Abstract Volume
8th Swiss Geoscience Meeting

Fribourg, 19th – 20th November 2010

12. Phenology and Seasonality

sc | nat

Geosciences
Platform of the Swiss Academy of Sciences

Department of Geosciences
UNIVERSITAS FRIBURGENSIS

12. Phenology and Seasonality

This Rutishauser, Martine Rebetez, Thomas Herren

MeteoSwiss, University of Bern, Oeschger Centre for Climate Change Research

12.1

Spring flush of native forest trees at rising spring temperatures is controlled by photoperiodism and temperature

David Basler and Christian Körner

Botanisches Institut, Schönbeinstr. 6, 4056 Basel (david.basler@unibas.ch)

Warmer spring temperatures, as caused by climate warming, led to an earlier spring bud burst and an extended growing season in many temperate and boreal species. To which extent will the phenology of these species keep tracking rising temperatures in future? Phenology is controlled by three important factors: the degree of winter chilling, photoperiod and temperature. Contrary to the high inter-annual variation of spring temperatures, the length of photoperiod is an astronomical and thus weather independent signal for the progression of the season. Photoperiodic control of spring development protects trees from flushing too early under mild winter and early spring temperatures, before the period of potentially fatal freezing damage is over. Photoperiod sensitive species may therefore stop tracking climate the closer temperature modulated bud break is shifted toward the genetically fixed photoperiod threshold. We assessed the photoperiod sensitivity of spring bud break in several common temperate tree species using phytotron experiments with variable photoperiod x temperature interaction. While early successional species showed photoperiod-insensitive and thus mostly temperature controlled bud break, the timing of bud break in late successional species was strongly photoperiodic. Climate warming will thus not lead to much longer growing seasons in such species, as is often assumed.

12.2

Climate change and grapevine's vegetative growth development in Western Switzerland

Bloesch Bernard, Spring Jean-Laurent, Viret Olivier and Dubuis Pierre-Henri.

Agroscope Changins-Wädenswil, Rte de Duillier, 1260 Nyon, contact: pierre-henri.dubuis@acw.admin.ch

The main development stages of grapevine have been recorded for the cultivar Chasselas since 1925 in Pully (VD) and 1958 in Changins (VD). The increasing temperatures observed during the last two decades did influence the development of grapevine. The early stages, from bud break (BBCH 09) to initiation of flowering (BBCH 51) do not show any tendency to precocity related to temperature increase, while flowering (BBCH 65), fruit maturation and grape harvest (BBCH 89), were in average ten days earlier during the last years, reducing thus considerably the vegetation period. When considering a longer period of time as in the observation made in Pully, such conditions have already been observed during the decade1940 – 1950. Before the forties and after the fifties, slower development periods have been registered. The earliness of the last two decades, marked by significant warming especially during the summer months, must be put into perspective by the climate variability of our regions and the cyclic character of warmer or cooler episodes succession overlapping the global trend of climate evolution.

REFERENCES

Bloesch, B., Viret, O., Fabre, A.-L. & Spring J.-L. 2009: Evolution climatique et phénologie de la vigne de 1958 à nos jours. Revue Suisse Vitic. Arboric. Hortic. 41(3), 146-149

Spring, J.-L., Viret, O. & Bloesch, B. 2009 : Phénologie de la vigne : 84 ans d'observation du Chasselas dans le bassin lémanique. Revue Suisse Vitic. Arboric. Hortic. 41(3), 151-155

12.3

Airborne pollen: phenological aspects and observed trends.

Clot Bernard & Gehrig Regula

Federal Office of Meteorology and Climatology MeteoSwiss, Station aérologique, CH - 1530 Payerne (bernard.clot@meteoswiss.ch)

In Switzerland, airborne pollen monitoring with volumetric method started in Basel in 1969, in Neuchâtel in 1979 and in Zürich in 1981. Since 1993, MeteoSwiss is responsible for the National pollen network, comprising 14 stations. The main goal of this service is to deliver information and forecasts for prevention and treatment of allergic diseases. As airborne pollen reflects in large part the flowering of local anemophilous plants, it also represents an interesting source of phenological data.

In spring and early summer, the pollen season has shifted remarkably towards earlier occurrence dates, as it has also been observed in many European countries. The pattern of trend is not linear, but a shift towards earlier dates seems to have occurred in the late Eighties. Trends in the abundance of pollen are not uniform: some taxa show a positive trend in SPI (seasonal pollen index), other a negative trend; both increases and decreases can occur for the same species in different regions. The local vegetation and land use management have probably had up to now a stronger influence on pollen abundance than the effect of climate change.

12.4

Forest phenology and extreme climatic events

Dobbertin, M.[1]

[1]WSL Swiss Federal Research Institute for Forest, Snow and Landscape Research (matthias.dobbertin@wsl.ch)

Phenological observations on trees in forests have been made at various stations in Switzerland and on different forest tree species since 2000. In contrast to the classical phenological observations on selected shrubs and tree species in open-grown conditions in the tree phonological network several trees in forest stands are assessed. For the study of climate and climate change effects on forest growth and condition, the actual assessment of forest tree phenology is important. Extreme climatic events that may become visible in forest phenology includes late frost, warm spring months and drought.

In this preliminary evaluation the first 8 – 9 years of available data were used to study the phenological phases of leaf unfolding, flowering, leaf discoloration and leaf fall for common beech (*Fagus silvatica*), oaks (*Quercus petrea* and *Qu. robur*), common ash (*Fraxinus excelsor*), European larch (*Larix decidua*) and Norway spruce (*Picea abies*).

First, differences between species, social crown position, and locations were compared. Second, the two extreme warm years 2003 and 2007 were compared against the other years. Although within site and species variation can be high, differences between species could be detected as was expected. These differences varied between years showing different reactions of species to warming versus radiation. The years 2003 for spring and summer pheno phases and in particular 2007 for spring pheno phases were significant. Possible differences in assessment were also discussed.

Long-term time series of phonological observations of forest trees species growing in forests give additional information to the existing network of phonological observation sites. Thus a continuation of these sites is highly recommended.

REFERENCES

Brügger, R. & Vasella, A., 2003: Pflanzen im Wandel der Jahreszeiten – Anleitung fur phänologische Beobachtungen. Geographica Bernensia. p.19, 23, 50-53, 116-121.

Jolly, W.M., Dobbertin, M., Zimmermann, N.E. & Reichstein, M. 2005: Divergent growth responses of Alpine forests to 2003 heat wave. Geophys. Res. Lett. 32 (18): Art. No. L18409, DOI:10.1029/2005GL023252.

