

## CLIMATE CHANGE AND ITS POTENTIAL EFFECTS ON TREE LINE POSITION: AN INTRODUCTION AND ANALYSIS

Mukti Ram Subedi

Institute of Forestry Pokhara Campus Pokhara

Email: suvedimukti@gmail.com

### Abstract

*Global warming is a real, rapidly advancing, and widespread threat facing humanity this century. Climate change is expected to accelerate water cycles and thereby increase the available, renewable freshwater. Recent observations suggest that at global scales, rapid environmental changes may be altering the structure, composition and dynamics of forests. Predicted global warming will probably affect range sizes and the geographical distribution of biota. Climatically determined ecotones, arctic and alpine treelines are assumed to be particularly sensitive to altered temperature regimes and climate warming is expected to drive treelines upslope and poleward at the expense of alpine and arctic ecosystems, respectively. Currently, there is much interest in the rate at which the tree line may advance in response to environmental change, especially global warming. The reason for the renewed interest in tree lines is clear: an advancing tree line, or a denser forest below the tree line, would have important implications for the global carbon cycle (increasing the terrestrial carbon sink) and for biodiversity of the alpine ecotone (possibly ousting rare species and disrupting alpine and arctic plant communities).*

**Key words:** Climate Change, GHGs, Global warming, Impact, Treeline

### INTRODUCTION TO GLOBAL WARMING AND CLIMATE CHANGE

There is a worldwide consensus that global warming is a real, rapidly advancing, and widespread threat facing humanity this century. Scientists have presented evidence and tested models to substantiate this truly alarming fact (Permesan 1996, Pounds et al. 1999, IPCC 2001, Woodward 2002, Klanderud and Birks 2003, Hall and Fagre 2003 in Chaudhari and Aryal 2009). Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods’. Climate change is expected to accelerate water cycles and thereby increase the available, renewable freshwater resources (Oki and Kanae 2006). The impacts of climate are superimposed on a variety of environmental and social stresses, many of them already recognised as severe (Ives and Messerli 1989), causing uncertainty (Thompson and Warburton 1985), and leading to contradictory perceptions (Ives 2004).

Climate Change is the result of a great many factors including the dynamic processes of the Earth itself, external forces including variations in sunlight intensity, and more recently exacerbated by anthropogenic activities such as deforestation, agriculture, industries, automobiles, and the burning of fossil fuels, are contributing to Greenhouse Gas (GHG) emission, a major cause of global warming (IPCC 2001). External factors that can shape climate are often called climate forcings and include such processes as variations in solar radiations, deviations in the Earth's orbit, and the level of greenhouse gas concentrations. Six main greenhouse gases are carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) (which is 20 times as potent a greenhouse gas as carbon dioxide) and nitrous oxide (N<sub>2</sub>O), plus three fluorinated industrial gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF<sub>6</sub>). Water vapor is also considered a greenhouse gas.

Temperature and moisture regimes are among the key variables that determine the distribution, growth and productivity, and reproduction of plants and animals. Changes in hydrology can influence species in a variety of ways, but the most completely understood processes are those that link moisture availability with intrinsic thresholds that govern metabolic and reproductive processes (Burkett *et al.*, 2005). The changes in climate that are anticipated in the coming decades will have diverse effects on moisture availability, ranging from alterations in the timing and volume of streamflow to the lowering of water levels in many wetlands, the expansion of thermokarst lakes in the Arctic, and a decline in mist water availability in tropical mountain forests (Bates *et al.*, 2008).

Recent observations suggest that at global scales, rapid environmental changes may be altering the structure, composition and dynamics of forests. For example, over the last several decades average global forest Net Primary Productivity (NPP) apparently has increased, perhaps due to various combinations of increasing temperature, precipitation, cloudless days, atmospheric CO<sub>2</sub> and nutrient deposition (Boisvenue & Running 2006).

### **MODELING CLIMATE CHANGE DRIVEN TREE LINE SHIFT**

Various definitions have been used to describe the upper limits of forests on high mountains. Körner and Paulsen, 2004 define “timberline” as the upper limit of closed forest and the “tree-limit ecocline” as the climatically sensitive zone between the timberline and alpine communities that are characterized by the occurrence of trees >2 m in height, as well as shrub and herbaceous species (Tinner and Theurillat, 2003). Sometimes these two zones are collectively known as “treeline” (baker and, moseley 2007).

