COST Action FP1202 - Strengthening conservation: a key issue for adaptation of marginal/ peripheral populations of forest trees to climate change in Europe

Short Term Scientific Mission Final Report

Xylem sap flow of *Quercus pubescens* Willd. from sub-Mediterranean area in Slovenia

Martina Lavrič

Slovenian Forestry Institute, Slovenia

Ljubljana, April 2016

Applicant: Martina Lavrič, PhD student, Slovenian Forestry Institute, Slovenia (martina.lavric@gozdis.si)

STSM period: 01/02/2016 – 31/03/2016

Host institution: Ghent University, Faculty of Bioscience Engineering, Department of Applied Ecology and Environmental Biology, Coupure Links 653 Bl. A, 9000 Gent, Belgium (www.ugent.be/bw)

Host person: Kathy Steppe, prof. dr. ir., Professor - Head of the Laboratory of Plant Ecology and Head of the Department (Kathy.Steppe@UGent.be)

Abstract

Among all European regions, the Mediterranean appears to be the most vulnerable to climate change, so information about tree water regulation strategies and survival in marginal areas is therefore crucial for our understanding of tree functioning and is necessary for future forest management. Pubescent oak (*Quercus pubescens* Willd.) is one of the dominant native tree species of the Slovenian Karst region with sub-Mediterranean climate where drought periods frequently occur leading to a great impact on plant and ecosystem functioning. For investigating tree water management thermal sap flow methods become more and more widespread in forest ecophysiology and hydrology. The aim of our study was to evaluate intra-annual water regulation with the Heat Ratio sap flow method (HRM) in connection with different environmental factors performed in mature pubescent oak trees from marginal-edge habitat in sub-Mediterranean climate in one growing season from March to October. Through a STSM visit at the Faculty of Bioscience Engineering in the Laboratory of Plant Ecology I gained knowledge of the methodology for processing and evaluating xylem sap flow. I learned new skills to work with the software Sap Flow Tool and in statistical program R.

Table of contents

Introduction

In Central Europe, it is expected that a changing climate will lead to an increase in the frequency and severity of drought events, which will strongly affect the physiology, growth patterns and survival of different tree species (Eilmann et al., 2009; Galle et al., 2010). Among all European regions, the Mediterranean appears to be the most vulnerable to climate change, where water resources management is becoming a critical issue for land management policies (Hernández-Santana et al., 2009).

Pubescent oak (*Quercus pubescens* Willd.) is typically growing in Mediterranean-type climate worldwide (Damesin and Rambal, 1995). It is a winter deciduous species with ring-porous xylem and it developed different mechanisms and adaptations to survive in drought prone environments. With respect to water economy strategies it maintained higher relative sap flow during intense drought and showed less stomatal closure (Poyatos et al., 2008).

In Slovenia, pubescent oak is a native tree species in karst region, which is located in SW part of Slovenia (Eler, 2007). During the last decades karst area has been significantly changed due to long lasting human influences and abandonment of marginal agricultural lands which all have strong effects on plant and ecosystem functioning. Surface is rocky and has very uneven depth. It prevails sub-Mediterranean climate, where drought is the main environmental constraint. Shallow soil, repeated wind and severe weather conditions diminish impact of high precipitation, resulting in frequent water stress during growing seasons, i.e. in the period April–October (Ferlan et al., 2011). Such conditions are typical of marginal habitats where species with good adaptation capability prevail.

The impact of climate-change induced drought on the resilience or vulnerability of forest is currently under intense debate and investigated in different research disciplines using different methodologies (Luo et al. 2011; Jentsch et al. 2011). We can follow water transport through the conducting system using thermal sap flow methods (Smith and Allen, 1996; Vandegehuchte and Steppe, 2013). They become more and more widespread in forest ecophysiology and hydrology, because they are relatively inexpensive and simple. We can get information about physiological processes with high temporal resolution and, in parallel, long-term recordings of transpiration, accounting for intra- and inter-annual variability of forest transpiration, can be acquired (Poyatos et al., 2005).