Menzel A. & Fabian, P. 1999: Growing season extended in Europe. Nature 397: 659.

Reist, M. 2006: Auswirkungen von Fruhling und Sommer 2003 auf die Phänologie der Buche und Esche. Wintersemesterarbeit 2006. Universität Bern, 36 p.

Rutishauser., T., Luterbacher, J., Defila, C., Frank, D. & Wanner, H. 2008: Swiss spring plant phenology 2007: Extremes, a multi-century perspective, and changes in temperature sensitivity. Geophys. Res. Lett. 35: L05703.

12.5

50 years of needle length measurements on Larch in the Engadin Valley closely reflect spring temperature changes

Dobbertin, M.[1], Baltensweiler, W.,[3] Giuggiola A.[2], Li M.-H.,[2] Cherubini, P.[2]

[1]*WSL Swiss Federal Research Institute for Forest, Snow and Landscape Research (matthias.dobbertin@wsl.ch)*
[2]*WSL Swiss Federal Research Institute for Forest, Snow and Landscape Research*
[3] *passed away 2008.*

Phenological observations have been used to determine and to quantify the effect of warming on vegetation development. While long-term observations of plant phenological phases are numerous, almost no studies exist that have actually measured the seasonal growth of foliage. Here, we present results from almost 50 years of needle length measurements of deciduous European larch (*Larix deciduas Mill.*) at two high altitude sites (1630 m a.s.l. and 1830 m a.s.l.) in the Engadine valley and relate it to spring temperature and outbreaks of the larch bud moth (*Zeiraphera diniana Gn*). Measurements had been initiated to monitor the interaction between defoliation by the larch bud moth and needle growth.

Needles of larch are formed annual in clusters on short shoots or in spirals on long shoots. Needles on short shoots grow simultaneously allowing periodic measurements of its mean needle length. Needle length was measured on 3 short shoots proximal and 3 distal to the base of the 2-year old shoots of branches of the same trees. Needle elongation in early June in percent of the final needle length was computed for each tree and site and correlated with mean April and May temperature obtained from the adjacent MeteoSwiss climate station. Measurements at the site Sils started in 1963 and at the site Brail in 1965. Before 1971 the individual tree and short shoot measurements have been lost, but mean plot-wise means for each observation dates are available.

Data were grouped into five decades (i.e. 1963-1970, 1971-1980, …., 2001-2010) and into the period until 1987 and following 1987 when a strong temperature increase was observed in spring. Symmetric sigmoidal logistic growth curves were separately fit for the needle length in mm and for the relative needle length in percent of the final length against the day of year. The day of year when 50% of the final needle length is reached was determined as the parameter estimate of the function. For each year the percentage of final needle length reached by the end of May were also determined and compared. Larch bud moth outbreaks have been determined from larvae counts and visual needle discolorations.

Larch bud moth outbreaks, that occurred every 7 to 10 years and usually last 2 years, reduced needle length in the year following an outbreak, but had no influence on phenology. Needle length increased during the observation period for both sites. However, this was mainly due to the lack of severe larch bud moth outbreaks in recent decades. 50% needle length at the lower site was on average reached 8-10 days before the high altitude site. The relative needle length to final needle length at the beginning of June correlated highly with April-May temperatures. Needle elongation during 1988-2006 occurred 8 to 11 days earlier than during 1972-1987. Needle growth at the higher site is identical or earlier than growth at the lower site before 1987 suggesting a more than 200 m shift in altitude. This is in agreement with the observed warming of 1.6 °C in April and May. In 2007, with the warmest April ever recorded in Switzerland, needle development was even 15 days earlier than during the period up to 1987 and 23 days earlier than during the period since 1987. The presented results stress the importance of long-term ecological observations to assess the impacts of environmental change.

REFERENCES

Baltensweiler, W., Weber, U.M. & Cherubini, P. 2008: Tracing the influence of larch-bud-moth insect outbreaks and weather conditions on larch tree-ring growth in Engadine (Switzerland). Oikos 117: 161-172.

Baltensweiler, W. 1993: Why the larch bud-moth cycle collapsed in the subalpine larch-cembran pine forests in the year 1990 for the first time since 1850. Oecologia 94: 62-66.

Bjornstad, O.N., Peltonen, M., Liebhold, A.M. & Baltensweiler, W. 2002: Waves of larch budmoth outbreaks in the European Alps. Science 298: 1020-1023

12.6

Trends in fruiting phenology of wild forest mushrooms from 1975-2006 in the fungus reserve La Chanéaz (FR)

Egli Simon[1], Ayer François[2], Franc Alain[3]

[1]*Eidg. Forschungsanstalt für Wald, Schnee und Landschaft WSL, Zürcherstrasse 111, CH-8903 Birmensdorf (simon.egli@wsl.ch)*
[2]*Routes des roches 8, CH-1553 Châtonnaye*
[3]*UMR Biodiversité Gènes et Communautés INRA, 69 route d›Arcachon, F-33612 Cestas Cedex*

Increasing spring temperature and delayed arrival of biological winter have lengthened the green-cover season and influenced phenological events in many plants and animals (Penuelas et al., 2009; Root et al., 2003; Menzel et al. 2006).

The study of temporal trends in the fruiting phenology of mushrooms by Kauserud et al. (2008) showed that the mean time of fruiting of 83 examined fungal species has changed considerably over the period 1940-2006 in Norway. Across the whole period there has been a delay of 13.3 day in mean time of fruiting. These findings do not exactly correspond to those of Gange et al. (2007). They noticed an expansion of the mushroom fruiting season in both directions in the United Kingdom.

The studies of Gange et al. (2007) and Kauserud et al. (2008) are based on herbarium collections, which may contain biases in the data (e.g. possible temporal shifts in the collecting effort).

Our study was carried out in the fungus reserve “La Chanéaz” established in 1975 in Southwestern Switzerland, located in a representative forest type of the Swiss Central Plateau at 575 m a.s.l., a mixed old-growth forest with deciduous and coniferous tree species of different age beech (*Fagus sylvatica* L.), oak (*Quercus robur* L.), spruce (*Picea abies* (L.) Karst.), fir (*Abies alba* Mill.), pine (*Pinus sylvestris* L.), and larch (*Larix decidua* Mill.). Fruit bodies of the epigeous mycorrhizal and saprotrophic macromycetes were identified and counted at weekly intervals from May to December (weeks 21-52). When first recorded, the fruit bodies were marked with methylene blue on the cap to avoid double counting in the subsequent week. The survey was started in 1975 and continued until 2006.

