# Tree Species' Tolerance to Water Stress, Salinity and Fire

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**Abstract** According to climate change predictions, water availability might change dramatically in Europe and adjacent regions. This change will undoubtedly have an adverse effect on existing tree species and affect their ability to cope with a lack or an excess of water, changes in annual precipitation patterns, soil salinity and fire disturbance. The following chapter will describe tree species and provenances used in European forestry practice which are the most suitable to deal with water stress, salinity and fire. Each subchapter starts with a brief description of each of the stress factors and discusses the predictions of the likelihood of their occurrence in the near future according to the climate change scenarios. Tree species and their genotypes able to cope with particular stress factor, together with indication of their use by forest managers are then introduced in greater detail.

## 3.1 Introduction

Predicted scenarios of global climate change on the European continent and adjacent geographic regions by 2100 include a rise of average air temperature by about 2°C, shifting geographical and seasonal rainfall patterns, a concurrent intensification of rainstorms and heavy rain events (mm $h^{-1}$), as well as a rise of the sea level. These changes may profoundly affect forest vegetation by shifting species' climatic boundaries and hence by forcing substantial changes in species composition of forest communities as they adapt to the new environmental conditions. These conditions will probably include increased frequency and length of heat and drought spells, leading to subsequent rise of fire risk. At the same time, intensification of rainfall events may raise the probability of severe flooding of lowlands, heavy erosion and disruption of normal annual cycle in seasonally flooded forests. The rise of the sea level may severely affect coastal forest areas by exposure to salt spray during severe weather evens, infiltration of salt water into the underground water table and by the salt contamination of fresh-water coastal marshes. It is of importance to consider available climate change scenarios and to use the forewarning they provide to prepare measures to reduce the severity of their impact on forest ecosystems. One has to bear in mind that a forest planted today is likely to exist in a different climate when it reaches maturity. As discussed in Chapter 2, forest area in Europe is expanding due to afforestation of marginal land, often with allochtonous tree species. This process brings a host of interrelated problems and further highlights the need for considering the impacts of changing environment on European forests. Future conditions, as well as future requirements for forest ecosystem services, need to be taken into account when selecting tree species for afforestation. It is likely that future management practices will need to be adapted and improved to ensure forest sustainability.Therefore, we think it useful to explore the existing knowledge on forest tree species, whether indigenous to the Mediterranean basin or from other homologous climatic zones, which have evolved the necessary features to withstand the new climatic and environmental conditions.

## 3.2 Water stress

### *Drought*

Firstly, since there is no precise and universally accepted definition of drought, it is often difficult to ascertain whether a drought has occurred, what was its length and severity. It is considered to be a slow-onset natural hazard, often referred to as a 'creeping phenomenon' (Gilette 1950). In relation to forest stands, it is usually not a one-off event that causes severe damage, but a cumulative effect of several years' below average rainfall that induces dieback of resident tree species. Moreover, it is fair to assume that any definition of drought will be region specific, since different regions have vastly different rainfall amounts and rainfall distribution throughout the growing season. On this basis, a drought is, unlike aridity, an aberration from the norm and as such must also be distinguished from seasonal aridity

(Wilhite and Buchanan-Smith 2005). According to Chapter 11 of the IPCC 2007 Assessment Report (Christensen et al. 2007), it is very likely that European territory will suffer geographical shifts and alterations of its precipitation patterns. It is forecasted that the southern half of Europe, including the Mediterranean area will suffer a significant reduction in rainfall, while northern half will see an increase in the amount of precipitation inside 2100 (Figure 1).

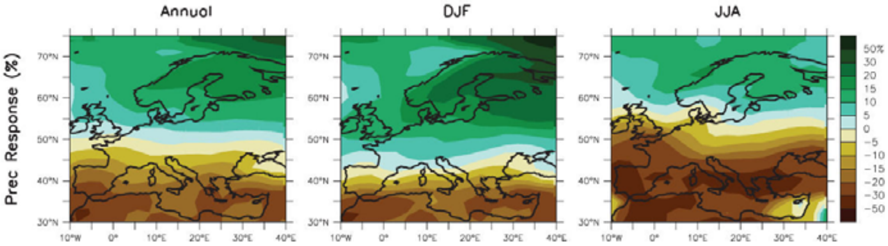

**Fig 1** Precipitation changes over Europe from the MMD-A1B simulations, DJF and JJA fractional change in precipitation between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Source: Christensen et al.(2007).