In search of a functional explanation for climatic tree line positions globally, a recent model suggests a  $6.7 \pm 0.8^{\circ}\text{C}$  mean growing season temperature threshold (Körner & Paulsen 2004). The consistency of this tree line isotherm, irrespective of latitude, season length, geology, moisture regime and tree taxa suggests a common low temperature impact on plant metabolism (Hoch & Körner 2003), either related to carbon gain (source activity, photosynthesis) or sink activity (tissue formation).

Various researchers presented different models vary from process-oriented, causal models (Loehle and LeBlanc, 1996, Bugmann, 2001, Lischke et al., 2007) to more empirical indicator-driven (Körner, 1998, Jobbagy and Jackson, 2000, Grace et al., 2002, Körner and Paulsen, 2004, Moen et al., 2004) or dendrochronological analyses (Tessier et al., 1997, Briffa et al., 2004). Some of these models focus on the description of actual treelines and specific aspects or timeframes such as species composition, growth simulations or historic reproduction of treelines, while others try to investigate drivers such as climatic changes, land use intensity, topographic elements or natural hazards to simulate treeline dynamics or spatial changes. However, to date no comprehensive complex model covering all criteria to determine current and future treeline is developed. Therefore, large spatial scale representations of models and scenarios are currently limited to describing “potential” treeline positions or developments using selected limiting factors, the most important of which being the temperature limitations (Garing-Faser, 2007).

Predicted global warming will probably affect range sizes and the geographical distribution of biota (e.g. Grabherr *et al.* 1994; Parmesan 1996; Sturm *et al.* 2001; Thomas *et al.* 2001; Walther *et al.* 2002; Parmesan & Yohe 2003). As climatically determined ecotones, arctic and alpine treelines are assumed to be particularly sensitive to altered temperature regimes and climate warming is expected to drive treelines upslope and poleward at the expense of alpine and arctic ecosystems, respectively (Kittel *et al.* 2000; Hansen *et al.* 2001; Theurillat & Guisan 2001). However, study made by Gehrig-Fasel *et al.*, (2007) in Swiss alps find that treelines have been shown to respond slowly to recent climate changes. Moreover, several field studies and remote sensing analyses that have investigated recent treeline shifts in response to increasing temperatures during the last century have provided ambiguous results that span the whole gradient from rapid dynamics to apparently complete inertia (e.g. Kullman 1993; Lavoie & Payette 1994; Szeicz & MacDonald 1995; Hessel & Baker 1997; Meshinev *et al.* 2000; Cullen *et al.* 2001; Masek 2001; Motta & Nola 2001; Sturm *et al.* 2001; Klasner & Fagre 2002; Kullman 2002). Apart from variation in regional climatic trends, these equivocal findings probably result from differences between individual treeline systems.

Treeline elevations seem to be correlated more strongly with temperature than with any other variable (Grace, 1989). The latitudinal gradient in alpine treeline elevation indicates that this is a global scale control (the suggested  $-40^{\circ}\text{C}$  isotherm limit (Becwar *et al.*, 1981).

The multiplicity of exogenous factors and the nonlinearity introduced by endogenous factors make problematic the interpretation of alpine treelines as indicators of climatic change (Kupfer and Cairns, 1996; Malanson, 1999, 2001; Lloyd *et al.*, 2002; Cairns and Waldron, 2003). To the extent that tree ring data can resolve a decadal scale, however, a treeline can show definitive responses to climatic variability (Alftine *et al.* 2003). In fact, tree line responses to the global warming over the last century have been detected in many parts of the Northern Hemisphere (Rocheffort *et al.* 1994; Peterson *et al.* 2002 adapted from Rainwald 2008).

