Project title: Investigation of *Pinus halepensis* ground water utilization in response to extreme changes in the precipitation regime of the eastern Mediterranean across habitats with different moisture holding capacity

PURPOSE OF THE VISIT

My visit to the Institute of Botany at the University of Basel (Switzerland) hosted by Prof. Ch. Körner facilitated the analysis and interpretation of findings resulting from a joint project with my home Institution, the Department of Biology of the University of Patras (Greece). Our project was designed to test whether forest trees growing in "wet" and "dry" habitats respond differently to changes in moisture availability. We also tested the hypothesis that *Pinus halepensis* sp. ground water utilization changes from surface to deeper ground moisture and vise versa in response to extreme changes in precipitation. We used sharp contrasts both in time and space in this quasi manipulation experiment 'by nature'. The two 'manipulations' were a replicated short distance moisture contrast between gully and rim position of trees and the effect of a climatic singularity, an extreme drought. The final aim of this visit was to assist the production of an original scientific paper, intended for a highly ranked peer-reviewed scientific journal.

DESCRIPTION OF THE WORK CARRIED OUT

During my stay at the Institute of Botany in Basel I analyzed growth of low elevation (ca. 300m a.s.l.) *Pinus halepensis* sp. forests trees form "dry" habitat slopes (no access to permanent water supplies; only source of moisture from rainfall) in 4 island regions of the eastern Mediterranean (namely Zakinthos, Skiros, Samos and Ierapetra, all island regions of southern Greece). These data were compared with "wet" site data (e.g. trees growing in gullies and dry river beds). The wet-site tree cores taken from valleys and depressions situated a few tens of meters a.s.l. at the bottom of the ridges from which the upslope trees were sampled.

In a second step, I tested whether the above trees experienced changes in ground water utilization related to the variability of precipitation within 1971-2000. Both “wet” and “dry” habitat trees were explored to additionally assess the role of differences in soil–root depth. As a tool in investigating such changes running correlation analysis was preformed (using 5-year moving “windows”) between tree growth and different integration periods of precipitation (Sarris et al. 2007; Sarris 2008). Through the above analysis I explored the stability of tree growth-precipitation correlations. This determined the critical levels of precipitation needed for tree growth in dry (wet) habitats of shallow (deep) soil and presumed deep (shallow) tree rooting, as climatic conditions changed from wetter to drier conditions and vice versa at short time intervals (Sarris et al. 2007).

The tested precipitation periods were based on potentially ecological effective rainfall periods promoting tree growth in Mediterranean climate type conditions. The bottom range of these integration periods was monthly precipitation from 1 to 12 months within the calendar year of tree-ring formation. The top range of these integration periods was multiple years of precipitation from 2 to 6 years prior to and including the year of tree ring-formation. This for testing the effects of moisture stored in deeper ground accumulated from rainfall events during years prior to growth. In total 21 different precipitation integration periods were tested.

As a measure of climatic dryness, the deviation from the 1980-1999 and 1961-1990 annual precipitation average was calculated for the “wettest” and “driest” calendar periods of meteorological records. The 1980-1999 and 1961-1990 periods have been used in various climate model studies as a basis for precipitation projections in the Mediterranean during the 21st century (Deque et al. 2005; Somot et al. 2008; Giorgi and Lionello 2008, IPCC 2007). The magnitude of precipitation’s deviation and the corresponding tree ground water utilization responses were compared to such projections in order to help assess potential drought impacts for eastern Mediterranean forest ecosystems under future global warming.

Finally I visited the Paul Scherrer Institute (PSI) half an hour east of Basel. There together with Dr. Rolf Siegwolf and Dr. Matthias Saurer we interpreted results from carbon and oxygen stable isotopes coming from tree rings of Samos pine forests. These data were used as an additional tool in investigating the mechanism of *P. halepensis* deeper ground moisture utilization as drought conditions intensify.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The two regions where I found the greatest difference in “dry” vs. “wet” habitat tree growth during the last 3 decades of the 20th century were selected, namely Samos and Zakinthos. In the second half of these last 30 years, annual precipitation dropped by 17% in Samos (P=0.07) and 19% in Zakinthos (P=0.03) compared to the first half. Thus, one period of “wet” and one of “dry” climate conditions for tree growth was determined (1971-1985 vs. 1986-2000).