However, the temporal pattern of precipitation has been predicted to change too, resulting in wet winters and dry springs and early summers in northern Europe (Figure 2, Kont et al. (2003)). Although annual rainfall will increase in northern Europe, vegetation may still suffer from drought in summer at the height of the growth period. As a consequence of spring and early-summer drought, plants may reduce their leaf area, which in turn may cause decline in growth throughout the growing season (Nilsen et al. 1996). For example, Jalkanen and Pensa (unpublished) reconstructed leaf dry weight dynamics of Scots pine (*Pinus sylvestris*) in northern Lapland by using the well defined relationship between leaf size and leaf trace diameter (Pensa et al. 2004). The reconstruction indicates that the years with higher dry mass of a single leave tend to coincide with high precipitation in May and June (Figure 3)

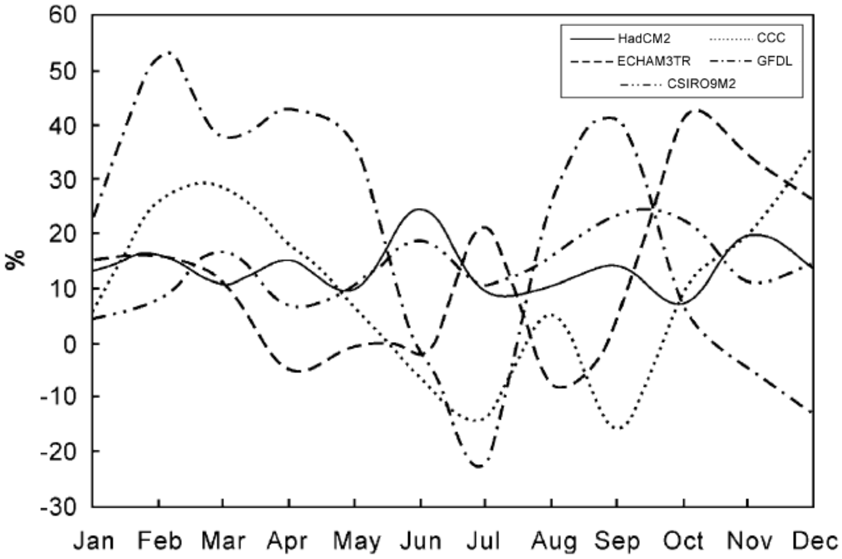

**Fig 2.** Percentage change in monthly mean precipitation in Estonia for the year 2100 calculated by five alternative General Circulation Models; HadCM2, ECHAM3TR, CCC, GFDL and CSIRO9M2 (Kont et al. 2003).

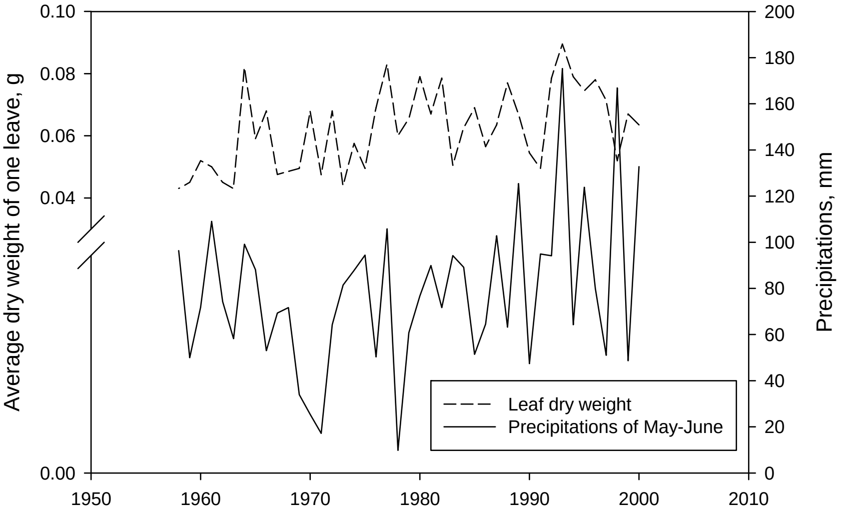

**Fig 3.** Changes in average needle dry weight attached to the topmost shoot of Scots pine stem measured in Laanila, northern Lapland. The variation in the dry weight may indicate the effect of spring precipitation on leaf size (Pensa, unpublished).

