Monika Mándoki

Climate ≈ water

Bridging the gap between adaptation strategies of climate change impacts and European water policies

Funded by the Seventh Framework Programme

VITUKI, Nonprofit Kft.
(Partner No. 1)

Monika MÁNDOKI
(with contribution of
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Eszter TÓTH,
and UNILEI)

Topic 2.2.2 Impacts on terrestrial ecosystems

of
WP2.2 Water-related impacts on nature, the terrestrial and aquatic ecosystem

27.05.2010., Bratislava

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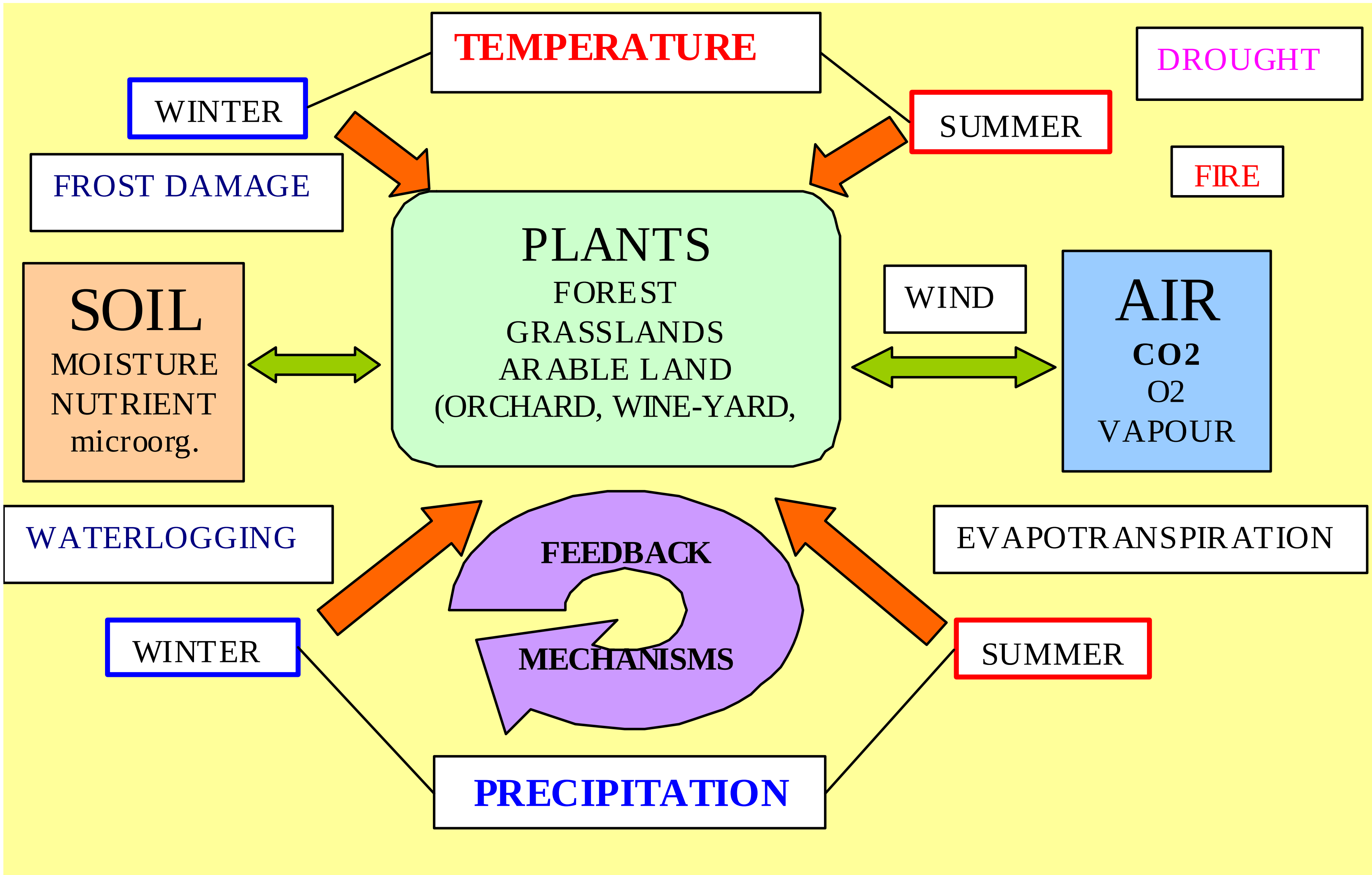

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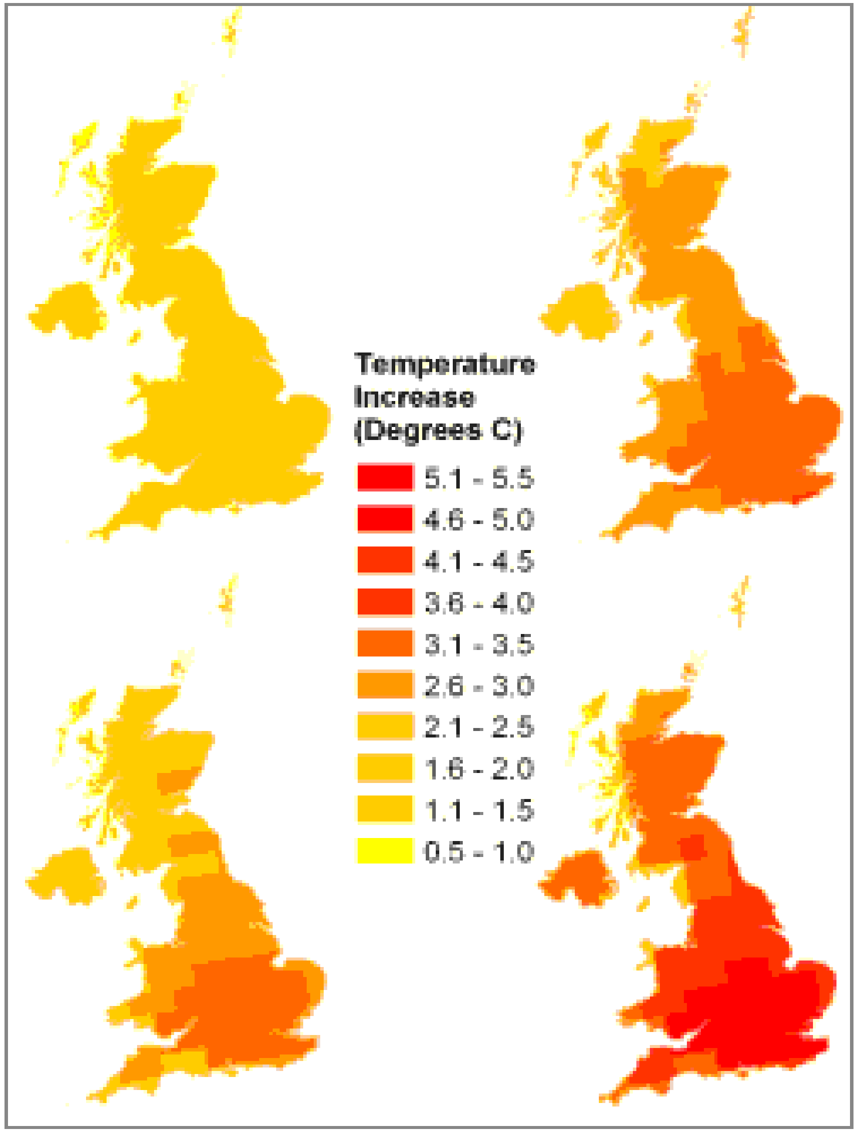
TEMPERATURE forecasts:

by 2080 for 4 emission scenarios **(UKCIP02 predictions)**



- Overall the UK climate will become warmer.
- The average annual temperature in the UK may rise by between 2°C-3.5°C (Low and High emission scenarios respectively) greater warming in the south and east rather than in the north and west
- There may be greater warming in summer and autumn than in winter and spring.
- High summer temperatures will become more frequent, whilst very cold winters will become increasingly rare .
- The temperature of UK coastal waters will also increase, although not as rapidly as over land