Objective of the STSM

The principal objective of the visit was to study the methodology for the processing and evaluation of xylem sap flow in combination with environmental factors performed in mature pubescent oak (*Quercus pubescens* Willd.) trees from marginal-edge habitat in sub-Mediterranean climate. The training in the Laboratory of Plant Ecology shall improve our knowledge on analysis and quality of xylem sap flow data.

Links with Cost Action FP1202 MaP FGR

I believe that this STSM would contribute to the progress of the Action MaP-FGR to reach its mission and main objectives. Proposed topic is perfectly in line with mission of the action, thus its will contribute to reducing the fragmentation in European research on marginal populations, i.e. from the edge of distribution areas, that are particularly important for adapting forests to global changes and it will increase knowledge about tree adaptation to climate changes. Information about tree water management in marginal areas where drought frequently occurs is therefore crucial for our understanding of tree functioning and is indispensable and necessary for future forest management on national and global scale what is in accordance with Task 3. New knowledge gained through STSM will give great contribution to marginal areas, not only threatened by climate change but also by disturbances deriving from human activities.

Materials and Methods

The study was conducted in the sub-Mediterranean region in the SW part of Slovenia where we selected four healthy pubescent oak (*Quercus pubescens* Willd.) trees. For insight into xylem water conductivity continuous measurements of xylem sap flow according to the Heat Ratio Method (HRM, ICT, Australia) that is based on the application of heat pulses that provide us sap flow as sap flow density ($cm^3cm^{-2}h^{-1}$), assessing the amount of sap flowing through a certain surface per time (Vandegehuchte and Steppe, 2013). Measurements were carried out every 10 minutes in one growing season from March to October. Meteorological data were acquired from the meteorological tower located nearby the research plots (Ferlan et al., 2011).

Results

SAP FLOW DATA ANALYSIS

In this report we are presenting first preliminary results, as the data analysis is still in process.

First step was to processed sap flow data in software Sap Flow Tool (ICT International / Phyto-IT, version 1.4.1). There we did process of removing, renaming, inspecting and reordering files. We entered wood and sensor properties as stem diameter, bark thickness, sapwood depth and sapwood fresh weight, sapwood dry weight and sapwood fresh volume to calculate thermal diffusivity. After these steps we performed 2D and 3D visualisation of sap velocities, sap flux densities and sap flow rates. At the end we export sap flow data in .csv files for further analysis (Figure 1).