For Samos during the period of “wet” climate the difference in growth between “wet” and “dry” habitat trees (10 vs. 15 trees) was 60% and remained similar (61%) when climate became drier. For Zakinthos under “wet” climate conditions the difference in growth between “wet” and “dry” habitat trees (5 vs. 10 trees) was 37% and again remained similar (34%) under drier climate conditions. Hence, reducing precipitation by close to 20% produced the same tree growth response in both “wet” and “dry” habitat *P. halepensis* forest trees.

The wettest calendar periods within 1971-2000 occurred in the late 1970s-early 1980s for Samos and the early 1970s and early 1980 for Zakinthos. They read 19% (19%) and 5% (3%) above the 1980-1999 and 1961-1990 precipitation average for Samos (Zakinthos).

In this case growth of trees from “wet” habitats of Samos produced best correlations with precipitation ranging from February-April to October-April. For “dry” habitat Samos trees this was from January-May to 2-year precipitation. Under the wettest climatic conditions for trees of Zakinthos, “wet” habitat growth produced best correlations with precipitation of April and May months alone. For “dry” habitat trees of Zakinthos significant correlations with annual tree growth were produced with February-April precipitation.

Thus, during periods of abundant rainfall tree growth seems to be determined by shorter integration periods of precipitation for “wet” habitat trees than for “dry” habit ones. In this case moisture located at top soil layers, supplied from spring precipitation concurrent with growth initiation and/or winter rainfall prior to growth generally appears sufficient for sustaining annual pine growth.

The driest calendar periods within 1971-2000 occurred in the late 1980s-early 1990s and the late 1990s in Samos. For both dry periods annual precipitation was -10% and -21% bellow the 1980-1999 and 1961-1990 precipitation average. Growth of both “wet” and “dry” habitat trees produced best correlations with precipitation of the past 4-6 years (including the year of growth). For Zakinthos the driest calendar periods within 1971-2000 occurred in the mid 1970s and in the late 1980s-early 1990s. The latter being the most severe. Under the moderate precipitation reduction (-6% and -18% bellow the 1980-1999 and 1961-1990 precipitation average) growth of both “wet” and “dry” habitat trees was correlated best with the past 3-4 years of precipitation.

However, under the most severe rainfall decline of the late 1980s-early 1990s (-25% and -35% bellow the 1980-1999 and 1961-1990 precipitation average) “wet” and “dry” habitat trees of Zakinthos showed a differential response. “Wet” habitat trees appeared to be better correlated with precipitation of February, while “dry” habitat trees were better correlated with precipitation of the past 5 years in the late 1980s. During the absolute minimum of precipitation in the early 1990s, no precipitation integration period produced significant correlations with tree growth for “dry” habitat trees.

Hence, during periods of moderate rainfall decline tree growth seems to be determined by similarly long integration periods of precipitation in both “wet” and “dry” habitat trees. Moisture from deeper ground accumulated from multiple years of precipitation prior to and concurrent to the year of growth was utilized to sustain pines’ annual growth. However, when climate became even drier (and deeper moisture pools were gradually depleted) tree growth in “wet” habitats could only depend on any winter rainfall supplied at the beginning of the growing season. Compared to “dry” habitats, “wet” habitat topography allows surface runoff to accumulate producing deeper soils which in turn have the ability to hold extra winter moisture. More extensive surface roots in “wet” habitats can also come into play, enabling pines to still absorb enough moisture for producing some growth under very dry conditions. “Dry” habitat trees, growing on shallow soils with increased surface runoff, under very dry climate do not seem to be able to take full advantage of any winter rainfall. Thus they can be much more vulnerable to desiccation when deeper moisture pools from past rainfall are depleted.

Responses reported above could very well resemble future drought impacts for *P. halepensis* forests. The precipitation decline of the late 1980s-early 1990s reported for the island regions we selected falls into the upper range of greatest projected reductions in precipitation for the Mediterranean based on various climate model studies (Deque et al. 2005; Somot et al. 2008; Giorgi and Lionello 2008, IPCC 2007).

Carbon stable isotope analysis confirmed that the decline in precipitation intensified drought stress in pines, coinciding with the utilization of water from deeper ground. We arrived at this conclusion by comparing tree-ring oxygen isotope signatures with those of water reported from top soil and from deeper ground.

FUTURE COLLABORATION WITH HOST INSTITUTION

My collaboration with the host institution has the potential to continue in terms of studying resent drought responses of other forest species from the Mediterranean such as Oaks, Junipers and Firs, in assessing their future impacts under global warming.

PROJECTED PUBLICATIONS TO RESULT FROM THE GRANT

Sarris D, Christodoulakis D, Körner Ch (2010) Topography and climate interactions drives the future distribution of *P. halepensis. (In preparation)*

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