year	Menzel 1998
Flowering of locust tree in Hungary	1851–1994	From –3 to –8 days (total)	Walkovszky 1998
Plant flowering in Estonia	1952–1996	From –0.14 to –0.29 day/year	Ahas 1999
Animal phenology			
Spawning of fish in Estonia, arrival of migrant birds	1952–1996	From –0.11 to –0.34 day/year	Ahas 1999
Arrival of migrant birds in the United Kingdom	1966–1996	Trend towards earliness	Sparks 1999
Egg-laying of birds in the United Kingdom	1971–1995	31% of species sign. earlier	Crick et al. 1997
	1939–1995	53% of the birds earlier through the 1980s and 1990s	Crick and Sparks 1999
Butterfly species/Europe	Past century	Poleward shift in geographical ranges	Parmesan et al. 1999
Others			
CO_2 record (Mauna Loa)	1970–1994	–0.28 day/year	Keeling et al. 1996
CO_2 record (Pt. Barrow)	1975–1994	–0.20 day/year	Keeling et al. 1996
AVHRR NDVI data 45°–70° latitude north	1982/3–1989/90	–8±3 days (total) –1.0 day/year	Myneni et al. 1997
Thermal seasons in Germany	1949–1985	up to –0.38 day/year (max)	Rapp and Schönwiese 1994
Autumn data			
Trees in Europe (IPG)	1959–1993	+0.16 day/year	Menzel and Fabian 1999
AVHRR NDVI data 45°–70° latitude north	1982/3–1989/90	+4±2 days (total) +0.5 day/year	Myneni et al. 1997
Thermal seasons in Germany	1949–1985	up to +0.32 day/year (max)	Rapp and Schönwiese 1994
Vegetation period			
Trees in Europe (IPG)	1959–1993	+0.36 day/year	Menzel and Fabian 1999
Birch in Germany	1951–1996	+0.17 day/year	Menzel 1998
European beech in Germany	1951–1996	+0.11 day/year	Menzel 1998

Table 2: Changes in the phenological phases in Europe (review). (IPG International Phenological Gardens). (Source: Menzel, 2000)

Anyhow, some studies pointed out an increased water use efficiency caused by rising of CO_2 level; thus, some of the negative effects of increasing water limitation and extreme events may be compensated.

The impact of climate changes should be considered when forest management choices are taken in terms potential impacts to forest protection regimes, changes in nutrient leaching and accelerated breakdown of soil organic matter.

Therefore, in order to increase efficiency, production, and to reduce risks and impacts on vegetation and mitigate climate change effects, it might be necessary to recalibrate forest management practices and reforestation programs. Moving from a traditional approach historically developed in the context of a stabile climatic condition to a new climatically dynamic context .

The climate change in the Mediterranean area

Annual mean temperatures in the Mediterranean area shows a trend considerably higher than the mean WMO trend reference period (1961-1990) (+0.41°C/decade for the period 1979 to 2005; updated from Jones and Moberg, 2003) (Figure 2). In particular winter temperatures are increasing more than summer temperatures (Jones and Moberg, 2003).
Concerning extreme events, an increase of daily range temperature variability is observed during the period 1977-2000 due to an increase of warm extremes, rather than a decrease of cold extremes (Klein Tank et al., 2002; Klein Tank and Können, 2003) (Figure 4).
Annual temperatures over Europe are warming at a rate of 0.1-0.4℃/decade. Moreover, this trend is higher in southern Europe (Spain, Italy, Greece).

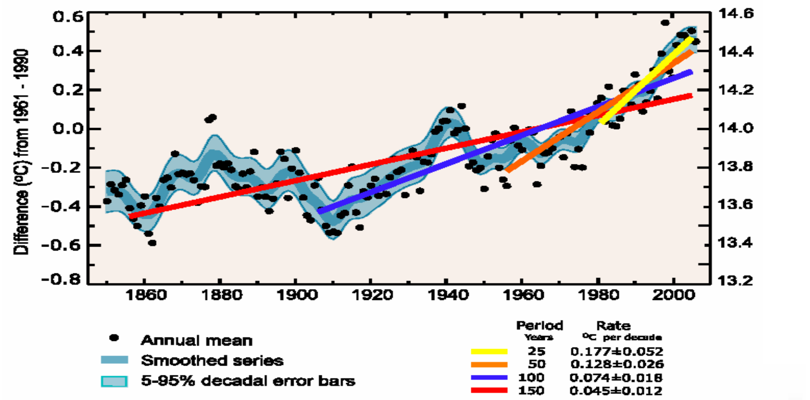


Figure 2: Mean global temperature (℃) trends (1850-2004 years) and rate of increasing temperature of 1980-2004, 1955-2004, 1905-2004, 1855-2004 periods.
On the left temperature anomalies (℃) between 1961-1990. Source: IPCC, 2007a.

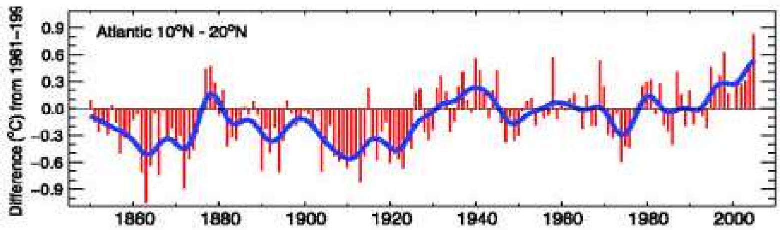


Figure 3:Temperatures anomalies trends on Atlantic ocean surface. The values were calculated as anomalies (℃) of 1850-2004 period versus 1961-1990 WMO period of reference. Source: IPCC, 2007a.

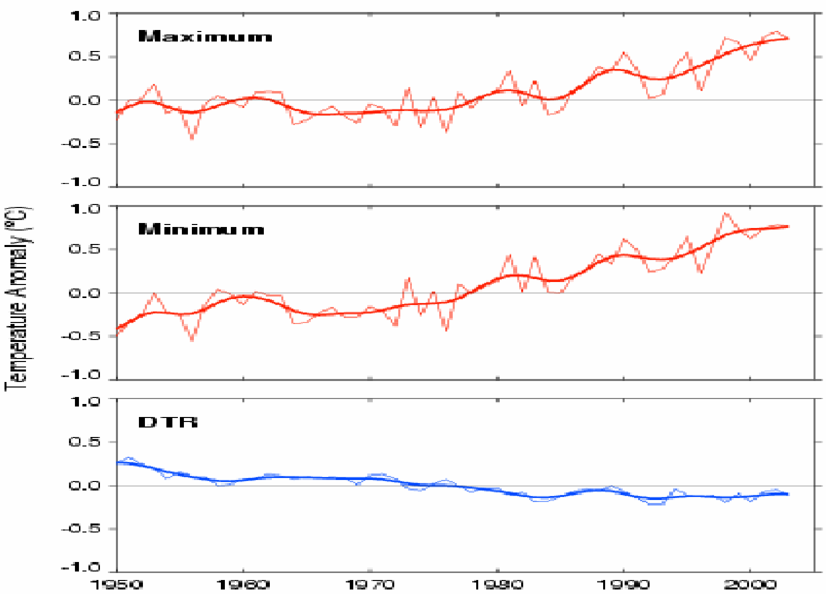


Figure 4: Global temperature anomalies of minimum, maximum and daily temperature range (DTR) of 1950-2005 period
Source: Vose et al., 2005.

Precipitation trends are more spatially variable. In the Mediterranean area, yearly precipitation trends are negative in the east, while they are not-significant in the west (Norrant and Douguédroit, 2006). Furthermore, contrasting trends have been highlighted between an increase in the central Mediterranean (Italy) and a decrease over the Balkans (Kostopoulou and Jones 2005). In Italy as well, a high variability of results has been obtained: an analysis of daily precipitation records over the 1951-1996 period shows that insular zones have often opposite results to the peninsular ones, where the rainfall is slightly decreasing during autumn and winter (Brunetti et al. 2001).

Italy: climate and phytoclimatic profile

Phytoclimatic zones define the geographic distribution of specific plant communities on the basis of the relationship with climatic parameters (
Figure 5).
Changes in altitude and latitude and consequent changes in thermal and pluviometric regimes determine changes in potential vegetation communities.

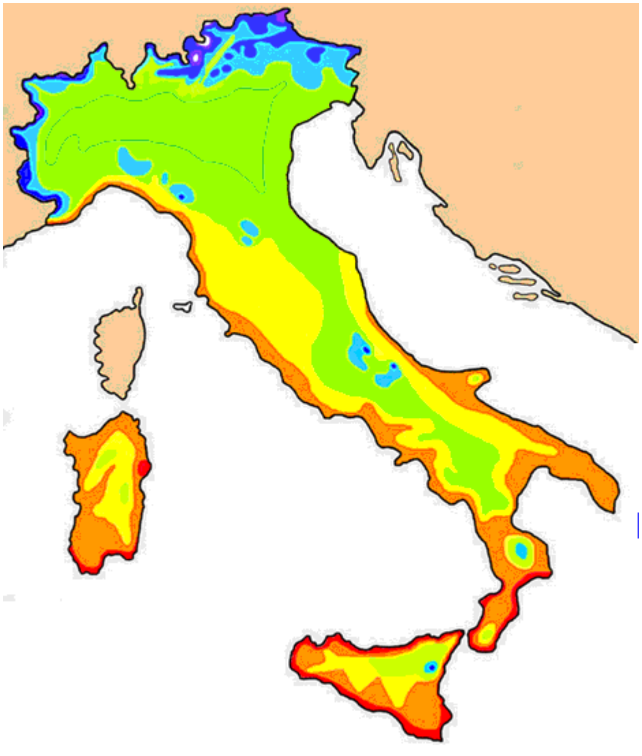


Figure 5: Köppen climate classification

Sub-tropical: annual mean temperature > 17°C; mean temperature of the coldest month > 10°C; mean temperature of consecutive five month>20°C; mean annual thermal range> 13-17°C.
Temperate-warm: annual mean temperature=14.5-16.9°C; mean temperature of the coldest month=-6/9.9°C; mean temperature of consecutive four month>20°C; annual thermal range> 15-17°C.
Temperate sub-coastal: annual mean temperature=10-14°C; mean temperature of the coldest month -1-3.9°C; mean temperature of consecutive two month>20°C; annual thermal range> 16-19°C.
Temperate sub-continental: annual mean temperature 9.5-15°C; mean temperature of the coldest month -1.5-3°C; mean temperature of consecutive three month>20°C; annual thermal range> 19°C.
Temperate-cold: annual mean temperature=3-5.9°C; mean temperature of the coldest month<-3°C; mean temperature of the warmest month 10-14.9°C; annual thermal range 16-19°C.
Cold:. mean temperature of the warmest month< 10°C
Ice-cold: Altitude> 2000 m. Annual mean temperature <0›; mean temperature of the coldest month<-6°C; mean temperature of the warmest month < 9.9°C; annual thermal range15-18°C.
Perennial snow: Altitude>3500 m. Perpetual snow

In Italy the first phytoclimatic model was developed by Pavari (Pavari,1816) Erreur ! Source du renvoi introuvable..

The model is an adaptation to Italian conditions of the original model previously developed by Heinrich Mayr.

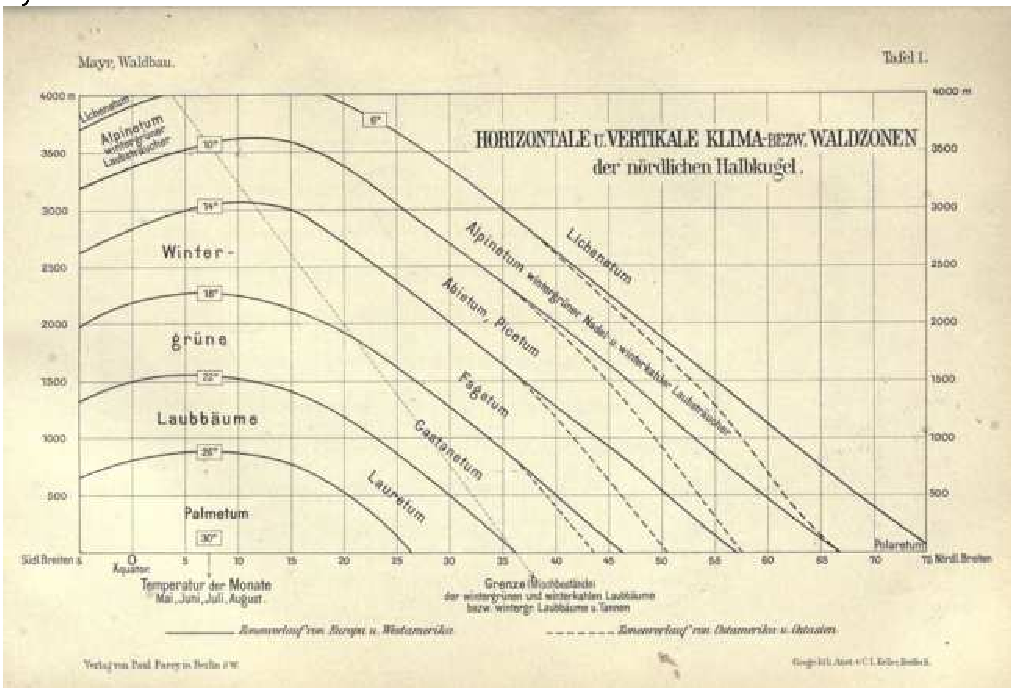


Figure 6: Mayr climate classification

The Pavari classification is based on five zones named on the basis of the most representative tree forest species. The climatic parameters used are: annual mean temperatures of the coldest month, the warmest month of the year, the mean of minimum and annual rainfall. The Pavari phytoclimatic zones were mapped by Alessandro De Philippis in 1937 (Figure 7).