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545

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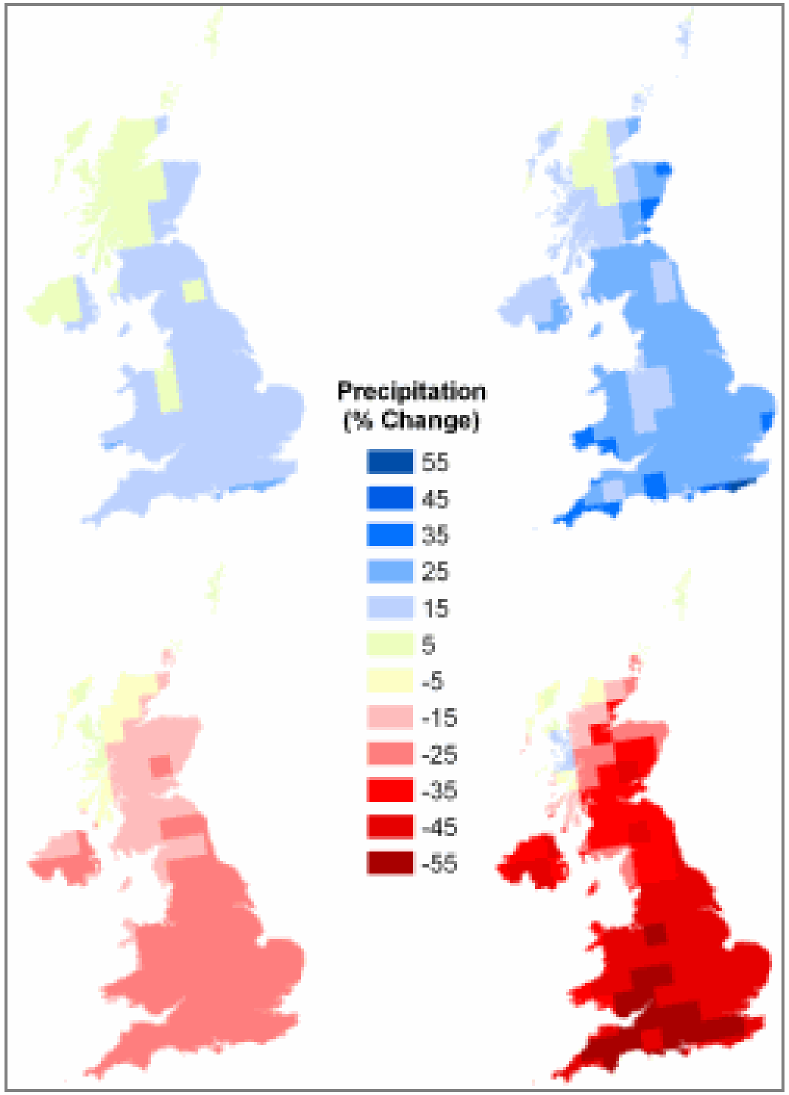
Precipitation (rain and snow)

forecasts: 2020, 2050, 2080



- Winters will become wetter
- Summers may become drier throughout the UK, the relative changes will be largest for the High emissions scenario and in the south and east of the UK
- Summer soil moisture by the 2080s may be reduced by 40% or more over large parts of England for the High emissions scenario
- Snowfall amounts will decrease
- Heavy winter precipitation will become more frequent .

UKCIP02 seasonal rainfall predictions (winter upper, summer lower) for the 2080s Low and High emission scenarios relative to the 1961-90 baseline

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545

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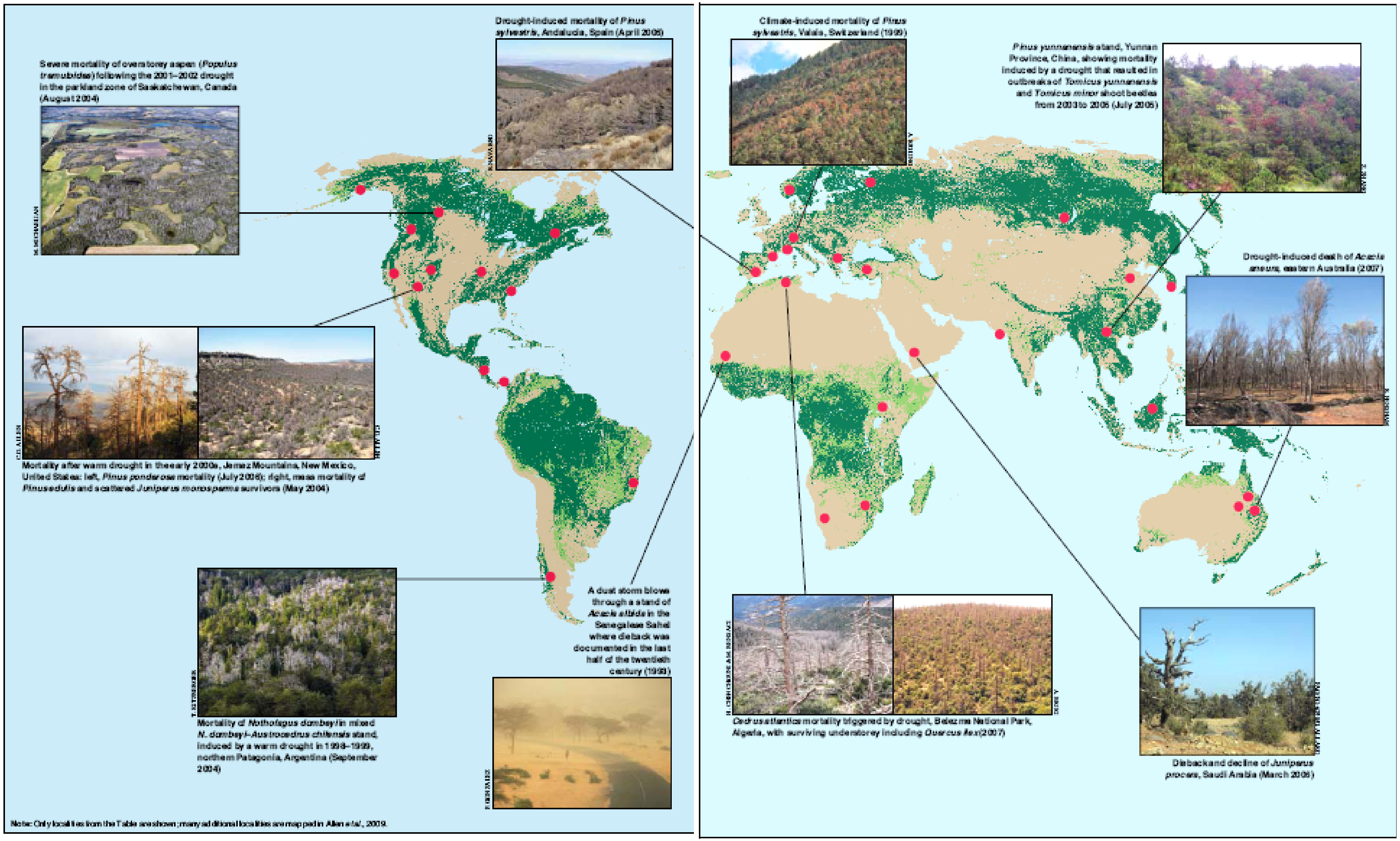
Localities with increased forest mortality related to climatic stress from drought and high temperatures



