

## Growth dynamics of *Podocarpus falcatus*

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### Introduction

The tropical mountain forests in equatorial Africa are threatened by climate change and increasing land use intensity. In Ethiopia, the forest cover decreased during the last century to an alarmingly minimum. Recent remote sensing studies (Dessie & Kleman 2007) revealed a further reduction to 3% forest coverage in the vicinity of our study area due to an increasing population and expansion of agricultural land. On the other hand, additional environmental stress is caused by climate variability with a high frequency of drought events, possibly aggravated by long-term climate change. Therefore, understanding growth reactions and ecological behaviours of indigenous tree species to the changing environmental conditions are of great importance for a sustainable utilization of the remnant natural forest.

During recent years, several dendroclimatological studies were conducted in Ethiopia working with different tree species and dealing with various problems. Gebrekirstos (2006) analysed stable isotopes of *Acacia* species of the savannah woodlands for a paleoclimatic reconstruction and later assessed climate-growth relationships (Gebrekirstos et al. 2008, 2009). Furthermore, wood anatomical investigations of the highland species *Juniperus procera* showed clear distinct ring boundaries or faint to indistinct ring boundaries including many wood anatomical anomalies like wedging rings, causing serious constraints for cross-dating (Couralet et al. 2005, Sass-Klaassen et al. 2008, Wils et al. 2009). This variable wood anatomy is the result of regional and temporal differences in seasonal rainfall patterns. So far, the dendrochronological potential of the indigenous *Podocarpus falcatus* was only explored on a species from South Africa. February and Stock (1998) stated that the evergreen conifer tree is not useful for dendrochronological analyses because of its lobate growth and multiple rings. On the other hand, different species of Podocarpaceae (e.g. *Podocarpus totara*, *Podocarpus hallii*) were successfully analysed and crossdated in New Zealand (Bell & Bell 1958, Dunwiddie 1979, Norten et al. 1987).

Hence, the objective of our study is to investigate native Podocarpaceae in Ethiopia and check its dendrochronological potential. In this extended abstract we present first results of varying approaches to collect knowledge about the growth dynamics of *Podocarpus falcatus*.

### Material and Methods

The study was conducted in the Munessa-Shashamene Forest, which is located on the eastern escarpment of the Main Ethiopian Rift Valley, 240 km south of Addis Abeba (7°26'N 38°52'E). The remnant natural forest covers an area of about 23.000 ha in the mid-highlands (ca. 2300m a.s.l.) and is highly disturbed due to selective logging by local people and due to cattle grazing. A bimodal climate pattern is characterized by an unreliable short rainy season from March to May and a long rainy season from July to September. Climate data collected close to the study site indicate an average annual rainfall (mean of 2006-2008) of 1121mm and annual mean temperatures of 15°C. In addition to *Podocarpus falcatus*, other indigenous tree species can be found: *Juniperus procera* (evergreen coniferous species), *Syzygium guineense* and *Prunus africana* (evergreen broadleaved species), *Croton macrostachyus* and *Celtis africana* (deciduous broadleaved species). Since March 2008, electronic point dendrometers (Ecomatik, Germany) registered stem diameter changes in 30 minute intervals that mainly result from variations of the tree's water status. From the original dendrometer data, daily radial change (dR) of the stem

diameter is calculated from the difference between two consecutive daily stem diameter maxima. Increment cores and stem disks were collected for ring-width analyses (Lintab System, Rinntech, Germany) and high frequency density measurements (LignoStation, Rinntech, Germany). Furthermore, wood microcores were extracted with a trephor microcorer (Rossi et al. 2006). After embedding the wood samples in polyethylenglycol (PEG) or Paraffin, microsections of 10-30 $\mu$ m thickness were cut with a rotation microtome (Leica, Germany) and stained with solutions of astra blue and safranin red to distinguish living and lignified cells.

Local temperature, precipitation and air humidity were measured less than 0.5 km from the study site at 30 minute intervals. Vapour pressure deficit was calculated from the saturation vapour pressure of the air minus the actual saturation vapour pressure according to Häckel (1993).

## Results

The old individuals of the up to 40 meter high *Podocarpus falcatus* are characterized by a complicated and winding lobate stem form (Fig. 1). The wood anatomical structures of *P. falcatus* are depicted in Figure 2. The coniferous tree generates quite distinct ring boundaries in the form of rather narrow bands of tracheids with slightly thickened latewood cells. Furthermore, pronounced intra-annual density variations within the earlywood, closely located to the former growth ring boundary, are found. These “false rings” were not formed annually and are sometimes difficult to differentiate from growth ring boundaries. The lobate stem growth causes wedging and missing rings resulting in serious constraints for crossdating.