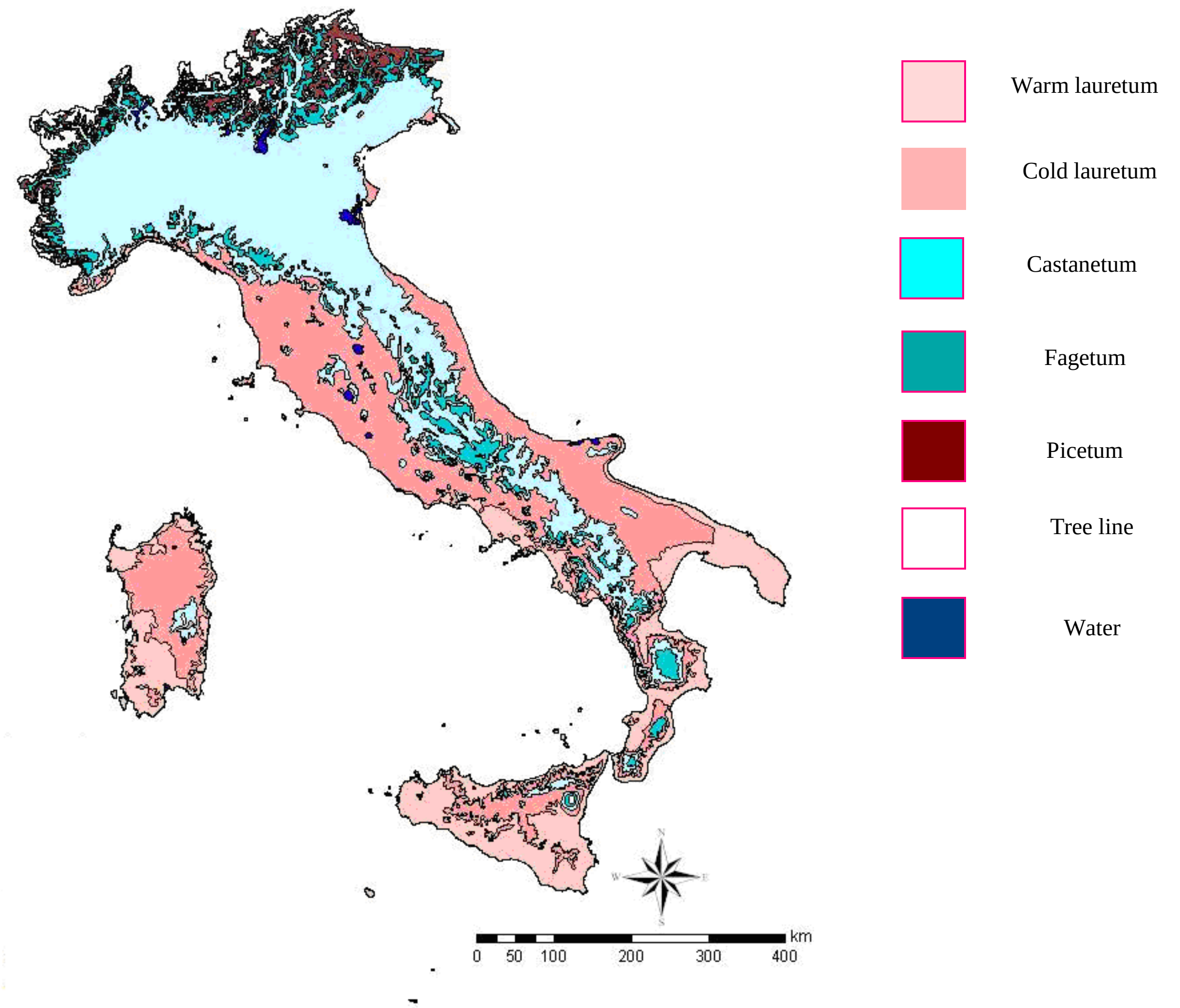


Figure 7: Italian map of phytoclimatic distribution (De Philippis, 1937) represented by using Pavari zones.

Recently, Blasi and collaborators proposed a new phytoclimatic map of Italy (Figure 8) based on thermo-pluviometric data analyzed applying multivariate analysis and than ombrothermic index analysis (Blasi C, 2007).

Figure 8: Blasi phytoclimatic map of Italy

Temperate oceanic bioclimate; western and central Alps, also on highest peaks of Apennines and Sicilia (Criorotemperate ultrahyperhumid/hyperhumid)

Temperate semicontinental bioclimate; western and eastern Alps (Supratemperate/Orotemperate humid subhumid/hyperhumid)

Temperate oceanic bioclimate; Alps (Orotemperate hyperhumid)

Temperate semicontinental-oceanic bioclimate; Alps and pre-Alpine District (Supratemperate/Orotemperate hyperhumid-ultrahyperhumid)

Temperate oceanic semicontinental bioclimate; mainly on northern and central Apennines, locally also on Ligurian Alps (Supratemperate hyperhumid-ultrahyperhumid)

Temperate oceanic bioclimate; Apennines and locally also on high mountain of Sicilia (Supratemperate ultrahyperhumid-hyperhumid

Temperate oceanic bioclimate; mainly on central and southern Apennines, also in Calabria, Sicilia and Sardegna (Supratemperate hyperhumid)

Temperate oceanic (transitional) bioclimate; mainly on Preapenninic District, also in Sicilia and Sardegna (Mesotemperate/Mesomediterranean humidlhyperhumid)

Temperate ocean ic-semicontinental bioclimate; mainly on pre-Apenninic Adriatic District (Supratemperate/ Mesotemperate humid/hyperhumid)

Temperate oceanic bioclimate; Apennines (Suprate mperate/Mesotemperate hyperhumidlhumid)

Temperate semicontinenta-oceanic bioclimate; mainly at mid-altitudes on the Adriatic side of the Apennines (Supratemperate/Mesotemperate humid)

Temperate semicontinental bioclimate; mainly Alpine valleys in western and central Alps (Supratemperate humidlhyperhumid)

Temperate semicontinental-subcontinental bioclimate; northern Italy only (Supratemperate hyperhumidlhumid)

Mediterranean oceanic bioclimate; southern Italy, Sicilia, Sardegna (Thermomediterranean/Mesomediterranean/I Inframediterranean dry/subhumid)

Mediterranean ocean ic-semicontinental bioclimate; southern and central Adriatic District, Ionian District, Italy, Sicilia, Sardegna and also along Tyrrhenian coasts (Mesomediterranean/Thermomediterranean dry/subhumid

Temperate ocean ic-semicontinental bioclimate; central Adriatic plains, southern Adriatic lower hills, central Apenninic inner valleys, Sardegna (Mesotemperate humid/subhumid)

Mediterranean oceanic (transitional) bioclimate; lower altitude in the Tyrrhenian and Ionian Districts (Mesomediterranean/Thermotemperate humid/subhumid)

Mediterranean oceanic bioclimate; plains of the Tyrrhenian and Ionian coasts, also in Sicilia (Thermomediterranean/Mesomediterranean subhumid)

Temperate oceanic/semicontinental (transitional) bioclimate; inner areas of Marche, Abruzzo and Toscana (Mesotemperate/Mesomediterranean subhumid

Mediterranean oceanic (transitional) bioclimate; plains of central and northern Tyrrhenian District, also in Sicilia and Sardegna (Mesomediterranean subhumid)

Temperate oceanic-semicontinental bioclimate; inner hills of central Italy (Mesotemperate subhumid/humid

Temperate oceanic-semicontinental (transitional) bioclimate; central Adriatic coasts, inner plains of the pre-Apenninic District and Sicilia (Mesotemperate/Mesomediterranean humid/subhumid)

Temperate subcontinental/semicontinental bioclimate; alluvial plains of northern Italy and inner hills of the Adriatic coasts (Supratemperate/Mesotemperate humid/subhumid)

Temperate subcontinental bioclimate; Po valley (Supratemperate humid subhumid)

Temperate bioclimate; northern Italy (Mesotemperate/Suprate mperate humid

Temperate subcontinental bioclimate; northern Italy (Suprate temperate/Mesotemperate humid-subhumid)

Temperate semicontinental-oceanic (transitional) bioclimate; inner valleys of southern and central Apennines (Supratemperate/Supramediterranean humid/subhumid)

Temperate semicontinental bioclimate; inner valleys of central and southern Apennines and western Alps (Supratemperate humid-subhumid)

Italy: forest profile

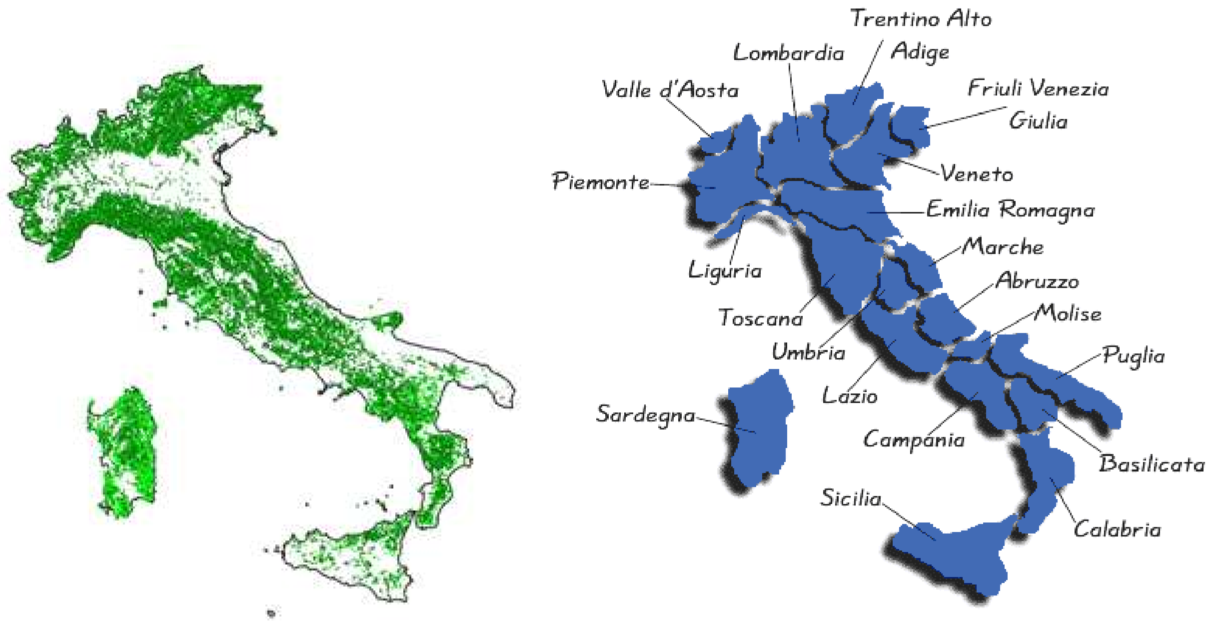


Figure 9: forest distribution in Italy (INFC 2005) and Italian administrative regions (NUT2 level).

On the basis of last National Forest and Carbon stock Inventory (INFC) of 2005 (Figure 9), the forest area in Italy is 10.467.533 ha, 34.7% of the land.
Woodland represents 83.7% of forest area, the remaining are other wooded lands (OWL) 16.3%.

Regions with more percentage of forest are: Trentino Alto Adige, Friuli Venetia Giulia, Liguria, Toscana, Umbria, Abruzzo, Calabria and Sardegna. Regions with the highest rate of forest area are Liguria and Trentino (respectively with 62.6 and 60.5% of the land). The regions where forests are scarce are Puglia (7.5%) and Sicily (10.0%).Other wooded lands (1.708.333 ha, 16.3% of Italian land), are for 58.0% shrubland. The more common forest species are: Quercus pubescent, Quercus robur, beech wood, Quercus frainetto, Quercus trojana and vallonea (Table 3)

Wood		Other woodlands		Italian forest surface		Italian surface
ha	%	ha	%	ha	%	ha
87 59200	0.4	17 08333	1.3	10 467533	0.3	30 132845

Woods									
Pure coniferous woods		Pure deciduous woods		Mixed woods of coniferous and deciduous		Not coded area for mixture degree		Total woods	
ha	%	ha	%	ha	%	ha	%	ha	%
1 172 806	1.5	5 942 912	0.6	840883	2.0	802600	2.1	8759200	0.4

Other woodlands									
Pure coniferous woods		Pure deciduous woods		Mixed woods of coniferous and deciduous		Not coded area for mixture degree		Total woods	
ha	%	ha	%	ha	%	ha	%	ha	%
76347	7.0	891705	1.8	94 738	6.3	645542	2.3	170833	1.3

Tall Wood		arboriculture		Areas temporarily without vegetation		Wood in Italy	
ha	%	ha	%	ha	%	ha	%
8582968	0.4	122252	4.5	53981	8.1	8759200	0.4

Low wood		Thin wood		brush		scrub		Woodlands not coded or not accessible		Other woodlands in Italy	
ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
124229	5.5	146415	4.9	48678	8.7	990916	1.7	398095	2.9	1708333	1.3

Wood of larch and Pinus cembra		Spuce fire wood		Silver fir		Scotch pine and mountain pine		Pinus nigra, pinus nigra subsp.laricio and e Pinus heldreichii		Mediterranean pinewoods	
ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
382372	3.0	586082	2.2	68 460	7.4	151671	4.9	236467	3.9	226101	4.0

Conifer woos pure or mixed		Beechwood		Quercus robur, pubescens, petrea		Quercus frainetto quercus trojana, quercus macrolepis		chestnut grove		"Orno-ostrieti" (Fraxinus ornus and Ostrya carpinifolia)	
ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
63407	7.7	1035103	1.8	1084247	1.8	1010986	1.7	788 408	2.1	852202	2.0

Hygrophilous woods		Other deciduous woodlands		Holm hoac woods		Quercus suber woods		Other deciduous woodlands evergreen		Tall woods in Italy	
ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
229054	4.0	994777	1.8	620318	2.3	168602	4.5	84712	6.6	8582968	0.4

Poplar woodlands Planted		Other woods planted		Conifer planted		Planted woods for wood production	
ha	%	ha	%	ha	%	ha	%
66269	5.8	40985	8.6	14998	15.8	122252	4.5

Table 3: Data of Italian forest distribution. Source: INFC

1. Impacts

The observation of climate change impacts is the basis for problem identification and understanding. The comprehension of the occurred situation allows simulations in order to predict expected impacts. Forest monitoring is the best way to detect and monitor impacts on forest ecosystems. Some impacts appear progressively according to trends and can be taken into account as they go along. Most of the effects from extreme events (such as storms, floods, droughts, forest fires, disease outbreaks, etc.) may determine local crises.

1.1. Observed impacts

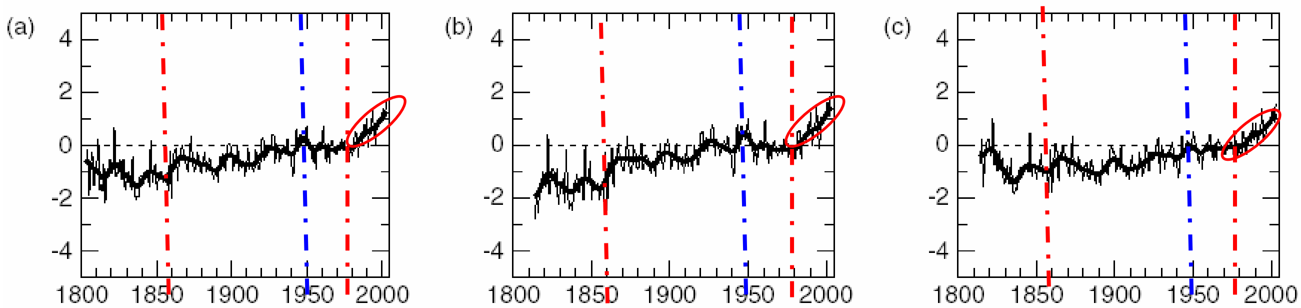
The Mediterranean area might be highly sensitive to future climate change (Gualdi & Navarra 2005, Peñuelas et al. 2004a, Peñuelas et al. 2004b, Ogaya et al. 2003, Carrión 2002, Peñuelas et al. 2002, Lavorel et al.1998). In fact, the predicted lower precipitations and higher temperature cause a general degeneration of Mediterranean forests through direct effects on plants, (increased transpiration, photodamage, lower photochemical efficiency, decreased water use efficiency, decrease of productivity) and indirect effects on the abiotic component (soil erosion, nutrient leaching, more frequent wildfires).

