REPORT ON OVERSEAS VISIT – ISHS XI INTERNATIONAL WORKSHOP ON SAP FLOW

7-11 October 2019, Hyytiälä (Finland)
Prof Stephanie Midgley
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1. Conference:

Stephanie Midgley attended the XI International Workshop on Sap Flow (International Society for Horticultural Science) held on 7-11 October 2019 in Finland. The focus of the Workshop was plant water relations and their measurement, and more specifically the use of various sap flow measurement techniques and their applications in agricultural and ecological systems. The International Workshop on Sap Flow is held in a different country every 2-4 years and this was the eleventh workshop. Approximately 100 researchers from every continent attended. The venue was the Hyytiälä forestry field station of the University of Helsinki. It is located ca. 275 km north of Helsinki in boreal forests with facilities for international multidisciplinary research and meetings.
https://www.helsinki.fi/en/research-stations/hyytiala-forestry-field-station
Workshop website: http://www.atm.helsinki.fi/sapflow/

Lindsay Muchena, PhD student in the Department of Horticultural Science, Stellenbosch University, was registered as a remote attendee and was able to stream several of the presentations.



2. Itinerary

- Arrived Monday 7th October (Cape Town – Istanbul – Helsinki).
- Organised bus transport from Helsinki airport to Hyytiälä on Monday 7th October and back to Helsinki airport on Friday 11th October.
- Evening flight via Istanbul on Friday 11th October, arriving in Cape Town on Saturday 12th October.

3. Programme

The Abstract Book with full details of the programme and the presenters is attached to this report as a separate file.

Tuesday 8th October, Session 1: Irrigation
This session was one of the key sessions of interest to me at the workshop. It was concerned with sap flow as a tool for understanding water use of fruit tree and other crops and the achievement of optimal yield and fruit quality with reduced irrigation. The global leaders in this field are researchers from Spain and Israel, and although the Israelis were unfortunately unable to attend, two speakers from one of the leading Spanish groups presented in this session. The keynote speaker was Prof Antonio Diaz-Espejo of IRNAS, Seville, with a presentation entitled “Sap flow as an ideal tool to apply a rational deficit irrigation”. He described how diurnal dynamics of stomatal conductance can

be inferred from continuous measurements of sap flow density and then used to estimate photosynthesis using a biochemical model. Using this approach, a series of trials over many years have shown that an optimum level of water deficit (irrigation below ETo) can lead to the achievement of near-maximum yield and/or higher fruit quality.

Later in this session, Virginia Fernandez-Santana of the same research group spoke about "Sap flow as a tool to enhance the quality of fruits: the case of olive oil". She showed how sap flow measurements were used to evaluate and control the water deficit of olive trees in order to improve the synthesis and presence of high value health-promoting compounds in olive oil. Thus, certain physiological targets can be achieved through managed deficit irrigation. This group has also concluded that reductions in photosynthesis and stomatal conductance during water deficit in olive trees does not negatively influence the continued partitioning of carbohydrate assimilates into fruit and oil yield.

I was the first speaker in this session following Prof Diaz-Espejo. The title of my talk was "Using sap flow sensors to study the influence of rootstock and mid-summer water deficit on transpiration of apple trees in South Africa". This work forms part of the first PhD thesis chapter of Lindsay Muchena. The project is funded by Hortgro Pome for the period 2017/2018 to 2019/2020: Sensitivity of various apple rootstocks to water stress (A-17-USH-CP01). My presentation is attached to this report. It was well received, and several participants conveyed their compliments to me afterwards. No technical or interpretive issues were identified.

The next speaker was a fellow South African: Phumudzo Tharaga of Free State University. He presented the methods used in his current PhD study on "Transpiration rates of rainfed sweet cherry (Prunus avium L.) using sapflow under warm temperate conditions." Phumudzo was trained in sap flow methods by Dr Sebinazi Dzikiti when he was employed by the CSIR. He would make a potential collaborator on fruit orchard water use projects in the central part of South Africa.

The presentation by Diriba Nemera (Hebrew University of Jerusalem, Israel) was not directly relevant to the research we are doing in South Africa, but I took away some analytical approaches which could be useful for conducting more in-depth physiological analysis using sap flow data.