Since there is very little, or nothing, that a forest manager can do to prevent a drought from occurring and since the means of irrigation of forest stands are very limited or non-existent, a choice of tree species or provenances suitable for the forecasted climatic conditions appears to be the only viable course of action. One can utilize non-native tree species already adapted to dry conditions, or if this is not possible due to, for example, a ban on planting foreign stock, the most promising line of approach is a selection of drought resistant varieties of existing species, as suggested already by Maximov (1929). Tree species choice is especially important in the case of large-scale afforestation programmes (see Chapter 1), where future impacts on water yields, soil protection and biodiversity conservation must be taken into account.

As with other stress factors, biotic or climatic, trees respond to drought stress by reducing the annual radial growth. Tree ring analysis can therefore be used as a tool for assessing whether tree species in a particular forest or area are suffering from drought stress (Pichler and Oberhuber 2007). Since the constraint water scarcity puts on carbon fixation is well established (Ciais et al. 2005), an analysis of annual growth rings during drought years can identify tree species which are more or less sensitive to drought in a particular location. However, different tree species respond to climatic influences in varying fashion, it is important to possess a reliable database characterizing site conditions since similar climatological conditions yield divergent growth response patterns (Neuwirth et al. 2006).

Species coexisting in a given forest do not experience the same level of water stress, trees evolved several alternative strategies to cope with drought. For example, Mediterranean species have been classified as drought-tolerant, when they are able to maintain photosynthetic activity under severe water stress as certain evergreen oaks do, and drought avoiders, when they either shed leaves or close stomata during the dry periods, as certain pines do. Further, species composition of a forest stand directly influences its water balance. Trees influence the amount of water in the soil through crown interception and evapotranspiration. Schume and Hager (2004) have shown that evapotranspiration in a mixed Norway spruce (*Picea abies* Karst.) and European beech (*Fagus sylvatica* L.) stand was disproportionately greater than in single species stands. The increase in evapotranspiration in the mixed stand was exclusively attributable to beech, which in mixture deepened and intensified its fine-root system, while spruce rooted more shallowly. During prolonged drought, beech could thus gain a competitive advantage since the mixed stand extracted a higher percentage of water from deeper soil layers than the pure stands.

In general, drought tolerance is associated with high water use efficiency (Ferrio et al. 2003), leading to the development of forest ecosystems able to persist under constant and significant lack of water. However, as Bréda et al. (2008) point out in their analysis, extreme drought events surpassing the tolerance threshold can substantially increase tree species' probability to decline. This is valid both for arid environments with regular occurrence of drought and for localities not normally exposed to lack of water during the growing season. Kozlov and Niemelä (2003) have found that the vitality of Scots pine populations at the Arctic northern tree is greatly affected by lack of late summer precipitation, even though water availability during the rest of the year is not a limiting factor. Tree vitality reduced by a drought event usually leads to a higher susceptibility to pests and is therefore very difficult to single out as the primary cause of forest decline. The issue is further complicated by the fact that trees affected by a severe drought do not decline immediately, sometimes taking decades to die (Pedersen 1998). Drought stress can change the development trajectory of a forest ecosystem in several ways, whether directly through different species' mortality, by changing the viability of reproductive structures and seeds (Ogaya and Penuelas 2007) or by reductions in biotic associations (e.g. avian seed dispersers, ectomycorrhizas and nurse plants; (Mueller et al. 2005)).

This far, drought resistance research has been leaf-centric, seeking to establish the mechanisms behind water loss reduction during transpiration. Drought tolerance is not achieved by a single combination of trait values and that these combinations can differ at different levels of analysis, i.e., in individual responses to drought vs. interspecific comparisons of drought tolerance (Valladares and Sanchez-Gomez 2006). Recent developments in plant genetics, perhaps unsurprisingly, indicate that root biology does play a very significant role in drought tolerance and drought adaptation at the root level might have significant role to play when dealing with effects of climate change on trees (Pennisi 2008).

Alongside choosing suitable tree species tolerant of drought conditions in certain areas, forest managers have developed a host of afforestation strategies aimed at helping tree survival and at ensuring minimal impacts on water yields and water quality from afforested catchments (see Chapter 2 for more details) ,

### ***Hypoxia***

Moving across the European climate gradient from the very dry environment to the very wet, both the amount of rainfall and its intensity are forecasted to increase in the Central and Northern parts of Europe in the latter half of the 21st century. Together with increasing probability of substantial surface runoff and higher risk of soil erosion (see Chaper 4), this weather pattern is likely to bring an increased incidence of flooding in lowland areas. In addition, forecasted increase in sea level might result in severe and prolonged flooding of coastal areas by sea water. The increased risk of these events highlights the need to find and utilize tree species capable of withstanding long periods of flooding, especially in areas already considered flood-prone at present. Restricted gas exchange between the rhizosphere and aerated environment during a flooding event reduces the concentration of oxygen and elevates the concentration of carbon dioxide in the root zone. Air within soil pores is replaced by water and any remaining oxygen is quickly consumed by root and soil microbial respiration (Kreuzwieser et al. 2003), a process which gives rise to a condition commonly defined as hypoxia. This induces severe stress onto all aerobic organisms, including tree roots, since functions such as mitochondrial respiration, oxidation and oxygenation processes cannot take place (Vartapetian and Jackson 1997).