Taking into consideration drier conditions, castanetum, ostrio-carpinetum and fagetum (Figure 7) are potentially more sensible to drought and warmer climate hazards.

Lauretum and warm lauretum (Figure 7) represent an important vegetation component, also including shrublands ecosystems that are sometime resulting from the degradation of Mediterranean forests due to climate change and/or anthropogenic pressures (agriculture, pasture, wood, and recently tourism, etc.) active since thousands of years by local populations (De Dato G 2008).

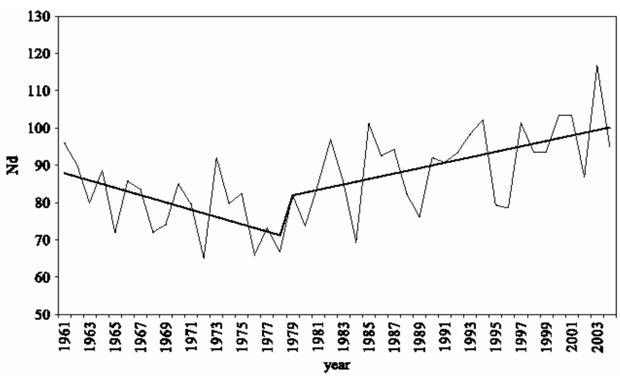
1.1.1. Observed Italian climatic evolution

Italian temperatures register a warming trend (+ 0.8 °C during XX c. and of 1 °C ± 0.1 1865 - 2003 period, Brunetti et al., 2006), that is comparable with the European average condition (Brunetti et al., 2006).
The studies made by Brunetti et al. (2006) on climate change shows that the warming trend started in the 1860 and stopped in the 1950 (Figure 10).



compared with the 1961-1990 WMO period of reference. Source: Brunetti et al., 2006.

From 1950 since 1970 there was no trend, then warming period started again in 1980 and temperature trend shows a high slope of increased tendency. As for minimum and maximum temperature the first one raises more and more during 1865-2003 periods (Brunetti et al., 2006) then the daily temperature range decreased.
Last decade due to high frequency and intensity of extreme warm events, maximum temperature increased more and more versus; consequently daily temperature range trend reversed the back phase trend.
Seasonal analysis showed significant differences. In particular spring and summer temperatures increases starting from 1980. Concerning extreme event, bibliography on national level is not substantial. Anyway one recent study (Toreti e Desiato, 2007) emphasize that, starting from 1980, the number of frost days (days with minimum temperature<0°C) reduced (Figure 12), while the number of summer days (days with maximum temperature>25°C) and tropical nights (days with minimum temperature>20°C) increased (Figure 11).



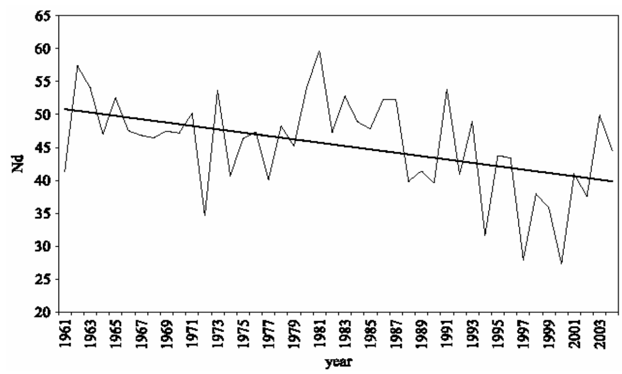


Figure 11 (on the left):Summer days (temp max>25°C) trend in Italy. Source: Toreti e Desiato, 2006.
Figure 12 (on the right):trend of number of frost days (temp. min <0°C) in Italy. Source: Toreti e Desiato, 2006.

As for rainfall, Italian trend shows a decrease. In fact, 1951-1996 periods in Italy the cloudiness decreased especially in winter (Maugeri et al., 2001).
Concerning rainfall analysed in 1866-1996 period, number of rainfall days decreased of 10% on national level but intensity events increased (Brunetti et al., 2001, 2002a, 2004) (Figure 13).

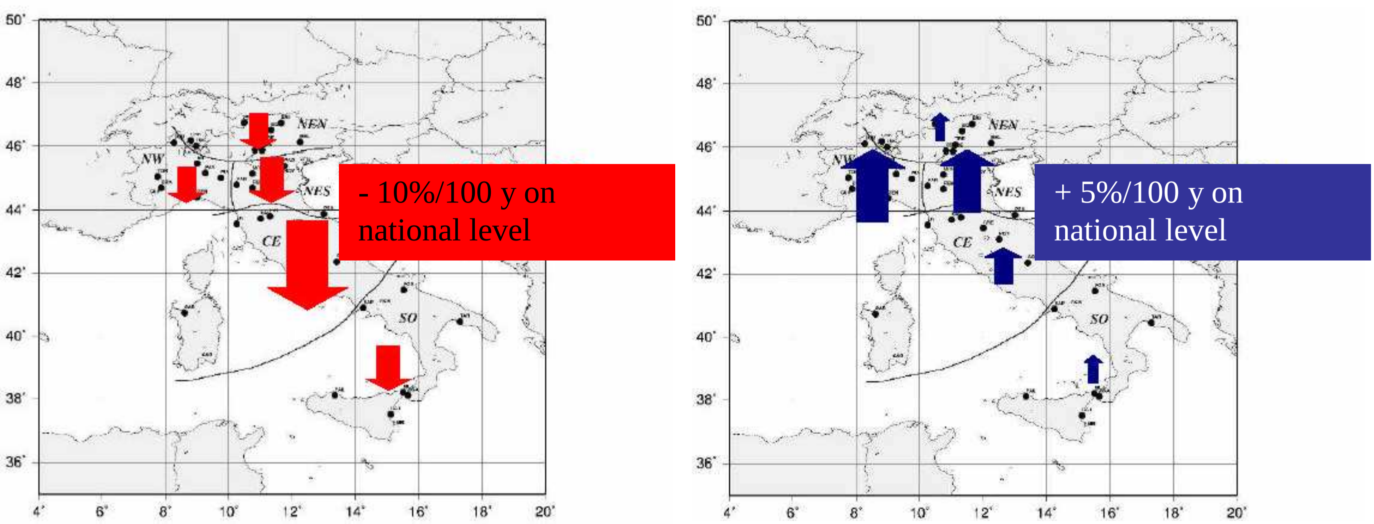


Figure 13: Number of rainfall days (1866-1996 period) (red) and number of extreme events (blue)(1866-1996 period). Source: Brunetti et al., 2004.

NW =North west; NEN = North-Est.-North; NES = North-Est. South; CE =Centre; SE = South-Est; SO= South-west. Source: Brunetti et al., 2006.

1.1.2. Disturbances and extreme events

1.1.2.1. Hot Waves

Last decades in Italy extreme events of temperature such as hot wave increased in frequency and duration (Table 4). On the contrary, the number of frost waves decreased, in frequency and duration too. This condition has both potentially positive and negative impacts on forest ecological system because Chilling Unit (CU) will decrease (Table 11) but is not completely clear the impact on late frost risks.

Hot waves			Frost waves	
Period	number of days	% of days in the period	number of days	% of days in the period
1951-1960	66	16	18	12
1961-1970	38	9	35	22
1971-1980	18	4	89	57
1981-1990	98	24	8	5
1991-2000	187	46	6	4
TOT	407	100	156	100

Table 4: Hot and frost waves in 1951-2000 period in Italy. Source: Ibmet- CNR.

Agro-forest index	trend	Impact
Consecutive hot waves	↑	Forest fire Phytopatogenous attacks
Thermal summation (GDD	↑	Chilling unit losses Delay in entrance into dormancy Physiological stresses
Number of extreme events	↑	Interannual variability Risks of management Management cost

Table 5: Trends of some agroforest indices connected with hot waves and observed impacts

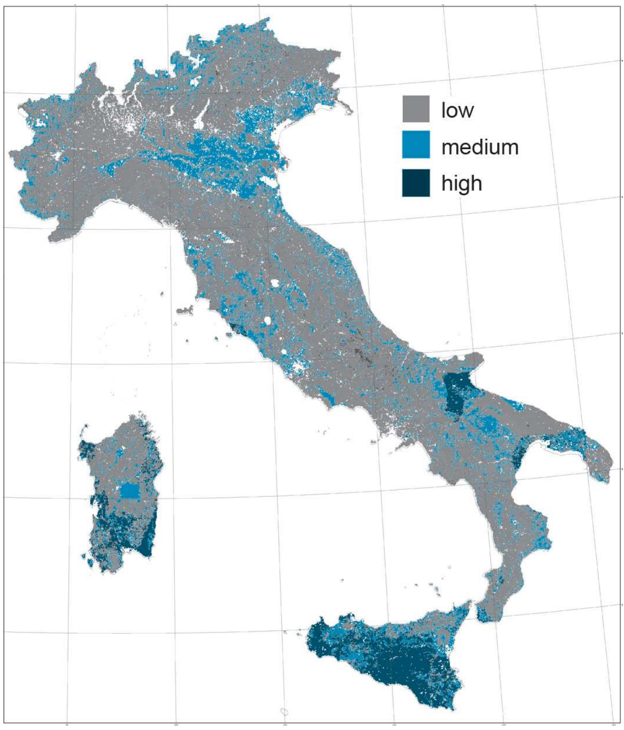
1.1.2.2. Extreme drought

Agro-forest index	trend	Impact
Consecutive dry days	↑	Forest fire Phytopatogenous attacks
Number of rainfall days in winter	↓	Forest fire in winter
Number of intense rainfall days in spring (> 40 mm)	↑	Erosion Floods Nutritive soil component loss
Number of extreme events	↑	Interannual variability Risks management Cost management

Table 6: Trends of some agroforest indices correlated with drought and observed impacts connected.

1.1.2.3. Desertification

Mediterranean area is affected by a strong desertification risk due to long drought periods, high soil erosivity, high forest fire frequency, excessive water resources exploitation, salinization of the statum.
Moreover, during the last decade due to the increase of climate extreme events such as drought and warming temperatures, Italian desertification risk could rise affecting forest ecosystem.
The most vulnerable areas are: Sicily, Sardinia, Pelage island, Pantelleria, Egadi island, Ustica, Calabria and Basilicata. ARPAB (Regional Agency for the Environmental Protection) developed a project to monitor desertification trends based on the calculation of desertification indices and indicators. The project is mainly based on climate data (e.g.: rainfalls regimes, extreme events). Until now, this study produced historical trends of temperatures and rainfalls, maps of desertification indicators (Figure 14), annual maps of aridity, and monthly and quarterly maps of drought. These basic dataset were used to evaluate regional desertification trends.



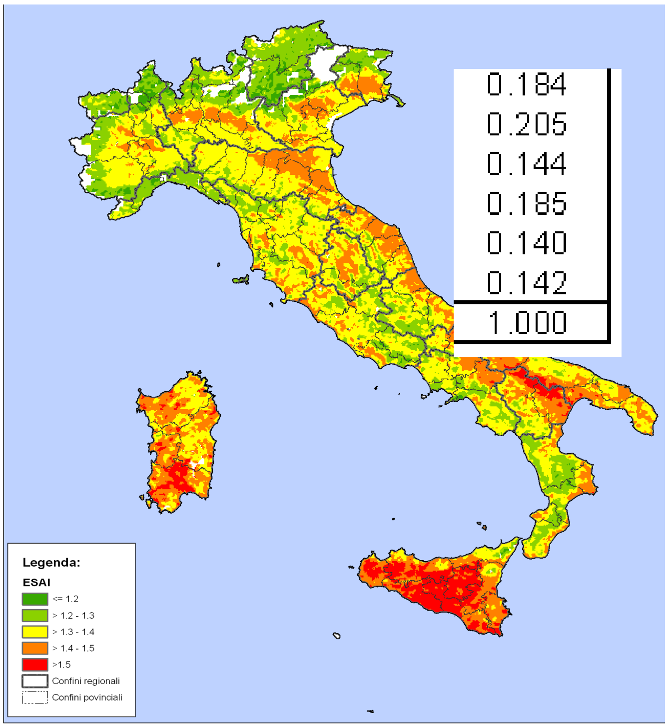


Figure 14: On the left, map of the Sensitivity to desertification Source: DISMED project

Figure 15: On the right, sensitivity to land degradation and desertification in Italy ESAI (Environmental Sensitive Areas Index)

1.1.2.4. Forest fire

Trends in forest fires are potentially related to global warming in terms of fire frequency, fire severity and extension of burned areas. Several studies described this relationships (Goldammer and Price, 1998; Stoks et al., 1998; Flannigan et al., 2000, 2005,2008; Mouillot et al., 2002; Wotton et al., 2003; Brown et al., 2004; Fried et al., 2004; Hennessy et al., 2005; MCCoy and Burn, 2005; Kasischke and Turetsky, 2006; Pearce et al., 2006; Moriondo et al. 2006; IPCC, 2007;Miller, 2007; Sirca et al., 2007; Balshi et al., 2008; Camia et al., 2008; Good et al., 2008; Krawchuk et al 2008; Arca et al., 2009).
In Europe the Mediterranean area is the most vulnerable to fires.

Figure 16). Table 7 shows that when the extreme warm events occurred, such as summer 2001, 2003 and 2007 the class of fire severity is higher.

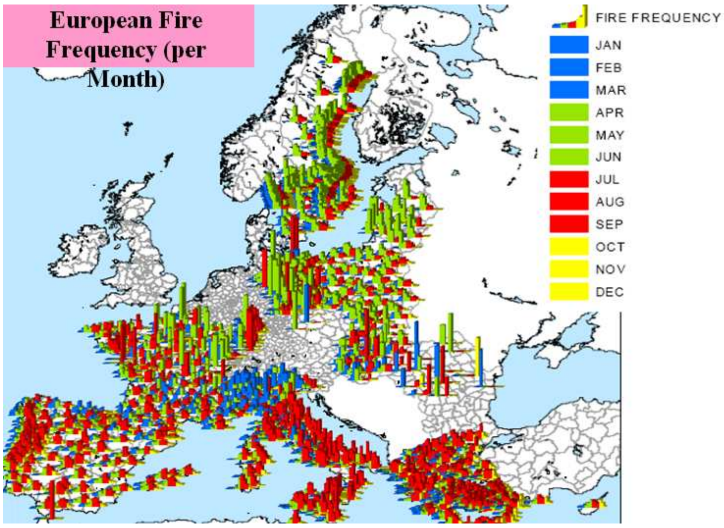


Figure 16: Fire frequency per month. Source: Camia, 2008

class	2000	2001	2002	2003	2004	2005	2006	2007
1	0	0	0	0	2	3	10	0
2	30	21	57	31	36	56	37	21
3	35	36	26	18	31	35	47	43
4	42	50	26	30	49	28	24	53
5	15	15	13	43	4	0	4	5
4-5	57	65	39	73	53	28	28	58
FN	2115	3446	4187	2998	3113	2995	2339	3325
BA (10^3 ha)	15,6	18,8	19,8	22,4	21,4	13,3	7,7	34,4

Very low
Low
Medium
High
Extreme

Table 7: Forest fire coded in class of severity occurred in June-September during 2000-2007 period in Sardinia, Italy. Source: Sirca et al., 2008

1.1.3. Impacts on vegetation

In Italy several networks for forest monitoring exist. The Italian monitoring networks of forest ecology is coordinated by the Forest service of Ministry of Agriculture and Forests (CONECOFOR project, ecology research network on long and short time scale). The CONOCOFOR network is the national side of the ICP-forests. The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP forests) started in the ‘80 with the aim of monitoring the forest condition in Europe by two monitoring intensity levels. The ICP Level I grid is based on about 6000 plots located on a nominal systematic transnational grid with a size of 16 x 16 km throughout Europe. The intensive monitoring level is based on about 800 ICP Level II plots which were selected by the responsible Countries to represent different forest ecosystems in Europe.

