#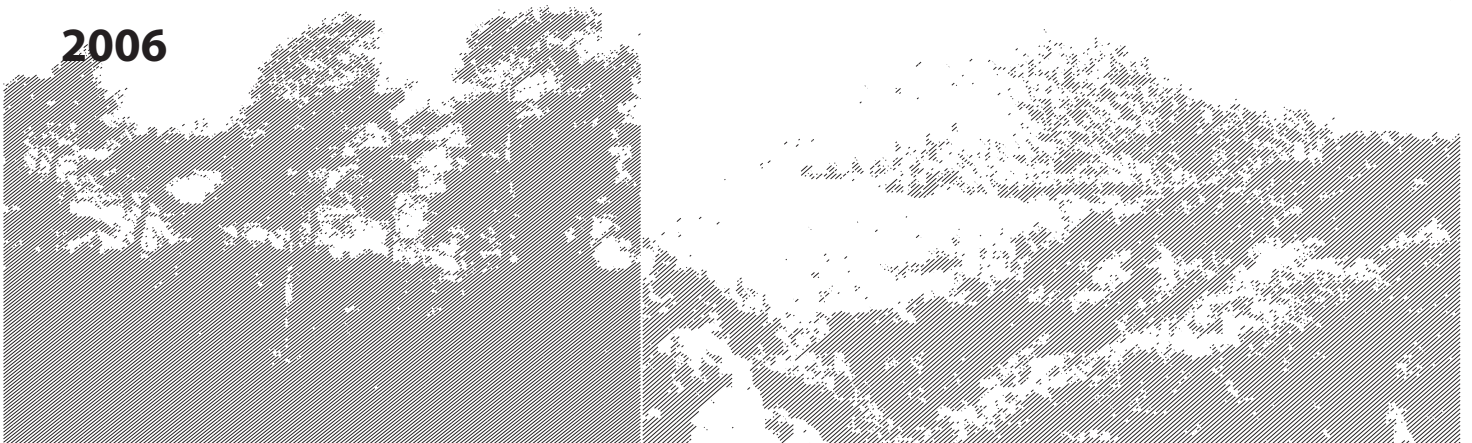 Measuring and modelling transpiration of pine and oak forest stands in a Mediterranean mountain area (Vallcebre, NE Spain)

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General Conclusions

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The studied Scots pine stand transpires more water than the pubescent oak stand, having similar leaf area indices (Chapters 2 and 3). However, the Scots pine stand has a higher basal area and virtually no understorey cover. These observed differences in transpiration contradict the traditional views that transpiration rates per unit leaf area are higher in angiosperms than in conifers (Pallardy et al. 1995), but when fluxes are related to stand basal area, the differences are reduced. Transpiration of the dense understorey in the oak stand should be assessed to confirm the view that transpiration of entire forests is similar across different forest types and structures (Roberts 1983). A simple transpiration model derived for Scots pine, only dependent on daily reference evapotranspiration and soil moisture deficit, was found to perform relatively well, given its simplicity. The boundary-line technique, widely used in parameterising multiplicative models of stomatal conductance, was successfully applied with reference evapotranspiration as an evaporative demand index and soil moisture deficit as the controlling limiting factor.

Pubescent oak sap flux density showed varied radial patterns among different trees (Chapter 3). Whether these differences were due to azimuthal variation in sap flow or to real variability among trees could not be determined using only one radial pattern sensor. The most frequently observed pattern showed sharp decreases in relative sap flux density with sapwood depth. The use of radial patterns showed that the visual identification of sapwood underestimated sapwood depths. Combined with the correction of single-point measurements to radially integrated sap flux density, corrected stand transpiration estimates were up to 25% higher than the values found in Chapter 2. We also observed how radial patterns varied diurnally, with opposite dynamics to recent findings in *Pinus* species (Ford et al. 2004), confirming that differences in anatomical features and physiological behaviour may also determine different diurnal courses in radial patterns of sap flux density. Whereas this diurnal variation does not significantly affect daily estimates of water use, its impact on transpiration rates can be more important if higher temporal resolutions are required.

The two-source evaporanspiration model adapted to the studied Scots pine stand could not simulate canopy transpiration adequately throughout the study period (Chapter 4). While good results were obtained at the daily time scale for the years 2003 and 2004, the model showed a poor agreement for the year 2005. The Generalise Likelihood Uncertainty Estimation (GLUE) methodology was useful because Monte Carlo sampling yielded better results than the widely used boundary-line parameterisation of

multiplicative models of stomatal conductance. In addition, different GLUE calibrations for 2003 and 2004 revealed the importance of parameters controlling maximum stomatal aperture and sensitivity to vapour pressure deficit, whereas soil moisture parameters only appeared sensitive when calibrating with data including an extremely dry period (2003). The recent development of more physically-based models, with a sound physiological basis and fewer parameters to calibrate (e.g. Williams et al., 1996), offer real alternatives to multiplicative models, which may fail to represent the variations in hydraulic conductance and the various feedbacks among environmental variables involved in the transpiration process.

Differences in the response to water deficits between Scots pine and pubescent oak growing under identic climate were evident when dry conditions occurred, although the overall response of sap flow to increasing vapour pressure deficit showed that, above a threshold, sap flow decreased with increasing evaporative demand for both species (Chapter 5). Whole-plant hydraulic conductance was much higher for Scots pine, but it was strongly reduced as summer developed. Both species showed positive correlations between hydraulic and leaf-level stomatal conductance, suggesting a coordination between water supply and gas exchange characteristics. Stomatal avoidance of embolism was observed for Scots pine, whereas the lower reduction in pubescent oak stomatal conductances at low water potentials and under drought conditions, confirms that this species has a less strict stomatal regulation. Given the observed vulnerability to drought-induced mortality of Scots pine and the resistance to drought shown by pubescent oak , future increases in the occurrence of extreme droughts may favour the latter species.

Finally, in Chapter 6, we related the previously observed hydraulic acclimation patterns with the geographic variation in sap flow responses to environment for Scots pine. There was not an increase in relative sensitivity of stomatal conductance to vapour pressure deficits, and accordingly, transpiration rates per unit leaf area increased in drier/warmer climates. These findings have several implications, as for example the confirmation that Scots pine in southern latitudes is at its limit to cope with drought. More information on how hydraulic traits vary across climates would be needed to clarify the observed patterns. For example, although vulnerability to embolism is usually regarded as showing very little plasticity in pines (Martínez-Vilalta et al. 2004), Scots pine populations in NE Spain are more resistant to embolism than populations growing in Central Scotland (Poyatos et al., unpublished results). A full explanation of the observed patterns in the context of whole plant and stand resource use (carbon, light, nutrients) would need the use of complex coupled models (Buckley and Roberts 2006).

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