Tree responses to submersion vary among species, the most commonly observed reaction is a reduction in shoot growth probably accompanied by decline in root growth. Other responses can include injury, inhibition of seed germination, changes in vegetative and reproductive growth, changes in plant anatomy, and promotion of early senescence and mortality (Kozlowski 1997). There are several adaptations to submerging, riparian tree species frequently exposed to flooding such as willows, poplars and alders often feature some or all of them. For example, hypertrophied **lenticels** develop around the stems of *Salix* spp. and *Populus* spp, generally where the stomata once occurred. During flooding, lenticels provide a gas exchange pathway between the living cells in the bark and ambient air, substituting normal gas exchange within the soil. **Aerenchyma** tissues are extensive intercellular air spaces that form continuous passageways allowing the diffusion of oxygen from the aerial portions of the plants to the roots. Several species form **adventitious roots** after the death of the original roots due to flooding. These roots are produced as an extension of the surviving portion of the original root system and on the submerged portions of stems. These roots are generally negatively geotropic, thicker and possess larger intercellular spaces than original roots and can tolerate higher $CO_2$ concentrations and maintain respiration, despite the lack of oxygen. *Salix* spp., *Populus* spp., A*lnus glutinosa* and *Fraxinus excelsior* have all been reported to form adventitious roots during flooding, together with several other European tree and shrub species. In addition, there are thought to exist numerous **metabolic adaptations** to flooding, most of which still need to be investigated further (Armstrong et al. 1994, Drew 1997). Choosing tree species for a specific site should be accompanied by a tailored forest management plan. Trees have been shown to alter soil conditions in the rooting zone, both in the humus and in the mineral layers (see Chapter 5). Under suitable management, forest tree can contribute to the removal of excess water from the soil profile, thus contributing to soil amelioration.

In conditions of hypoxia, the ability of roots to supply shoots with water may decrease due to restricted hydraulic conductivity of roots (Sellin 2001). Consequently, as the atmospheric evapotranspirational demand (AED) increases, trees suffering from root hypoxia cannot compensate for transpirational water losses from shoots, which is reflected by lower shoot water potential of trees in waterlogged sites as compared with the trees on drier sites. For example, Sellin and Pensa (unpublished) compared the shoot water potential of Norway spruce trees growing on ombrotrophic peat with that of spruce trees growing on free-draining soils in Estonia. They found that spruces in the ombrotrophic peatland had lower values of shoot water potential at the same AED than the trees on the non-flooded soil (Figure 3.4). This effect leads to lower leaf conductance and consequently to lower rate of photosynthesis as shown by Sellin (2001) in Norway spruce. Paradoxically, this proves that hypoxia caused by excess of water at the root level may lead to a water deficit at the shoot level.