### **IMPACT OF CLIMATE CHANGE ON TREE LINE**

Photosynthetic rates and carbon allocation of trees are influenced by leaf and root temperature (e.g., Korner, 1998). Temperature also affects snowmelt and soil thaw, and the presence of late lying snow influences photosynthesis (Lehner and Lutz, 2003). Alpine treelines

also respond to the availability of water (Grace, 1989; Hessel and Baker, 1997a; Lloyd, 1997) and can be relatively dry environments. Alpine treelines are typically subject to high wind velocities. Deformed and flagged trees and migrating tree islands demonstrate the influence of wind on growth form (Marr, 1977; Holtmeier and Broll, 1992). Wind affects the actual precipitation by redistributing snow, often removing it altogether from treeline locations, and can increase evapotranspiration, thus exacerbating water shortages (Hiemstra et al., 2002). Snow may be the most important single climatic factor at some treelines (Walker et al., 1993, 2001).

The interaction of many exogenous factors make it difficult to assess what treeline change may indicate. A number of endogenous factors, including competition with tundra species and negative and positive feedbacks between plants and microclimate can interfere with interpretation of climatic signals (Malanson and Butler, 1994; Malanson, 1997; Korner, 1998; Alftine and Malanson, 2004), the positive feedbacks introducing nonlinearity (Malanson, 1999, 2001; Lloyd et al., 2002; Cairns and Waldron, 2003).

Currently, there is much interest in the rate at which the tree line may advance in response to environmental change, especially global warming. There are at least three aspects of environmental change to which plants are generally thought to respond: increasing temperature, rising concentration of carbon dioxide, and increasing deposition of nitrogen. There may be other contributing factors which are poorly understood: for example, the decrease in solar radiation as a result of increases in cloudiness or aerosols may be especially important at the tree line (Stanhill and Cohen, 2001). The reason for the renewed interest in tree lines is clear: an advancing tree line, or a denser forest below the tree line, would have important implications for the global carbon cycle (increasing the terrestrial carbon sink) and for biodiversity of the alpine ecotone (possibly ousting rare species and disrupting alpine and arctic plant communities). It would also change drastically the montane landscapes and the livelihood of their inhabitants.

Stevens and Fox (1991) emphasized the idea that the size and complexity of trees cause, at the tree line, a particularly unfavourable balance between resource acquisition and consumption. Herbaceous plants, on the other hand, have a much more favourable relationship between productive tissues and their support structures, which may explain their predominance above the tree line.

#### CONCLUSION:

There is abundant evidence that changes in many aspect of biota are already underway in response to recent climate change eg, shifts of species range poleward and to higher elevation. However, several investigations show the ambiguous results. Under continuing climate change each tree species will be affected in particular ways and ranges will adjust at different rates and by different process. Few major ecosystem types are likely to be lost entirely, because of physical limits, barriers to the movement of key species, or the complete loss of the required climate conditions. Climate change will be the particularly important factor in ecosystem impacts. With advancing treelines, species with restricted niche widths may experience severe fragmentation or loss of habitats or even become extinct. More generally, plant communities and species compositions are expected to change both as an effect of a possible climate change and as an effect of altered competition followed by treeline shifts.

