INTENSIVE PHENOLOGICAL MONITORING OF DECIDUOUS TREES BY PHENOLOGICAL CAMERAS

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OBJECTIVE

The objective is to test whether the continuous and automated monitoring with digital cameras can serve as an alternative to traditional phenological observations by human observers and to use this method for a description of the dynamics of canopy development of deciduous trees.

STUDY SITE AND CAMERAS

The aim of this study was to investigate the utilization of digital cameras for long-term phenological observations of invidual trees, based on 6-years of daily images captured at the International Phenological Garden in Doksany (Czech Republic, 50°27'31" N, 14°10'14" E, at 158 m asl, 45 km northwest of Prague).

Figure 1. International Phenological Garden (IPG) Doksany

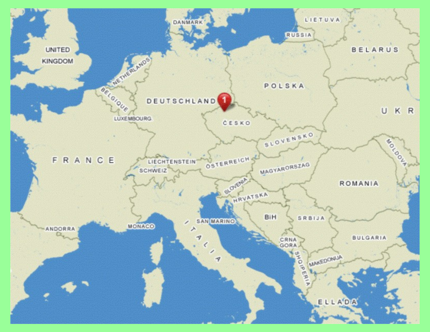

Figure 2. Digital cameras for phenological monitoring (Canon PowerShot S3 IS, Olympus E-410

Canon PowerShot S3 (CPS) with a 1/2,5 " CCD sensor of 6 megapixels and Olympus E-410 (OE) with Live MOS sensor of 10 megapixels. The images were downloaded in the automatic mode every hour via an USB extender cable to a computer. For each image, the same default settings (zoom, image size, automatic aperture and exposure mode) were applied for continuous shooting.

CAMERAS AS A REPLACEMENT FOR MANUAL OBSERVATIONS

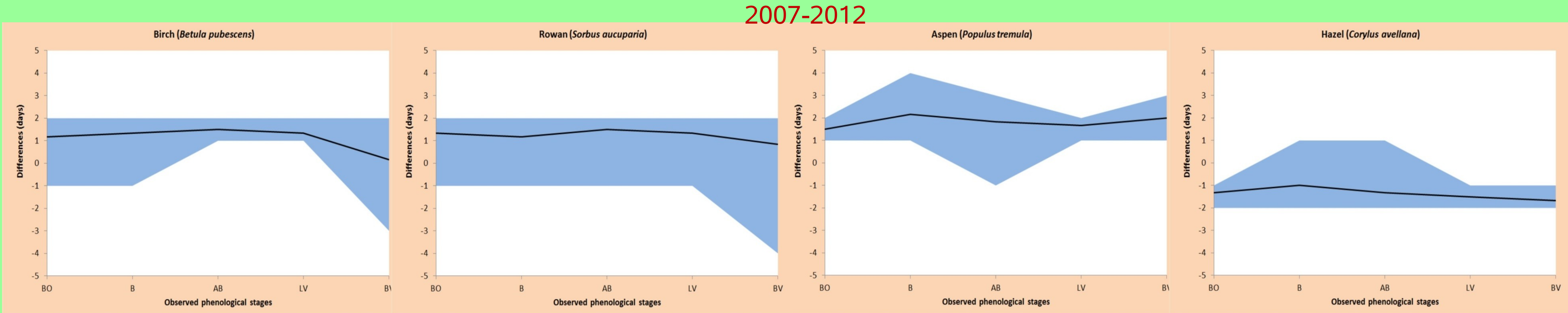

Figure 3. The mean phenophase difference of *Betula pubescens* (birch), *Populus tremula* (aspen), *Sorbus aucuparia* (rowan) and *Corylus avellana* (hazel) between traditional manual monitoring and camera systems for the period of comparison 2007-2012 at IPG Doksany. Blue area shows the range of values.

Cameras - tracking of individual trees - high resolution images

Manual observations – observer - made by direct visual observations in situ

Observed phenological stages :
BO: Beginning of leaf-unfolding
B: Beginning of flowering
AB: General flowering
LV: Autumn colouring
BF: Leaf fall

The differences between the traditional manual phenological observations (TM) and the camera systems (CS) over the 2007-2012 comparison period were very small (Fig. 3). The average differences between the TM and CS for the comparison period fluctuated between –2 and 2 days.

The results of the comparative observations at IPG Doksany confirm the possibility of using compact digital cameras for phenological observations.