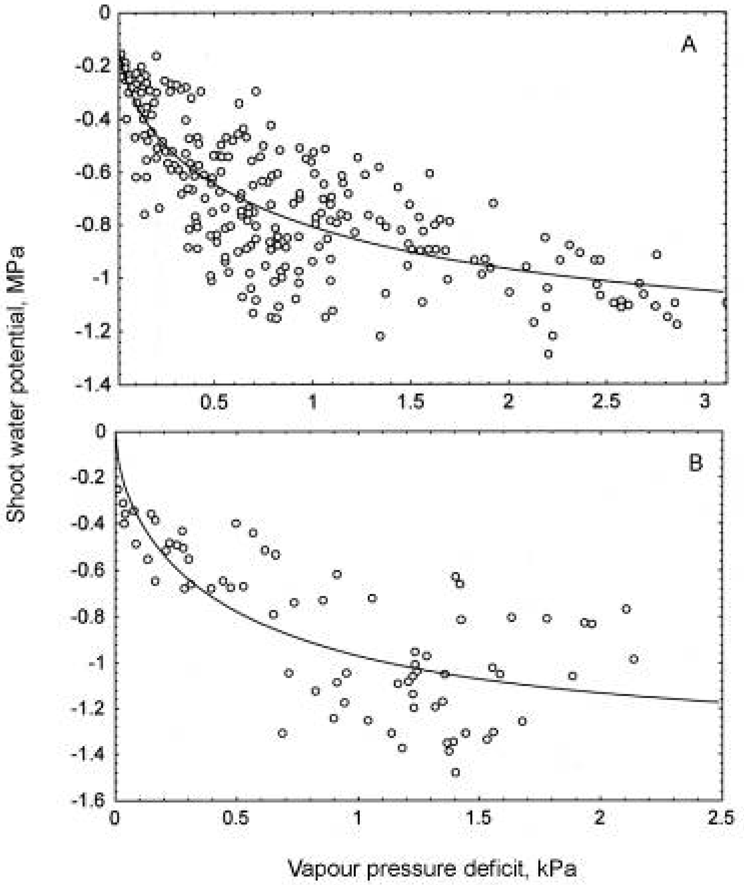

**Fig 4.** The comparison of Norway spruce shoot water potential response to atmospheric evapotranspirational demand (measured by vapour pressure deficit) in two contrasting habitat in central Estonia. (A) trees on fresh soils; (B) trees on waterlogged ombrotrophic peatland. (Pensa, unpublished)).

Recently, there are indications of a shift in the approach to flood protection of inhabited areas - away from constricting the flood water in the present river bed and towards creating water overflow and retention zones often located in areas of lowland forests (Buijse et al. 2002). If the periods of flooding are relatively short and happen predominantly during winter or early spring when the trees are dormant, the risk of damage to the trees should be relatively low. However, prolonged and frequent flooding during the growing season can cause severe damage to the tree stands, especially if unsuitable species used to afforest such areas (Fig 5).

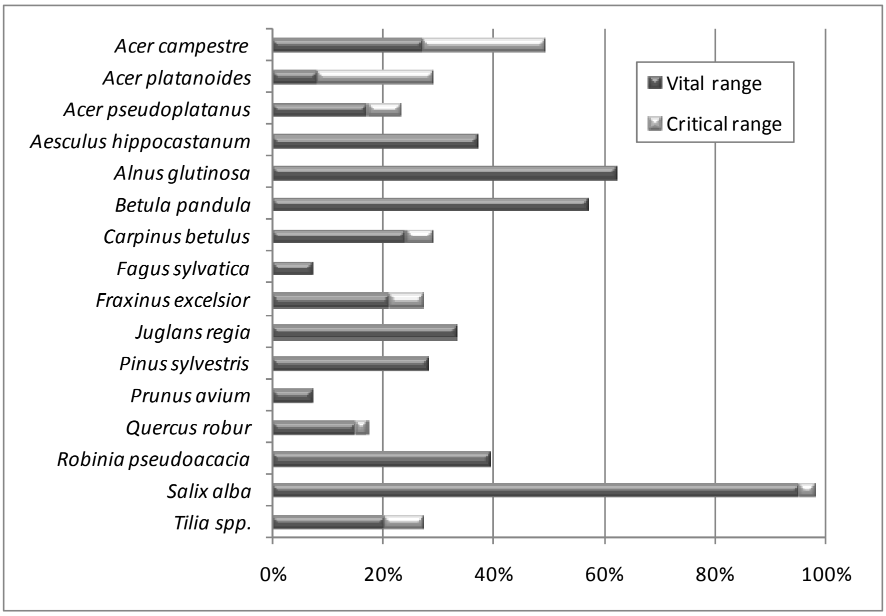

**Fig 5** Proportion of flooding during the growing season without negative impact on tree vitality (vital range) and with observed tree mortality (critical range). Adapted from (Glenz et al. 2006), data from (Späth 2002).

Increased precipitation, together with rising winter temperatures, in many areas in northern Europe present an increasing risk of peatland encroachment, with adverse consequences for forest growth and regeneration (Crawford et al. 2003). Together with the ground water level, water nutrient and oxygen concentrations determine the impact of bog environment on trees. For example, the measurements of tree basal area in an Estonian peatland fed by precipitation only(hence lacking in nutrients; ombrotrophic bog) indicated that the water table depth determines Scots pine (*Pinus sylvestris*) growth rates (Figure 6). Scots pine is among the few tree species that grow in nutrient-poor peatlands, as well as on nutrient rich soils, and shows corresponding variability in its morphological traits (Pensa et al. 2007).