Even if the CONECOFOR network is not specifically designed to assess impacts of climate changes, the multitemporal trends acquired showed in mountain forest ecosystems a slow a dynamic condition, such as an increase in forest species more adapted to drought, dry and degraded conditions.

Beech, chestnut, hornbeam and pedunculate oak show to be more vulnerable to water stress risks and warming temperature especially during the winter (National Forest Service report, 2009). Actually during the 2007, damage rate was 43% while in 2008 decreased to 28%. Anyway, from the last Italian forest monitoring of 2009 (CONECOFOR project) it appears that the Italian forests have recovered the severe drought crisis of 2007 and of 2003.

Concerning beech woods, a study located in Alps, tried to evaluate the relationships between climate variation and bioclimatic gradients on the spatial patterns of Fagus sylvatica radial growth. It was founded a direct response to winter temperature at all elevations; moreover such relationships are different at the upper elevations depending of the biogeographical area (Alps vs. Apennines populations) (Di Filippo, 2007).

The Italian “gariga”, such as the formation with Cistus, represents the first step of vegetation recovery after disturbances (fire, grazing, and deforestation). Its distribution could be favoured from new climatic variation. As a consequence it may benefit even against more evolved vevegation types such as maquis and holm oak (De Dato et al., 2008). A field experiment (De Dato et al., 2008) demonstrated such trends in the Mediterranean shrubland community as a consequence of warmer and dryer conditions (Table 8).

$g\ m^{-2}\ yr^{-1}$	Control	Warming	Drought
Cistus monspeliensis	13.7 (± 5.3)	21.5 (± 5.2)	22.7 (± 16.5)
C. creticus	4.7 (± 3.1)	0.7 (± 0.3)	2.9 (± 1.1)
Pistacia lentiscus	0.6 (± 0.5)	0.9 (± 0.4)	5.0 (--)
Helichrysum italicum	36.3 (± 18.1)	28.8 (± 17.1)	21.3 (± 13.0)
Dorycnium pentaphyllum	6.0 (± 3.2)	11.6 (± 6.1)	8.0 (± 2.0)
Total[a]	61.2 (± 23.2)	63.5 (± 7.4)	56.6 (± 17.3)

Table 8: Annual biomass accumulation (g m-2-2 yr-1-1) in drought and warm conditions calculated during the period 2002-2004. [a] = above ground biomass growth of the total biomass (De Dato et al., 2008).

1.1.4. Impacts on parasites

In the recent years Mediterranean forests were interested by an increasing trend in pest disease. This is potentially in response to different meteo conditions (or trends in claimate conditions) that essentially led to an increase in average temperatures and an altered pattern of annual and interannual rainfalls. Increased water stress, due to drier conditions, is limiting plants tolerance to biotic factors and at the same time may influence the bio-ecology of many parasites.
Concerning climate change impact on insects, it was estimated that the areal distribution is moving to north at a rate of 6,1 km/decade; and the phenology is advancing by 2.1 day/decade; 80% of the studied species showed a phenological shift (Masutti, 2005). Moreover, while some phytopathogenic fungi were restricted in their spread by a reduction in rainfall, many others have found optimal conditions for gradually extending their range and causing epidemics. Poikilotherms insects were influenced by climatic conditions both directly, because of the survival of a greater number of individuals, and indirectly, because of the changes induced in host phenology. This is particularly true for opportunist fungi and insects which are responsible for the decline in Mediterranean forests (Franceschini, 2008).
For example, Armillaria, Biscogniauxia, Botryosphaeria, Chalara, Collybia, Cyclaneusma, Gremmeniella, Heterobasidion, Mycosphaerella and Seiridium are favourite because of plants stress condition (Franceschini et al., 2004; Slippers and Wingfield, 2007; La Porta et al., 2008) and may be directly related to increasing dry and warm spells frequency.
Rising temperature selected more thermophilus units fitted to new conditions. An indirect effect of climate change is the pullulate of *Rhizina undulate*. Which is also favourite by forest fires.
Ceratocystis platani (Moricca e Panconesi, 2000), some species of Botryosphaeriaceae and Xylariaceae may increase their own areal distribution because of these climate changes. Rising temperatures may have a positive impact on Botryosphaeria. (*B. parva* e *B. obtuse*), (Franceschini et al., 1999; Linaldeddu et al., 2006; 2007; B. dothidea, B. obtusa, Moricca et al., 2008).
In this scenario *Biscogniauxia mediterranea* is going to extend its areal to north (Desprez-Loustau et al., 2006; Jurc e Ogris, 2006), while, *Biscogniauxia nummularia* is going to extend it to the south (Granata e Sidoti, 2004).
Those leaf patogeni whose spreading is connected with rainfall may be limited (for example Marssonina spp. and Gloeosporium spp.).
Phytophthorae (P. cambivora, P. cinnamomi, etc.) benefit by warmer-wet winters (Brown e Brasier, 2007).
Pollulations of *Amphicytostroma quercinum*, *Apiognomonia quercina*, *Biscogniauxia mediterranea*, *Colpoma quercinum*, *Diplodia corticola*, *Phomopsis quercina* were observed (Moricca e Ragazzi, 2008) in relationship with the increasing stress condition related to dry spells frequency and intensity.
Climate changes have also favoured exotic pathogens and pests disease (Franceschini, 2008). Exotic pathogens introduced such as *Anoplophora chinensis* Forster, *Paysandisia archon* (Burmeister), *Rhynchophorus ferrugineus* (Olivier), *Corytuca cliliata* (Say), *Cameraria ohridella* Descka & Dimic, *Leptoglossus occidentalis*, *Dryocosmus kuriphilus* Yasumatsu., *Megaplatypus mutatus* (Chapuis,), *Xylosandrus crassiusculus* (Motschulsky), *Xylosandrus germanus* (Blandford), *Callidiellum rufipenne* (Motschulsky) and inter specific ibrida such as it happens in genera Heterobasidion, Melampsora, Ophiostoma e Phytophthora (Brasier, 2000) may lead to serious consequences in Italy.

1.1.5. Productivity

A debate is in progress concerning the possible effects of climate changes on the primary production of both natural and artificial ecosystems. Increasing CO_2 can affect tree growth through increased photosynthetic rates and through improved water-use efficiency (Steffen and Canadell 2005).
According to both field- and satellite-based data found in the literature, the climatic changes in the last 55 years seem to have a generally positive impact on forest productivity on sites where water is not strongly limiting.The many interacting factors preclude the identification of one factor causing these changes as each site has specific, and possibly unique, combinations of factors (Figure 17); however, the changes in productivity correspond to reported changes in temperature, precipitation, and radiation (Boisvenue C, 2006).

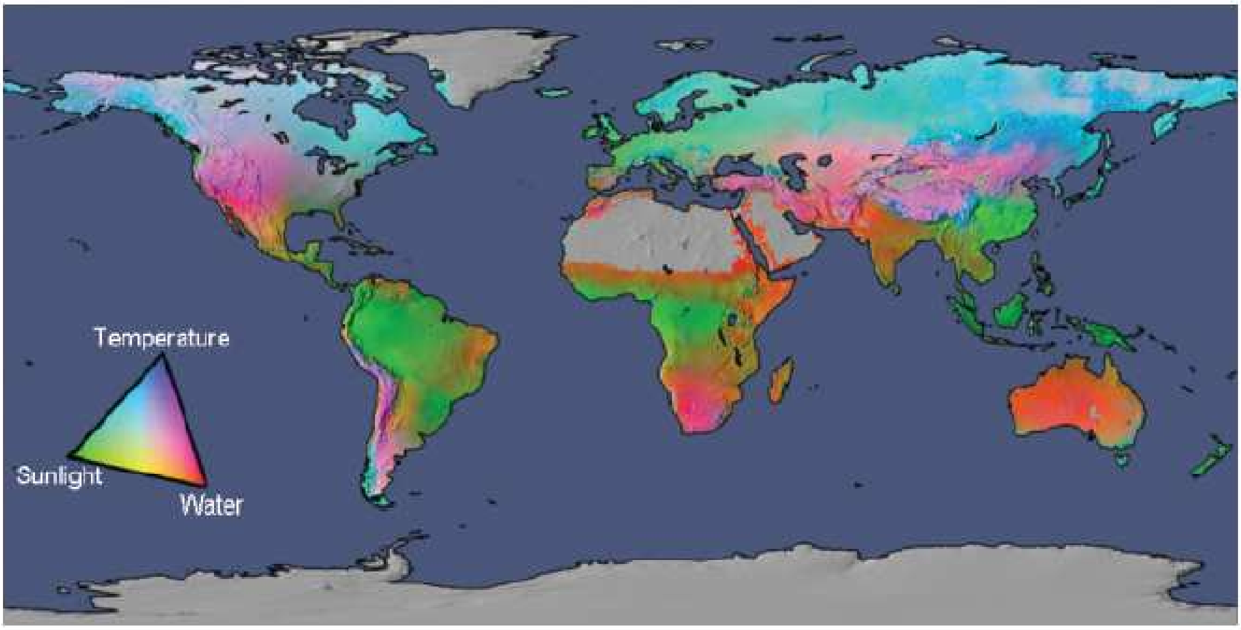


Figure 17: Potential limits to vegetation net primary production based on fundamental physiological limits by vapor pressure deficit , water balance, and temperature (from Churkina & Running, 1998; Nemani et al., 2003; Running et al., 2004).

However, the magnitude and extent to which effects are sustained under different conditions in different tree species are not clear. Forest growth rates may well be increased in some cases by rising levels of atmospheric CO_2, but rising temperatures, higher evaporation rates and lower rainfall may limit growth rates in other cases. Complex relationships exist between the different ecophysiological processes. For example, benefits of increased water-use efficiency may not take place in some cases because of poor soil nutrition (Seppälä R, 2009).
A studied carry out in Tuscany, Italy, was built on the hypothesis that trends of increasing air temperature observed in several Italian regions should positively affect productivity of mountain forest ecosystems. Temperature rise in the Mugello valley (central Italy) in the period 1986-2001 was first confirmed by the analysis of data from a local station. The effects of this rise on the productivity of deciduous forest ecosystems (dominated by beech, *Fagus sylvatica* L.) were estimates. These results are a first indication that the rise in temperature that has occurred in Italy in the last decades has positively affected the productivity of mountain forest ecosystems (Rodolfi, 2007).

A ten-year data-set descriptive of Italian forest gross primary production (GPP) has been recently constructed by the application of Modified C-Fix, a parametric model driven by remote sensing and ancillary data. That data-set is currently being used to develop multivariate regression models which link the inter-year GPP variations of five forest types (white fir, beech, chestnut, deciduous and evergreen oaks) to seasonal values of temperature and precipitation. The five models obtained, which explain from 52% to 88% of the inter-year GPP variability, are then applied to predict the effects of expected environmental changes (+2 ℃ and increased CO_2 concentration). The results show a variable response of forest GPP to the simulated climate change, depending on the main ecosystem features. In contrast, the effects of increasing CO_2 concentration are always positive and similar to those given by a combination of the two environmental factors (Maselli et al., 2009).

1.1.6. Impacts cost

Alpine forests are important multi-output production systems, alongside their productive function, we can also recognise their protective functions, their landscape and recreational function and their ecological function. A work in progress (Goio and Gios, in press) is trying to evaluate the consequences of climate changes on these functions within the logic of the total economic value method, by means of which it is possible to estimate an economic profile of the sum of the values of utility flow which derives from alpine forests. The authors are proposing a simulation model for the forests of the Autonomous Province of Trento (where the 56% of the overall surface is covered by forests) in order to evaluate which effects an increase of temperature of 1 or 2℃ might have on the landscape/recreational function and the hydro-geological function, but also on the tourist sector. In fact, according to different studies, the possible impacts of climate change on forests are ecological but also social and economic. Consequently climate change prospect has a variety of implications for all levels of government which will have to consider possible climate change implications when planning their actions, project and decisions.

1.1.7. Socio-economic

WITCH (World Induced Technical Change Hybrid model) is one of the main modelling tools developed within the FEEM Research Programme "Sustainable Development" and designed to assist in the study of the socio-economic dimension of climate change”.

The model has been developed with the aim of studying mitigation and adaptation policies for climate change control. It is currently applied to generate emission scenarios for various international macro-regions, and to evaluate the economic implications of national and international climate agreements, such as Post-Kyoto treaties. The model results have been used in various projects funded by international organizations, as well as governmental agencies and private institutions.

WITCH is a Regional Integrated Assessment Hard-Link Hybrid Model. Its top-down component consists of an intertemporal optimal growth model in which the energy input of the aggregate production function has been expanded to give a bottom-up like description of the energy sector. World countries are grouped in twelve regions that strategically interact following a game theoretic structure. The climate system is described by a climate module and a damage function provides the feedback on the economy of carbon dioxide emissions into the atmosphere. The dynamic and strategic features of the model, the energy sector specification and the technical change options make WITCH an especially suited tool to explicitly analyze the climate change issue, marked by medium term investment choices and long term economic dynamics and environmental responses.

1.2 Expected impacts

Mediterranean ecosystems in Europe are very likely to be strongly influenced by climate change and other global changes (Shaver et al., 2000; Blennow and Sallnäs, 2002; Askeev et al., 2005; Kellomäki and Leinonen, 2005; Maracchi et al., 2005) (Figure 18).