SEASON CHANGES IN CANOPY GREENNESS

Camera greenness vs. MODIS NDVI

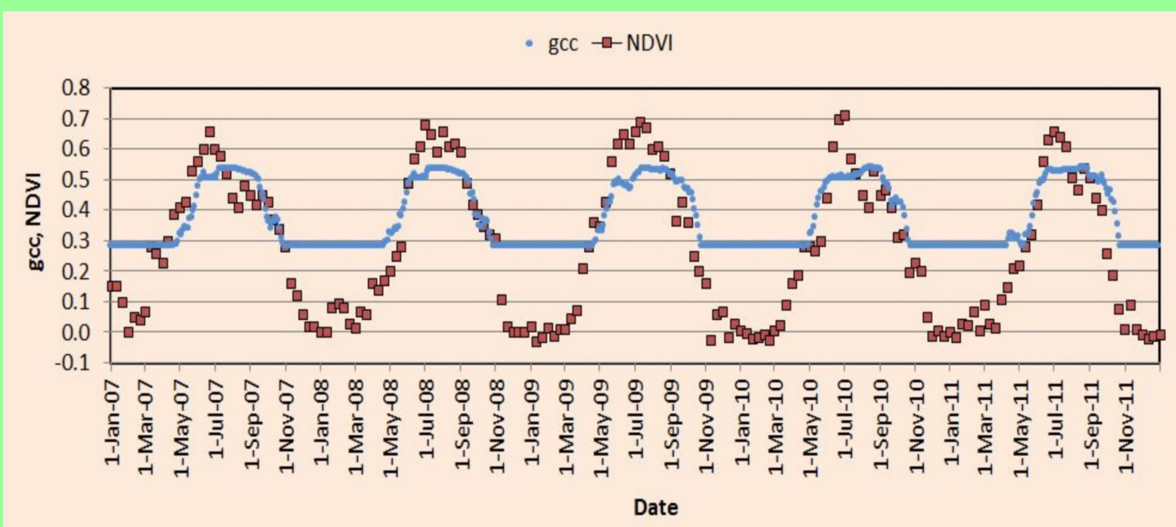

Figure 4. Comparison of the dynamics of NDVI (Source: MODIS – Terra satellite; resolution 250 m) and the green chromatic coordinate (gcc) derived from digital camera imagery as the average of four species (hazel, aspen, birch and rowan) at IPG Doksany in the period 2007-2011.

Cameras – automatic mode - interval: every hour - temporal coverage: 05 am - 07 pm

For each available digital image we have extracted ROI-averaged RGB (R - red, G - green and B - blue) brightness levels, for which we have calculated the green chromatic coordinate (gcc = G/[G+R+B]). The images obtained were analysed using Sigma Scan Pro software.

To reduce the effects of changes in scene illumination we used the method by Sonnentag *et al.*, 2012. We used a moving window approach that assigns the 90th percentile of all daytime values within a three-day window to the center day (per90), resulting in threeday gcc. First, we calculated gcc for each species, then the average value of gcc. Local polynomial regression fitting (Loess curve; Cleveland and Devlin, 1988) with a low degree of smoothing of gcc was used.

Figure 7. Images document the changes in canopy greenness of hazel at IPG Doksany.

Camera greenness vs. GPP

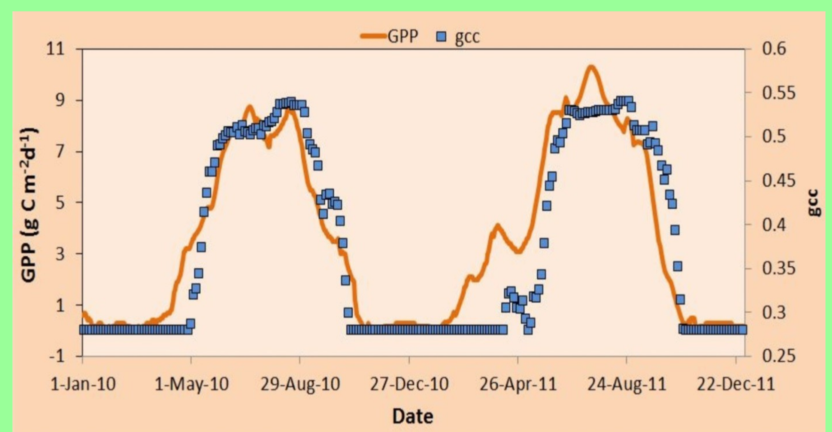

Figure 5. Daily gross primary productivity (GPP) averaged over 10-day intervals and the green chromatic coordinate (gcc) derived from digital camera imagery as the average of four species (hazel, aspen, birch and rowan) at IPG Doksany in the period 2010-2011.

Start (end) of season

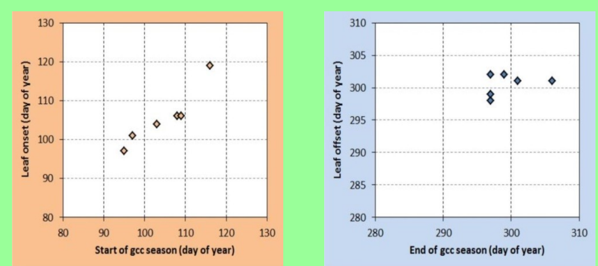

Figure 6. Comparison of the observed start of leaf unfolding (leaf onset) and start of autumn colouring of more than 50 % of the leaf (leaf offset) with an estimated start and end of season from the green chromatic coordinate (gcc) at IPG Doksany in the period 2007-2012.

CONCLUSIONS

- continuous monitoring with digital cameras can serve as an alternative to traditional phenological observations
- the gcc is an appropriate tool for monitoring temporal changes in canopy development and phenological events
- the gcc provides data required for the calibration and direct validation of satellite observations and products

REFERENCES

Sonnentag *et al.*, 2012: Digital repeat photography for phenological research in forest ecosystems. Agricultural and Forest Meteorology, volume 152, January 2012, p. 159–177.

Cleveland, W. S. and Devlin, S. J., 1988: Locally Weighted Regression: An Approach to Regression Analysis by Local Fitting. Journal of American Statistical Association, Volume 83, Issue 403, 1988, p. 596–610.