Tuesday 8th October, Poster session:

The following posters were of interest to me:

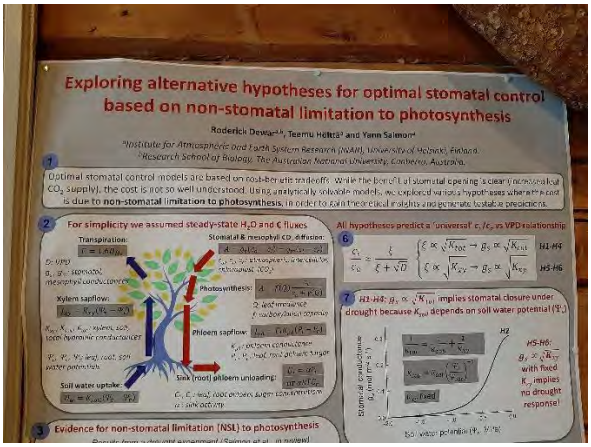
1. Jonghyun Choi (Plant and Food, New Zealand): Testing of low-cost microprobe sap flow sensors on woody plants
   (See write-up of the oral presentation by Junghoon Lee in Session 2.)
   The poster presented the methods and results of the evaluation of the new minimally invasive microprobe sap flow sensors in woody plants, specifically kiwifruit vines. Sensors were shown to be reliable and durable. They yielded sap flow patterns that closely matched those obtained from conventional thermal dissipation probes when both were installed in the same vine.

2. Sandra Denham (Indiana University, USA): Soil moisture effects on species-specific sensitivity of stomata to vapor pressure deficit
   This study investigated tree species along the continuum from isohydric to anisohydric water use strategy, and how they respond to soil water availability and atmospheric demand for water (VPD) across three geographic sites. Tree-level stomatal conductance was estimated using sap flow. The questions were thus: (1) How is stomatal sensitivity to VPD affected by changing soil moisture condition? (2) Does this relationship remain constant across sites and species? The results are of interest in understanding similar responses in isohydric versus anisohydric (e.g. apple) fruit tree species. The methods used could be transferred to some

of our apple water use projects for additional in-depth analysis of environmental drivers of water use in trees having different strategies.

3. Roderick Dewar (Australian National University, Australia): Exploring alternative hypotheses for optimal stomatal control involving co-ordination between non-stomatal limitation to photosynthesis, phloem-xylem transport and sink strength
   Dewar presented an improved modelling approach to understanding the optimisation of stomatal control, by incorporating leaf sugar status, phloem unloading and sink strength in addition to water-related parameters. The model provides testable predictions and it would be very interesting to apply this model to apple trees under different conditions to gain a better understanding of stomatal regulation and resulting carbon balance.

4. Aleksanteri Mauranen (University of Helsinki, Finland): Comparison of the USO and CAP stomatal control approaches using JSBACH
   Mauranen is working with Dewar on modelling of stomatal control in woody species.



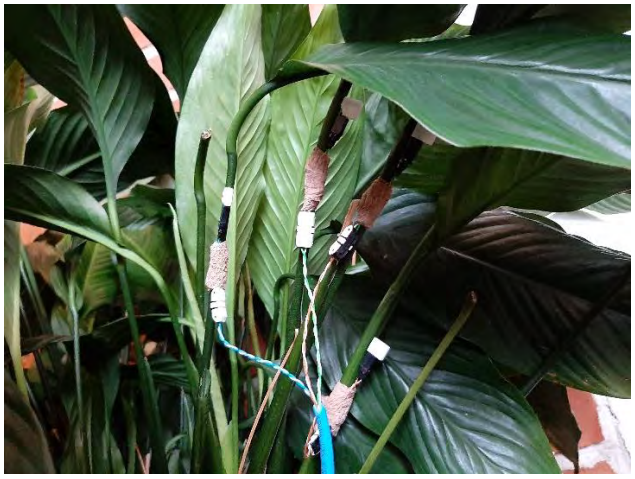
Wednesday 9th October, Session 2: Methods