Climate-induced forest dieback: an escalating global phenomenon? C.D. Allen, Fort Collins Science Center, ftp://ftp.fao.org/docrep/fao/011/i0670e/i0670e10.pdf

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Fixation of the CO_2

- **CAM**

Crassulacean Acid Metabolism

- **Day/night**

- **C3 plants**
- Chlorophyl-a in mesophyll cells only,
- Common pathway (Calvin cycle)
- 3-phosphoglyceric acid
- RuBisCo (the first enzyme of Calvine cycle) carboxylase/oxygenase activity
- PHOTORESPIRATION pathway
- **18 ATP** / 1 molecule of glucose
- **At 30 °C 833 molecule water/ CO_2 is fixed**
- Convergent evolution, Miocene

Increased **water use efficiency** of **C4 grasses** means that **soil moisture is conserved**, allowing them to **grow** for longer **in arid environments**

- **C4 plants (separate in space in the cell)**
- Chlorophyl-a not only in mesophyll cells, but boundle sheath as well, Kranz antomy (wreath)
- **Malate** or aspartate (4-C atom organic acid) Pyruvate or alanine back
- More energy consuming (CO_2 is fixed twice)
- **30 ATP** / 1 molecule of glucose
- (tropical plants lose more than half of C in photorespiration)
- Dry, high temperatures, nitrogen or CO_2 limitation
- **At 30 °C only 277 molecule of water/ CO_2 is fixed**
- Increased water stress
- **5%** Earth's plant biomass
- **1%** of known plant species
- **30%** terrestrial Carbon fixation
- In the tropics (below 45° latitudes)

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Climate water

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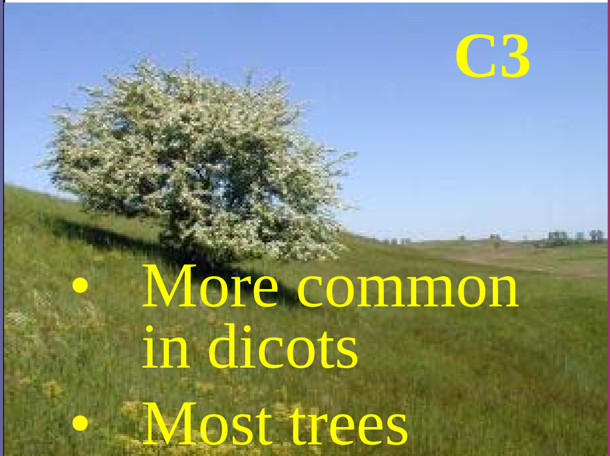

C3

- More common in dicots
- Most trees

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C4 - examples

7600 species

- **3% of terrestrial species of plant** only angiosperms,
- 3 families of monocots and 15 families of dicots
  - **Grasses** (Poaceae) 46% = 61% total C4
  - **Maize**,
  - **sugare cane**,
  - millet,
  - sorghum
  - Ciparaceae,
  - Asteraceae,
  - Caryophyllales,
  - Chenopodiaceae, 550 / 1400 species (Chenopods in salty dry deserts SE-Asia)
  - 250 /1000 species of Amaranthaceae
  - Brassicaceae,
  - Euphorbiaceae

(Source: Sage,Rowan, Russell Monson (1999): C4 Plant biology pp.228-229

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- **Carbon dioxide fertilization**
  is another pathway by which climate change could **directly affect** Pacific Northwest forests.
  Increased atmospheric concentrations of CO_2 tend to **increase the photosynthetic rate** and **water efficiency** of plants and trees,
  increasing their p**roductivity**.
  However, field studies find that **forests** often display a **minimal** growth **response** to increased levels of CO_2.
- It has been suggested that if such a fertilization mechanism exists, it may only be **transient**,
  yielding benefit for a **short period** of time
  until trees **adjust** to the elevated CO_2, or
  until the **stress** caused by higher temperatures
  overwhelms the positive effect of CO_2 fertilization.

CO_2 balance


Photo:István Fekete

•<u>sink</u> of carbon: FOREST

maximum carbon stock of about **250 tC ha-1** can be achieved in biomass in woodland.

healty, mature,

When woodland is mature, losses of carbon through **<u>respiration</u>** and **<u>decay</u>** **balance** **<u>uptake</u>** through **<u>photosynthesis</u>**

wood

- <u>source</u> of CO_2
  - microbial decomposition of dead leaves in soil


Photo:István Fekete

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- In comparison to herbaceous species, the **stomatal response** of trees to **elevated CO_2** is generally **weaker** and far **more variable**, adding to the uncertainty of future effects on real forest systems.
- While **oak** always showed large reductions in stomatal conductance at elevated CO_2, in **beech** this response was restricted to relatively cool, cloudy days. On hot, sunny days, there was no effect of CO_2 concentration on the stomatal conductance of beech.
- The degree of **stomatal closure** in elevated CO_2 was shown to be related to the **leaf-to-air vapour pressure deficit (LAVPD)**, the **main driving force** for evaporation from the leaves. Hence, during periods of high evaporative demand, when water economy should be most important, beech actually benefited *least* from CO_2 enrichment. Furthermore, during an **extended** period of **drought**, stomatal conductance of **beech** (*Fagus sylvatica*) was significantly ***increased*** **at elevated CO_2**, resulting in substantially **greater rates of soil moisture depletion**.
- CO_2 enrichment would result in substantially **reduced water use in oak (*Quercus sp.*)**; but in **beech** the effect would be **much smaller** than previously **expected**, due to the altered stomatal responses to LAVPD and soil moisture deficit. A further consequence of these results was that the protective effect of elevated CO_2 against **ozone uptake** (through reduced stomatal conductance) was also predicted to be substantially weaker in beech
- **Beech** has important landscape, amenity and commercial value (in the UK); it is already **very sensitive to drought,** so that even **small changes in tree water relations** could be **critical to growth and survival.** More generally, forest growth is often **limited by water availability**
- Indeed, patterns of **stomatal conductance** will themselves directly **influence future climates**, since the **rate of evaporation** from forests affects not only **humidity** and **precipitation** but **surface temperatures** as well.

Atmospheric CO2 enrichment and the growth and water relations of forests, by James Heath, Terry Mansfield & Gerhard Kerstiens http://biol.lancs.ac.uk/psi/research/forestry.html
Stomatal Conductance of Forest Species after Long-Term Exposure to Elevated CO2 Concentration: A Synthesis,
by B. E. Medlyn, C. V. M. Barton, M. S. J. Broadmeadow, R. Ceulemans, P. De Angelis, M. Forstreuter, M. Freeman, S. B. Jackson, S. Kellomäki, E. Laitat, A. Rey, P. Roberntz, B. D. Sigurdsson, J. Strassemeyer, K. Wang, P. S. Curtis and P. G. Jarvis