Sectors and Systems	Impact	Mediterr.
Water resources	Floods	↓
	Water availability	↓↓↓
	Water stress	↓↓↓
Coastal and marine systems	Beach, dune: low-lying coast erosional 'coastal squeeze'	↓↓
	SLR- and surge-driven flooding	↓↓
	River sediment supply to estuaries and deltas	↓↓↓
	Saltwater intrusion to aquifers	↓↓
	Northward migration of marine biota	↑
	Rising SSTs, eutrophication and stress on biosystems	↓↓
	Development of ICZM	↑↑
	Deepening and larger inshore waters	↑
Mountains, cryosphere	Glacier retreat	↓↓↓
	Duration of snow cover	↓↓↓
	Permafrost retreat	na
	Tree line upward shift	↑
	Nival species losses	↓↓↓
Forest, shrublands and grasslands	Forest NPP	↓
	Northward/inland shift of tree species	↑ to ↓
	Stability of forest ecosystems	↓↓↓
	Shrublands NPP	↓↓↓
	Natural disturbances (e.g., fire, pests, wind-storm)	↓↓↓
	Grasslands NPP	↓↓↓
Wetlands and aquatic ecosystems	Drying/transformation of wetlands	↓↓↓
	Species diversity	↓↓
	Eutrophication	↓↓↓
	Disturbance of drained peatlands	na
Biodiversity	Plants	↓↓↓
	Amphibians	↓↓↓(SW) ↑↑(SE)
	Reptiles	↓↓↓(SW) ↑↑↑(SE)
	Marine mammals	↓↓↓
	Low-lying coastal birds	↓↓↓
	Freshwater biodiversity	↓↓↓

Figure 18: Summary of the main expected impacts of climate change in Mediterranean areas during the 21st century

Forest area is expected to expand in the north (Kljuev, 2001; MNRRF, 2003; Shiyatov et al., 2005), but contract in the south (Metzger et al., 2004).

In northern Europe, climate change will alter phenology (Badeck et al., 2004) and substantially increase net primary productivity (NPP) and biomass of forests (Jarvis and Linder, 2000; Rustad et al., 2001; Strömgren and Linder, 2002; Zheng et al., 2002; Freeman et al., 2005; Kelomäki et al., 2005; Boisvenue and Running, 2006). In the northern and maritime temperate zones of Europe, and at higher elevations in the Alps, NPP (Net Primary Production) is likely to increase throughout the century. However, by the end of the century (2071 to 2100) in continental central and southern Europe, NPP of conifers is likely to decrease due to water limitations (Lasch et al., 2002; Lexer et

al., 2002;Martínez-Vilalta and Piñol, 2002; Freeman et al., 2005; Körner et al., 2005) and higher temperatures (Pretzch and Dursky, 2002).
A substantial increase in wind damage is not predicted (Barthod, 2003; Nilsson et al., 2004; Schumacher and Bugmann, 2006).
Snow cover will decrease, and soil frost-free periods and winter rainfall increase, leading to increased soil water logging and winter floods. Warming will prevent that chilling requirements are being met, reduce cold-hardiness during autumn and spring, and increase needle loss (Redfern and Hendry, 2002).

1.2.1. Expected climatic evolution

Climate change impact scenarios are mainly based on General Circulation Model simulations.
A recent work carried out within the ACACIA project and subsequently developed further for the IPCC (Hulme and Carter, 2000) provided a complete set of future climate scenarios for Europe (0.90℃ for 1901 to 2005; updated from Jones and Mo berg,2003).
In Europe climate change is expected to magnify regional differences in Europe's natural resources and assets. Negative impacts will include increased risk of inland flash floods and more frequent coastal flooding and increased erosion (due to storminess and sea level rise).
Mountainous areas will face glacier retreat, reduced snow cover, thus causing a decrease in winter tourism, and extensive species losses (in some areas up to 60% under high emissions scenarios by 2080). In southern Europe, climate change is projected to worsen conditions (high temperatures and drought): a region already vulnerable to climate variability, will reduced the water availability.
Over the last few years the EU has financed several large research projects on regional climate modelling and impact assessment (Table 9). These maps are very useful for policy-making and awareness-raising purposes.
On national level various very recent scenarios were proposed (Figure 20, Figure 20: Scenarios of mean temperature (on the left) and rainfall variations (on the right). The considered period is 1961-1990 (WMO period of reference) vs. 2020. Perini, 2008).

Acronym	object
MICE	Modelling the Impact of Climate Extremes
PRUDENCE	Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects
STARDEX	Statistical and Regional dynamical Downscaling of Extremes for European regions
QUANTIFY	Quantifying the Climate Impact of Global and European Transport Systems
ENSEMBLES- ENSEMBLE	based Predictions of Climate Changes and their Impacts
CLAVIER	Climate Change and Variability: Impact in Central and Eastern Europe

Table 9: Some European research projects focused on climate change impacts

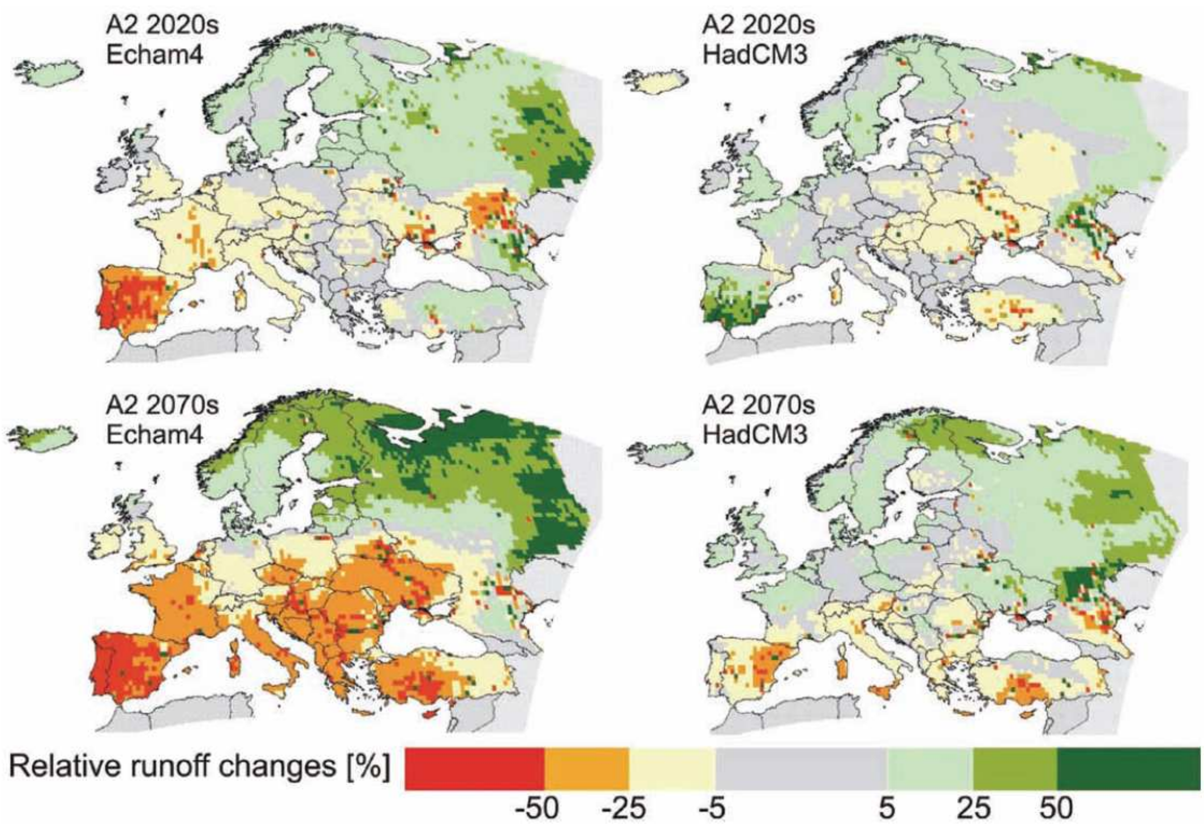
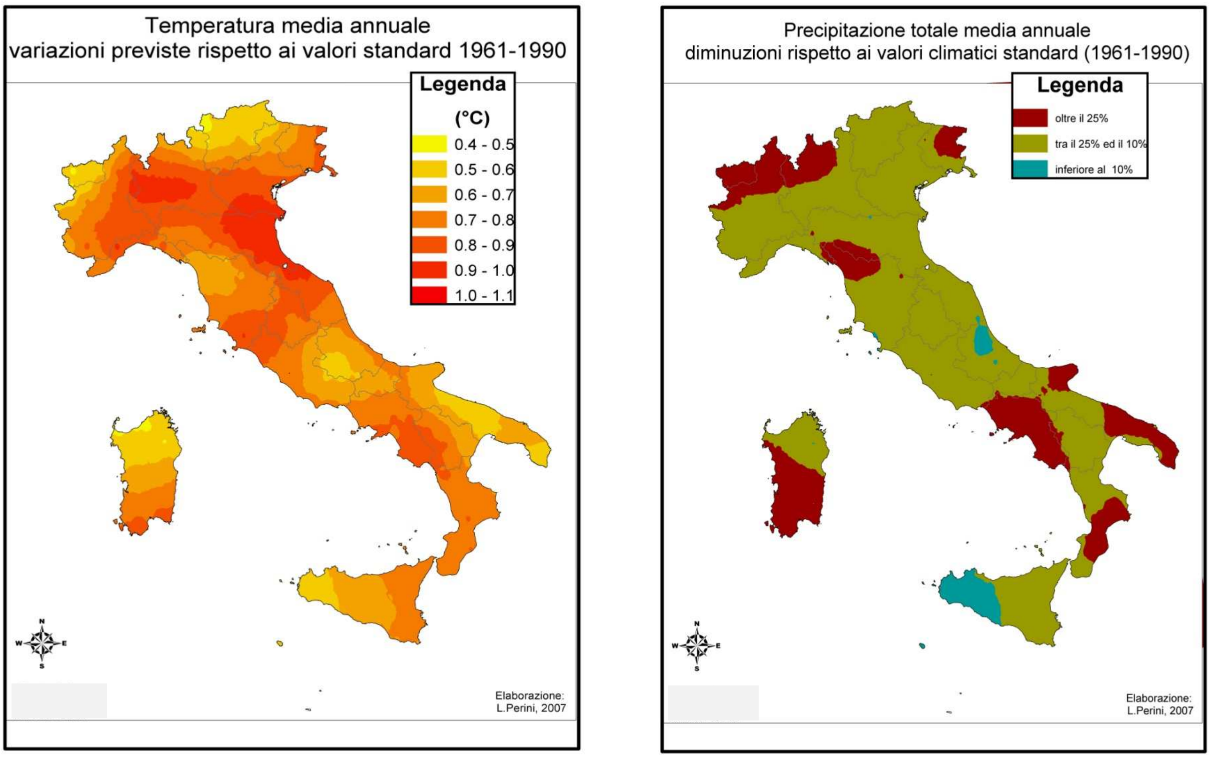


Figure 19: Change in annual river runoff between the 1961-1990 baseline period and two future time slices (2020s and 2070s) for the A2 scenarios (Alcamo et al., 2007).

Figure 20: Scenarios of mean temperature (on the left) and rainfall variations (on the right). The considered period is 1961-1990 (WMO period of reference) vs. 2020. Perini, 2008

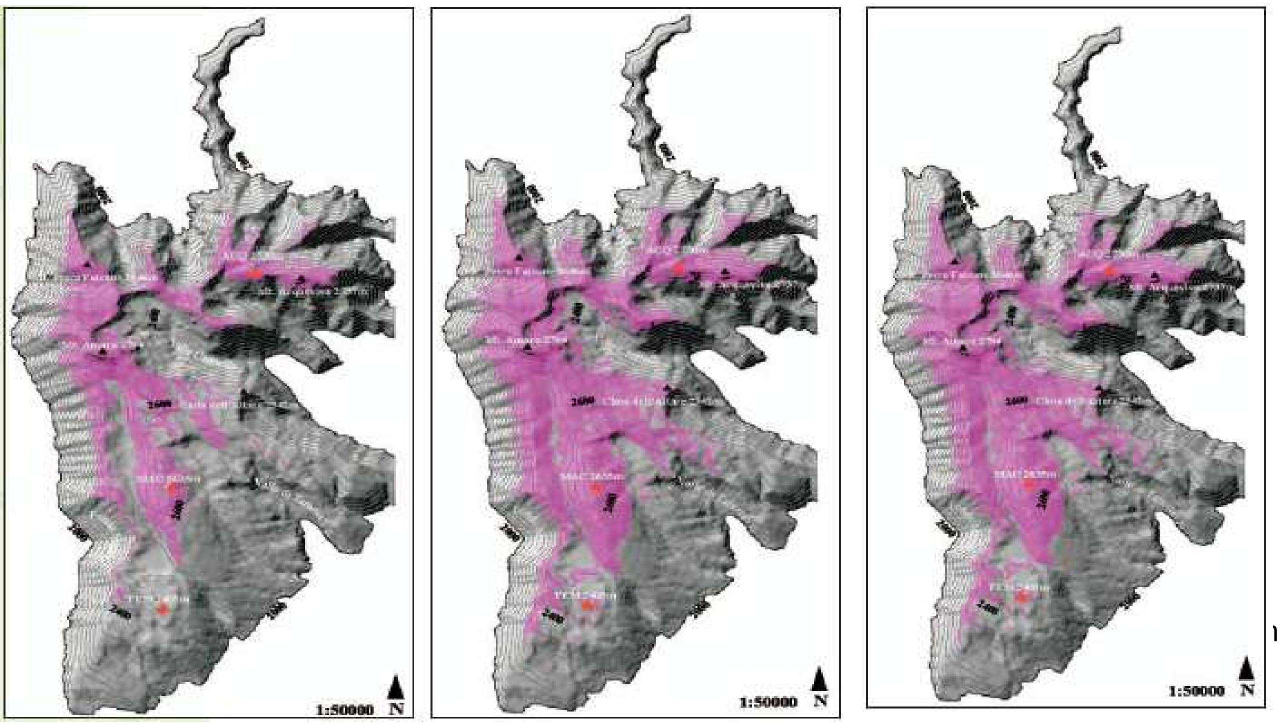


1.2. Expected impacts on vegetation and ecosystem

Important eco-physiological impacts are expected on national level connected with increase temperature (Table 10, Table 11, Figure 22).

Italian regions	1961-1990 n. days	Variation n. days	Variation %
Abruzzo	121	15	13%
Basilicata	156	18	11%
Calabria	190	13	7%
Campania	166	17	10%
Emilia Romagna	142	16	11%
Friuli Venezia Giulia	119	14	11%
Lazio	161	15	9%
Liguria	159	15	9%
Lombardia	117	14	12%
Marche	147	24	16%
Molise	149	17	11%
Piemonte	95	8	9%
Puglia	189	13	7%
Sardegna	193	11	6%
Sicilia	203	10	5%
Toscana	153	16	11%
Trentino Alto Adige	17	16	95%
Umbria	137	26	19%
Valle d'Aosta	0	0	-
Veneto	127	25	20%
Italia	**149**	**14**	**10%**

A research conducted in central Apennine area (STANISCI A) showed the high vulnerability of the flora to the warming temperature. In this region, the mean temperature rising with an annual rate of 0.08°C, that means 1°C in 10 years. The research de monstrates that with this trend, endemic species and rare ecosystems equilibrium of high elevation will be lost (Figure 21).