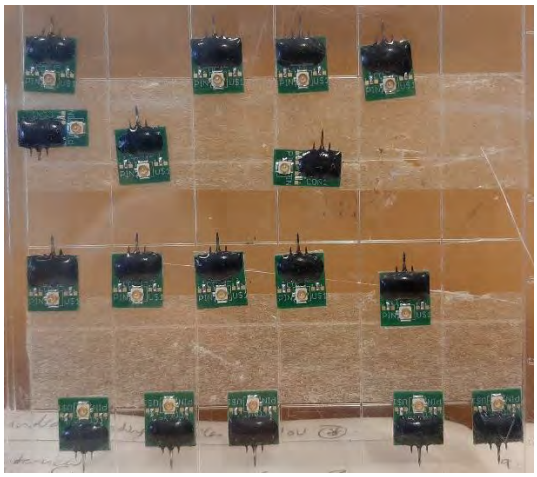
The keynote speaker in this session was Prof Kathy Steppe with a presentation entitled “Plant sensor synergy in tree hydraulics”. Prof Steppe is Head of the Laboratory of Plant Ecology at Ghent University and a world leader on plant-water relations and carbon metabolism, xylem and phloem functioning, plant sensors for monitoring and water stress detection, and advanced plant-based control strategies (e.g. irrigation scheduling). She is a core member of the Sap Flow group. In her presentation she described how different types of sensors measuring various aspects of tree water relations and water fluxes can be used in combination (synergistically) to gain a deeper understanding of tree hydraulic functioning. This can be scaled to global monitoring and modelling networks that can help researchers to track and understand responses to climate change and other stresses. New fields of interest include the impact of sugars on hydraulic vulnerability to water stress, and the dynamics of foliar water uptake and negative sap flow.

Also in this session, Junghoon Lee of Seoul National University, South Korea, gave a presentation on “Microprobe Sap Flow Sensors”. This new sap flow sensor was developed using herbaceous plants such as tomatoes, but the poster presented at the conference shows (see above) that it was also successfully tested on woody kiwi vines (collaboration with scientists from New Zealand who also attended the workshop). It has also been tested on coffee trees, date palms and palm oil trees. The developers are confident that it would also work on other woody plants and they could make the sensor longer on request (currently 2cm).

The benefits of the new sensor compared to existing technology include:
1. Only one probe (and very thin), minimally invasive, much less wounding, negligible heating
2. This means that the sensor can be left in the stem for much longer (ca. 2 years)

3. Battery life of more than 11 months (but batteries are not rechargeable)
4. Multiple sensors can be installed on one plant in different positions
The unit includes a central data processor and data is sent to their server but can be retrieved by the user. Users can also use their own data loggers. The sensor us currently not cheap but with greater sales maybe the price will start to come down and become an option for SA researchers and possibly farmers.





A significant theme of interest was the evaluation of different methods to determine zero-flow conditions on the sap flow of various tree species under contrasting environmental conditions (before, during and after drought or sub-freezing weather; during the night). This work needs to be taken into consideration for our diurnal sap flow data of apple trees since we have to ensure that our night-time baseline calibration is done correctly.

Methods to determine the time lags between crown and basal sap flows in trees were also addressed by several speakers (e.g. Wakana Azuma of Kobe University, Japan). Such time lags vary widely between species and are regarded as an indication of the capacity of internal stem water storage to supply water to transpiration, especially in the early morning. The factors that determine these dynamics remain largely unknown. Azuma referred to a method termed Cross-correlation Analysis which I would like to follow up since we are also analysing differences between shoot and basal sap flow to calculate internal water storage in apple trees.

Wednesday 9th October, Session 3: Ecology
In this session, speakers focused on the use of sap flow techniques to monitor stress in natural forests, especially stress arising from drought and disease. There was also an interesting presentation on the influence of forest stand age and thus species composition on evapotranspiration and forest water use.