Figure 1: *P. falcatus*, the conifer tree can reach heights up to 40 meter with a stem diameter up to 2.5 meters. Stems of older trees are characterized by a lobate growth.

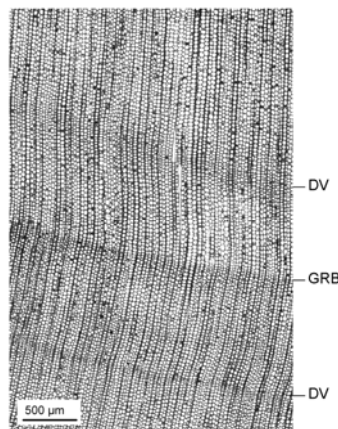


Figure 2: Wood anatomical structures of *Podocarpus falcatus*. The tentative growth ring boundaries (GRB) are formed by slightly thick-walled latewood cells. Intra-annual density variations (DV) can be found within the early wood cells.

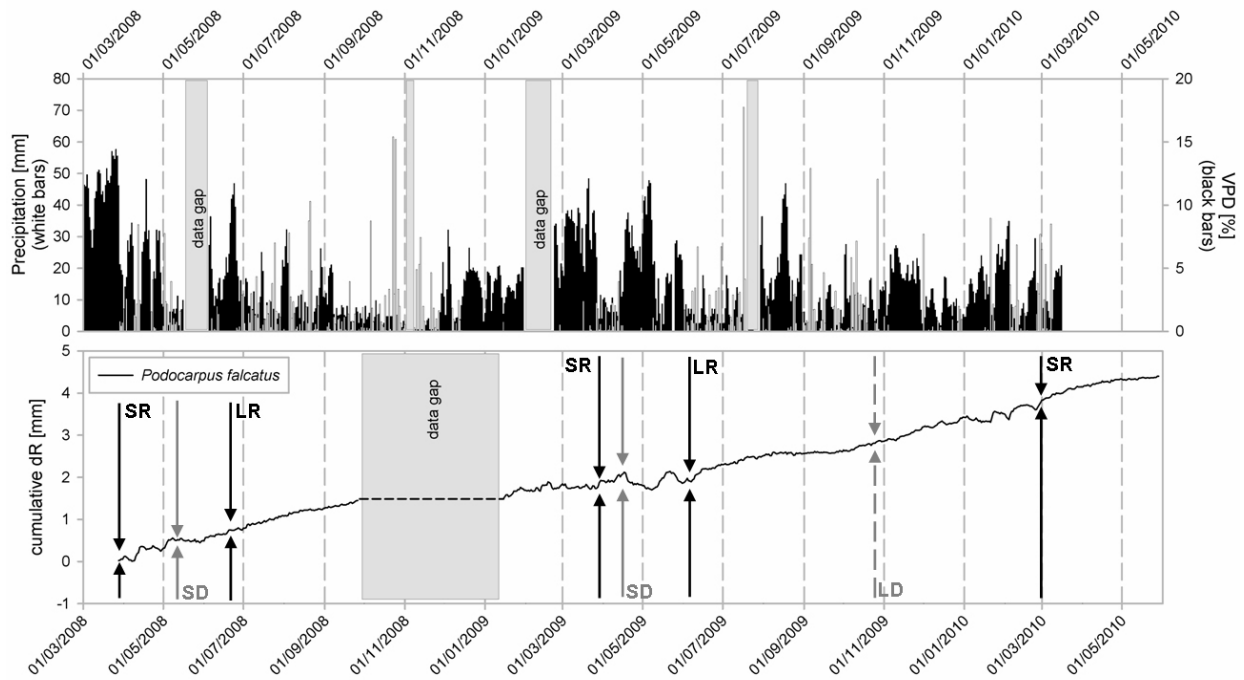


Figure 3: Climate data (precipitation and vapour pressure deficit VPD) and cumulative radial diameter change of evergreen conifer *Podocarpus falcatus* from March 2008 to May 2010. The black arrows indicate the rise of the dendrometer curve corresponding to the onset of the short rainy season (SR) and long rainy season (LR). The decrease of the dendrometer curve is initiated by the short dry season (SD) marked with grey arrows. Unfortunately, a data gap occurred during the long dry season of 2008 in the dendrometer data. However, data points before and after the data gap show the same value, suggesting cambial dormancy during dry season. On the other hand, the long dry season of 2009 (grey dashed arrow) was interrupted by many rain events causing a continuous increase of the stem diameter.