A general trend for later starting and later ending of the mushroom season can be detected. However, the changes differ strongly between species and groups of species. Total duration of mushroom season was more or less stable.
In the weighted time of fruiting a clear shift can be observed, with an average delay of about 2 weeks since 1975 (Fig. 1), for the mycorrhizal as well as for the saprobic species.

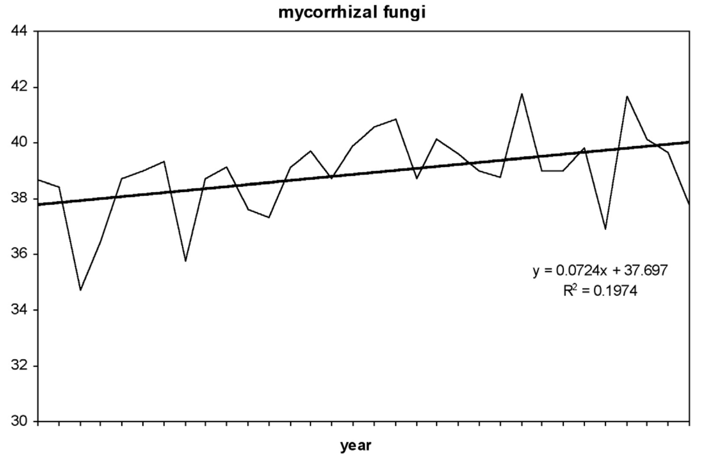

Figure 1. Weighted fruit body appearance (week number) of all 275 mycorrhizal species in the fungus reserve La Chanéaz 1975-2006.

REFERENCES

Gange, A.C., Gange, E.G., Sparks, T.H., Boddy, L. (2007). Rapid and recent changes in fungal fruiting patterns. Science 316: 71.

Kauserud, H., Stige, L.C., Vik, J.O., Okland, R.H., Hoiland, K., Stenseth, N.C. (2008). Mushroom fruiting and climate change. PNAS 105/10: 3811-3814.

Menzel, A., Sparks, T., Estrella, N., Koch, E., Aasa, A. et al. (2006) European phenological response to climate change matches the warming pattern. Global Change Biology 12: 1969-1976.

Penuelas, J., Rutishauser, T., Filiella, I. (2009). Phenology feedbacks on climate change. Science 324: 887-888.

Root, T.L., Price, J.T., Hall, K.R., Schneider, S.H., Rosenzweig, C., Pounds, A. (2003). Fingerprints of global warming on wild animals and plants. Nature 421: 57-60.

12.7

Phenological and seasonal observations in Swiss schools

Eugster Markus

Sekundarschule, Schöntalstrasse 2, 9244 Niederuzwil

Introduction:
I will show you how I integrated phenological and seasonal observations into our curriculum. Students observe plants in their region and around the school, enter data in a database and compare it with meteorological data and observations of other schools. They take pictures to document seasonal changes.

GLOBE
Switzerland is a member (http://www.globe-swiss.ch/de/) of GLOBE (= Global Learning and Observations to Benefit the Environment; http://globe.gov), and our school joined GLOBE in 2003.

Seasons and biomes
GLOBE started several Earth System Science Projects (ESSP) in 2007, among them "Seasons and Biomes". The Seasons and Biomes project is an inquiry- and project-based initiative that monitors seasons, specifically their interannual variability in order to increase students' understanding of the Earth system. This project connects GLOBE students, teachers, and communities with educators and scientists. By monitoring the seasons in their biome, students will learn how interactions within the Earth system affect their local environment and how it in turn affects regional and global environments.

Spaceship Earth
In collaboration with Nicolas Gessner, the director of 52 short films about our planet, I designed 52 worksheets to help my students understand the outside influences that determine the Earth's systems and with that the conditions for life on Earth and the forming of different biomes.

Phenological calendar
During the growing season we discuss the development of the vegetation and fill in an adapted protocol referring to the official list for the phenological observations of Meteo Schweiz.

Budburst and green-up
In spring my students determine the date of budburst for several trees and shrubs around our school. Henceforth they measure the length of the leaves that came out of the observed buds until they are fully grown in summer.

Green-down
In autumn the students protocol the color of tagged leaves until the leaves fall. Together with the green-up observations we define the length of the growing season.

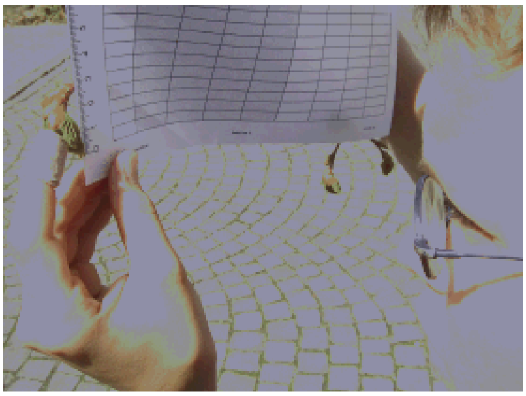

Figure 1: Green-up: Length of leaf

Figure 2: Green-down: Color table

GLOBE Phenological Garden (GPG)
According to the GLOBE instructions we made a phenological garden. The plants are the same in every GPG (clones). The students observe different phenological stages, fill in protocols and submit data to the international data base.

Data handling
I will explain how we collect and enter data and how it can be used by other people.

Student Research Campaign
GLOBE schools are organized by biomes into Global Learning Communities and students monitor their seasons through local research campaigns. Students interact with other students in schools from the Taiga, Tundra, Deciduous Forest, Desert, Grassland and other biomes in Global Learning Communities.

Seasons in my biome (SIMB) http://www.seasonsandbiomes.net
I started this project in 2009: Students, teachers and other persons choose a typical biome in their region and take a picture every month (exactly the same view). We document the seasonal changes and by comparing pictures get a new understanding of the diversity of biomes, the range of seasonal changes within a biome and how the Earth's systems interact.

Figure 3: My homepage SIMB
(All pictures by M. Eugster)

Photo phenology
We collect series of pictures to show seasonal changes and try to detect phenological stages. We have applied for a project of the Swiss Federal Institute of Technology Zurich that works with automated digital cameras to get phenological data.

12.8

RROD – A mathematical model for reversible rockslope deformations, caused by seasonal variations in the groundwater table, observed in the central Swiss Alps

Juergen Hansmann, Simon Loew[1] & Keith F. Evans[1]

[1] Geologisches Institut, Ingenieurgeologie, ETH Zürich, Sonneggstrasse 5, CH-8092 Zürich (Juergen.Hansmann@erdw.ethz.ch)

In the framework of the construction of a deep tunnel in crystalline rock in central Switzerland, a high-precision automatic geodetic monitoring network has been installed above the tunnel trajectory in order to detect possible ground surface deformations during the construction phase. This monitoring network includes a cluster of several total stations and reflectors that are located along profile lines in three alpine valleys. Measurements have been initiated several years before the tunneling process started. During this period only natural processes influenced ground surface motions and deformations.