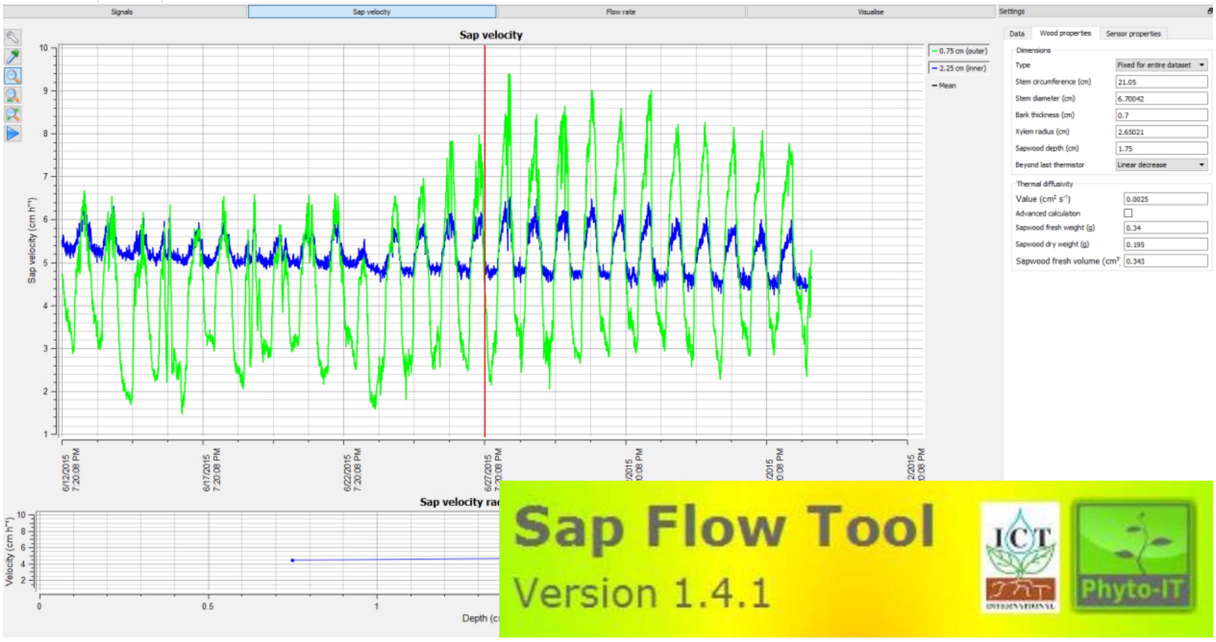

Figure 1: Sap Flow Tool software
(http://www.phyto-it.com/Phyto-IT_Software_Products.shtml)

All futher analysis were perfomed in statistical program R.

Second step in data analyzing was combining raw data of sap flow from four trees of pubescent oak. During measurement period we had some problems with providing of electrical energy, so there are few gaps in data where we had no measurements. With combining sap density data of all four trees together we got full seasonal course of measurements. Example of data for one tree is presented in Figure 2.

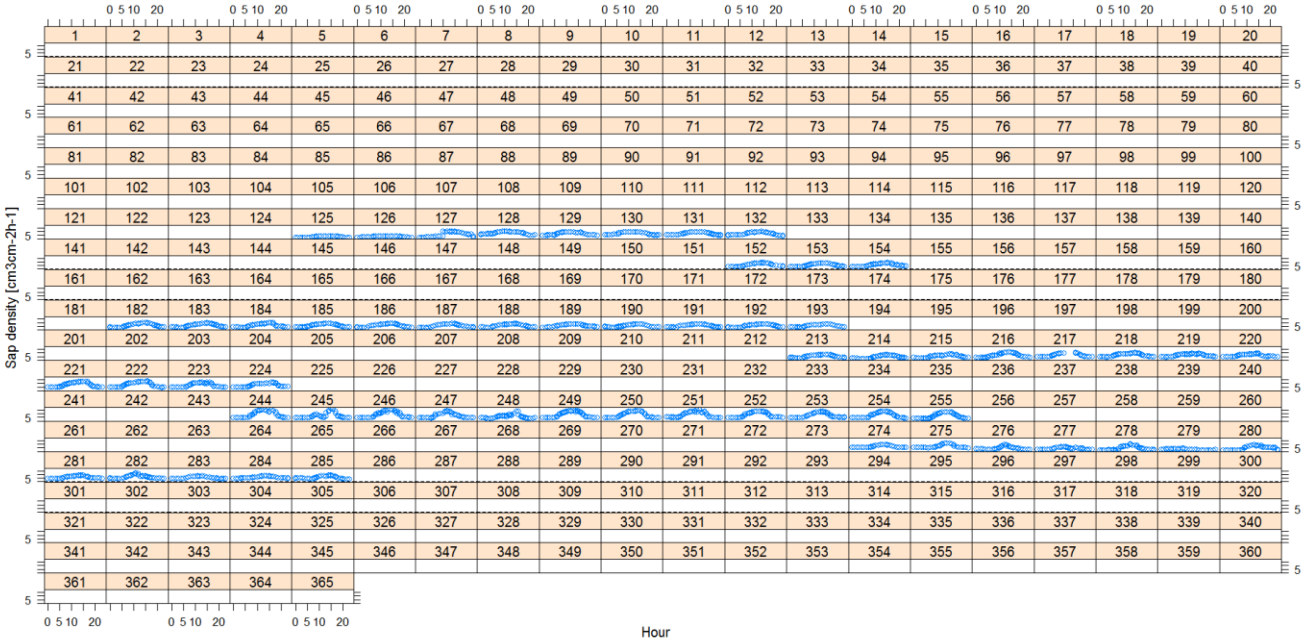

Figure 2: Raw data of sap density of one tree in one growing season.