The dendrometer and climate data are shown in Figure 3. The tree reacts on rain events with an increasing stem diameter. During the short rainy seasons (SR) of 2008, 2009 and 2010 the stem diameter increased, and decreased again due to no or low precipitation during the short dry season (SD). With the onset of the long rainy season (LR) the dendrometer curve increased again. Unfortunately, because of missing data we can not exactly delimit the growing period during LR in 2008. However, the stem diameter before and after the data gap (grey box with dashed line) shows almost identical values implying no further cambial activity during the data gap. So, we would determine the end of radial growth season to occur around the beginning of the long dry season in October 2008. In contrast, the LR of 2009 lasted until the end of October followed by an indistinct LD with a rather dry November and major rain events since December. Consequently, stem diameter increased continuously until January 2010.

However, dendrometer data alone do not indicate whether the stem diameter increases is due to stem swelling and water uptake or due to cambial activity and wood formation. Hence, we additionally analysed thin sections of microcores (Fig 4) showing the cambial part of the stem. All samples show growth ring boundaries formed during the LD of the years 2007 and 2008. The distinctness and the width of the tree rings vary between the samples due to different growth patterns in tangential direction around the stem. In March 2009, the cambium was active during the SR and first wide cells were formed resulting in stem diameter increment (Fig 3). Thus, an intra-annual density variation is visible in the following samples caused by a second short dormancy of the cambium during the SD in April and May 2009. After the onset of the LR in June 2009, the thin sections of June, August and September show bands of freshly formed unligified cells. Thereafter, cambial activity normally should cease with the beginning of the LD. However, after a dry November 2009 there were many rain events during the dry season of 2009/2010. Thus,

favourable growth conditions continued. The thin sections witness ongoing cambial activity in December and a lack of a distinct growth ring boundary in the following samples of 2010.

