SHORT-TERM SCIENTIFIC MISSION:
A PRELIMINARY STUDY OF DENDROMETER SIGNALS AS CLIMATE INDICATORS

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INTRODUCTION

Throughout the last decades, stem diameter variation (SDV) measurements have been extensively used to study plant hydraulic and carbon processes [e.g. 1, 2-4]. As such, the application of SDV has, amongst others, proved to be useful in functional plant models [2, 3, 5], as indicator for irrigation scheduling [6, 7] and in studying tree growth [8, 9]. Besides these applications, it is expected that SDV patterns could also be used as indicators of climatic effects and have the ability to provide integrated large-scale climatic information based on simple tree measurements.

Two of the key objectives of Topic Group 8 are to establish a worldwide catalogue summarizing available SDV data and to distinguish appropriate SDV parameters which can be used to assess global climatic effects. These parameters can then be tested on the obtained data with the aim of establishing an analysis protocol enabling to derive climatic information from SDV patterns. The aim of this STSM was to discuss and derive possibly useful SDV parameters during a preliminary study on selected datasets largely differing in microclimatic conditions. Additionally, the applicant had the opportunity to get acquainted with the mathematical environment R which will be the platform further used to analyze the global dataset.

OUTLINE

During the STSM, datasets from Ghent, Belgium; Davos, Switzerland and Barcelona, Spain were used to test the applicability of some basic parameters which could be linked to climate (Table 1). In a first stage, the microclimatic data from the three sites were analyzed to evaluate the main differences. As such, the differences in yearly SDV patterns could be linked to the microclimatic conditions of the field sites. As single microclimatic variables such as temperature or precipitation only reflect a fraction of the climatic information, a simple drought index was implemented which allowed a more profound comparison between sites and years. As it is expected that for the majority of the datasets only the standard microclimatic variables will be available, the drought index was chosen to encompass only temperature, relative humidity, solar radiation and precipitation. As such, based on these microclimatic variables, the yearly cumulative reference evapotranspiration (ET_0) was determined for each site according to the standard FAO procedure [10]. The drought index (DI) was then taken as the difference between the yearly precipitation and ET_0.

Table 1: Applied datasets

Location	Species	# Trees	# Years
Ghent, Belgium	*Fagus sylvatica*	1	3 (2010-2012)
Barcelona, Spain	*Quercus pubescens*	6	2 (2011-2012)
	Quercus ilex	6	
	Arbutus unedo	4	
	Pinus halepensis	4	
Davos, Switzerland	*Picea abies*	9	6 (2006-2011)

For the SDV analysis, the focus laid on the yearly pattern. To investigate the differences in seasonality, monthly positive and monthly negative stem diameter change were determined as the total positive and negative stem diameter changes within each month, respectively. From these values, the yearly positive and yearly negative stem diameter change and net yearly stem diameter change were determined. Additionally, tree water deficit as defined by Zweifel et al. [11] was calculated. From this tree water deficit, the cumulative yearly and yearly average tree water deficits were determined, as well as the average time span of a single tree water deficit period.

MAIN RESULTS

Figure 1 shows the average stem diameter pattern for all species and measurement years for the three measurement sites. For the Davos and Ghent site, the standard deviations are similar while for the Barcelona site, the standard deviations are much larger. This is due to the larger differences in microclimatic conditions on this site during the two measurement years and to the different species taken into account. More remarkable, however, is that the Ghent pattern is very smooth while both the Davos and Barcelona pattern are more jagged because of longer periods of negative stem diameter change.

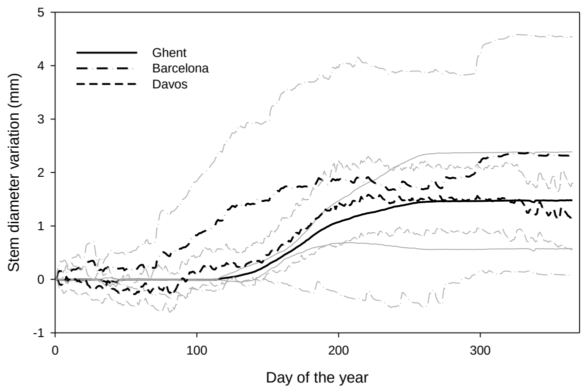

Figure 1: Stem diameter variation for the three measurement sites, averaged over all years and for all species. The thin grey lines indicate the standard deviations.