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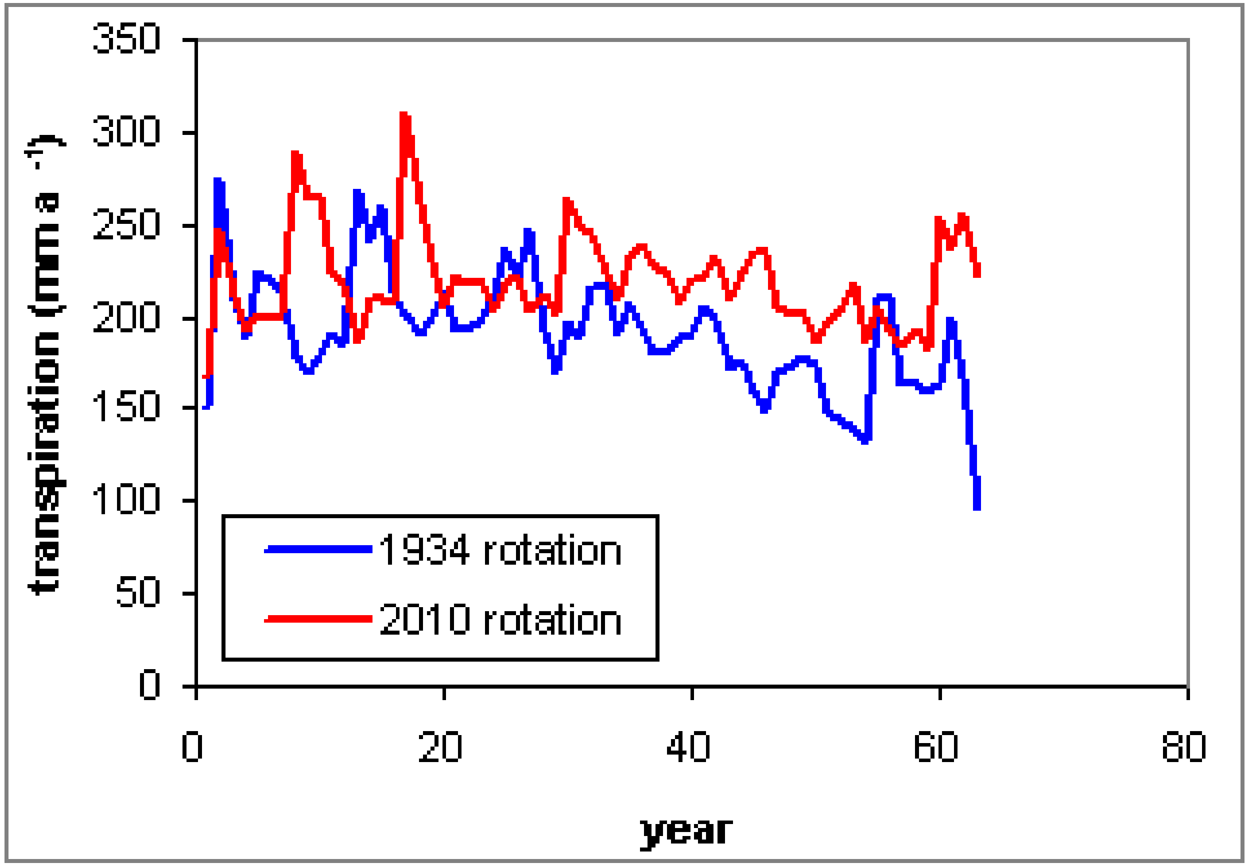

- **Canopy water use** expressed as total transpiration averaged over the entire rotation lengths

oak simulations, (i.e. ignoring canopy interception and evaporation)

  - 1934 rotation **191 mm/yr**
  - 2010 rotation **220 mm/yr**

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
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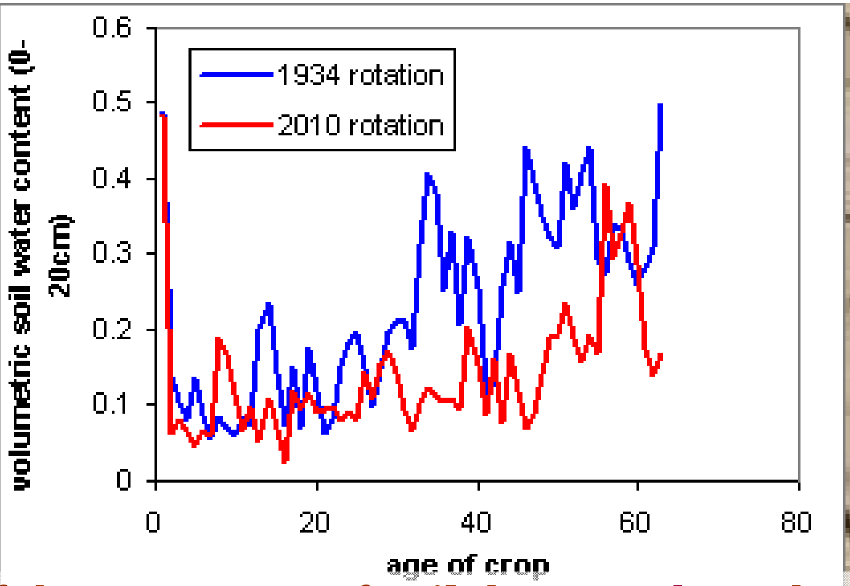

- the **moisture** content of the top 50 cm of **soil** during July and August was lower in the 2010 simulation than the baseline rotation average (23% vs. 16%)
  - simulation 1934 rotation average **23 %**
  - simulation 2010 rotation average **16 %**
    - soil moisture content also include losses resulting from increased canopy interception
- studies indicates significant reductions in stomatal conductance at elevated CO_2, there is also some evidence that for some species, elevated CO_2 reduces stomatal sensitivity to soil moisture deficits and VPD
  - that a simulation in which there was no stomatal closure to rising CO_2 did not show a reduction in yield as compared to the 2010 rotation
  - reduced carbon assimilation as a result of water limitation is **compensated** for by higher rates of assimilation (due to a lack of response to CO_2) when water is not limiting, thus potentially exacerbating summer droughts

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545

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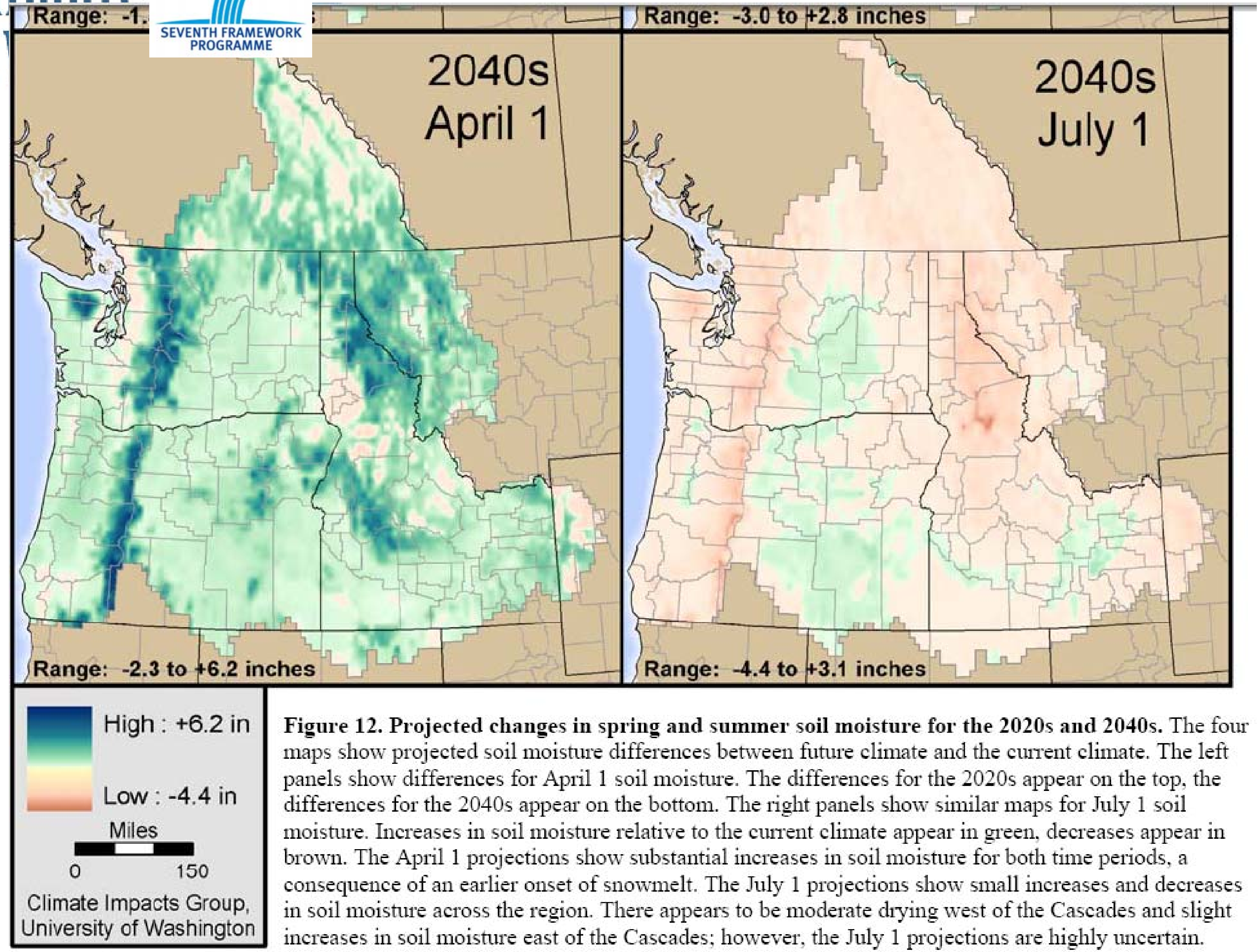