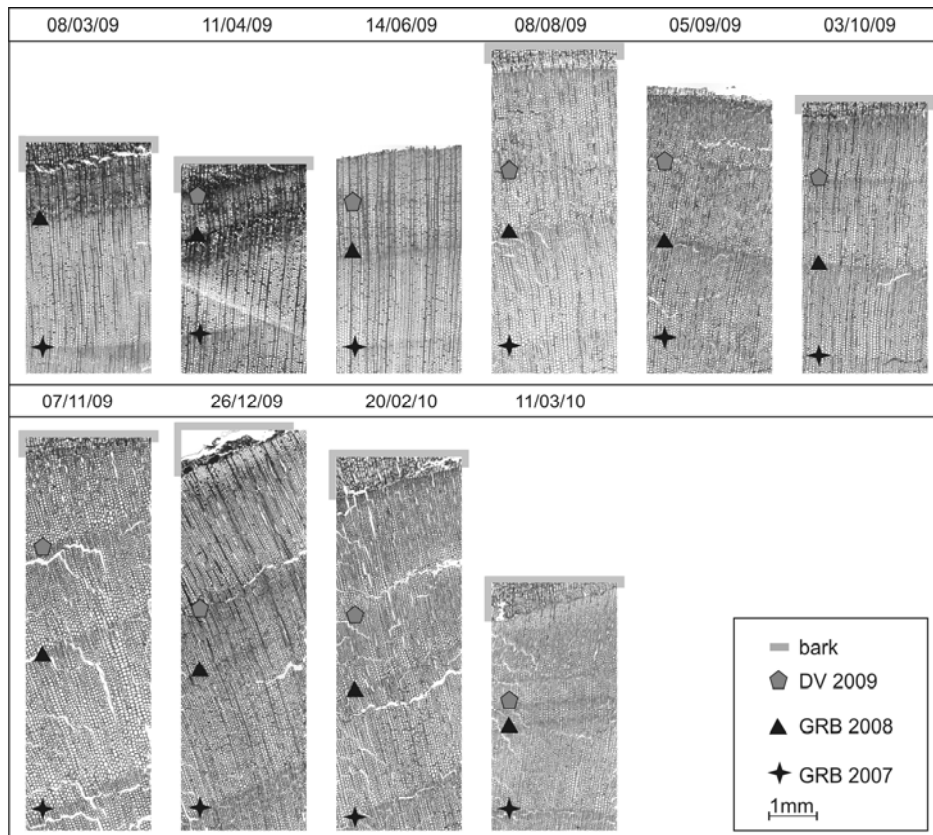


Figure 4: Thin sections of *P. falcatus* microcores extracted at different dates for detecting cambial activity. The symbols mark growth ring boundaries (GRB) and intra-annual density variations (DV) of the different years. Unfortunately, in greyscale the active cambium is difficult to recognize, but we determined that the samples of March 09, June 09, August 09, September 09, December 09 and March 10 are marked with fresh and wider cells. Furthermore, the varying number of cell rows in between the samples depends on the irregular and lobate stem growth of *P. falcatus*.

## Discussion

Dendrometer measurements and wood anatomical samples complement each other in a useful way. As outlined above, stem diameter change may correspond to water uptake after rain events. Thus, the cumulative radial diameter change can not unambiguously represent cambial growth. An additional look on the microcores helps determining the period of active cambium. We conclude that *P. falcatus* reacts on sufficient rain events with an activation of the cambium at any time of the year. This growing potential was also found for the exotic conifer tree *Pinus patula* planted by the local forest enterprise. On the other hand, the broadleaved trees, e. g. *Celtis africana* or *Prunus africana*, are not able to interrupt their dormancy due to rain events (even during SR), but reactivate their cambium with the onset of the LR (Krepkowski et al. 2011).

Although there was no indication for an active cambium, a zone with ongoing cell division, in the microcores (Fig 4) and no precipitation in November 2009 (Fig 3), the stem diameter of *P. falcatus* was increasing. This reaction is caused by the further maturation of the cells, especially the enlarging and secondary cell wall thickening of the xylem cells lasting up to one month longer after the cambium stopped activity (Deslauriers et al. 2009).

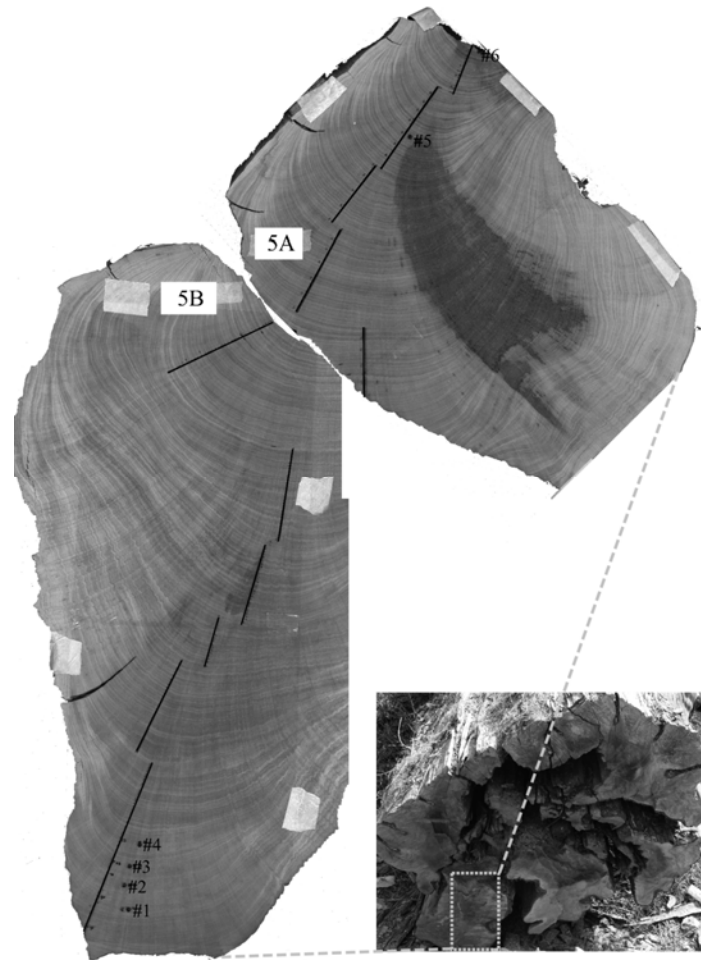


Figure 5: Total cross section and two stem disks of *P. falcatus* (5a/5b) with measurement paths from inner to outer part (top to bottom) for Lintab System. Wood density was measured on the backside of the disks along the same paths. Additionally six sampling points for  $^{14}\text{C}$ -dating are marked.