When comparing the average microclimatic conditions on the three sites (Fig. 2), Davos is characterized by lower average temperatures while Barcelona has higher average VPD values and less rainfall. When determining the drought index for the three sites, the averages were 159.5 ± 28.5; 122.8 ± 65.5 and -672.2 ± 68.5 for Ghent, Davos and Barcelona, respectively.

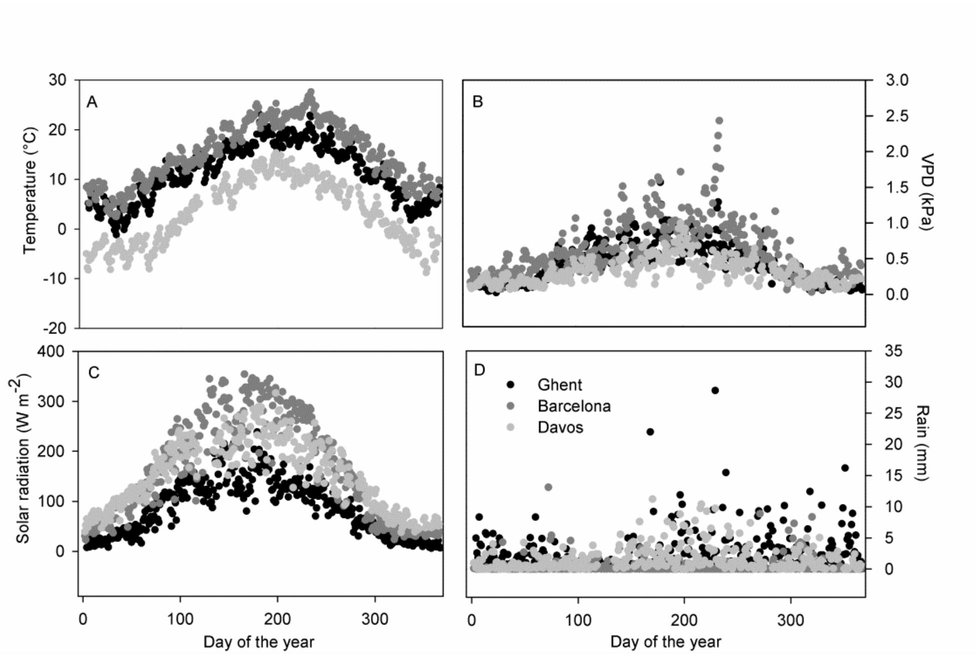

Figure 2: Microclimatic data for the different field sites, averaged over all measured years. (A: temperature, B: vapour pressure deficit, C: solar radiation, D: rainfall).

When calculating monthly positive and negative growth for the three sites (Fig. 3), it can be seen that for the Ghent site (Fig. 3A), negative stem diameter changes were very limited and mainly occurred during the winter months because of freezing. This pattern suggests that sufficient water was available to allow almost continuous positive growth. While for the Davos site, the yearly net average stem diameter increase was similar as for the Ghent site (Fig. 1), more negative stem diameter changes occurred throughout the year (Fig. 3C). As negative temperatures are common during winter and even autumn and early spring, these negative stem diameters can be partly explained by freezing events. However, also during summer, marked negative stem diameter changes occur, despite the similar drought index as for the Ghent site. This could indicate different soil conditions, resulting in a different soil water holding capacity and, hence, different water availability for the measured trees. Additionally, physiological differences between the measured species are undoubtedly also reflected in the stem diameter patterns. For the Barcelona site (Fig. 3C), the net positive growth started earlier on the year, during early spring, while the dry summer months August and September seemed to hamper growth and could even cause an overall stem diameter decline.