Because of climate conditions the distribution of a number of typical tree species is likely to decrease in the Mediterranean (Schröter et al., 2005) areas. In some areas, native conifers are likely to be replaced by deciduous trees (Maracchi et al., 2005; Koca et al., 2006).
Tree vulnerability will increase as populations/plantations are managed to grow outside their natural range (Ray et al., 2002; Redfern and Hendry, 2002; Fernando and Cortina, 2004).
Climate change may induce a reallocation of carbon to foliage (Magnani et al., 2004; Lapenis et al., 2005) and lead to carbon losses (White et al., 2000; Kostiainen et al., 2006; Schaphoff et al., 2006). Climate change may alter the chemical composition and density of wood while impacts on wood anatomy remain uncertain (Roderick and Berry, 2001;Wilhelmsson et al., 2002; Kostiainen et al., 2006).
Negative impacts of drought on deciduous forests are also likely (Broadmeadow et al., 2005), such as an increase of evapotranspiration (Figure 22). Water stress in the south may be partially compensated by increased water-use efficiency (Magnani et al., 2004), elevated CO_2 (Wittig et al., 2005) and increased leaf area index (Kull et al., 2005), although this is currently under debate (Medlyn et al., 2001; Ciais et al., 2004).

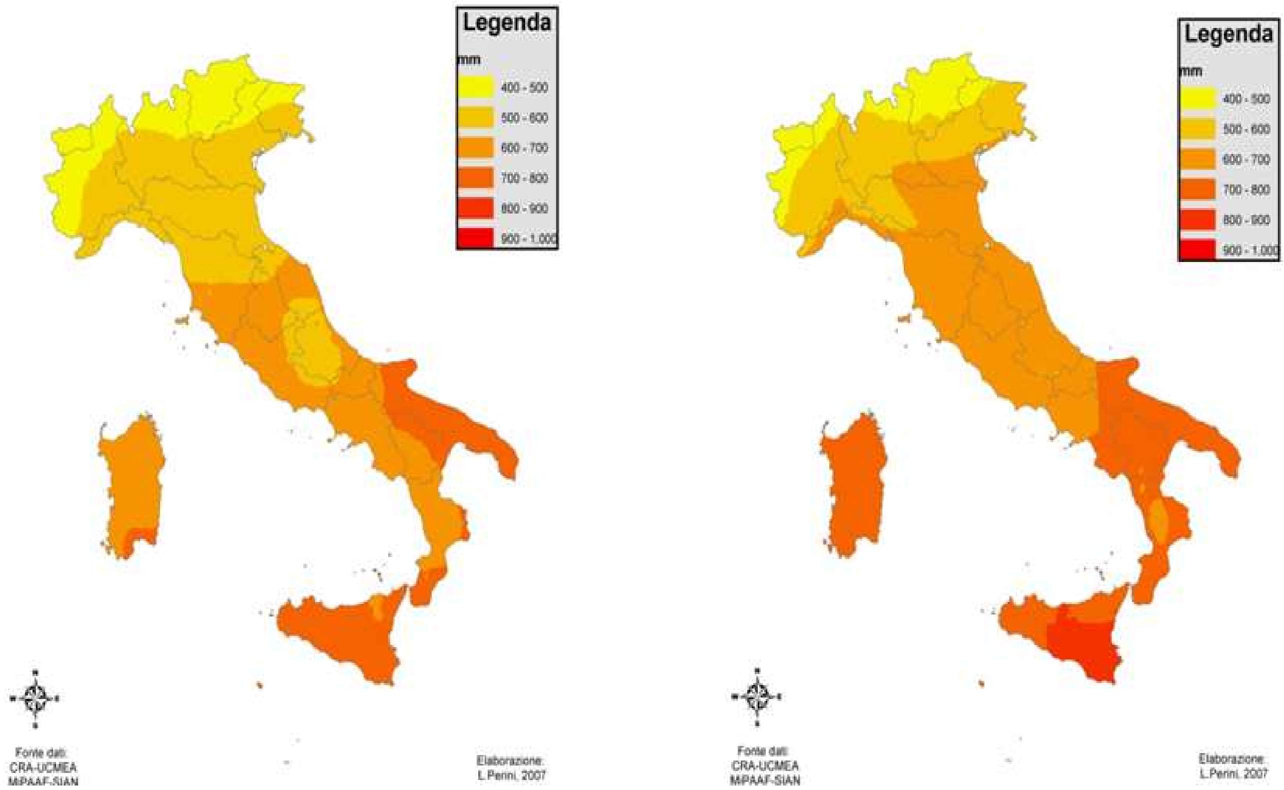


Figure 22: Cumulative evapotranspiration during the period May- September in 1961-1990 (WMO period of reference) on the left and in 2020 scenarios. Perini, 2008

Concerning pests, the range of important forest insect may expand northward (Battisti, 2004).
Abiotic hazards for forest are likely to increase, although expected impacts are regionally specific and will be substantially dependent on the forest management system used (Kellomäki and Leinonen, 2005).
Frost damage is expected to be reduced in winter, more severe in autumn due to later hardening (Linkosalo et al., 2000; Barklund, 2002; Redfern and Hendry, 2002) and spring due to phenological shift of bud-break , although this may vary among regions and species (Jönsson et al., 2004).
In fact frost damage risks increase after possible dehardening and growth onset during mild spells in winter and early spring (Hänninen, 2006).

Concerning Chilling Unit (CU) a decrease is expected (Table 11).

Regione	1961-1990	variazione	
		C.U.	%
Abruzzo	2352	-1402	-60%
Basilicata	2363	-1498	-63%
Calabria	1444	-917	-64%
Campania	2046	-1306	-64%
Emilia Romagna	2439	-1505	-62%
Friuli Venezia Giulia	2464	-1477	-60%
Lazio	1966	-1211	-62%
Liguria	2144	-1372	-64%
Lombardia	2479	-1518	-61%
Marche	2458	-1532	-62%
Molise	2388	-1500	-63%
Piemonte	2553	-1538	-60%
Puglia	1670	-1038	-62%
Sardegna	1269	-785	-62%
Sicilia	1147	-728	-63%
Toscana	2250	-1394	-62%
Trentino Alto Adige	2520	-1485	-59%
Umbria	2589	-1610	-62%
Valle d'Aosta	2535	-1376	-54%
Veneto	2425	-1479	-61%
Italia	**2017**	**-1242**	**-62%**

ear)(T>=15℃); in the first column CU calculated in WMO period of reference, in the second and third the variation for the next future (2020), Perini, 2008

Concerning, fire danger, length of the fire season, fire frequency and severity are very likely to increase in the Mediterranean area (Santos et al., 2002; Pausas, 2004; Moreno, 2005; Pereira et al., 2005; Moriondo et al., 2006), and lead to increased dominance of shrubs over trees (Mouillot et al., 2002). Albeit less, fire danger is likely to also increase in central, eastern and northern Europe (Goldammer et al., 2005; Kellomäki et al., 2005; Moriondo et al., 2006). This, however, does not translate directly into increased fire occurrence or changes in vegetation (Thonicke and Cramer, 2006).

1.2.1 Vegetation distribution area

The response of forest ecosystems to climate change can be expressed in terms of boundaries shift, changes in productivity and in risk of damages (e.g. fire damage). A concurrent increase of deciduous tree species is expected (Kellomaki and Kolstr¨om, 1993). Most climate change scenarios suggest a possible overall enlargement of the climatic zone suitable for Boreal forests by 150–550 km over the next century (Kirschbaum et al., 1996). Furthermore, the increase of winter temperature seems to allow the survival of exotic species (Cannell, 1985). In southern Europe, most part of forests consists of sclerophyllous and some deciduous species that are adapted to soil water deficit during the summer period. Climate scenarios indicate reduced water availability in the summer months and associated increases in temperature. These conditions may determine the relative importance of sclerophyllous and deciduous species changes, with, for example, expansion of some thermophilous tree species when water availability is sufficient (e.g. Gavil´an and Fern´andez-Gonz´alez, 1997).

In Italy, predicted climate change should expand the Mediterranean region to the detriment of the Temperate ones. This will accelerate the progressive xerophitization of the areas caused by the human activities as demonstrated by paleobotanical studies indicating the increase of pollen of sclerophyllous tree species, mainly *Quercus ilex,* starting from 1.500 B.C. This change can be ascribed to the prolonged exploitation of forests caused increasing soil erosion, especially in the southern exposures of the Apennine mountains, favouring *Quercus ilex*, which is more adapted to xeric environments than deciduous species.
Concerning sclerophyllous, the application of the HADCM3 climatic scenario was used to studied the climate change potential effects in the central Italy (Lazio e Abruzzi regions). For 2080 the model predicted a general increase of the mean potential altitude of this vegetation type.

Four different trends can be identified:

- species that could be advantaged by the predicted climate change (Table 12, group 1)
- species that could suffer a strong reduction of area and abundance (Group 2)
- species showing contrasting behaviour in relation to area and abundance (Group 3, 4).

The two Mediterranean species (*Quercus ilex* and *Quercus suber*) are likely to be favoured by the predicted increased drought, while the species belonging to the two other chorological types show quite differentiated behaviour: *Quercus pubescens*, *Quercus cerris* and *Ulmus minor* should be also favoured by the increased drought. *Quercus cerris* seems to show a great capacity to adapt to the new climatic regime (both the spatial distribution and the abundance). The same result is expected for *Quercus ilex*, notwithstanding that the analysed trend shows a reduction of abundance. On the opposite, typically mesophilous species such as *Fagus sylvatica*, *Acer obtusatum*, *Acer pseudoplatanus*, *Ostrya carpinifolia* will be the most threatened species. In particular, *Fagus sylvatica* is proved to be one of the most effected species by climate change in term of decreasing distribution and abundance.

Group	Species	Chorology type	Area (km²)			IV			Altitude (m)			T	M
			Current	Future	%	Current	Future	%	Current	Future	%		
Group 1: +IV +Area	*Quercus cerris*	SM	24417	24832	1.7	46	67.3	46.3	408.3	576.1	41.1	8	4
	Quercus ilex	M	9423	16453	74.6	37	37.9	2.4	212.4	342	61	9	3
	Quercus pubescens	SM	24732	27947	13	60.7	81.7	34.6	414.3	541.5	30.7	8	3
	Quercus suber	M	3006	5282	75.7	40.7	48.1	18.2	75.2	79.3	5.5	8	3
	Ulmus minor	E	2682	2926	9.1	24.9	33.4	34.1	163.2	216.6	32.7	7	X
Group 2: -IV -Area	*Acer obtusatum*	SM	3393	1863	-45.1	13.4	11.6	-13.4	698.6	1159	65.9	5	6
	Acer pseudoplatanus	E	2115	584	-72.4	12.7	10.6	-16.5	972.7	1297.6	33.4	5	6
	Castanea sativa	SM	5175	5051	-2.4	60.9	38.4	-36.9	578.2	932.6	61.3	8	X
	Fagus sylvatica	E	8946	6352	-29	83.5	81	-3	1144.2	1330.7	16.3	5	5
	Ostrya caprinifolia	SM	7497	4183	-44.2	24.8	23	-7.3	736.5	1082.7	47	8	4
	Quercus robur	E	5634	3747	-33.5	28.9	21.7	-24.9	238.2	248.2	4.2	6	6
Group 3: -IV +Area	*Acer campestre*	SM	6255	7400	18.3	25.3	18.5	-26.9	330.5	358.3	8.4	7	5
	Carpinus betulus	E	3645	6616	81.5	14.7	8.1	-44.9	442.7	862.8	94.9	6	X
Group 4: +IV -Area	*Carpinus orientalis*	SM	1242	532	-57.2	18.2	30.9	69.8	616.8	1244.1	101.7	7	3
	Fraxinus ornus	SM	7101	5681	-20	13.4	13.7	2.2	468.6	380	-18.9	8	3
	Quercus frainetto	SM	3645	2278	-37.5	12.8	21.7	69.5	63.7	79.8	25.3	6	6

Table 12: Current, future and percentage of change of the potential area (km2) and average IV and altitude (m); the percentage changes are due to the HadCM3 model outputs; Ellenberg's scores for temperature (T) and moisture (M). In the last columns, X means the species has a wide spectrum for that parameter. Abbreviations for chorology: M, Mediterranean; SM, Sub-Mediterranean; E, Eurosiberian. Percentage changes due to the HadCM3 model output. Source: Attorre, 2008.

1.3. Impacts monitoring

1.3.1 Impact monitoring system/network

Table 13: Some of Italian network

Name of the project	Description	Objectives
CONECOFOR http://www3.corpoforestale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/475	Italian monitoring of forest ecosystem	Forest ecology monitoring
DESERTNET I http://www.desertnet.org	The Project DESERTNET (2002-2004) was integrated and coordinated with the previous project "International Network of Multifunctional Environmental Laboratories" in the frame of the Interegg IIC-MED-OCC Program, both projects aiming to the study, monitoring and sustainable management of desertification risk areas in the Mediterranean basin. The DesertNet project has brought to the systemization and organization of the scientific information and experiences provided and elaborated for the areas at desertification risk identified by the Italian Regional and National Programs, so as to contribute to desertification processes control by means of building an homogeneous system for the exchange of information and data. DesertNet partnership included scientific institutions of known international value and 10 Regions directly involved with the study of some environmental priorities recognized within the Italian Regional and National Action Programs (Delibera CIPE 229 del 21/12/1999).	The general objective of the project was: to implement a platform as a common system of services to support National and European policies to combat desertification, according to the United Nations Convention to Combat Desertification (UNCCD), and to promote sustainable management of natural resources (especially soil and water) by means of: • a system of pilot areas/actions; • a common geographic information system; • a scientific supporting network to exchange and share of information and to spread them toward end users. The specific objectives can be summarized as follows: • state of the art of the scientific knowledge on causes and effects of desertification processes in Mediterranean European Regions and on the measures to reduce it; a network of subjects and institutions involved with international, national and local actions aimed at exchanging, sharing, sensitizing people and disseminating information concerning both desertification and the project results; • a system of thematic pilot actions to experience and test on the field technologies and methods for sustainable management and for prevention and monitoring of desertification processes; • definition of common indicators and models to monitor desertification at different scales and testing of homogeneous indicator systems in chosen pilot areas/actions.
DESERTNET II http://www.desertnet.org	Implementation of a Platform of Services to combat desertification and drought through a system of pilot actions in the Mediterranean Regions	General Objective: To carry on the DesertNet 1 experience, at the same time developing, improving and integrating it with innovating aspects.