While our studies indicate that the formation of annual growth ring boundaries of *P. falcatus* is variable, we conducted first ring width measurements on two stem disks of a fallen *Podocarpus* tree (Figs. 5 and 6). After a visual differentiation between growth ring boundaries and intra-annual density variations due to the distinctness and quantity of the latewood cells, we measured 372 tree-rings on the two disks. In contrast, the measurement of wood density and the subsequent calculation of growth ring boundaries yielded 353 tree-rings. For an additional testing of the annual nature of the detected growth ring boundaries and the resulting age determination of the samples, we commissioned the  $^{14}\text{C}$ -dating of selected rings (Fig 5) that according to ring counts should postdate the mid-1960 radioactivity peak and that predate the  $^{14}\text{C}$ -plateau lasting until around A.D. 1650. These results should enhance our understanding of the dendrochronological potential of *P. falcatus*.

Moreover, to proof the annual nature of growth rings in *P. falcatus*, our further work will include the analysis of additional stem disks and increment cores with multiple sampling within and between trees and species. The microcoring of trees shall be continued over several vegetation periods to analyse the inter-annual variation of climate parameters and their impact on growth boundary formation.

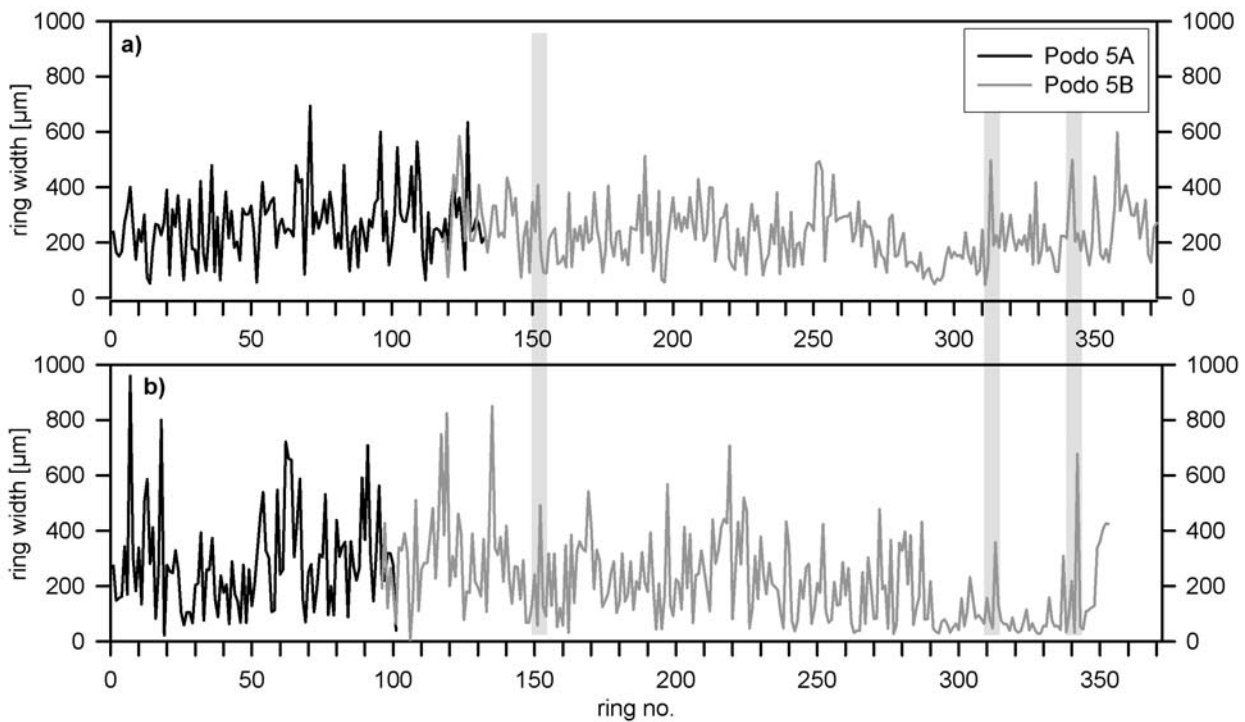


Figure 6: Tree-ring width of two overlapping *P. falcatus* stem disks (5A/5B) from pith (left) to bark (right). The overlap of the stem sections includes 20 tree-rings.

a) Growth ring boundaries identified visually and measured with a Lintab System.

b) Growth ring boundaries calculated by LignoStation due to max. wood density.

Similar results between measured (a) and calculated (b) growth ring boundaries are marked in grey.

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