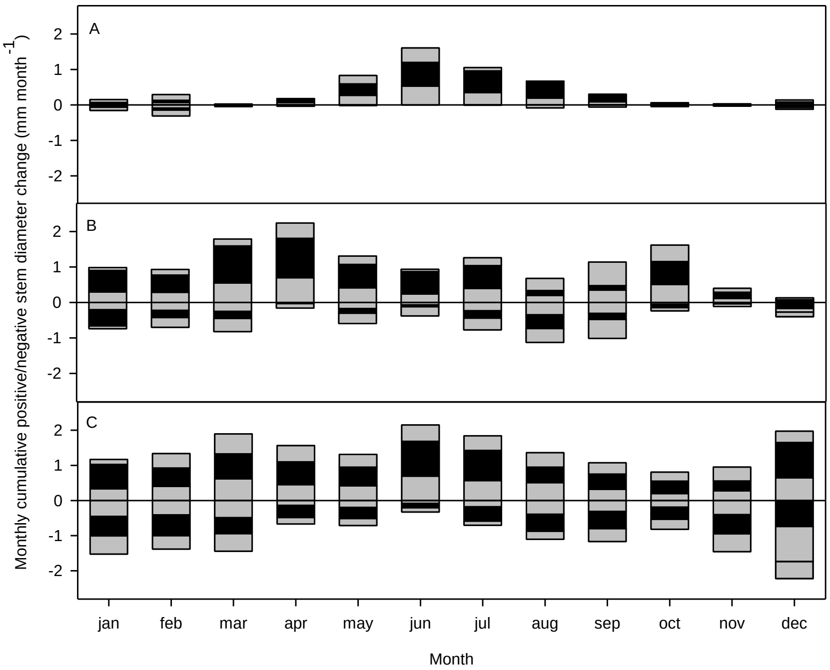

Figure 3: Average monthly positive and negative growth for the Ghent (A), Barcelona (B) and Davos (C) site, averaging all species and measurement years. The grey bands indicate the standard deviations.

In Fig. 4, key parameters such as average and cumulative yearly tree water deficit, yearly total positive and negative growth and the average tree water deficit event duration are represented for the different sites and species, related to the corresponding drought index. For the Ghent site, the cumulative yearly TWD can be clearly distinguished from the other sites (Fig. 4A). This pattern is more or less consistent for the average TWD, even though some trees also showed low average TWD values (Fig. 4B). For the average TWD duration, the Ghent site again shows the lowest values (Fig. 4C). *Quercus ilex*, a drought prone species from the Barcelona site, can be distinguished by both the high average TWD and average TWD duration values during the driest year (Fig. 4B, C). These values also show the highest standard deviations (Fig. 5). In Fig. 4D, it can be seen that for the Ghent site hardly any negative growth occurs while the yearly negative growth for the Davos site is clearly pronounced for most trees.

When only considering the period from April 1 to July 15, which coincides largely with the period during which the trees gain their largest stem diameter increase, some differences can be noted (Fig. 6, 7). The distinction in cumulative and average TWD is less pronounced between the Davos site, the Ghent site and the wettest year of the Barcelona site, while the driest year of the Barcelona site is more pronounced. Both for the Davos and the Barcelona site, large positive and negative growth events apparently occurred outside of this predefined period (Fig. 5D, 6D). For the Davos site, the standard deviations on the determined TWD and TWD duration were much smaller when only considering this period (Fig. 7). This indicates that the major TWD events occurred outside of this period.

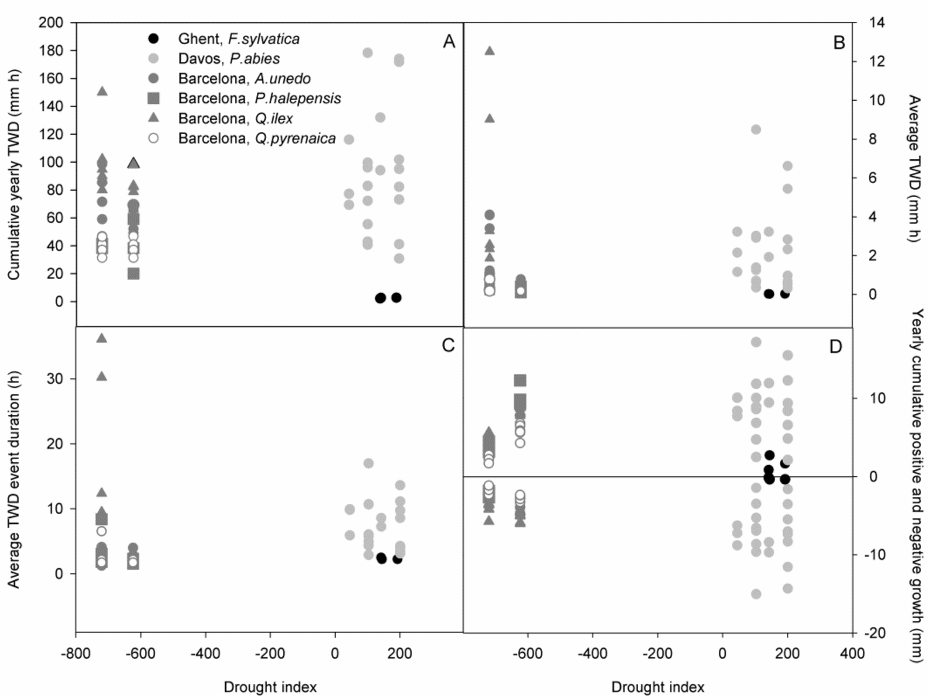

Figure 4: Cumulative yearly tree water deficit (TWD) (A); yearly average TWD (B); yearly average TWD event duration (C) and yearly cumulative positive and negative growth (D) for each measured species and year.