Name of the project	Description	Objectives
	Duration of the Project: 1st October 2005 – 30th June 2008	Specific Objectives: Enforcing and widening the partnership, by means of: - Implementation, animation, integration of innovating functions in the Platform of Services (PoS) created during the DesertNet Project; - Structuring a system of pilot actions linked to local planning processes; - Intersectorial and territorial integration, creation of an efficient system of transfer of the results to the Institutions; - Promotion of actions aimed to sensitize local populations and to spread the results, at national and international level.
FLUXNET http://www.fluxnet.ornl.gov/fluxnet/index.cfm	It is a global network of micrometeorological tower sites that use eddy covariance methods to measure the exchanges of carbon dioxide, water vapour, and energy between terrestrial ecosystem and atmosphere. At present, over 400 tower sites are operating on a long-term and continuous basis. Researchers also collect data on site vegetation, soil, hydrologic, and meteorological characteristics at the tower sites. FLUXNET data available at the ORNL DAAC include monthly and annual heat, water aper vapour, and carbon dioxide flux, gap-filled flux products, ecological site data, and remote-sensing products	FLUXNET provides information to FLUXNET investigators and the public. The goals of FLUXNET is • understand the mechanisms controlling the exchanges of carbon dioxide, water vapour, and energy across a spectrum of time and space scales. FLUXNET provides ground information for validating estimates of net primary productivity, evaporation, and energy absorption that are being generated by sensors on the NASA TERRA satellite.
INFC	National Forest and Carbon stock Inventory	
IPHEN Italian Phenological Network	IPHEN Started from 2006. It is based on voluntary activities for the monitoring and the production of the documents (maps, data analysis)	General objective of the project: • A Collection of phenological data • Phenological maps production

2. Adaptation

Adaptation strategies have effects on short time scale and represent direct and immediate actions to climate change impacts. The effect of adaptation must be visible.
Disadvantages of adaptation strategies are:

- it doesn't solve the problem;
- the solutions are focused to specific species/ecosystem/locations therefore it is difficult to apply on wide areas.

It is likely that adaptation practices should be easier to implement more in artificial forest systems than in natural forests (IPCC annual report, 2007).
Several adaptation strategies and practices may be used in forestry (Kabat et al., 2005): change in management intensity, species selection, harvesting systems within and between regions, changes in rotation periods, dead wood management. The landscape perspectoive and the spatial arrangements of sylviculture types are important to minimize fire and insect damage, and to provide connectivity (Spittlehouse and Stewart, 2003).

A primary aim of adaptive management is to reduce as many stress sources as possible on the on forest resources. Maintaining widely dispersed and viable populations of individual species and minimising the probability that localized catastrophic events will cause extinction (Fischlin et al., 2007). While regrowth of trees due to effective protection will lead to carbon sequestration, adaptive management of protected areas also leads to conservation of biodiversity and reduced vulnerability to climate change. For example, ecological corridors create opportunities for migration of flora and fauna, which facilitates adaptation to changing climate (IPCC annual report,2007).

2.1.Adaptation and mitigation linkages

Adaptation and mitigation relationships and vulnerability of mitigation options to climate change are summarized in Table 14, which presents four types of mitigation actions. Adaptive practices may be complex. Forest conservation is a critical strategy to promote sustainable development due to its importance for biodiversity conservation, watershed protection and promotion of livelihoods of forest-dependent communities in existing natural forest (IPCC, 2002).

Afforestation and reforestation are the dominant mitigation options in specific regions. Plantations consisting of multiple species may be an attractive adaptation option as they are more resilient, or less vulnerable, to climate change.

This as result of different tolerance to climate change characteristic of each plantation species, different migration abilities, and differential effectiveness of invading species (IPCC, 2002).

Agro-forestry provides an example of a set of innovative practices designed to enhance overall productivity, to increase carbon sequestration, and that can also strengthen the system's ability to cope with adverse impacts of changing climate conditions. Agro-forestry management systems offer important opportunities creating synergies between actions undertaken for mitigation and for adaptation (Verchot et al., 2006). Agro-forestry can also help to decrease pressure on natural forests and promote soil conservation, and provide ecological services to livestock.

Bio-energy. Bio-energy plantations are likely to be intensively managed to produce the maximum biomass per unit area. To ensure sustainable supply of biomass feedstock and to reduce vulnerability to climate change, the practices mentioned above for afforestation and reforestation projects need to be explored: changes in rotation periods, salvage of dead timber, shift to more productive species under the new climatic conditions, mixed species forestry, mosaics of different species and ages, and fire protection measures.

2.1.1 Adaptation and mitigation synergy and sustainable development

The need for integration of mitigation and adaptation strategies to promote sustainable development is presented in Klein et al. (2007). The analysis has shown the complementarity or synergy between many of the adaptation options and mitigation (Dang et al., 2003). Promotion of synergy between mitigation and adaptation will also advance sustainable development, since mitigation activities could contribute to reducing the vulnerability of natural ecosystems and socioeconomic systems (Ravindranath, 2007).

Quantification of synergy is necessary to convince the investors or policy makers (Dang et al., 2003). The possibility of incorporating adaptation practices into mitigation projects to reduce vulnerability needs to be explored. Particularly, Kyoto Protocol activities under Article 3.3, 3.4 and 12 provide an opportunity to incorporate adaptation practices.

Thus, guidelines may be necessary for promoting synergy in mitigation as well as adaptation programmes and projects of the existing UNFCCC and Kyoto Protocol mechanisms as well as emerging mechanisms. Integrating adaptation practices in such mitigation projects would maximize the utility of the investment flow and contribute to enhancing the institutional capacity to cope with risks associated with climate change (Dang et. al., 2003).

Mitigation option	*Vulnerability of the mitigation option to climate change*	*Adaptation options*	*Implications for GHG emissions due to adaptation*
A. Increasing or maintaining the forest area			
Reducing deforestation and forest degradation	Vulnerable to changes in rainfall, higher temperatures (native forest dieback, pest attack, fire and, droughts)	Fire and pest management Protected area management Linking corridors of protected areas	No or marginal implications for GHG emissions, positive if the effect of perturbations induced by climate change can be reduced
Afforestation / Reforestation	Vulnerable to changes in rainfall, and higher temperatures (increase of forest fires, pests, dieback due to drought)	Species mix at different scales Fire and pest management Increase biodiversity in plantations by multi-species plantations. Introduction of irrigation and fertilisation Soil conservation	No or marginal implications for GHG emissions, positive if the effect of perturbations induced by climate change can be reduced May lead to increase in emissions from soils or use of machinery and fertilizer
B. Changing forest management: increasing carbon density at plot and landscape level			
Forest management in plantations	Vulnerable to changes in rainfall, and higher temperatures (i.e. managed forest dieback due to pest or droughts)	Pest and forest fire management. Adjust rotation periods Species mix at different scales	Marginal implications on GHGs. May lead to increase in emissions from soils or use of machinery or fertilizer use
Forest management in native forest	Vulnerable to changes in rainfall, and higher temperatures (i.e. managed forest dieback due to pest, or droughts)	Pest and fire management Species mix at different scales	No or marginal
C. Substitution of energy intensive materials			
Increasing substitution of fossil energy intensive products by wood products	Stocks in products not vulnerable to climate change		No implications in GHGs emissions
D. Bio-energy			
Bio-energy production from forestry	An intensively managed plantation from where biomass feedstock comes is vulnerable to pests, drought and fire occurrence, but the activity of substitution is not.	Suitable selection of species to cope with changing climate Pest and fire management	No implications for GHG emissions except from fertilizer or machinery use

Table 14: Adaptation and mitigation matrix. Source: IPCC, 2007

2.2 Adaptation projects in Italy

AdaptAlp is an Alpine Space Programme project, which is part of the European Territorial Cooperation 2007-2013.

16 project partners from six different countries are involved in AdaptAlp with the overall aim of assessing impacts of adaptation to climate change in the Alpine Space.

In the course of the project, recommendations for policy-makers and local stakeholders will be derived regarding adaptation strategies and disaster risk management. In various pilot regions the experiences and results of the project activities will be brought together in order to find 'best-practice' examples.

AdaptAlp focuses exactly on the harmonization of the various national approaches and methods. Beside harmonization of terminology, an important issue tackled by AdaptAlp is to provide reliable data and design events for the Alpine Space (i.e. knowledge concerning flood events and droughts taking CC - precipitation - into account).
There is a great need for a common and homogenous terminology, for innovative methods enabling better and especially faster modelling (e.g. design events), forecast (e.g. floods) and thus prevention of impacts in consideration of CC. The dialogue between scientists, experts, politicians and local stakeholders will be carried on and efficient methods identified in the vertically and horizontally integrated transnational approach of AdaptAlp.

Objectives of the project
•1 - EU/National
Enhancing transnational exchange and cooperation regarding risk prevention and risk management methods; provision of input to the European Floods directive and the European INSPIRE directive.
•2 - EU/Programme Area/National/Regional/Local
Reducing uncertainties by provision of precise data, design events and innovative methods considering climate change for improved modelling and prediction of natural hazards and its impacts in the alpine space.
•3 - EU/Programme Area/National
Improving efficiency of transnational risk management by elaboration of a common transnat. understanding (i.e. glossary) concerning the assessment of risks and harmonization of different approaches of geological hazard mapping and other natural hazards -> Development of a basis for inter-sectoral hazard maps (multi-process hazard maps) .Setting over-transnational guidelines for (cross-sectoral) hazard mapping taking into account climate change.
•4 - Programme Area
Raising awareness and supporting adaptation actions on local, regional, national and transnational level by implementation of trans-nationally concerted and regionally coordinated campaigns on risk management and communication.
•5 - Regional/Local
Elaboration of a sound decision basis for adaptation measures, improvement of knowledge to facilitate decision-making and implementation of pilot activities taking climate change into account. Initiating long-term communication process and kick-off for individual adaptation strategies.

2.3 Forest adaptation measures

2.3.1 An example of research applicable on political level

The ACCELERATES project (Assessing Climate Change Effects on Land Use and Ecosystems from Regional Analysis to the European Scale), was located the Belluno province (north-east Italy), a context chosen as representative of the Alpine area. Selected results of the analysis of the relationships between future scenarios of change, farming systems, land use and biodiversity were obtained. In this research, an initial historical analysis of the dynamics of land use was conducted with respect to the agricultural, socio-economic and demographic dynamics identified the main drivers of change and the positive and negative factors for conservation of the rural land and of biodiversity. In a subsequent stage the scenarios of future climate and land use changes were used to analyse the future for the species selected as indicators of biodiversity in the studied area. The results obtained provided useful information for the identification of suitable agri-environmental policies at the local scale. Maintenance of the livestock production systems typical of mountain agriculture is shown to be the key factor for contrasting land abandonment and the consequent expansion of woodlands, with negative effects in terms of simplification of landscape and impacts on species of naturalistic interest (Giupponi, 2006).

3.Mitigation

In the context of global change and sustainable development, forest management activities play a key role through mitigation of climate change. However, forests are also affected by climate change and their contribution to mitigation strategies may be influenced by stresses possibly resulting from it.
Forest mitigation options include reducing emissions from deforestation and forest degradation, enhancing the sequestration rate in existing and new forests, providing wood fuels as a substitute for fossil fuels, and providing wood products for more energy-intensive materials. Properly designed and implemented, forestry mitigation options will have substantial co-benefits in terms of employment and income generation opportunities, biodiversity and watershed conservation, provision of timber and fibre, as well as aesthetic and recreational services.
Each mitigation activity has a characteristic time sequence of actions, carbon benefits and costs (Table 15).

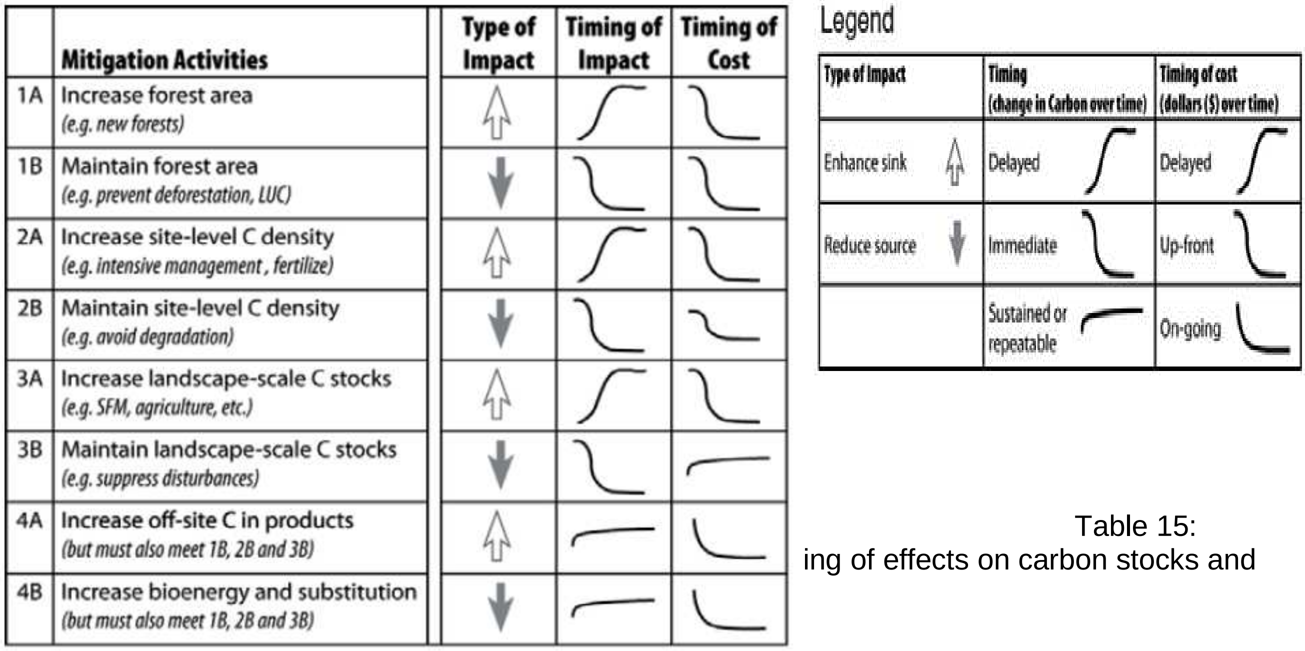


Table 15:
ing of effects on carbon stocks and

3.1 Carbon accounts

Forests play an important role in the mitigation of the effects of climate change thanks to their ability to sequestrate carbon dioxide from atmosphere. The assessment of the carbon fixed by forest ecosystems (stocks) and the carbon accumulated over a period of time (sinks) is focal for environmental protection scopes, as well as for accessing the carbon credits market.

The CARBOITALY project is the Italian net for measuring forest and agriculture carbon sinks and developing a system to predict the absorption of greenhouse gases by terrestrial ecosystems. The structure and the objectives are described of a national project recently started in Italy with the aim of quantifying carbon sinks by forest and agriculture ecosystems. Five main research lines are planned:
(1) Measurement of CO_2 fluxes in terrestrial ecosystems
(2) Regionalization;
(3) Building and experimental testing of a predicting system;
(4) Fluxes of non-CO_2 trace greenhouse gases;
(5) Scenarios and politics.

3.1.1 Carbon accounts and Kyoto protocol: some case of study

- **Source: Lamedica, 2007**

Variation of forest surface and carbon fixation in mountain areas of the Regione Veneto (Italy) and the application of the Kyoto protocol.