The recorded deformation signal normal to the valley axis, observed before the tunnel excavation was initiated, undergoes a seasonal, periodic change, reaching maximum extension in early summer and maximum compression in late winter time. The deformation appears to be elastic, as the amplitude remains quite constant. A strong correlation between measured deformations and the timing and amount of spring snow melt and summer rainstorm precipitation can be clearly shown. While in winter time the ground water reservoir depletes, deformation measurements indicate extensive movements of the valley slopes. Within only some days after intensive rainfall events or with the onset of snow melt, the groundwater reservoir is recharged and the measurements indicate that the valley slopes move towards each other.

The amplitude of the measured deformation signal differs with the elevation of the measured points. Reflector pairs in higher elevation show larger amounts of relative horizontal displacement (or strain) than reflector pairs close to the valley bottom. Furthermore a difference in the amount of deformation could be observed in different valleys. This paper identifies possible reasons for these differences in horizontal reversible deformations. Possible causes that are explored include (1) the geometry of the valley slopes, especially steepness and exposition of the terrain, (2) differences in hydromechanical rock mass properties, especially hydraulic conductivity and stiffness, (3) differences in soil cover, (4) differences in climatic conditions, especially altitude dependent precipitation and snow melt, and (5) variations in size of mountain chains separating the valleys.

Based upon precipitation and snow height data, a mathematical model has been formulated, that predicts the expected natural deformation components for each valley profile. This model takes into account three key processes influencing the natural deformations: (1) infiltration of snow melt water, (2) infiltration of rainstorm precipitation during snow-free periods, and (3) depletion of the groundwater reservoir during times when there is no recharge. The correlation between the measured and modeled natural deformations is very good and the model allows to predict the temporal evolution of such deformations.

12.9

The Swiss Spring Index as a novel integral metric for spring phenology

Herren Thomas, Meier Nicole, Rotach Mathias W, Liniger Mark A., Appenzeller Christof

Federal Office of Meteorology and Climatology MeteoSwiss, Krähbühlstrasse 58, CH-8044 Zürich

Numerous studies have shown the tendency to earlier onset of spring in response to climate change. Most of these studies were confined to one single phenological phase, observations from one location or combinations of such results. To achieve more generalised information, a multispecies estimate for spring phenology was worked out using principal components analysis (PCA) on a combination of 10 spring phases from the Swiss phenological network.

Universally applicable information on the beginning of spring is often difficult to devise, because the appearance date of a single phenological phase may vary strongly between regions depending on the actual temperatures and individually observed plants. Using PCA analysis of the data from a combination of different species it can be shown that the dominant spatial pattern of spring phenology is essentially uniform in Switzerland and highly correlated to temperature. Thus a Spring Phenological index is constructed from the first principle component which yields spatially averaged information on spring appearance rather than an information for a specific location or a specific phenological phase. A further advantage of the method, is the fact that it is not mandatory to have every observation at all stations to give a suitable result.

However, the main benefit of the spring index lies in its simplicity. Comparable to an annual mean temperature the spring index provides one single value for a whole region, that can be monitored over longer periods of time thus establishing the pattern of spring phenological phases and their relation to climate signals.

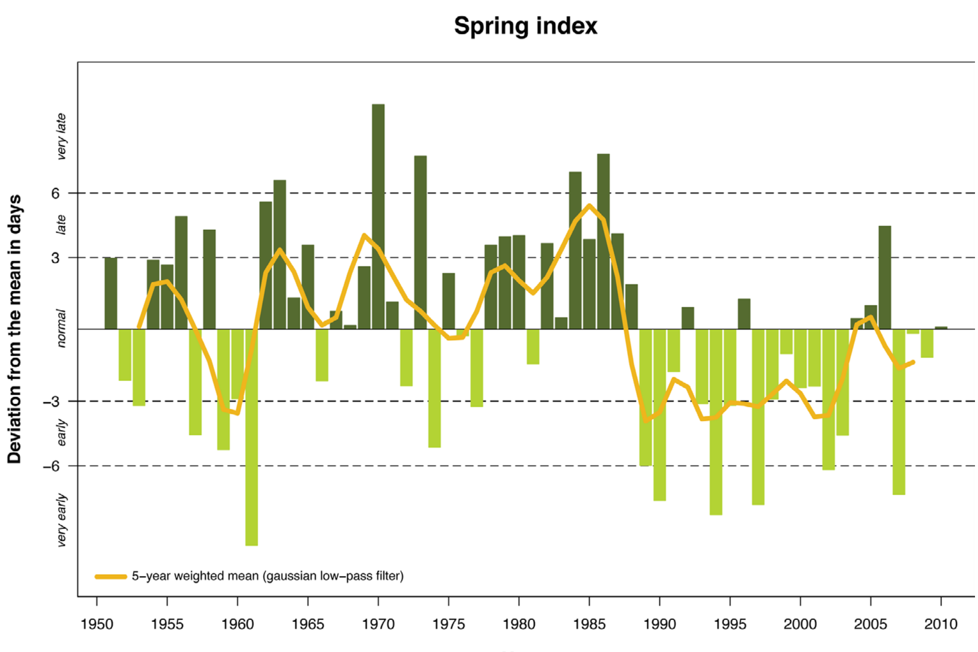

Figure 1: The spring index as a graph. From 1978 to 1988 the development of the vegetation was almost exclusively late, whereas between 1989 and 2003 greening in spring was mainly early. Similar to 2008 the timing of the actual year was at an average.

12.10

A comparison of ground-based phenological observations and NOAA AVHRR NDVI data

Dominic Kottmann

Geographic Institute of the University of Berne, Hallerstrasse 12, CH-3012 Bern

Seasonal variations of the Normalized Difference Vegetation Index (NDVI) are closely related to vegetation phenology, such as green-up, peak and offset of growing cycle. Methods have been developed in order to estimate the timing of single phenological dates and characteristics, such as the start of the growing season (Beck et al., 2006). This thesis aims to compare 11 years (1998 - 2008) of NDVI time series data derived from the North Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) with ground-based phenological observations provided by MeteoSchweiz in order to reveal the potential of modelling specific phenological phases on a local or regional scale.