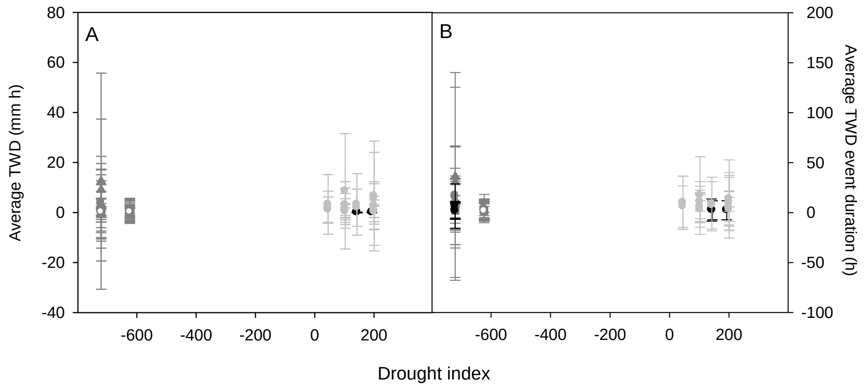

Figure 5: Yearly average TWD (A) and yearly average TWD event (B) for each species and each year with standard deviations. Legend is the same as for Fig. 4.

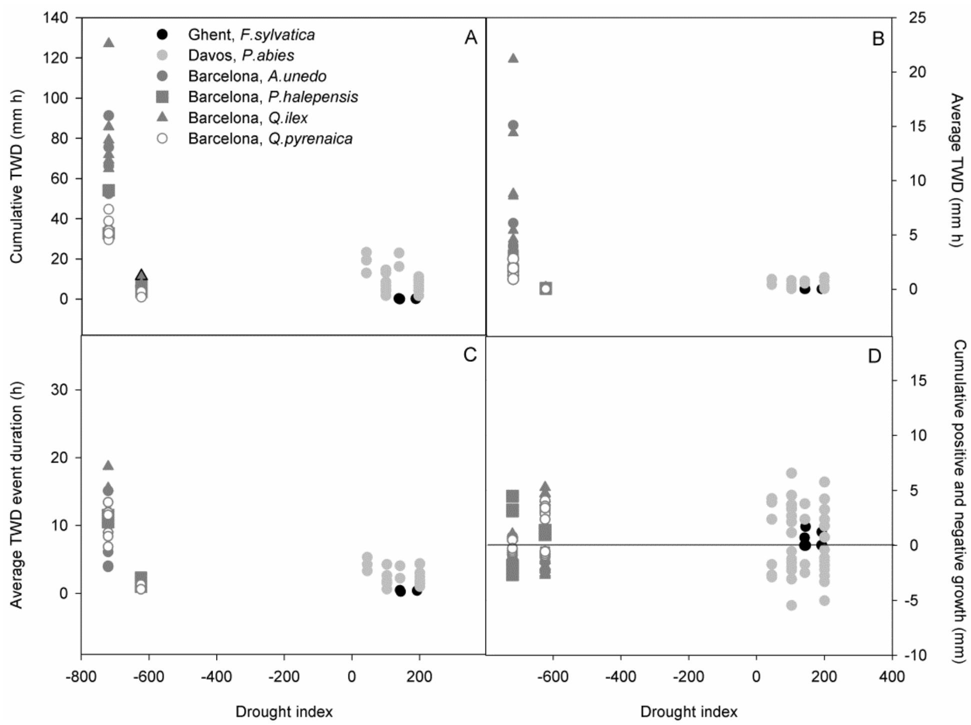

Figure 6: Cumulative tree water deficit (TWD) from April 1 till July 15 (A); average TWD from April 1 till July 15 (B); average TWD event duration from April 1 till July 15 (C) and cumulative positive and negative growth from April 1 till July 15 (D) for each measured species and year.