The Parties that have signed the Kyoto Protocol must reduce global emissions of Greenhouse Gasses (GHG) during the First Commitment Period (2008 - 2012) by at least 5% with respect to 1990. This share is 6.5% for Italy. The Kyoto Protocol lays down some measures for reducing GHG emissions, which include actions in agriculture and forestry. It will thus be possible to take emissions and absorptions resulting from land use changes into account in the National Balances. Given the widespread forests in Italy, it is very important to have an assessment of the aptitude of this sector to act as a carbon sink. In this study we analysed the variation of forestland cover in a mountain area of the Veneto Region (NE Italy). The analysis was done by comparing aerial photos taken in 1991 with ortho-photos reported to 2003, by photo interpretation of points with casual distribution on sample areas, according to a stratified sampling. We estimated a statistically relevant increment of about 0.095% of forest land only up to 1500 m compared to the estimated forest cover for 1990 (about 42 ha), underlining how this low increase is mainly due to forest management. The second step was to estimate the fixed carbon in the areas where forests increased. This was achieved by collecting biometrical data in the field, and then using allometric functions. The annual carbon sink was estimated as 0.69 Mg ha-1 year-1. Comparing these results with previous studies done in the pre-alpine region we estimate the annual increment of the forest area in the whole Veneto region to be about 409.94 ha and that the total carbon sink is about 282.86 Mg C year-1. A method for estimating carbon sink in afforestation/ reforestation areas is proposed that could also be applied to other sites in Italy.

- **Source: Pilli,2006**

Inventory data usage in carbon stock assessment for targeting Kyoto protocol requests.

Parties included in Annex I of the Kyoto Protocol, like Italy, may choose to elect Forest Management as additional human induced activity to attain the goals of reduction of greenhouse gas emissions. In Italy the majority of areas subjected to forest plans satisfy the definition of Forest Management proposed by the Marrakesh Accords.

However, the data commonly available from forest compartments cannot be directly used to estimate the total aboveground biomass by allometric equations because the data are not spatially (data differ among compartments) or temporally (data sampled in different years) uniform. This study proposes a methodology for using such non-uniform data, which has been tested on a dataset of forest compartments provided by the Veneto Region (NE Italy). The results met the requirements of the "Good Practice Guidance for Land Use, Land Use Change and Forestry " of The Intergovernmental Panel on Climate Change since the uncertainties were quantified.

- **Source: Salvadori I, 2006**

A methodology for analysing temporal changes of forest surface using aerial photos for the application of the Kyoto Protocol,

Italy, like other Parties included in Annex I, shall report the net changes in greenhouse gas emissions by sources and removals by sinks resulting from afforestation, reforestation and deforestation activities (ARD). To evaluate these activities, Italy has to elaborate methods to estimate the conversion of non-forested to forested land, occurred after 31 December 1989.

The approach was experimented in the Comunità Montana del Grappa (about 10500 ha) considered as a pilot area in the Prealpine region (NE Italy). The land-use change relative to the forest area was assessed by sampling points on orthocorrected aerial photos relative to 1991, 1996 and 1999. The forest area based on different definitions was also assessed. Between 1991 and 1999, the total increment of the forest area was equal to 224 ha. However, the estimated increment was strongly related to the minimum surface (2000 m^2 vs 5000 m^2) of the forest definition.

- **Source: Magnani F, 2005**

What role for afforestation in Italian strategies towards the Kyoto Protocol?

Hints from a Kyoto forest in the Po Valley (Northern Italy). The carbon balance of an afforested area in the Emilia-Romagna floodplain has been monitored for a 4-year period. Detailed measurements covering both above- and below-ground components of biomass production and accumulation were complemented by eddy-covariance measurements at the ecosystem level. Experimental results have been extrapolated in time by means of a process-based ecosystem model, so as to better assess the potential role of afforestation towards the carbon-reduction goals of the Kyoto Protocol.

- **Source: Marino, 2005**

Climate change in the Mediterranean basin: a case study on carbon cycle in a forest of southern Italy

Since the industrial revolution, the increased burning of fossil fuels has caused large emissions of greenhouse gases in the atmosphere with, as a consequence, the increase of their atmospheric concentration, particularly in the case of carbon dioxide. This increase is proven by long-term atmospheric monitoring and it is related to relevant climate changes as increased mean temperatures and frequency of extreme events (flooding, heat waves, etc.). In this respect, the Mediterranean area is one of those that, according to forecasts and simulations, will suffer mostly from these changes. The experimental site is equipped with micrometeorological sensors and with the instrumentation to measure net carbon exchange at ecosystem level with the eddy covariance technique. The site has been established to study carbon and water cycle dynamics of this important Southern Italian ecosystem, in order to better understand ecosystem responses to environmental factors and climate change. Preliminary data point to the fact that the pine forest is a carbon sink practically all-year-round. Soil water availability and atmospheric evaporative demand proved to be important and concurrent factors in determining adaptative responses by the ecosystem. The study will continue in the coming years, in order to reach a better reliability of carbon balance monthly and annual sums particularly by improving the estimate of ecosystem respiration and its components (storage and advection terms, soil respiration) and to verify interannual and long-term responses to climate.

- **Source: Costa, 2005**

The role of the Mediterranean maquis in carbon sequestration.

In the last decades human activities have fundamentally altered many biogeochemical cycles. The most prominent of these changes has been the modification of the global carbon cycle, and in particular the increase in the concentrations of atmospheric carbon dioxide. The CO2 increased from a preindustrial concentration of ca 280 ppm to 368 ppm in the year 2000. In 1997, the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) met in Kyoto, Japan, and produced a document (the Kyoto Protocol) of appropriate actions to reduce the emission of greenhouse gases. Inside the protocol, the emission of carbon dioxide by anthropogenic activities is estimated together with the carbon stored in the vegetation. Forests play an important role to capture carbon. The vegetation accumulates through the absorption of atmospheric CO2 carbon into biomass. The carbon is stored in various pools in a ecosystem: living biomass, necromass, soil organic matter. Remarkable variations among carbon accumulates do occur, while little information on carbon stored by Mediterranean formations is available.

The results of studies confirm the importance of Mediterranean vegetation, called ”macchia“, in terms of surface and the role played in the carbon storage. In fact the surface occupied in Sicily by macchia is about 300000 ha (12% of 2500000 ha total surface of Sicily) and the carbon storage is estimated from 2.25 to 18Mt of carbon. Implementation of such studies is necessary to estimate: 1) the carbon storage with more accuracy; 2) the carbon storage within the annual growth; 3) the carbon storage into the soil during the evolution of vegetation from degraded forms (e.g., annual praires) to high forest; 4) the effects of fire.

3.2. Research projects on mitigation strategies

Name of the project	Description	Objectives
Biorefugia http://sweb01.dbv.uniroma1.it/bruno/biorefugia/index.html	An evaluation of the current and future potential distribution of the main tree forest species of Central Italy (Lazio and Abruzzo regions).	the elaboration of conservation strategies at regional scale: protection of strategic ecosystem refugia, ecological networks and corridors
CARBOITALY	Italian net for measuring forest and agriculture carbon sinks	developing a system to predict the absorption of greenhouse gases by terrestrial ecosystems
CIRCE Climate change and impact research: the Mediterranean environment http://www.circeproject.eu/	CIRCE wants to understand and to explain how climate will change in the Mediterranean area. The project will investigate how global and Mediterranean climates interact, how the radiative properties of the atmosphere and the radiative fluxes vary, the interaction between cloudiness and aerosol, the modifications in the water cycle. Recent observed modifications in the climate variables and detected trends will be compared. The economic and social consequences of climate change shall be evaluated by analysing direct impacts on migration, tourism and energy markets together with indirect impacts on the economic system. CIRCE will moreover investigate the consequences on agriculture, forests and ecosystems, human health and air quality. The variability of extreme events in the future scenario and their impacts will be assessed. A rigorous common framework, including a set of quantitative indicators developed specifically for the Mediterranean environment will be developed and used in collaboration with regional stakeholders. The results will be incorporated in a decision support system tool and disseminated to the relevant users. Possible adaptation and mitigation strategies will be identified.	CIRCE aims at developing for the first time an assessment of the climate change impacts in the Mediterranean area. The objectives of the project are: - to predict and to quantify physical impacts of climate change in the Mediterranean area; - to evaluate the consequences of climate change for the society and the economy of the populations located in the Mediterranean area; - to develop an integrated approach to understand combined effects of climate change; - to identify adaptation and mitigation strategies in collaboration with regional stakeholders.
CLIMALPTOUR	This project addresses the need to provide both a sound knowledge of the different aspects of the possible impact of climate change on Alpine tourism and concrete adaptation strategies to apply in selected	The ClimAlpTour project aims at dealing with the internationally recognized possible effects of climate change on Alpine tourism, with reference to winter tourism and winter sports in some areas of

	areas. The choice to directly and indirectly involve local actors (e.g. municipalities) was led by the intention to bring concrete outcomes on the Alpine territory and to include the topic of the effect of climate change on tourism in the policy agendas.	the Alps (e.g. Italian Alps, French Alps, Slovene Alps, etc.) and to all-season tourism in other areas (e.g. German Alps).
RECIPE	Report on Energy and Climate Policies in Europe The RECIPE project highlights crucial strategic options for Europe's climate and energy policy at two different scales. • Firstly, it informs the relevant stakeholders about the most important barriers to implementation in the European power and heat, industry, transport and agriculture sectors. • Secondly, it highlights Europe's main strategic options in the international arena. The involved research teams are convinced that both questions are highly interlinked. Europe could lose its leading role in the international climate arena if its domestic energy policy fails. However, a successful European domestic energy policy will be much more likely if a credible international climate regime emerges within the next decade. Addressing these highly relevant questions requires a careful synthesis of quantitative modelling results and qualitative information derived from case studies.	The project aims at filling the research gaps on abatement costs and mitigation options in the European context by: 1. Calculating the mitigation costs and strategies for Europe dependent on scenarios about the future of an emerging post-2012 climate regime 2. Identifying the barriers to implementation within key sectors (e.g. the power and transport sectors) 3. Analysing appropriate policy instruments and the potential scope of their application 4. Exploring the role of financial markets as well as risks and opportunities of carbon abatement for stakeholders in the financial industry
SAFELAND http://www.safeland-fp7.eu	SafeLand will develop and implement an integrated and comprehensive approach to help guide decision-making. The methodologies developed will be tested in selected hazard and risk "hotspots" in Europe, in turn improving knowledge, methodologies and integration strategies for the management of landslide risk.	(1) provide policy-makers, public administrators, researchers, scientists, educators and other stakeholders with an improved harmonised framework and methodology for the assessment and quantification of landslide risk in Europe's regions; (2) evaluate the changes in risk

	The harmonised methodologies and technical developments, combined with the social, economic and environmental dimensions will play a significant role in the detection, prediction and forecasting of landslides and landslide risk posed to individuals, society and the environment. SafeLand stresses the necessity of integrating the technology and social aspects to ensure that the risk assessment and management strategies are realistic and representative of the forces at play in an actual situation. Global changes, due to both climate and human activity, will provide insight in future risk patterns. The landslide risk assessment and management strategies developed in the SafeLand project will be implemented to forecast future risk.	pattern caused by climate change, human activity and policy changes; (3) provide guidelines for choosing the most appropriate risk management strategies, including risk mitigation and prevention measures. To be able to produce results at the European scale, SafeLand needs to link hazards and risks at the local scale, i.e. individual slopes and slides to the hazards and risks at the European scale. The smallest scale of interest in this proposal refers to the local slope scale (less than 3 km^2) where most of research on the triggering factors will be done. The regional studies, including the "hotspots" evaluations, form the intermediary scale: from 10 to 200 km^2, depending of the site. The largest scale will be the "country" and Europe scales.

Table 16: Some of the research studies on mitigation strategies in Italy

3.3. Implications of forestry mitigation

Climate mitigation policies may have benefits that go beyond global climate protection at the local level (Dudek et al., 2002). Since ancillary benefits tend to be local, rather than global, their identification can reduce or partially compensate the costs of the mitigation measures. However, forests fulfil many important environmental functions and services that can be enhanced or negatively disturbed by human activities and management decisions. Negative effects can be triggered by some mitigation options under certain circumstances. Positive and negative impacts of mitigation options on sustainable development are presented in Table 17 Literature describing in detail the environmental impacts of different forest activities is still scarce and focuses mostly on planted forests. For these reasons, the discussion focuses more on plantations. It is important to underline that while benefits of climate change mitigation are global, co-benefits and costs tend to be local (OECD, 2002) and, in accordance, trade-offs have to be considered at local level.

Activity Category	*Sustainable development implications*		
	Social	**Economic**	**Environmental**
A. Increasing or maintaining the forest area			
Reducing deforestation and forest degradation	*Positive* Promotes livelihood.	*Positive or negative* Provides sustained income for poor communities. Forest protection may reduce local incomes.	*Positive* Biodiversity conservation. Watershed protection. Soil protection. Amenity values (Nature reserves, etc.)
Afforestation/ Reforestation	*Positive or negative* Promotes livelihood. Slows population migration to other areas (when a less intense land use is replaced). Displacement of people may occur if the former activity is stopped, and alternate activities are not provided. Influx of outside population has impacts on local population.	*Positive or negative* Creation of employment (when less intense land use is replaced). Increase/decrease of the income of local communities. Provision of forest products (fuel wood, fibre, food construction materials) and other services.	*Positive or negative* Impacts on biodiversity at the tree, stand, or landscape level depend on the ecological context in which they are found. Potential negative impacts in case on biodiversity conservation (mono specific plantations replacing biodiverse grasslands or shrub lands). Watershed protection (except if water hungry species are used) . Losses in stream flow. Soil protection. Soil properties might be negatively affected.
B. Changing to sustainable forest management			
Forest management in plantations	*Positive* Promotes livelihood.	*Positive* Creation of employment Increase of the income of local communities. Provision of forest products (fuel wood, fibre, food, construction materials) and other services.	*Positive* Enhance positive impacts and minimize negative implications on biodiversity, water and soils.
Sustainable forest management in native forest	*Positive* Promotes livelihood.	*Positive* Creation of employment. Increase of the income of local communities. Provision of forest products (fuel wood, fibre, food,	*Positive* Sustainable management prevents forest degradation, conserves biodiversity and protects watersheds and soils.

		construction materials) and other services.	
C. Substitution of energy intensive materials			
Substitution of fossil intensive products by wood products	*Positive or negative* Forest owners may benefit. Potential for competition with the agricultural sector (food production, etc.).	*Positive* Increased local income and employment in rural and urban areas. Potential diversification of local economies. Reduced imports.	*Negative* Non-sustainable harvest may lead to loss of forests, biodiversity and soil.
D. Bio-energy			
Bio-energy production from forestry	*Positive or negative* Forest owners may benefit. Potential for competition with the agricultural sector (food production, etc.)	*Positive or negative* Increased local income and employment. Potential diversification of local economies. Provision of renewable and independent energy source. Potential competition with the agricultural sector (food production, etc.)	*Positive or negative* Benefits if production of fuel wood is done in a sustainable way. Mono specific short rotation plantations for energy may negatively affect biodiversity, water and soils, depending on site conditions.

Table 17: Sustainable development implications of forestry mitigation (source: IPCC report, 2007)

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