To reduce noise in the NDVI time series, a 10-day Maximum Value Composite (MVC) has been applied on the daily data (Holben, 1986). Also, two smoothing functions – an asymmetric Gaussian function-fitting (Jönsson & Eklundh, 2002) approach and a double logistic function-fitting (Beck et al., 2006) approach – have been separately applied on the NDVI time series. Another method concerning noise reduction lied within enlarging the area of interest to approximately 10 km x 10 km surrounding each phenological station and summing up land cover information derived for the years between 1992 and 1997, information derived from a digital elevation model (DEM), information on scan geometry, a cloud mask and a distance-based gradient to weighting procedures which all in all aimed to lead to a realistic representation of the vegetation dynamics observed at the stations (Doktor et al., 2009). In order to extract phenological information from the smoothed NDVI time series, a threshold-based method regarding the annual maximum NDVI and its amplitude has been used.

It has been shown, that applying these weighting procedures, especially concerning land cover statistics and altitude, lead to a slight improvement in the linear correlation of the two datasets. Even though the phenological dataset provided by MeteoSchweiz was rather small, high correlations ($r > 0.5$) for specific regions and onsets of phenological phases have been found. Still, the overall correlations are not yet high enough to establish a model on a regional nor temporal scale. But the results indicate that better and more accurate results can be achieved by using bigger phenological datasets and by analysing longer time series. In near future, other, more advanced remote sensing technologies such as the Moderate Resolution Imaging Spectroradiometer (MODIS) will provide a longer time span of records with a more accurate spatial resolution which will be leading to an improved possibility of comparison with the available ground-based phenological observations. Concerning noise reduction, especially at high altitudes, it could also be considered to take datasets into account which give information about water stress or snow cover.

REFERENCES

Beck, P. S. A., Atzberger, C., Høgda, K. A., Johansen, B., Skidmore, A. K. 2006: Improved monitoring of vegetation dynamics at very high latitudes: A new method using MODIS NDVI. Remote Sensing of Environment, 100, 321-334.

Doktor, D., Bondeau, A., Koslowski, D., Badeck, F. 2009: Influence of heterogeneous landscapes on computed green-up dates based on daily

AVHRR NDVI observations. Remote Sensing of Environment, 113, 2618-2632.

Holben, B. N. 1986: Characteristics of maximum-value composite images from temporal AVHRR data. International Journal of Remote Sensing, 7(11), 1417-1434.

Jönsson, P., & Eklundh, L. 2002: Seasonality Extraction by Function Fitting to Time-Series of Satellite Sensor Data. IEEE Transactions On Geoscience And Remote Sensing, 40(8), 1824-1832.

12.11

Predicting the impact of warming on tree phenology: experimental and modelling results

Morin Xavier[1], Chuine Isabelle[2] & Bugmann Harald[1]

[1]*Forest Ecology, ETH Zürich, Universitätstr. 22, CH-8092 Zürich (xavier.morin@env.ethz.ch)*
[2]*CEFE, CNRS, 1919 route de Mende, FR-34293 cedex 5, France*

Because phenological events are strongly responsive to environmental factors such as temperature, they have been among the first documented fingerprints of climate change. Phenological changes in temperate forests have been observed in the last decades (Menzel et al. 2006). These changes have important implications, not only for forest products and biodiversity, but also for the global climate itself. Although other drivers such as photoperiod will also constrain the future response of trees (Körner and Basler 2010), accurate predictions of the response of tree phenology to climate change are urgently required to better forecast the future of forest ecosystems (Chuine et al. 2010). Here we present modelling and experimental results on the effect of warming on budburst phenology of European and North American tree species.

First we aimed to experimentally determine whether projected levels of warming for the upcoming decades will lead to linear changes in the phenology of trees or to more complex responses. We report the results of a 3-year common garden experiment designed to study the phenological response to artificial climate change – obtained through experimental warming and reduced precipitation – of several populations of three European oaks: two deciduous species (*Quercus robur*, *Quercus pubescens*), and one evergreen species (*Quercus ilex*), in a Mediterranean site (Morin et al. 2010).

Experimental warming advanced the seedlings vegetative phenology, causing a longer growing season, and caused higher mortality. However, the rate of advancement of leaf unfolding date was decreased with increasing temperature (Fig. 1). On the contrary, soil water content did not affect the phenology of the seedlings nor their survival.

Second, we showed predictions of change in budburst date made at the species distribution level with phenological models. Indeed, to advance our understanding of phenological responses to climate change, more reliable predictions made with process-based models are required.

We calibrated and validated models of leaf unfolding for 22 North American tree species. Using daily meteorological data predicted by two scenarios (A2: +3.2°C and B2: +1°C) from the HadCM3 GCM, we predicted and compared range-wide shifts of leaf unfolding in the 20th and 21st centuries for each species. Model predictions suggest that climate change will affect leaf phenology in almost all species studied, with an average advancement during the 21st century of 5.0 days in the A2 scenario and 9.2 days in the B2 scenario (Morin et al. 2009).

Our model also suggests that lack of sufficient chilling temperatures to break bud dormancy will decrease the rate of advancement in leaf unfolding date during the 21st century for many species. Some temperate species may even have years with abnormal budburst due to insufficient chilling. At the interspecific level, we predicted that early-leafing species tended to show a greater advance in leaf unfolding date than late-leafing species; and that species with larger ranges tend to show stronger phenological changes.

Thus our results show that the phenological response of temperate and boreal trees to climate change may be non-linear, and suggest that predictions of phenological changes in the future should not be built on extrapolations of current observed trends.

REFERENCES

Chuine, I., X. Morin, and H. Bugmann. 2010. Warming, photoperiods, and tree phenology. Science 329:277-278.

Körner, C. and D. Basler. 2010. Phenology under global warming. Science 327:1461.

Menzel, A., T. H. Sparks, N. Estrella, E. Koch, A. Aasa, R. Aha, K. Alm-Kubler, P. Bissolli, O. Braslavska, A. Briede, F. M. Chmielewski, Z. Crepinsek, Y. Curnel, A. Dahl, C. Defila, A. Donnelly, Y. Filella, K. Jatcza, F. Mage, A. Mestre, O. Nordli, J. Penuelas, P. Pirinen, V. Remisova, H. Scheifinger, M. Striz, A. Susnik, A. J. H. Van Vliet, F. E. Wielgolaski, S. Zach, and A. Zust. 2006. European phenological response to climate change matches the warming pattern. Global Change Biology 12:1969-1976.

Morin, X., M. J. Lechowicz, C. Augspurger, J. O'Keefe, D. Viner, and I. Chuine. 2009. Leaf phenology changes in 22 North American tree species during the 21st century. Global Change Biology 15:961-975.