Third step was to calculate zero flow. Zero flow is present in conditions when through conducting elements there is now flow. In practice it is often not reached because of night-time water uptake for vegetative or reproductive growth, replenishment of internal storage and water loss due to a high vapour pressure deficit in combination with a high wind speed (Vandegehuchte and Steppe, 2013). However to evaluate correct and exact sap flow data, calculations of zero flow are required. We used different approaches for calculating zero flow. In Figure 3 is presented zero flow calculation for one tree as example.

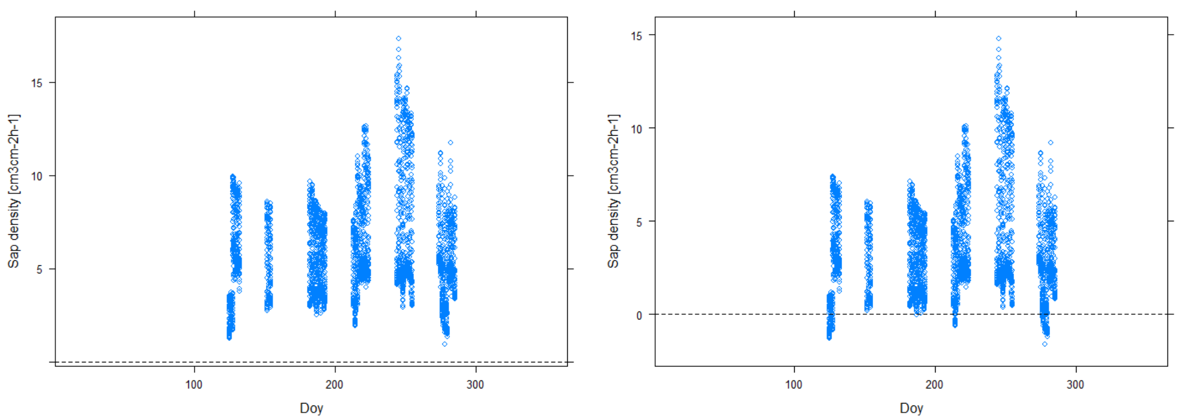

Figure 3: Raw data of sap density per Doy (day of year) (left) and corrected data of sap density with zero flow calculation (right) for one tree in one growing season.

From obtained corrected sap density we calculated mean sap density per day. On figure 4 we can observe seasonal pattern of mean sap density. During growing season its value was relatively constant with high variation, we assume that this was due to influence of environmental factors.