Figure 12. Projected changes in spring and summer soil moisture for the 2020s and 2040s. The four maps show projected soil moisture differences between future climate and the current climate. The left panels show differences for April 1 soil moisture. The differences for the 2020s appear on the top, the differences for the 2040s appear on the bottom. The right panels show similar maps for July 1 soil moisture. Increases in soil moisture relative to the current climate appear in green, decreases appear in brown. The April 1 projections show substantial increases in soil moisture for both time periods, a consequence of an earlier onset of snowmelt. The July 1 projections show small increases and decreases in soil moisture across the region. There appears to be moderate drying west of the Cascades and slight increases in soil moisture east of the Cascades; however, the July 1 projections are highly uncertain.

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Pests


2.bp.blogspot.com/.../Acanthocinus-griseus-1.jpg


Climate change impacts on goods and services of European mountain forests *M. Maroschek*
ftp://ftp.fao.org/docrep/fao/011/i0670e/i0670e16.pdf

- may become more prevalent, as higher temperatures enhance **reproduction rates**. Milder winters **could increase survival rates for insect larva and adult reproductive rates may increase, allowing pests to increase their abundance and migrate northward or up in elevation.**
  Pests could also capitalize on **heat- or moisture-stressed forests**, as these trees are **more susceptible to infestation**. Looking at the past decade, we see a potential harbinger of climate change impacts as the observed warming trend has been correlated with more frequent and severe outbreaks of **bark beetles** in the forests of the Pacific Northwest and British Columbia.
  The **interactions among fire and pest outbreaks** are often **two-way**: fire and pest disturbances can enhance one another. The presence of dead or weakened trees that have suffered pest infestation generally increases fire risk; areas that have experienced fires can provide ideal hatching grounds for insects.

Climate change implications for insect pests

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- Climate change is likely to alter the **balance** between insect pests, their **natural enemies** and their **hosts**; **predictions** of the impact of climate change on insect damage to UK forests are therefore **difficult to make**.
- One of the most important effects of climate change will be to **alter** the **synchrony** between **host** and **insect pest development**, particularly in spring, but also in autumn; the predicted rise in temperature will also generally favour insect development and **winter survival**, although there will be some exceptions.
- The green spruce **aphid** is one example of an insect that is likely to benefit from the increase in winter survival, leading to more intense and frequent tree **defoliation**. A decline in the productivity of Sitka spruce might therefore be expected.
- Modelling work suggests that under a warmer climate, **exotic pests** such as the **southern pine beetle** could **establish populations** in Europe, and that climatic warming could make UK forests susceptible to damage; other **bark beetles** such as *Ips typographus*, which is present in some parts of Europe, but not the UK, could become a serious problem.
- Rising atmospheric CO2 concentrations may lead to a decline in **food quality** for plant-feeding insects, as a result of **reduced foliar nitrogen levels**.
- Changes have already been observed in the distribution of **native European butterfly populations**, with **northern ranges extended** and **southern ranges reduced**. The same is likely to be the case for forest insect pests.
- The combined effects of increased global trafficking of timber and wood products and climate change are likely to result in exotic pests such as **Asian longhorn beetle** becoming more **prevalent**; it is therefore essential that we remain **vigilant** in reporting new pests and altered patterns of damage.

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545 Forestry Commission Publications Bulletin 125

Effects of climate change on fungal diseases of trees

- More difficult to predict the effects of climate change on **host–pathogen relationships** than on the individual organisms.
- The impact on those **pathogens** whose **reproduction or dispersal** is clearly affected by temperature is relatively predictable.
- **Warmer summers** may in particular **favour** certain **thermophilic rust fungi** on poplar, which are currently rare or non-native in Britain; this has important implications for poplar breeding programmes.
- **Insect vectors of pathogens** such as the fungi causing ***Dutch elm disease*** are likely to respond to warmer summers **by extending their geographic ranges** and hence the ranges of disease incidence.
- The likely effects of higher year-round temperatures have been modelled in the case of *Phytophthora cinnamomi*, a very widespread fungus which causes root and stem-base diseases of a wide range of broadleaved and coniferous species. The models show a probable significant increase in the activity of this fungus across the UK and Europe in general.
- **Warmer winters** may increase the activity of some **weak pathogens**, such as *Phacidium coniferarum*, which are **active only when the host is dormant**.
- An increased incidence of summer drought would probably favour diseases caused by fungi whose **activity is dependent on host stress**, particularly root pathogens and latent colonisers of **sapwood**.
- A reduction in the number of summer rain-days may **reduce the incidence of various foliar diseases** such as **Marssonia** leaf spot of poplar. Generally, however, it is difficult to predict the impact of climate change on **pathogens whose reproduction or dispersal is strongly affected by rainfall or humidity.**
- The protective effects of mycorrhizas against various root diseases may be altered by changes in the relative fitness of different **mycorrhizal fungi** under conditions of altered soil temperature or moisture regime.

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
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Summer drought

- Stress for photosynthesis
- Less soil moisture
- Less productivity
- Increased mortality
- RISK of **FIRE**

Source: cdn.webecoist.com/.../2008/10/forest-fire.jpg

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- "…In southern Europe, warming and, particularly, increased **drought,** are likely to lead to reduced plant growth and primary productivity, **reduced** nutrient turnover and nutrient availability, altered plant recruitment, changed phenology, and changed species interactions…" „…Furthermore, increased **torrentiality** is likely to lead to increased erosion risk due to reduced plant regeneration after **frequent fires**."