Morin, X., J. Roy, L. Sonié, and I. Chuine. 2010. Climate change impact on the phenology of three European oak species: results from a field experiment. New Phytologist 186: 900–910.

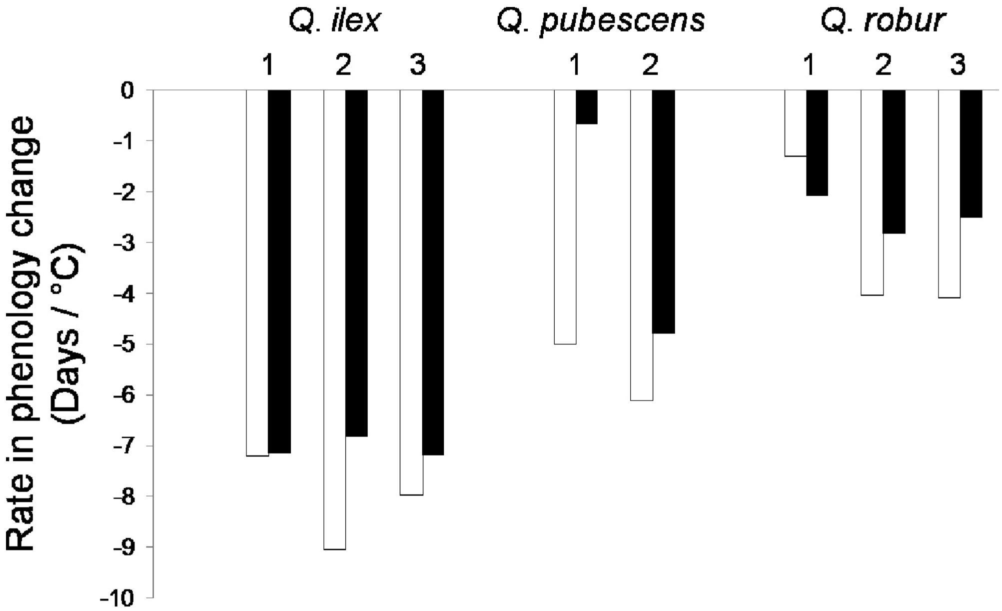

Figure 1.: Mean advancement rates between the warming treatments (T+: open bars, and T++: black bars) and the control treatment in days/°C (Rate+: advancement rate in days/°C for the T+ treatment, Rate++: advancement rate in days/°C for the T++ treatment) for each sampled population. The number corresponds to different populations.
Note: T+: level of warming about +1.5°C, and T++: level of warming about +3°C.

12.12

Changes in alpine plant phenology under future climate conditions

Rixen Christian[1]

[1]Alpine Ecosystems Group, WSL Institute for Forest, Snow and Landscape Research (rixen@slf.ch)

Alpine shrub- and grasslands are shaped by extreme climatic conditions such as a long-lasting snow cover and a short vegetation period. Such ecosystems are expected to be highly sensitive to global environmental change. Prolonged growing seasons and shifts in temperature and precipitation are likely to affect plant phenology and growth.

In a unique experiment, climatology and plant growth was monitored for almost a decade at 17 snow meteorological stations in different alpine regions along the Swiss Alps. Regression analyses revealed highly significant correlations between mean air temperature in May/June and snow melt out, onset of plant growth, and plant height.

These correlations were used to project plant growth phenology for future climate conditions based on the gridded output of a set of regional climate models runs. Melt out and onset of growth were projected to occur on average 17 days earlier by the end of the century than in the control period from 1971–2000 under the future climate conditions of the low resolution climate model ensemble.

Plant height and biomass production were expected to increase by 77% and 45%, respectively. The earlier melt out and onset of growth will probably cause a considerable shift towards higher growing plants and thus increased biomass.

Our results represent the first quantitative and spatially explicit estimates of climate change impacts on future growing season length and the respective productivity of alpine plant communities in the Swiss Alps.

12.13

Altitude, slope and aspect: Are there local-scale effects in temporal trends in a spatially high-resolved plant phenological network in the Swiss Alps 1971–2000?

Rutishauser This[1], Brügger Robert[1] & Jeanneret François[1]

[1]*Geographisches Institut, Hallerstrasse 12, CH-3012 Bern (rutis@giub.unibe.ch)*

Shifts in phenology of plants and animals have been widely observed as consequence of climate change impacts and temperature increase. Species-specific data are often assigned to limited and generalized site information on the precise location of the observation. However, as much meta-information as possible on the individual plant under observations is necessary to assess the impacts of changing weather patterns at the local scale that are related to changes in radiation, fog, frost and dominating circulation.

Here we used plant phenological data of the BERNCLIM network that collects data in the Canton of Bern (Switzerland) and adjacent areas covering a total area of 7,000 km^2 since 1970 (Messerli 1978, Jeanneret and Rutishauser 2010). The number of observation sites reached up to 600 observation sites with detailed meta-information of several locations within each site. The precision of coordinates for each location is generally less than one hectare. This information allows differentiating several terrain-types, based on altitude, slope and aspect. We used original observations including the blooming of hazel (*Corylus avellana* L.) for early spring, dandelion (*Taraxacum officinale* aggr.) for mid spring, and apple trees (*Malus domestica* Borkh.) for late spring.

For this contribution we analysed the impact of local terrain differences on phenological trends of three plant species. Specifically, we addressed the question whether differences in altitude, slope and aspect lead to systematic differences in temporal trends for the 1971–2000 period. Whereas altitude shows generally high correlations with phenology, we aimed at quantifying additional impacts on phenological trends such as microclimate and local adaptation of individual plants. Strongest variations between locations are expected for *Corylus* and *Malus* whereas *Taraxacum* is most strongly influenced by temperature along altitudinal gradients. This information derived from a regional observations network with long-term observations and high precision meta-information can be useful for detailed analyses of large data sets that stored in a number of European databases.

REFERENCES

Messerli, B. 1978: Klima und Planung. Ziele, Probleme und Ergebnisse eines klimatologischen Forschungsprogrammes im Kanton Bern, Jahrbuch der geographischen Gesellschaft von Bern, 52, 11-22.

Jeanneret, F. & Rutishauser, T., 2009: Phenology for topoclimatological surveys and large-scale mapping, in: Keatley, M. & Hudson, I. (eds.): Phenological Research: methods for environmental and climate change analysis, pp. 153-169, Springer.