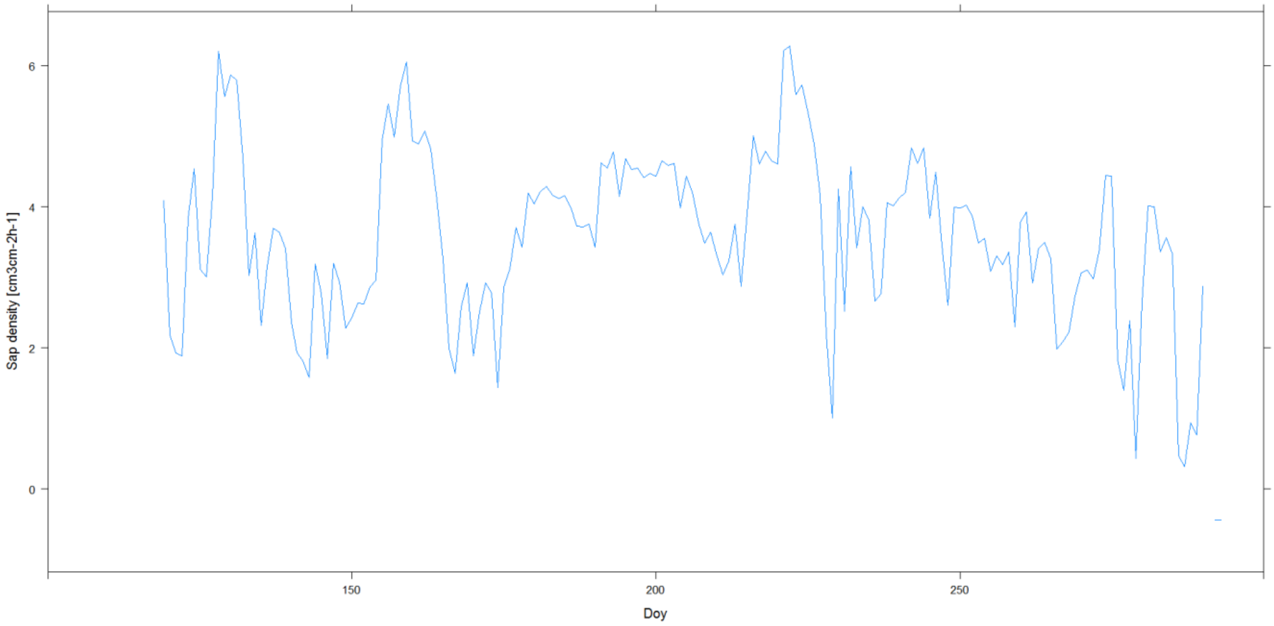

Figure 4: Seasonal pattern of sap density per DOY in one growing season.

LINKING SAP FLOW DATA WITH ENVIRONMENTAL FACTORS

Sap flow through the xylem is driven by process transpiration with its main driver VPD. We examined link between sap flow and VPD. From the Figure 5 we can confirm that VPD is the main driver as environmental factor that enables flow through xylem elements.

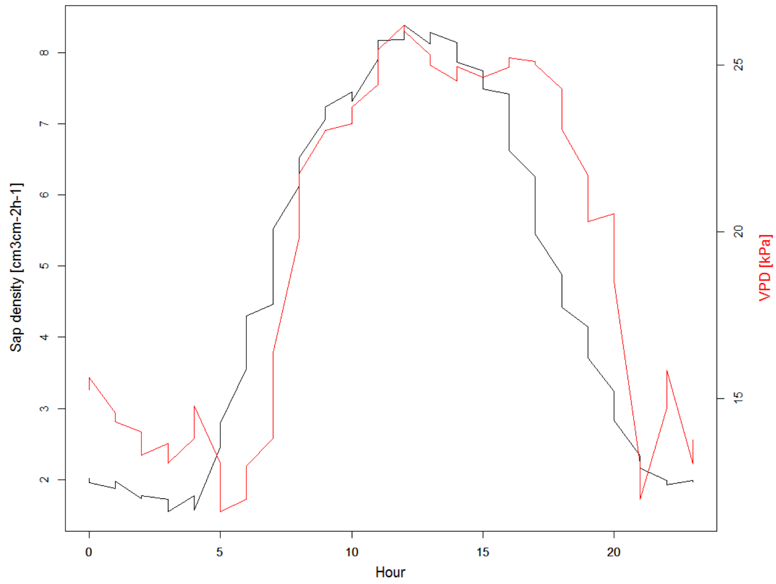

Figure 5: Linking sap density with VPD on DOY 185 (04/07).

Discussion and Conclusions

As a PhD student (University of Ljubljana, Slovenia) interested in water management and growth response of trees growing in sub-Mediterranean climate, visiting the Faculty of Bioscience Engineering, the Laboratory of Plant Ecology to carry out sap flow analyses represents an important chance for my career development. Gained knowledge of the methodology for processing and evaluating xylem sap flow in ring-porous pubescent oak (*Quercus pubescens* Willd.) during the growing season will contribute to a better understanding of the underlying mechanisms, and their importance for the regulation of the tree water balance in sub-Mediterranean ecosystems.