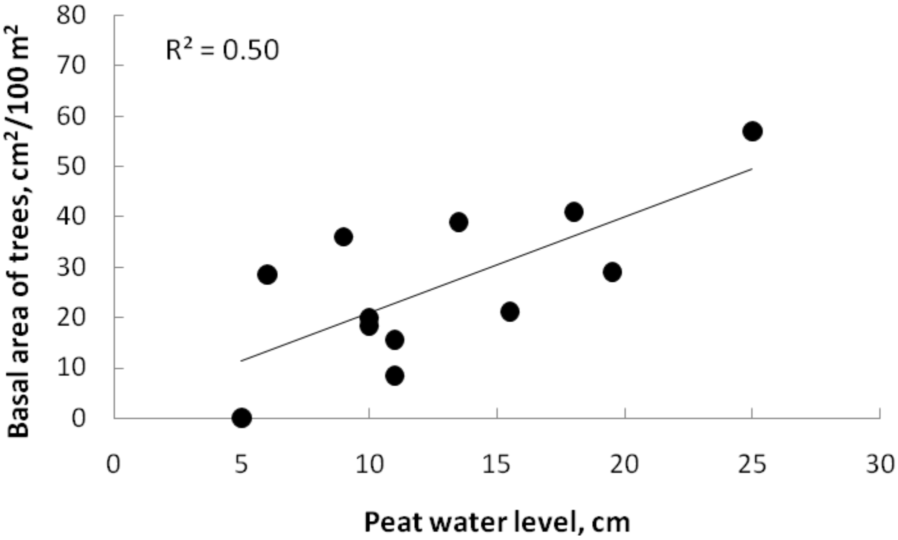

**Fig 6.** Relationship between the depth of peat water table and the basal area of Scots pine (*Pinus sylvestris*) trees in a raised bog (Selisoo, Estonia). The trees were measured within plots of 100 $m^2$ and the level of peat water was recorded in tree replicates (Pensa, unpublished).

Ultimately, forecasting of the impact of flooding on tree species, success of floodplain forest restoration projects, planning of retention basins and even on the estimates of economic losses in forestry due to flooding will only be improved through better knowledge of the flooding stress response of individual tree and shrub species. More systematic investigation is called for in this area, starting with physiological responses and up to community interactions and forest survival in stands exposed to flooding. (Glenz et al. 2006).

### 3.3 Salinity

Soil salinity has several origins: intrinsic salt content of the soils' parent material, redistribution of salt by water flow from higher ground into the valleys that lack natural drainage and, most commonly, high groundwater tables which enable capillary rise. In coastal areas, soil salinity can also be the result of sea water spray by high winds or sea water penetration into underground aquifers due to sea level rise or excess fresh water extraction. In arid areas soil salinity is mainly the result of high evaporation rate, a process during which an upward movement of soil water leads to salt deposits on or close to the surface. Global climate change scenarios predicted for the Mediterranean region include rising temperature and decline of rainfall, combined with rising sea levels. All these factors are likely to increase the area affected by soil salinity.

Apart from the Mediterranean, areas affected by salinity are found in many arid regions of the world and are thought to cover over 397 million hectares worldwide, which is an area three times larger than that used for agriculture (FAO 2000, www.fao.org). Saline soil is an area where soils contain high concentrations of various mineral salts in both as cations ($Na^+$, $Ca^{2+}$, $Mg^{2+}$, and $K^+$) and anions ($Cl^-$, $SO_4^{2-}$, $HCO_3^-$, $CO_3^{2-}$, and $NO_3^-$; Tanji,(2002)). A common response of trees to salt toxicity is a reduction in productivity. Several mechanisms explaining negative effects of excess soil salt content on plant physiology have been proposed, such as decrease in plant water potential resulting in alteration of water use efficiency (Glenn and Brown 1998), disturbances in ion homeostasis and toxicity (Monteverdi et al. 2008). The salinity tolerance varies widely both among and within species, the drop in productivity is especially dramatic in not- salt tolerant species when exposed even to minor increases of soil salinity (Brugnoli and Lauteri 1991). Generally, plants adapted to saline conditions are characterised by higher water use efficiency (WUE, unit of biomass produced per unit of water utilised) than salt sensitive plants. Monteverdi et al. (2008) suggest that high WUE could be looked at as one of desirable traits in trees to be planted in areas affected by salinity. High WUE implies that fewer salts are taken up by the plant to produce a unit biomass, which subsequently reduces the energy costs of compartmentation and extrusion of salts.