#### REFERENCES:

- Alftine, K. J. and Malanson, G. P. (2004) Directional positive feedback and pattern at an alpine tree line. *Journal of Vegetation Science*, Vol. 15, 3–12.
- Alftine, K.J., Malanson, G.P., Fagre, D.B. (2003). Feedback-Driven Response to Multidecadal Climatic Variability at an Alpine Treeline. *Physical Geography*, 2003, 24, 6, pp. 520–535.
- Bake, B. B. r and Moseley R. K. (2007) Advancing Treeline and Retreating Glaciers: Implications for Conservation in Yunnan, P.R. China, Arctic, Antarctic and Alpine Research, Vol. 39, No. 2, 2007, pp. 200–209.
- Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., 2008: Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 210 pp.
- Becwar, M. R., Rajashekar, C., Bristow, K. J. H., and Burke, M. F. (1981) Deep undercooling of tissue water and winter hardiness limitations in timberline flora. *Plant Physiology*, Vol. 68, 111–114.
- Boisvenue, C. & Running, S.W. (2006). Impacts of climate change on natural forest productivity – evidence since the middle of the 20th century. *Glob. Change Biol.*, 12, 1–21.
- BRIFFA, K. R., OSBORN, T. J. & SCHWEINGRUBER, F. H. (2004) Large-scale temperature inferences from tree rings: a review. *Global and Planetary Change*, 40, 11–26.
- BUGMANN, H. (2001) A review of forest gap models. *Climatic Change*, 51, 259–305.
- Burkett, V.R., D.A. Wilcox, R. Stottlemeyer, W. Barrow, D. Fagre, J. Baron, J. Price, J. Nielsen, C.D. Allen, D.L. Peterson, G. Ruggerone and T. Doyle, (2005): Nonlinear dynamics in ecosystem response to climate change: case studies and policy implications. *Ecological Complexity*, 2, 357–394.
- Cairns, D. M. and Waldron, J. D. (2003). Sigmoid wave transitions at alpine treeline. *Geografiska Annaler*, Vol. 85A, 115–126.
- Chaudhari, Pashupati and Kamal P. Aryal. "Global Warming in Nepal: Challenges and Policy Imperatives." *Forest and Livelihood* 8.1 (2009): 3–13.
- Cullen, L., Stewart, G.H., Duncan, R.P. & Palmer, G. (2001) Disturbance and climate warming influences on New Zealand *Nothofagus* tree-line population dynamics. *Journal of Ecology*, 89, 1061–1071.