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- Fire
- Pests
- Frost or wind or drought triggered damaged trees,
- Forest management: clear cut rotation
- On the slopes of hills or mountains
- **EROSION** increases (soil wash away)

Water quality

Inability of forest recovery (karstic hills in the Mediterranean)

Changing wind climate as a result of climate change

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- **Mortality** of young plants through desiccation or toppling
- Restriction of **growth**
- Effects upon tree form through branch and leader loss
- Mortality through **windthrow** and wind snap.
- larger **leaf area** resulting in increased **wind resistance** and thus vulnerability

- A more southerly storm track
- A shift in the seasonal pattern of windiness, resulting in an increase in autumnal windiness and a decline in summer windiness
  A slight increase in **mean** windspeed
- A possible increase in the **frequency** of gales
- The increases in winter windspeed may be largest in the south.
- the **magnitude** of these predicted changes is generally less than the inter-annual variability that we would expect to occur naturally.
- **EROSION**

•Climate change could have **indirect consequences** for wind risk management, including:

•changes to the frequency and duration of **waterlogging**;
increased frequency of **wet snow** leading to more snow damage;
•**larger leaf area** resulting in increased wind resistance and thus vulnerability.

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
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Effects of the predicted changes in temperature

- **Winter cold injury** may become less frequent
- The changes in **spring flushing** data that have already been observed will continue to advance, however may make some species more susceptible to the risk of spring **frost injury**,
- The planting of **southern provenances** in anticipation of climate change should be avoided, because of the potential damage of unseasonal frosts,
- **Autumn frost** may become more damaging in England because of **later hardening** ,
- **Increasing heat and drought** in the south and east can be expected to increase losses, particularly among **newly established trees** and mature trees in hedgerows and urban environments,
- Defects in **conifer timber** due to **crack** are also likely to increase in England.

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
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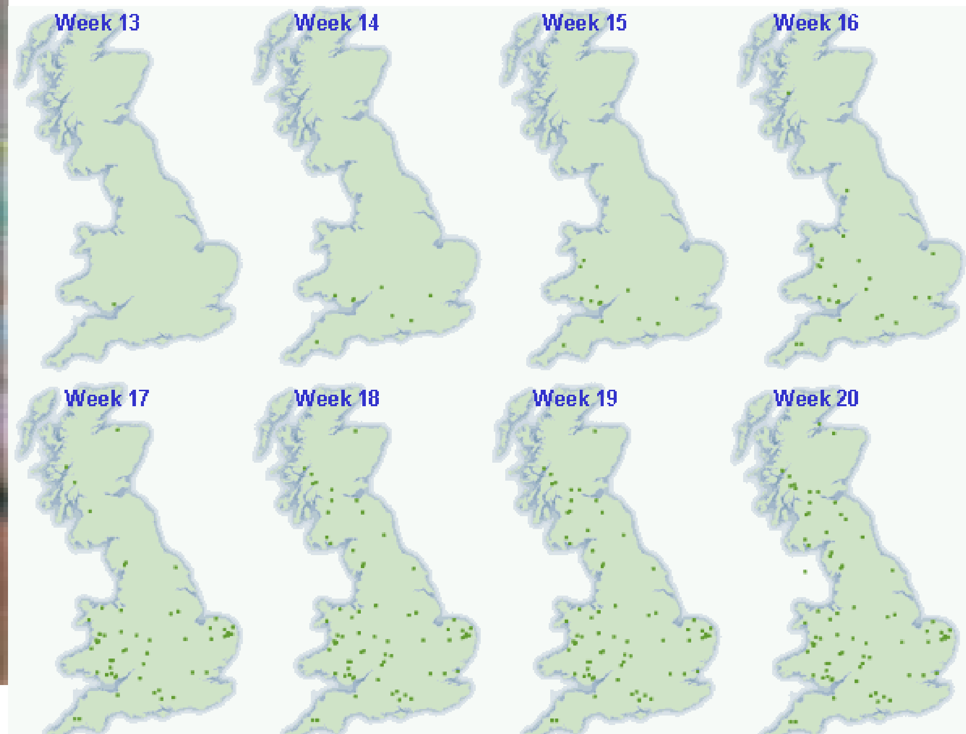
Phenology



Observed budburst in oak based on responses received by the FC/RSPB Wildsquare project in 2001

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
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Climate change and the seasonality of woodland flora and fauna

- **Phenology** is a significant resource allowing us to examine how species have responded to natural temperature variation in the past, and also to ongoing anthropogenically-driven climate change.
- The temperature response of spring activity has been examined for a wide range of **native flora and fauna**.
- Documented **changes in timing** in recent decades have been very marked with **spring activity** of several species advancing by up to a **month**.
- Changes appear to be more marked in the UK than elsewhere in Europe and are **stronger for plants and invertebrates than for vertebrates**.
- Differences in species response to temperature may result in an altered competitive advantage and thus to a **changed community composition** in the future.
- The consequences of a changed **phenology** must not be considered in isolation from other direct climate-change-related problems such as changed **frequency of extreme events** (drought, flood, storms) or through **indirect effects** such as **land use change or habitat fragmentation.**

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
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- **Less natural areas (2000 - 2050 with 7,5 mill. km^2; with 15-25%)**

•More arable land

Photo © János Scheffer

Source: Scheffer János: www.schefferj.ps.hu/.../Pilis_Panorama.jpg

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- Populations of **deer** and **squirrels** are **adversely affected** by **cool, wet weather**, through **reducing food availability and increasing mortality**.
- Predicted climate change is therefore likely to result in **increased population densities** and ranges if **appropriate control measures** are not put in place.

Photo: **Remo Savisaar** http://www.hellohunter.info/upload/images/szarvas1.jpg

Forest - habitat

- Decreased area of forest in the Mediterranean (Fagus sylvatica have already shifted towards higher elevations during recent decades in Spain.)
- Overpopulation of game stocks
- Overgrazing the grasslands
  - changing the interception, infiltration, runoff
- Increase the loss of habitats