Reforestation is one of the most practical and effective strategies to solve the problem of soil salinity. Trees phyto-remediate the soil by lowering saline water table, utilising underground water and by decreasing the rate of water evaporation from soil surface (Barrett-Lennard 2002). However, a lack of information or, perhaps, a lack of salt-tolerant tree species is an important barrier to wide application of afforestation. Screening for salt tolerant genotypes has been investigated in many woody plant species such as Thai neem (*Azadirachta siamensis* Val.), olive (*Olea europaea* L.), eucalyptus (*Eucalyptus* sp.), acacia (*Accacia* sp.), pine (*Pinus* sp.), toothbrush tree (*Salvadora persica* L.) and mulberry (*Morus* sp.) (Cha-um and Kirdmanee 2008). The quantification of salt tolerance is not straightforward as it is confounded by several other factors related to both site and tree species. Aspects such as soil fertility, soil physical conditions, distribution of salt in the soil profile, climate, stage of tree development, variety, and rootstock are all thought to affect salt tolerance (Kozlowski 1997).

A substantial amount of research still needs to be carried out before salt tolerant tree genotypes can be reliably used on saline soils. To date, most of the available knowledge has been acquired through field trials of various species and their varieties and hybrids. For example, *Populus euphratica* Oliv. has long been recognised as one of the most salt-tolerant poplar species (Chen et al. 2002), together with *Populus deltoides* Marshall (Singh 1998) or *Populus alba* L (Imada et al. 2009). In Australia, *Eucalyptus camaldulensis* has been hybridised with *Eucalyptus grandis* and *Eucalyptus globulus* and subjected to field trials to combine the salt tolerance of the former with growth rate, stem form and wood properties of the latter two species (Dale and Dieters 2007). Similarly, several varieties of olive (*Olea europaea* L.), a major crop tree grown almost exclusively in the Mediterranean appear to be salt tolerant and merit further study, especially to assess long-term acclimation to salt stress (Chartzoulakis 2005).

At present, advances in plant genomics have presented a new opportunity to assess salt tolerance in trees. The genes responsible for the variability of salt tolerance could be valuable resources in breeding programs, but they are often difficult to identify since the responses identified in salt-stressed plants are often common to other stresses. Here, comparative genomics based on the comparison of genotypes differing in pheno-typical behaviour looks like a promising approach to identify genes that control the heritable genetic variation of salt tolerance (Beritognolo et al. 2008).

## 3.4 Fire

There is no species or vegetation that can withstand a furious fire. However, since not all fires are lethal, plant species have developed various adaptations and strategies to tolerate and to survive fire, both at individual and population level. There is therefore a need to distinguish between the survival of trees at the time or immediately after the fire event and the survival of the forest community over a longer time frame. Forest fires resulting from volcanic activity or due to meteorological phenomena have always been one of the main natural forces significantly influencing tree species morphological and anatomical traits, regeneration modes and life cycles (Bond and Keeley 2005). Not all fire events are the same, the frequency, intensity, duration and behaviour of each forest fire is governed by an interplay of several factors, such as climate (e.g. air temperature, relative humidity, wind velocity), fuel load, topography (e.g. slope incline) and several others. The heat load imposed on trees during a fire event is the main stress factor determining the level of disturbance and the survival of trees.

In addition to the characteristics of the fire itself, several anatomical, morphological and life cycle features contribute to tree survival. Persisting fire individually or at the population level, trees have evolved several strategies which are not mutually exclusive. These could be grouped into the following three categories:

(a) living tissue protection and enhancing survival during the fire, such as bark thickening (e.g., *Quercus suber* L.), reduced bark heat conductance (Vines 1968), trunk circumference and height growth rate, sapwood to heartwood area ratios (Gignoux et al. 1997, Wilson and Witkowski 2003, Nefabas and Gambiza 2007) or underground storage organs and contractile roots (Bond and van Wilgen 1996);

(2) stimulating regrowth after the fire, such as epicormic resprouting from preformed preventitious buds hidden within bark (e.g. *Pinus canariensis* Sweet ex *Spreng*), enhanced flowering, drought tolerance and short leaf life-span;

(3) post-fire seed dispersal and propagule persistence, such as cone serotiny and heat or smoke stimulated germination.