- Gehring- Fasel, Jacqueline Anita, (2007). Treeline and Climate Change: Analysing and Modeling Patterns and Shifts in the Swiss Alps. PhD Thesis. Faculté de Biologie et de Médecine. Lausanne: Ingénieur forestière diplômée.
- Grabherr, G., Gottfried, M. & Pauli, H. (1994) Climate effects on mountain plants. *Nature*, 369, 448.
- Grace, J. (1989) Tree lines. *Philosophical Transactions of the Royal Society, London, B*, Vol. 324, 233–245.
- GRACE, J., BERNINGER, F. & NAGY, L. (2002) Impacts of climate change on the tree line. *Annals of Botany*, 90, 537–544.
- Hall, M.H.P. & Fagre, D. 2003. Modeled Climate-Induced Glacier Change in Glacier National Park, 1850–2100. *BioScience*, 53(2): 131–140.
- Hansen, A.J., Neilson, R.P., Dale, V.H., Flather, C.H., Iverson, L.R., Currie, D.J. *et al.* (2001) Global change in forests: response of species, communities, and biomes. *Bioscience*, 51, 765–779.
- Hessl, A. E. and Baker, W. L. (1997a) Spruce-fir growth form changes in the forest-tundra ecotone of Rocky Mountain National Park, Colorado, USA. *Ecography*, Vol. 20, 356–367.
- Hessl, A.E. & Baker, W.L. (1997) Spruce and fir regeneration and climate in the forest-tundra ecotone of Rocky Mountains National Park, Colorado, U.S.A. *Arctic and Alpine Research*, 29, 173–183.
- Hiemstra, C. A., Liston, G. E., and Reiners, W. A. (2002) Snow redistribution by wind and interactions with vegetation at upper treeline in the Medicine Bow Mountains, Wyoming, USA. *Arctic, Antarctic, and Alpine Research*, Vol. 34, 262–273.
- Hoch, G. & Körner, C. (2003) The carbon charging of pines at the climatic treeline: a global comparison. *Oecologia*, 135, 10–21.
- Holtmeier, F. K. and Broll, G. (1992) The influence of tree islands and microtopography on pedoecological conditions in the forest-alpine tundra ecotone on Niwot Ridge, Colorado Front Range, USA. *Arctic and Alpine Research*, Vol. 24, 216–228.
- IPCC 2001. Climate Change 2001: The Scientific Basis, Contribution of Working Group to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.
- Ives, J.D. (2004) *Himalayan Perceptions*. London and New York: Routledge
- Ives, J.D.; Messerli B. (1989) *The Himalayan Dilemma: Reconciling Development and Conservation*. London: John Wiley and Sons
- JOBBAGY, E. G. & JACKSON, R. B. (2000) Global controls of forest line elevation in the northern and southern hemispheres. *Global Ecology and Biogeography*, 9, 253–268.
- Kittel, T.G.F., Steffen, W.L. & Chapin, F.S. III (2000) Global and regional modelling of arctic-boreal vegetation distribution and its sensitivity to altered forces. *Global Change Biology*, 6, 1–18
- Klanderud, K. & Birks, H.J.B. (2003) Recent Increases in Species Richness and Shifts in Altitudinal Distributions of Norwegian Mountain Plants. *The Holocene*, 13: 1–6.
- Klasner, F.L. & Fagre, D.B. (2002) A half century of change in alpine treeline patterns at Glacier National Park, Montana, U.S.A. *Arctic, Antarctic, and Alpine Research*, 34, 49–56.
- Körner, C., and Paulsen, J. (2004) A world-wide study of high altitude treeline temperatures. *Journal of Biogeography*, 31:713–732.
- KÖRNER, C. & PAULSEN, J. (2004) A world-wide study of high altitude treeline temperatures. *Journal of Biogeography*, 31, 713–732.
- Körner, C. (1998) A re-assessment of high elevation treeline positions and their explanation. *Oecologia*, Vol. 115, 445–459.
- KÖRNER, C. (1998) A re-assessment of high elevation treeline positions and their explanation. *Oecologia*, 115, 445–459.
- Kullman, L. (1993) Pine (*Pinus sylvestris* L.) tree-limit surveillance during recent decades, Central Sweden. *Arctic and Alpine Research*, 25, 24–31.
- Kullman, L. (2002) Rapid recent range-margin rise of tree and shrub species in the Swedish Scandes. *Journal of Ecology*, 90, 68–77.
- Kupfer, J. A. and Cairns, D. M. (1996) The suitability of montane ecotones as indicators of global climatic change. *Progress in Physical Geography*, Vol. 20, 253–272.
- Lavoie, C. & Payette, S. (1994) Recent fluctuations of the lichen-spruce forest limit in subarctic Quebec. *Journal of Ecology*, 82, 725–734.
- Lehner, G. and Lutz, C. (2003) Photosynthetic functions of cembra pines and dwarf pines during winter at timberline as regulated by different temperatures, snowcover and light. *Journal of Plant Physiology*, Vol. 160, 153–166.
- LISCHKE, H., BOLLIGER, J. & SEPPELT, R. (2007) Dynamic spatio-temporal landscape models. IN KIENAST, F., GHOSH, S. & WILDI, O. (Eds.) *A changing world: challenges for landscape research*. Kluwer Academic Publisher.
- Lloyd, A. H., Rupp, T. S. Fastie, C. L., and Starfield, A. M. (2002) Patterns and dynamics of treeline advance on the Seward Peninsula, Alaska. *Journal of Geophysical Research Atmospheres*, 108D, article 8161.
- LOEHLE, C. & LEBLANC, D. (1996) Model-based assessments of climate change effects on forests: a critical review. *Ecological Modelling*, 90, 1–31.
- Malanson, G. P. (1997) Effects of feedbacks and seed rain on ecotone patterns. *Landscape Ecology*, Vol. 12, 27–38.
- Malanson, G. P. (1999) Considering complexity. *Annals of the Association of American Geographers*, Vol. 89, 746–753.
- Malanson, G. P. (2001) Complex responses to global change at alpine treeline. *Physical Geography*, Vol. 22, 333–342.
- Malanson, G. P. and Butler, D. R. (1994) Tree-tundra competitive hierarchies, soil fertility gradients, and the elevation of treeline in Glacier National Park, Montana. *Physical Geography*, Vol. 15, 166–180.
- Marr, J. W. (1977) The development and movement of tree islands near the upper limit of tree growth in the southern Rocky Mountains. *Ecology*, Vol. 58, 1159–1164.
- Masek, J.G. (2001) Stability of boreal forest stands during recent climate change: evidence from Landsat satellite imagery. *Journal of Biogeography*, 28, 967–976.
- Meshinev, T., Apostolova, I. & Koleva, E.S. (2000) Influence of warming on timberline rising: a case study on *Pinus peuce* Griseb. in Bulgaria. *Phytocoenologia*, 30, 431–438.
- MOEN, J., AUNE, K., EDENIUS, L. & ANGERBJORN, A. (2004) Potential effects of climate change on treeline position in the Swedish mountains. *Ecology and Society*, 9.
- Motta, R. & Nola, P. (2001) Growth trends and dynamics in sub-alpine forest stands in the Varaita Valley (Piedmont, Italy) and their relationships with human activities and global change. *Journal of Vegetation Science*, 12, 219–230.
- Oki, T.; Kanae, S. (2006) 'Global Hydrological Cycles and World Water Resources' In *Science*, 313: 1068–1072
- Parnesan, C. & Yohe, G. (2003) A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, 421, 37–42.
- Parnesan, C. (1996) Climate and species' range. *Nature*, 382, 765–766.