Thursday 10th October, Session 4: Ecophysiology
This session was started by the keynote speaker Prof Sandra Bucci of the National University of Patagonia San Juan Bosco (Argentina) who presented on “Linkages between water transport, hydraulic architecture and carbon assimilation in woody species”. She focused on the measurement and role of stem capacitance in woody species. Capacitance is defined as the amount of water released from a tissue per unit decrease in water potential. Stem and leaf capacitance is important to buffering water potential. Prof Bucci described the relationships between sapwood density, capacitance, volumetric water content, and the diurnal dynamics of stomatal conductance and carbon assimilation, as well as the vulnerability of leaves to dehydration/drought and the loss of hydraulic conductivity. Different tree species from contrasting environments have different daily patterns of stored water use, changes in stem sectional area, sap flow and leaf gas exchange. This makes them differentially vulnerable to drought. Some of these concepts and methods can be tested in our projects on water use of apple trees.

Dr Zweifel is with the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) and is a world expert on stem growth analysis using dendrometers, together with sap flow and other sensors to develop a systems model of tree water relations and growth. He presented research on measuring stem radius fluctuations on the tree periphery (the crown and ends of branches) which follows a very different trend to basal measurements. The development of dual-point dendrometers allows for the differential measurement of bark and xylem radius fluctuations during the course of a day in basal and peripheral positions. His research is part of a new interest by the leaders in the field in the role of sugars (osmolality) of different tree organs in relation to water fluxes. The aim is to develop a better integrated understanding of water (xylem) and sugar (phloem) fluxes and interactions in larger trees.

The presentation by Prof Brunella Morandi of the University of Bologna on the differential water relations between fruit of various species was interesting. This review of the literature focused on vascular flows and their relationship with fruit anatomical characteristics and developmental stage. Water fluxes through fruit surfaces are influenced by fruit size, surface conductance and atmospheric conditions (VPD). Internally, the xylem and phloem functionalities are key factors. Data were gathered and compared for apple, peach, kiwifruit, cherry, pear and grape, at different phenological stages. There is a clear relationship between fruit surface conductance and fruit transpiration rates, and fruit conductance decreases with fruit development. High surface conductance drives a high rate of xylem and phloem flows and increases the probability for passive phloem unloading. Mature apples have the lowest flows of all the fruit which means that they require active mechanisms for phloem unloading. Young apple fruit have average flows and better conditions for passive phloem unloading. The presentation was a reminder to take these characteristics into account when interpreting diurnal fruit diameter fluctuations (dendrometers) and growth patterns in our water use projects.

Thursday 10th October, Field trips

The group visited the SMEAR II station which is on the grounds of the Hyytiälä forestry field station and was started in 1995. The station measures forest ecosystem - atmosphere relations. Atmospheric measurements include aerosols, atmospheric chemistry, cloud microphysics and micrometeorology. Tree-based measurements include gas exchange, water flows, irradiance and energy use, and growth and structure. The sensors are attached to various towers in the forest ranging from 18 m to 128 m. Soil water and nutrients, gas concentrations and temperature are also monitored. Of particular interest to me was the custom-built chambers and other systems for continuously measuring gas exchange of various tree organs.


Friday 11th October, Session 5: Data and analysis

The keynote speaker was Prof Rafael Poyatos of the Universitat Autònoma de Barcelona. He is a forest ecophysiologist and ecohydrologist and his main interest is in improving our understanding of how terrestrial ecosystems control water and carbon fluxes. The presentation focused on the global SAPFLUXNET database which is being used to better understand global patterns in transpiration of trees and forests.

The other speakers presented new or improved tools and statistical approaches relevant to whole tree water use quantification, and the integration of water and carbon fluxes. The last speaker, Prof Jochen Schenk (who is also the Chair of the Sap Flow Group) presented methods and results as applied to avocado trees (and other species) in California. His research group studies the functioning and physiology of the water-conducting xylem, including its hydraulic conductance and capacitance, using a range of continuous, non-destructive measurements including sap flux density, the water potential gradient driving the flow, and a measure of stem water storage, together with environmental factors. His presentation provided a good primer for the fundamentals of hydraulic stem conductance and capacitance and how to analyse the diurnal data, and the benefits of *in situ* non-destructive measurements of conductance over time.