Because the data analysis is still in process our final results and conclusions will be presented in my PhD thesis. Results will also be published in a joint publication, and presented at national/international conferences where COST Action FP1202 - Strengthening conservation: a key issue for adaptation of marginal/peripheral populations of forest trees to climate change in Europe will be acknowledged.

At the end I want to acknowledge the COST Action FP1202 (MaP-FGR) to approve my application and gave me the STSM grant to do part of my data analysis at the Faculty of Bioscience Engineering, Ghent University in Belgium. I also want to give a warm thank you to host supervisor Prof. Dr. Kathy Steppe for accepting me, sharing knowledge of sap flow and all support and help during my visit. I also kindly thank the research group of the Laboratory of Plant Ecology for making my visit warm and pleasant.

References

Damesin C., Rambal S. 1995. Field study of leaf photosynthetic performance by a Mediterranean deciduous oak tree (*Quercus pubescens*) during a severe summer drought. New Phytologist, 131: 159-167

Eilmann B., Zweifel R., Buchmann N., Fonti P., Rigling A. 2009. Drought-induced adaptation of the xylem in Scots pine and pubescent oak. Tree Physiology, 29: 1011-1020

Eler K. 2007. Dinamika vegetacije travišč v slovenskem Submediteranu: vzorci in procesi ob spremembah rabe tal: doktorska disertacija = Vegetation dynamics in the submediterranean region of Slovenia: patterns and processes following land use change: doctoral dissertation. Department of Agronomy, Biotechnical Faculty, University of Ljubljana, Slovenia: 169 pp.

Ferlan M., Alberti G., Eler K., Batič F., Peressotti A., Miglietta F., Zaldei A., Simončič P., Vodnik D. 2011. Comparing carbon fluxes between different stages of secondary succession of a karts grassland. Agriculture, Ecosystems and Environment, 140: 199-207

Galle A., Esper J., Feller U., Ribas-Carbo M., Fonti P. 2010. Responses of wood anatomy and carbon isotope composition of *Quercus pubescens* saplings subjected to two consecutive years of summer drought. Annals of Forest Science, 67: 809

Hernández-Santana V., Martínez-Vilalta J., Martínez-Fernández J. 2009. Evaluating the effect of drier and warmer conditions on water use by Quercus pyrenaica. Forest Ecology and Management, 258: 1719-1730

Jentsch A. et al. 2011. Climate extremes initiate ecosystem-regulating functions while maintaining productivity. Journal of Ecology, 99: 698-702

Luo Y. et al. 2011. Coordinated approaches to quantify long-term ecosystem dynamics in response to global change. Global Change Biology, 17: 843-854

Poyatos R., Llorens P., Gallart F. 2005. Transpiration of montane *Pinus sylvestris* L. and *Quercus pubescens* Willd. forest stands measured with sap flow sensors in NE Spain. Hydrology and Earth System Sciences, 9: 493-505

Poyatos R., Llorens P., Piñol J., Rubio C. 2008. Response of Scots pine (*Pinus sylvestris* L.) and pubescent oak (*Quercus pubescent* Willd.) to soil and atmospheric water deficits under Mediterranean mountain climate. Annals of Forest Science, 65: 306

Smith D. M., Allen S.J. 1996. Measurement of sap flow in plant stems. Journal of Experimental Botany, 47, 305: 1833-1844

Tognetti R., Cherubini P., Marchi S., Raschi A. 2007. Leaf traits and tree rings suggest different water-use and carbon assimilation strategies by two co-occurring *Quercus* species in a Mediterranean mixed-forest stand in Tuscany, Italy. Tree Physiology, 27:1741-1751

Vandegehuchte M. W., Steppe K. (2013) Sap flux density measurement methods: working principles and applicability. Functional Plant Biology, 40: 213–223