Photo: http://www.hellohunter.info/upload/images/szarvas1.jpg

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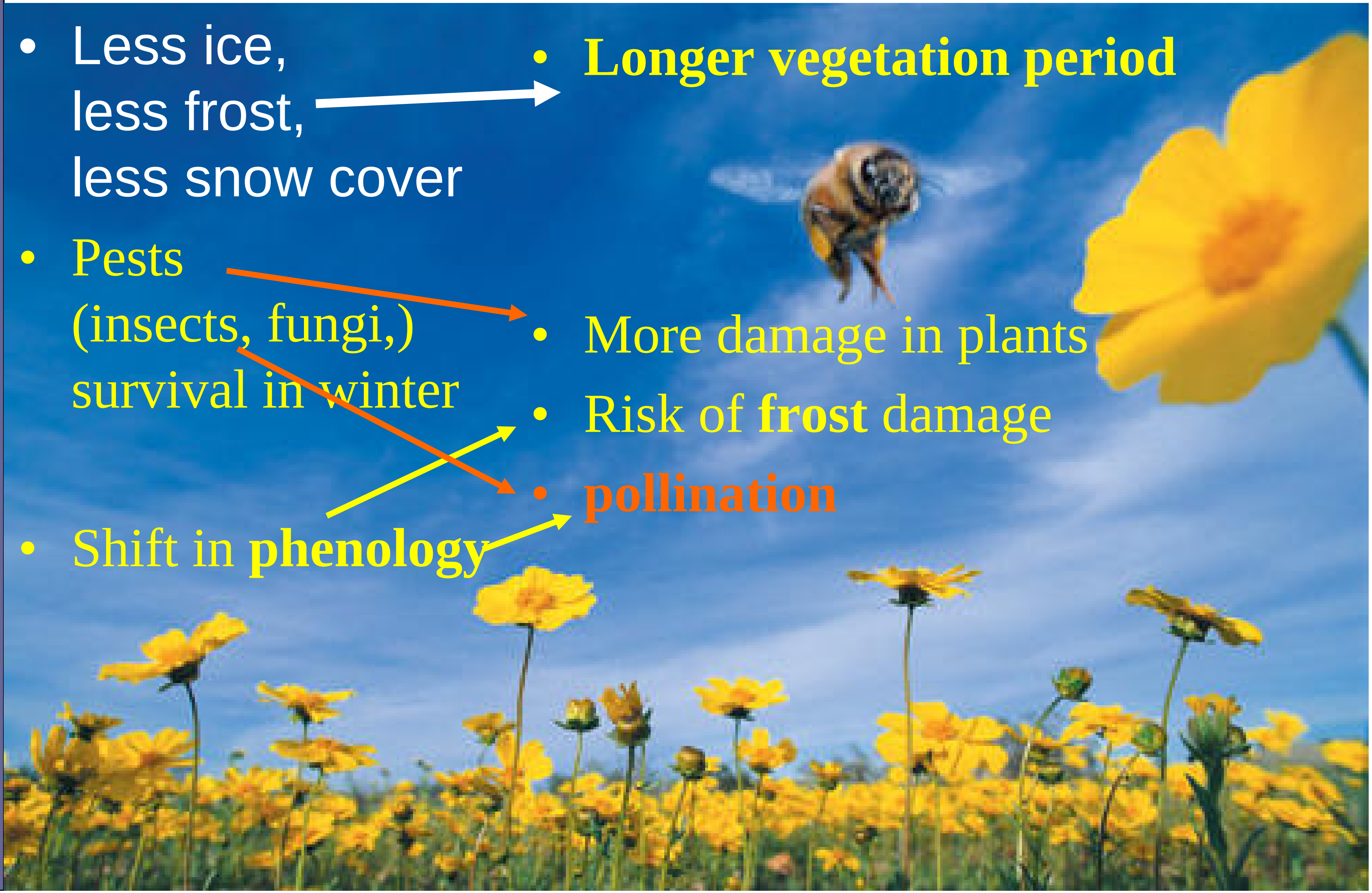
- **HABITAT**
- Ramsar sites
- Refugies
- Nesting birds
- **New species** appear from South
- **Migration** pathways changing

Photo:http://www.google.hu/imgres?imgurl=http://www.dinpi.hu/_user/browser/Image/nyari_lud_csonkapeter_8749.jpg&imgrefurl=http://www.dinpi.hu/print.php%3Fpg%3Dnews_42_1436%26nyelv%3D0&usg=__7XoL9DTTuiJj1aQwG_tQn7udP-U=&h=533&w=800&sz=33&hl=hu&start=27&um=1&itbs=1&tbnid=FP0agbNimRYlCM:&tbnh=95&tbnw=143&prev=/images%3Fq%3Dny%25C3%25A1ri%2Bl%25C3%25BAd%26start%3D18%26um%3D1%26hl%3Dhu%26sa%3DN%26rls%3Dcom.microsoft:hu:IE-SearchBox%26rlz%3D1I7GPEA_enHU290%26ndsp%3D18%26tbs%3Disch:1

Temperature increase winter warmer/milder



- Less ice,
  less frost,
  less snow cover
- Pests
  (insects, fungi,)
  survival in winter
- Shift in **phenology**

- **Longer vegetation period**
- More damage in plants
- Risk of **frost** damage
- **pollination**

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How will the increased occurrence of **summer drought** conditions effect trees?

- Initially the establishment of young trees may become more difficult
- Eventually the suitability and **distribution** of some species will change
- **Stress** caused by drought will make trees more **susceptible to pathogens**
- The predicted **increase in the severity and frequency of summer droughts** are likely to have the **most profound effects on trees** and woodland **of any of the climate change predictions**, particularly in the south of the UK.

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
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- Changes in plant growth
- Less CO_2 fixed
- Less mitigation effect on climate change
- Different species
- Different community
- Changes in longitudinal and altitudinal occurence/ abundance
  - *Fagus sylvatica* have already shifted towards higher elevations during recent decades in Spain.

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- Coniferous - deciduous forests
- Evaporation
- **Runoff**
- Hydrology of rivers
- Less precipitation
- More water use
- Groundwater level sinks
- Damage water budget
- **Transboudary Water Management** needed!

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Photo:Násfai Béla

- Warmer temperatures would lengthen the growing season for mature trees and enhance seedling establishment by reducing snowpack.
- However, for subalpine firs in lower elevation forests, forest extent and productivity are limited by summer soil moisture.
- Increased temperature and earlier snowmelt would likely enhance summer drought stress, especially if summer precipitation is also reduced.
- Productivity and regeneration of subalpine firs at lower elevations would likely decline as the species faces more frequent and longer lasting droughts.

- The **2010 simulation** of rising atmospheric CO_2 concentration and climate change suggests a relatively **large increase in production**,
- This is likely to be a result of both the lengthening growing season and the CO_2 fertilisation effect (CFE). The magnitude of this increase is surprising, given the predicted reduction in summer rainfall (up to 25%), and **increases in evaporative demand**.
- The simulations also predict a modest **increase in leaf area** (mean leaf area index rises from 4.4 to 5.2), which would **increase** both **interception** and **transpiration losses**, making the effects of the predicted droughts more severe. This is compensated for by the **reduction in stomatal conductance** in response to elevated CO_2.

Snow

Photo:Mándoki Monika

Photo:Mándoki Monika

- **Snowfall** and thus **snow damage** will become **less frequent** as a result of rising temperatures.
- However, concerns have been raised that **wetter snow** and **heavier falls** may cause **more serious damage to tree crops**, thus potentially **counteracting** the generally lower incidence of snow fall that is predicted.

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Effects of **wetter winters**

- Winter **waterlogging** will affect the **trafficability** of forest soils and will limit access for harvesting machinery
- Forest on waterlogged soils are more **prone to windthrow**
- Waterlogging of soils leads to the **death of fine roots**, this can make the effects of high **summer soil water deficits** worse
- Infection by various **soil-borne pathogens** is promoted by fluctuating water tables.

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
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Implications of climate change: soil and water

- Climate change can be expected to have a fundamental effect on soil properties and processes, and a direct impact on water resources.
- There is concern that global warming could result in a long-term loss of soil carbon stocks; however, the general view for temperate forests is that **productivity** currently **exceeds soil organic matter decomposition**, and global warming plus rising CO_2 concentrations are likely to enhance **carbon storage** for at least the **next 50–100 years**.
- Soil wetness, waterlogging and flooding are predicted to increase in winter (throughout the UK); wetter soils will **reduce trafficability** and **increase** the risk of **soil damage and erosion**; an increased incidence of **waterlogging** will also reduce root survival and tree stability.
- Opportunities for the **restoration** of floodplain woodland are likely to increase, with possible attendant **benefits of flood control**.
- An increased frequency and severity of **summer droughts** is thought likely, and would threaten tree health and survival.
- An increased risk of **water shortages** in the south will require greater consideration to be given to the water use of trees and the need for better **catchment management planning.**
- The mobility, retention, dilution and in-stream processing of **pollutants** may be affected by climate change; enhanced **acidification**, **eutrophication** and the discoloration of water supplies will continue to be important issues.
- **Freshwater biota** could be threatened by higher **water temperatures** and **altered river flows**.

Source: Scheffer János http://www.schefferj.ps.hu/AerialPhotos.htm

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Extremities in weather

- „Fagyosszentek" „Freazing Saints"
- Flash flood
- Wind storms

- Structural damage (breaking trees)
- Physiological (less NPP = net primary production)
- Less fruits/crops

source: www.tarpa.eu/home/fotok/arviz/tarpa4.jpg

source: www.agrobio.hu/images_upload/belvíz.jpg

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The table below is a summary of the key changes in atmospheric and meteorological variables that affect tree growth and it explains the likely effects that any changes may have in the future. More details of the likely impacts of changes to each environmental variable are in annexes.