12.14

KPS – eine Kommission für Phänologie und Saisonalität bei der «Plattform Geosciences»

Rutishauser This[1] und Mitinitiantinnen und -initianten

[1]*Geographisches Institut, Hallerstrasse 12, CH-3012 Bern (rutis@giub.unibe.ch)*

Der Wissenschaftszweig der Phänologie dokumentiert und erforscht Ablauf und Entwicklung der Jahreszeiten im System Erde («Timing»). Insbesondere untersucht sie die biotischen und abiotischen Faktoren, die auf das zeitliche Eintreten der untersuchten Erscheinungen (z. B. Blattentfaltung des Laubes und Blattfall, Beginn der Schneedecke) einwirken. Unter dem übergeordneten Begriff der Saisonalität werden die verschiedenen im Jahresverlauf wiederkehrenden Erscheinungen sowohl in der belebten Natur (Biosphäre: Pflanzen und Tiere) als auch in der unbelebten Natur (Hydrosphäre bzw. Kryosphäre: Schnee und Eis; Atmosphäre: Nebel, Pollen) zusammengefasst. Abfolge, Interaktionen und langfristige Veränderungen im Eintreten der Jahreszeiten beeinflussen Stoff- und Energieflüsse zwischen Boden, Vegetation und Atmosphäre im Erdsystem als auch Interaktionen in der belebten Natur («Matching»), machen saisonale Veränderungen des Klimas und der Umwelt sichtbar und haben wichtige Einflüsse auf Menschen und Wirtschaft in der Schweiz.

Die Kommission für Phänologie und Saisonaliät (KPS) hat zum Ziel, die phänologische Forschung national und international zu stärken, weiter zu entwickeln und breiter abzustützen. An Schweizer Universitäten und Eidgenössischen Forschungsanstalten ist eine Vielzahl von phänologischen Forschungsprojekten angesiedelt. Die Fragestellungen und Zielsetzungen sind so verschieden wie die Institutionen, Interessen und Anwendungen der Forschenden. Die Auswertungen von weltweit einzigartigen Archivaufzeichnungen (Pfister 1999, Rutishauser et al 2007), die Analyse von Satellitenbildaufnahmen (Stöckli und Vidale, 2003), die Entwicklung und Anwendung von neuartigen Sensortechniken, Bildaufnahme und -auswertungsverfahren (Ahrends et al. 2008, Fontana et al. 2008) sowie experimentelle Studien (Asshoff et al 2006) im Gebirgsland Schweiz tragen zur facettenreichen Forschungslandschaft bei. Die herausragende Qualität der Forschung findet international grosse Beachtung: So etwa darin, dass in den vergangenen eineinhalb Jahren drei Artikel in «Science» erschienen sind, die von Schweizer Autoren oder Co-Autoren verfasst worden sind (Peñuelas et al. 2009, Körner und Basler 2010, Chuine et al. 2010). Substantielle Beiträge konnte die Schweizer phänologische Forschung auch zum Bericht der Working Group II des IPCC (2007) beitragen.

Die KPS will die Phänologie als Instrument der integrativen Umweltbeobachtung fördern, den Nutzen der Phänologie zur Erfassung und besserem Verständnis komplexer Umweltveränderungen bekannter machen und Anwendungen der phänologischen Forschung vorantreiben. Dabei baut sie auf intensiven Austausch mit Beobachtenden verschiedener Netzwerke und fördert die geowissenschaftliche Bildung zusammen mit dem Bildungsprogramm GLOBE, mit pädagogischen Hochschulen und Schulen aller Stufen.

Die KPS vertritt mit ihren Zielen konkret die Mission der SCNAT. Insbesondere mit konkreten Aktivitäten fördert die KPS (1) die Bedeutung der Naturwissenschaften für unser tägliches Leben, (2) den direkten Dialog mit der Gesellschaft vor Ort, (3) inter- und transdisziplinäre Forschungsansätze, und legt (4) mit Initiativen zur Nachwuchsförderung die Basis für die nächste Generation von Naturwissenschaftlerinnen und Naturwissenschaftlern. Die KPS initiiert die Herausgabe eines Newsletters mit wissenschaftlichen und populärwissenschaftlichen Beiträgen. Sie wird 2011 erstmals aktiv sein und viele Aufgaben vom «Phänologiekreis Schweiz» übernehmen (www.phaenologiekreisschweiz.ch.vu, www.cerclephenologique-suisse.ch.vu, www.circolofenologicosvizzera.ch.vu, www.swissphenologicalcircle.ch.vu)

REFERENCES

Ahrends, H. E., Brügger, R., Stöckli, R., Schenk, J., Michna, P., Jeanneret, F., Wanner, H. & Eugster, W. 2008: Quantitative phenological observations of a mixed beech forest in northern Switzerland with digital photography, Journal of Geophysical Rersearch – Biogeosciences, 113, G04004, doi:10.1029/2007JG000650.

Asshoff, R., Zotz, G. & Körner, Ch. 2006: Growth and phenology of mature
temperate forest trees in elevated CO_2. Global Change Biology, 12, 1-14.

Chuine, I., Morin, X. & Bugmann, H. 2010: Warming, Photoperiods, and Tree Phenology, Science, 329, 277-e, doi: 10.1126/science.329.5989.277-e

Fontana, F., Rixen, C., Jonas, T., Aberegg, G. & Wunderle, S. 2008: Alpine Grassland Phenology as seen in AVHRR, VEGETATION, and MODIS NDVI Time Series - a Comparison with in Situ Measurements. Sensors 8: 2833-2853.

Körner, Ch. & Basler, D. 2010: Phenology Under Global Warming, Science, 327, 1461-1462.

Peñuelas, J., Rutishauser T. & Filella I. 2009: Phenology Feedbacks on Climate Change, Science, 324, 887–888.

Pfister, C. 1999: Wetternachhersage. 500 Jahre Klimavariationen und Naturkatastrophen, Paul Haupt, Bern.

Rutishauser, T., Luterbacher, J., Defila, C., Frank, D. & Wanner, H. 2008: Swiss Spring Plant Phenology 2007: Extremes, a multi-century perspective and changes in temperature sensitivity. Geophysical Research Letters, 35, L05703. doi: 10.1029/2007GL032545.

Stöckli R. & Vidale P.L. 2004: European plant phenology and climate as seen in a 20 year AVHRR land-surface parameter dataset, International Journal of Remote Sensing, 25, 3303-3330.