Lindsay Muchena was registered as a remote participant and was able to stream the following presentations:

1. Phumudzo Tharaga: Transpiration rates of rain-fed sweet cherry (*Prunus avium* L.) using sap flow under warm temperate conditions.
2. Diriba Nemera: Tuff trenches improve sap flow in avocado affected by long-term irrigation with treated wastewater.
3. Virginia Hernandez-Santana: Sap flow as a tool to enhance the quality of fruits: the case of olive oil.
4. Robert Skelton: New, open-source miniature external sapflow gauges for capturing plant water use.
5. Jeanne Simon: Combining flow-MRI method and modeling approach to assess the impact of conductive tissues on sap flow in tomato plant architecture
6. Shinichi Takeuchi: Calibration of heat ratio sap flow method by direct measurements of transpiration with weighing root-ball method for *Michelia figo*.
7. Alec Downey: From bud burst to leaf fall: A pilot study on observations of water relations.
8. Jeannine Cavender-Bares: In defence of trees: accurate detection of oak wilt disease and drought in oak forest canopies and seedlings using spectroscopy.
9. All the 1-2 minutes flash presentations of posters. Here are two examples:
    i. Roderick Dewar: Exploring alternative hypotheses for optimal stomatal control based on non-stomatal limitation to photosynthesis.

ii. Paulina Dukat: Evapotranspiration partitioning using eddy covariance and sap flow measurements at Scots pine forests.

4. Connections made

I made the following personal connections which will in some cases be followed up:

Name	Country	Connection	Follow up
Kathy Steppe	Ghent, Belgium	Brief introduction	Possibly. She is the "guru" but extremely busy. Connections to Sebinasi Dzikiti (CSIR) and David Drew (SU Forestry, collaborative project starting 2020) could pave the way for follow up.
Roberto Salomon	Ghent, Belgium	Lunchtime chat	Possibly. He may become involved in the collaborative project with David Drew (Forestry) who visited and had discussions with him in 2019.
Jochen Schenk	California, USA	Brief introduction	Possibly. Has worked on avocado trees. He is highly experienced.
Peter Braun	Geisenheim, Germany	Various chats	Possibly. Would welcome me on a visit to Geisenheim. Has very relevant ecophysiological experience in orchards/ vineyards.
Brunella Morandi	Bologna, Italy	Several chats	Yes. She has agreed verbally to be the external examiner for Lindsay Muchena (PhD) in 2020. This can be the start of a collaboration. She works on very similar topics.
Phumudzo Tharaga	UFS, South Africa	Several chats	Yes. He is very interested in collaboration. We also spoke about acting as external examiners for postgraduate students at UFS and SU.

Rob Skelton	SAEON, South Africa	Several chats	Yes. Rob is returning to South Africa to start his own lab at SAEON. He is technically very skilled in the sub-field of xylem hydraulics.
Junghoon Lee	South Korea	A couple of chats	Possibly. If funding allows, I would like to test the new micro sap flow sensor.
Jonghyun Choi, Keith Sharrock, Michael Clearwater	Plant & Food; Waikato; New Zealand	Several lunchtime chats	Possibly. If funding allows, I would like to test the new micro sap flow sensor. This group is hosting the XII International Workshop on Sap Flow in New Zealand in 2021.
Roderick Dewar	Canberra, Australia	Poster session chat	Possibly. He would welcome us testing his stomatal optimisation model since we are collecting all the necessary data in our apple projects. This would be time-intensive but perhaps suited to a PhD study.
Sander Denham	Indiana, USA	Poster session chat	Possibly. I would like to test her analytical approach using our various data sets on apples. She would be happy to help.
Roman Zweifel	Switzerland	Lunchtime chat	Possibly. Our analysis of dendrometrical data can benefit from studying his methods.

5. Publications

1. L. Muchena, S. Dzikiti, E. Lötze and S.J.E. Midgley, (to be submitted before 31/12/2019). Using sap flow sensors to study the influence of rootstock and mid-summer water deficit on transpiration of apple trees in South Africa. Acta Horticulturae.
2. Popular article in South African Fruit Journal. To be submitted before 31/12/2019.