Variable	Beneficial effect	Detrimental effect
Atmospheric carbon dioxide	Increase in growth rate. Reduction in stomatal conductance. Increased water use efficiency.	Increase in leaf area and thus higher wind resistance Possibe effects on ground vegetation. Reduction in timber quality. Possible nutrient imbalances.
Ozone pollution	None	Reduction in growth rate. Impared stomatal regulation - increased susceptability to drought.
Temperature	Longer growing season. Increased potential productivity. Lower risk of winter cold damage. Less snow damage. Potential use of species that are not hardy at present.	Delayed hardening. Risk of spring and autumn frost damage possibly increased. Longer growing season reducing winter soil water recharge period. Reduced winter mortality of insect and mammalian pests. More rapid development and increased fecundity of insect and mammal pest. Potential for exotic/alian pests to spread.
Rainfall	Reduced intensity of some foliar pathogens.	Winter waterlogging limiting access for forest operations. Reduced tree stability. Root death increasing susceptability to drought and soil bourne pathogens. Summer drought induced mortality.
Wind	None	Increased risk of wind damage.
Cloud cover	Increased potential productivity	Increased diurnal temperature range in autumn - increased risk of frost damage.

Source: Climate change: impacts on UK forests, http://www.forestry.gov.uk/website/publications.nsf/WebpubsbyISBN/0855385545
Forestry Commission Publications Bulletin 125

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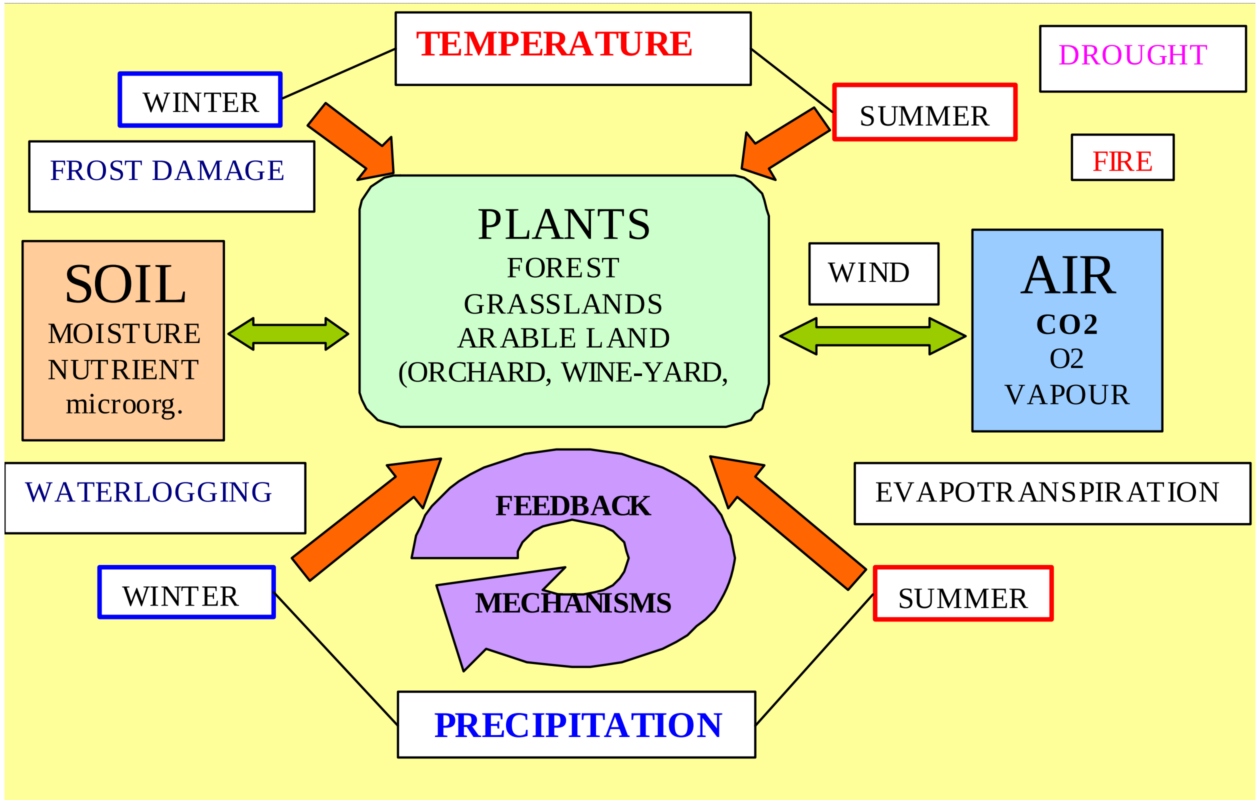

- HYDROLOOGIC CYCLE
  - INTERCEPTION,
  - INFILTRATION,
  - RUNOFF
- FLOOD - DROUGH
- EXTREMITIES
- EVAPOTRANSPIRATION
- CO_2 FIXATION: C3 - C4 - (CAM)
  - PHOTORESPIRATION
- PESTS
- different vulnerability – susceptibility of species

- **PHOTOSYNTHESIS**

PRIMARY PRODUCTION
  - quality of tissues
- FOOD - HERBIVORUS
- **HABITAT**
  - fragmentation
- SHIFTS
  - latitudinal
  - altitudinal
- **ECOSYSTEM !!!**
- **FEEDBACK MECHANISMS**

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Thank you for your attention!

photo:http://www.google.hu/imgres?imgurl=http://ismeret.virtus.hu/user_gfx/20080905/tn_aid6929_20080905194406_783.jpeg&imgrefurl=http://ismeret.virtus.hu/%3Fid%3Ddetailed_article%26aid%3D52202&usg=__Py4jssbnPUbhd_ebrB9p4mvQfGM=&h=320&w=400&sz=17&hl=hu&start=1&um=1&itbs=1&tbnid=bSLTk0Ff51kZtM:&tbnh=99&tbnw=124&prev=/images%3Fq%3D20080905194406%26um%3D1%26hl%3Dhu%26rls%3Dcom.microsoft:hu:IE-SearchBox%26rlz%3D1I7GPEA_enHU290%26tbs%3Disch:1

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What will be affected first?

- Initially, the impacts of climate change are likely to be most serious and apparent in southern England, particularly on the more freely draining soils.
- Young and newly established trees, together with street trees and trees in hedgerows are likely to be the first affected.
- The productivity of many species will fall, while mortality will increase, both as a result of more frequent and intense summer droughts.
  Species suitability will change, and it is therefore important to consider the planting stock in **adaptating** to climate change.

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- **indirect** consequences of environmental and climatic change have not been addressed such as
- changing **insect** and **disease epidemiology**, nor has **nutrient** availability,
- which may become **limiting** as a result of increased growth rates,
- management practice or reductions in **atmospheric deposition**.

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- The **2010 simulation** of rising atmospheric CO_2 concentration and climate change suggests a relatively **large increase in production**, with the site index rising from GYC4-6 to GYC6-8.
- This is likely to be a result of both the lengthening growing season and the CO_2 fertilisation effect (CFE). The magnitude of this increase is surprising, given the predicted reduction in summer rainfall (up to 25%), and **increases in evaporative demand**.
- The simulations also predict a modest increase in leaf area (mean leaf area index rises from 4.4 to 5.2), which would **increase** both **interception** and **transpiration losses**, making the effects of the predicted droughts more severe. This is compensated for by the **reduction in stomatal conductance** in response to elevated CO_2.

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