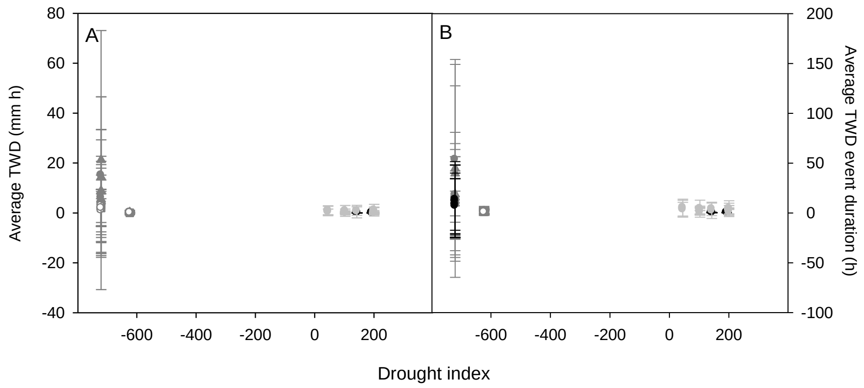

Figure 7: Average TWD (A) and Average TWD event (B) for each species and each year from April 1 till July 15 with standard deviations. Legend is the same as for Fig. 6.

DISCUSSION

While the drought index determined for the different measurement years at the Davos and Ghent site were similar, there were clear differences in stem diameter pattern. While the *Fagus sylvatica* at the Ghent site showed a smooth diameter pattern with very little negative growth, the *Picea abies* at the Davos site showed strong negative growths, especially during autumn and winter. This can partly be explained by freezing events which occurred frequently at the Davos site, even during spring and summer. As such, the stem diameter pattern at the Davos site seems to be more temperature dependent in comparison with the Ghent site. This can, however, not be confirmed based solely on the general parameters applied in this study as other factors such as soil composition or species specific effects were not taken into account.

For the Barcelona site, the calculated drought index was much lower in comparison to the Davos and Ghent site. The highly negative values of the index indicate a dry environment. However, for the least dry year at the Barcelona site, the determined yearly parameters did not largely differ from those calculated for the other two sites. For the drier year, nevertheless, the cumulative TWD, average TWD and TWD event duration for the period between April 1 and July 15 were significantly larger for the Barcelona site in comparison with the other two sites, corresponding to a strong drought during this period. These parameters also suggest that the species *Quercus ilex* and *Arbutus unedo* were most drought sensitive. Hence, while the Davos site was considered to be more temperature dependent, stem diameter variation at the Barcelona site can be assumed to be largely driven by soil moisture content and VPD.

When comparing simple yearly or seasonal parameters in relation to a climatic index such as the drought index applied in this study, the question raises whether the index under consideration encompasses sufficient information. As stem diameter variations are driven by different microclimatic factors [12-14], the index should ideally include detailed microclimatic information. In practice, however, many measurement sites only consider some key microclimatic variables. As such, the index will be a compromise between what is available and what is necessary to representatively describe the driving growth factors. It has been shown that temperature, relative humidity and soil moisture content (directly measured or derived from temperature, VPD and precipitation) are likely the most determining environmental variables [12, 15, 16]. Nevertheless, stem diameter variations are also determined by, often species-specific, plant physiological processes [3, 17, 18]. Therefore, the same environmental conditions may lead to large differences in stem diameter variation. Next to these species-specific responses, stem diameter patterns will also depend on the microclimatic conditions of the previous years [16].

The parameters applied in this study are appealing as they are easy to determine on large datasets and can readily be interpreted. Nevertheless, by calculating yearly cumulative or average values, information can be overlooked as illustrated by the calculation of the same parameters on during a shorter timeframe. This raises the question whether seasonal or monthly parameters might be more valuable for a global analysis of dendrometer data. Another approach could be to try and link the observed stem diameter patterns to the microclimatic conditions in a modelling approach [12]. Such a model can then further be extended to include time and/or species-specific effects. This way, the percentage of variance explained by specific variables can give an indication of the (micro)climatic conditions of the site. For the sites in this case-study, it can be expected that precipitation will largely explain the variance of the Barcelona data while temperature will have a larger contribution for the Davos site. While more complicated, this modelling approach may, once established, provide a rapid and more complete picture of the climatic conditions based on dendrometer data.

The data shown in this study indicate that based on simple parameters, some marked differences in stem diameter patterns between species and climatic regions can be distinguished. The analysis of additional data may prove that based on these, or similar, simple stem diameter parameters, a distinction can be made between climatic regions. However, additional analyses including a modelling approach may be needed to thoroughly link the stem diameter patterns to (micro)climatic conditions and allow the application of dendrometer data as a valuable tool to evaluate climatic conditions in situ.

Contribution to the Action aims

By conducting a preliminary study on a limited dataset, this STSM has contributed to the action aims by indicating the strengths and weaknesses of using basic parameters derived from yearly and seasonal dendrometer patterns to indicate microclimatic conditions.

This report may be posted on the Action website.

Confirmation by the host institution of the successful execution of the STSM can be found on the last page of the report.

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