12.15

Assessing the effects of climate change on the phenology of European temperate trees

Vitasse Yann[1], François Christophe[2,3], Delpierre Nicolas[2], Dufrêne Ericb[3], Kremer Antoine[4], Chuine Isabelle[5] & Delzon Sylvain[1]

[1] *Université Bordeaux, UMR BIOGECO-1202, Av. des Facultés, F-33405 Talence, France,*
[2] *Université Paris-Sud, UMR ESE-8079, F-91405 Orsay, France*
[3] *CNRS, F-91405 Orsay, France*
[4] *INRA, UMR BIOGECO-1202, 69 route d'Arcachon, F-33612 Cestas, France*
[5] *Centre d'Ecologie Fonctionnelle et Evolutive, UMR 5175, Equipe BIOFLUX, CNRS, 1919 route de Mende, 34293 Montpellier cedex*

Modelling phenology is crucial to assess the impact of climate change on the length of the canopy duration and the productivity of terrestrial ecosystems. Focusing on six dominant European tree species, the aims of this study were (i) to examine the accuracy of different leaf phenology models to simulate the onset and ending of the leafy season, with particular emphasis on the putative role of chilling to release winter bud dormancy, (ii) to predict seasonal shifts for the 21st century in response to climate warming.

Models testing and validation were done for each species considering two or three years of phenological observations acquired over a large altitudinal gradient (1500 m range, 57 populations). Flushing models were either based solely on forcing temperatures (1-phase models) or both on chilling and forcing temperatures (2-phases models). Leaf senescence models were based on both autumn temperature and photoperiod.

We show that most flushing models are able to predict accurately the observed flushing dates. The 1-phase models (based on forcing temperatures) are as efficient as 2-phases models (based both on forcing and chilling temperatures) for most species suggesting that chilling temperatures are currently sufficient to fully release bud dormancy. However, our predictions for the 21st century highlight that chilling temperature could be insufficient for some species at low altitude. Overall, flushing is expected to advance in the next decades but this trend substantially differed between species (from 0 to 2.4 days per decade).

The prediction of leaf senescence appears more challenging, as the proposed models work properly for only two out of four deciduous species, for which senescence is expected to be delayed in the future (from 1.4 to 2.3 days per decade). These trends to earlier spring leafing and later autumn senescence are likely to affect the competitive balance between species. For instance, simulations over the 21st century predict a stronger lengthening of the canopy duration for *Quercus petraea* than for *Fagus sylvatica*, suggesting that shifts in the altitudinal distributions of these species might occur.

12.16
Ecosystem carbon budgets of tropical pasture versus afforestation

Wolf Sebastian, Eugster Werner & Buchmann Nina

ETH Zurich, Institute of Plant, Animal and Agroecosystem Sciences, Universitaetsstrasse 2, LFW A54.1, CH-8092 Zurich

Tropical ecosystems play an important role for the global carbon cycle and account for about 60% of the global terrestrial gross primary production (Beer et al., 2010). They contain 40% of the carbon in the terrestrial biosphere and are considered to sequester large amounts of anthropogenic released carbon from the atmosphere (Grace et al., 2001). However, with ongoing deforestation and land-use changes, the tropical carbon sink is increasingly influenced by agroecosystems and pastures (Fearnside, 2005). It is not yet fully understood how carbon cycling in the tropics responds to climate and land-use change. In addition, the carbon sequestration potential of tropical afforestation and the carbon balance of tropical pasture are largely unknown. Land-use change from tropical forest to pasture was found to increase intra-annual variations in CO_2 fluxes, the sensitivity to seasonal drought and to modify ecosystem carbon budgets (Saleska et al., 2009). Despite the general importance of tropical ecosystems for global climate and carbon cycling, continuous flux measurements in the tropics are still scarce and thus, globally underrepresented.

Therefore, we performed comparative eddy covariance flux tower measurements of CO_2 in a tropical pasture and adjacent native tree species afforestation in Sardinilla, Panama from 2007 to 2009. We observed pronounced seasonal variations in gross primary productivity (GPP), total ecosystem respiration (TER) and net ecosystem exchange (NEE) that were closely related to irradiance, soil moisture and C_3 versus C_4 plant physiology. Shallow rooting depth of grasses compared to trees resulted in a higher sensitivity of the pasture ecosystem to water limitations in the dry season. During 2008, we observed an annual GPP of 2345 g C m^{-2} at the pasture and 2082 g C m^{-2} at the afforestation site: significant amounts of carbon were sequestered at the afforestation (-442 g C m^{-2}, negative value denotes ecosystem carbon storage) and we found close agreement with biometric observations in 2008. Soil carbon isotope data of $\delta^{13}C$ elucidate the C_4 to C_3 vegetation change and indicate the rapid carbon turnover in this tropical ecosystem. The pasture ecosystem was a strong carbon source in 2008 (261 g C m^{-2}) and 2009 (260 g C m^{-2}) and our results provide evidence that these carbon losses were induced by high stocking densities and periodical overgrazing.

Our results indicate that tropical afforestation can sequester large amounts of carbon, reduce the intra-annual variability of gross primary production and enhance the ecosystem resilience to seasonal drought. In contrast, we present the first multi-year eddy covariance measured carbon budgets for a tropical C_4 pasture, with persistent carbon losses observed over 2.5 years. These results have large implications on land management and suggest reduced livestock stocking densities and the benefit of increased afforestation efforts in the tropics. Moreover, the conversion from pasture to afforestation may become more relevant for Panama and other Latin American countries in the future, within the carbon accounting of the Clean Development Mechanism (CDM) as part of the Kyoto protocol.

REFERENCES
Beer, C., Reichstein, M., Tomelleri, E., Ciais, P., Jung, M., Carvalhais, N., Rodenbeck, C., Arain, M.A., Baldocchi, D., Bonan, G.B., Bondeau, A., Cescatti, A., Lasslop, G., Lindroth, A., Lomas, M., Luyssaert, S., Margolis, H., Oleson, K.W., Roupsard, O., Veenendaal, E., Viovy, N., Williams, C., Woodward, F.I. & Papale, D. 2010: Terrestrial Gross Carbon Dioxide Uptake: Global Distribution and Covariation with Climate. Science, 329(5993): 834-838.

Fearnside, P.M. 2005: Deforestation in Brazilian Amazonia: History, rates, and consequences. Conservation Biology, 19(3): 680-688.

Grace, J., Mahli, Y., Higuchi, N. & Meir, P. 2001: Productivity of tropical forests. In: J. Roy, B. Saugier and H. Mooney (Editors), Terrestrial Global Productivity. Academic Press, San Diego, CA, USA.

Saleska, S., da Rocha, H., Kruijt, B. and Nobre, A.D. 2009: Ecosystem carbon fluxes and Amazonian forest metabolism. In: M. Keller, M. Bustamante, J. Gash and P.S. Dias (Editors), Amazonia and Global Change. American Geophysical Union, Washington, DC, pp. 389-408.