- Parmesan, C., Ryrholm, N., Stefanescu, C., Hill, J.K., Thomas, C.D., Descimon, H., Huntley, B., Kaila, L., Kullberg, J., Tammaru, T., Tennent, J., Thomas, J.A. & Warren, M. 1999. Poleward Shifts in Geographical Ranges of Butterfly Species Associated with Regional Warming. *Nature*, 399: 579–583.
- Pounds J.A., Fogden, M.P.L. & Campbell, J.H. 1999. Biological Response to Climate Change on a Tropical Mountain. *Nature*, 398: 611–615.
- Rainwald, Amada (2008) The Arctic Tree Line and Climate Change power point presentation retrieved at 27<sup>th</sup> April 2009.
- Stanhill G, Cohen S. (2001) Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences. *Agricultural and Forest Meteorology* 107: 255±278.
- Stevens GC, Fox JF. (1991) The causes of treeline. *Annual Review of Ecology and Systematics* 22: 177±191.
- Sturm, M., Racine, C. & Tape, K. (2001) Increasing shrub abundance in the Arctic. *Nature*, 411, 546–547.
- Sturm, M., Racine, C. & Tape, K. (2001) Increasing shrub abundance in the Arctic. *Nature*, 411, 546–547.
- Szeicz, J.M. & MacDonald, G.M. (1995) Recent white spruce dynamics at the subarctic alpine treeline of north-western Canada. *Journal of Ecology*, 83, 873–885.
- TESSIER, L., GUIBAL, F. & SCHWEINGRUBER, F. H. (1997) Research strategies in dendroecology and dendroclimatology in mountain environments. *Climatic Change*, 36, 499–517.
- Theurillat, J.-P. & Guisan, A. (2001) Potential impact of climate change on vegetation in the European Alps: a review. *Climatic Change*, 50, 77–109.
- Thomas, C.D., Bodsworth, E.J., Wilson, R.J., Simmons, A.D., Davies, Z.G., Musche, M. *et al.* (2001) Ecological and evolutionary processes at expanding range margins. *Nature*, 411, 577–581.
- Thompson, M.; Warburton, M. (1985) 'Uncertainty on a Himalayan Scale'. In *Mountain Research and Development*, 5(2): 115–35
- Tinner, W., and Theurillat, J. P., 2003: Uppermost limits, extent, and fluctuations of the timberline and treeline ecocline in the Swiss Central Alps during the past 11,500 years. *Arctic, Antarctic, and Alpine Research*, 35: 158–169.
- Walker, D. A., Billings, W. D., and deMolenaar, J. G. (2001) Snow-vegetation interactions in tundra environments. In H. G. Jones, J. W. Pomeroy, D. A. Walker, and R. W. Hoham, eds., *Snow Ecology*. Cambridge, UK: Cambridge University Press, 266–324.
- Walker, D. A., Halfpenny, J. C., Walker, M. D., and Wessman, C. A. (1993) Long-term studies of snow-vegetation interactions. *BioScience*, Vol. 43, 287–301.
- Walther, G.-R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T.J.C. *et al.* (2002) Ecological responses to recent climate change. *Nature*, 416, 389–395.
- Woodward, F.I. (2002) Potential Impacts of Global Elevated CO<sub>2</sub> Concentrations on Plants. *Curr. Opin. Plan Biol.*, 5: 207–211.