Perhaps surprisingly, the co-occurrence of these persistence features differs among the Mediterranean zones in the Northern Hemisphere, i.e. between California and the Mediterranean basin (Pausas et al. 2006). Propagule persistence and resprouting are negatively correlated in the Mediterranean Flora, hence they probably evolved under a parallel selection scenario. Resprouting capability is thought to have evolved in the Tertiary as the response to frequent fire disturbances (Pausas and Verdu 2005). Having said that, there are tree species which possess features from all three categories of fire resistance. For example *Pinus canariensis* Sweet ex Spreng, a pine endemic to the Canary Islands, is thus protected with serotinous cones, has sprouting ability and a thick bark (Climent et al. 2004).

Sprouting ability is common both in Angiosperms and Gymnosperms at the seedling stage and with maturation that ability declines. Within the Gymnosperms, only very few species such as *Pinus canariensis* Sweet ex Spreng or *Sequoia sempervirens* D.Don do not lose this feature. Commonly, sprouting ability is altered with age, plant size and severity of injury. Various trees display a complexity of resprouting behaviour; there are root collar sprouters; lignotubers sprouters (e.g., *Eucalyptus* sp).; sprouters from roots and from layered branches (Bond and Midgley 2003).

Seeding after fire means the production and development of a vegetative body (cone or fruit) that has the capability to protect the seeds from fire (serotiny), thus implying late liberation of seeds into the post-fire ecological conditions (bradychory). In the Northern hemisphere this feature has been developed mainly in Gymnosperms in the *Pinus* genus, whereas in the southern hemisphere, this feature has been developed in closed-fruited angiosperms. Since none of the pines native to the Mediterranean basin are able to resprout, their post-fire regeneration depends on their seedbank. The most common lowland Mediterranean pines, such as *P. halepensis* Mill., *P. brutia* Ten. And *P. pinaster* Ait, thus rely on the canopy seed bank being protected in the serotinous cones (Pausas et al. 2004).

Apart from volcanic activity, during the Holocene there have been no phenomena, other than dry lightning storms, that can act as an ignition source in the Mediterranean basin and Europe. However, since mankind acquired fire as a tool several hundred thousand years ago (James 1989), and with the world-wide spread of human population, purposefully set fires, runaway fires, arson fires, fires due to negligence and many other reasons, forest fires became frequent to such a degree that fire became a significant ecological factor in environments not naturally prone to fire. Tree populations and forest ecosystems adapted to a particular fire regime can offer us a reference point and act as a source of fire-adapted provenances. Any information originating from these localities, at ecological, managerial or genetic levels, is likely to be used to plant and maintain more fire resistant forests.

Forests communities' species composition might change profoundly with time as a result of climate change, but will also be influenced by local topography. South facing slopes will become dryer and hotter than north facing slopes. Hence, vulnerability to fire will differ among topographic orientations. Current Global Circulation Models predict a rise in temperatures and drought occurrence, leading to the development of climatic conditions even more enhancing the risk of fire in today's Mediterranean basin and wider geographic regions in the south and south-east Europe. The eventual new climatic conditions will affect the forest vegetation both in the short and in the long term as the result of (a) weakening and dieback of species genetically not adapted to drought and/or higher temperatures, (b) resulting changes in the species composition of today's forest communities by shifting species’ distribution area boundaries in relation to the new environmental conditions, and (c) changing soil properties resulting from severe and frequent fire events may affect belowground functionality and nutrient cycle (Neary et al. 1999).

Taking into account future scenarios of forest fires and increasing forest vulnerability to fire, it is of importance to take preparatory measures and include fire prevention in forest management plans. If the predictions related to climate change are correct, it will be increasingly useful to explore the existing knowledge on fire resistance in forest tree species, whether indigenous to the Mediterranean Basin or of other homologous climatic zones in the world. The utilisation of tree species which have developed the necessary features to withstand, slow down or even prevent the spread of fire (e.g., *Cupressus sempervirens* L. var *pyramidalis* (Italian cypress); *Tamarix* sp.) not normally used in forestry is likely to become the norm over an expanding area not just in the Mediterranean. Hand in hand with species selection, it will also be necessary to adapt forest management techniques to cope with fire and its damages to the forest (see Chapter 6).

## 3.5 Conclusion

As illustrated in this chapter, stress factors related to water scarcity, soil salinity and forest fires are ever present natural phenomena. Tree species have evolved a variety of physiological, structural and life-cycle mechanisms to deal with these factors. To deal with adverse impacts of climate change on forests, we need to design management and policy approaches which would make use of this bank of adaptations to ensure future stability and sustainability of European forests. For example, presented findings on fire and water stress resistance in trees may help to make optimum choices with regards to tree species choice in areas prone to soil erosion or intended as water overflow and retention zones during periods of flooding.

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