Leaf physiognomy and climate: analysis of contemporary distribution patterns and fossil leaf assemblages

Christopher Traiser, Stefan Klotz, Volker Mosbrugger
Institut für Geowissenschaften, Universität Tübingen

EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

I. Leaf physiognomic patterns of extant European floras

The distribution pattern of leaf physiognomic characters in different geographic regions of the world is used in many environmental studies in order to analyse ecosystem interaction.

In this approach, the leaf physiognomic composition of woody angiosperm floras of Europe is investigated. The leaf physiognomic grid data set is compiled from "synthetic chorologic floral lists" based on distribution maps (MEUSEL & JÄGER 1965 - 1992) of 108 extant plants. The calibration data set considers only those grid cells with a minimum of 25 taxa and elevations lower than 400m. The leaf physiognomic composition of 25 different leaf characters (WOLFE 1993) is calculated for each grid cell.

To exemplify the distribution pattern of three leaf physiognomic characters are presented (**fig. 1-3**).

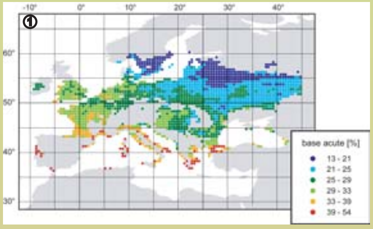

Fig. 1: Distribution pattern of leaves with an acute base in % of the woody flora

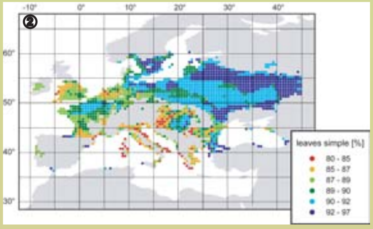

Fig. 2: Distribution pattern of simple leaves in % of the woody flora

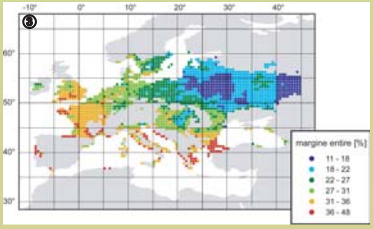

Fig. 3: Distribution pattern of leaves with an entire margin in % of the woody flora

II. Calibration with environmental data

Among other environmental parameters such as leaf area index, biomass and soil types, leaf physiognomic composition of floras is also correlated with climatic data (NEW ET AL. 1999) (**fig. 4**).

Transfer functions using different multivariate statistical approaches (multiple linear regression and redundancy analysis in ordination) are calculated in order to predict climatic parameters on the basis of leaf physiognomy. The prediction of climatic values (**fig. 5**) shows substantial similarity with present day climatic data. This is especially true for temperature related parameters e.g. mean annual temperature (MAT), whereas precipitation related parameters are predicted insufficiently.

The residuals plot of predicted and real MAT (**fig. 6**) shows some geographic regions which are characterised by overestimated (red) and underestimated (blue) values whereas the prediction for most regions is within the range of standard error of estimate (SE = 0.9 °C) (grey).

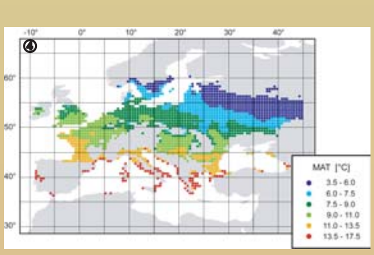

Fig. 4: Present day mean annual temperature (MAT) (NEW ET AL. 1999).

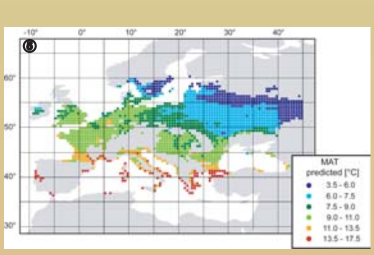

Fig. 5: Prediction of MAT with transfer function using leaf physiognomic composition of extant floras.

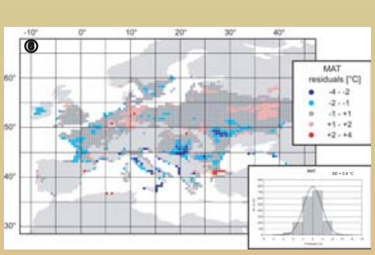

Fig. 6: Residuals of predicted and real MAT. red: sites overestimated; blue: sites underestimated; grey: sites predicted within SE.

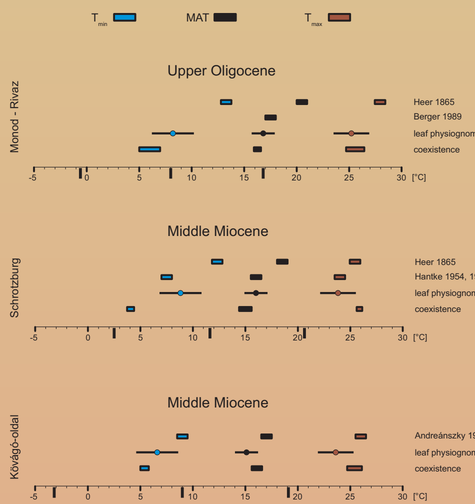

Fig. 7: Palaeoclimate estimates based on different approaches for three fossil sites. T_{min}: mean temperature of coldest month; T_{max}: mean temperature of warmest month; the arrows indicate the present day temperatures at the sites.

III. Application to fossil leaf assemblages:

The climatic transfer functions are applied to three fossil localities of Late Oligocene and Middle Miocene age (**fig. 7**). The palaeoclimatic results are compared to those derived from the coexistence approach (MOSBRUGGER & UTESCHER 1997) and other existing climatic analyses of this fossil sites.

The results reveal that palaeotemperature estimates are basically in agreement with other reconstruction methods. The new palaeoclimate estimates of the fossil sites indicate generally lower temperatures for T_{min}, MAT and T_{max} than predicted by former studies. The highest variance in reconstructed palaeo temperatures occurs in T_{min} whereas MAT and T_{max} show higher consistency.

IV. Conclusion:

This approach based on synthetic chorological floras permits the analysis of contemporary leaf physiognomic distribution patterns and their correlation with different parameters of environmental research.

The application of climatic transfer functions to European fossil floras provide palaeo temperature estimates which are basically in agreement with different palaeoclimatic reconstruction methods.

References:

ANDRÉANSZKY G. (1959): Die Flora der sarmatischen Stufe in Ungarn. Akad. Kiadó, Budapest: 360p.
BERGER J.P. (1989): Paläoökologie und Paläoklimatologie einiger oligozäner Floren der westschweizerischen subalpinen Molasse. *Cour. Forsch.-Inst. Senckenberg, 109:* 207-228.
HANTKE R. (1980): Die obere Süsswassermolasse der Schweiz, ihr Paläorelief und ihre stratigraphische Fortsetzung in die Vogesen-Schüttung. *Vierteljahrschrift der Naturf. Gesellsch. Zürich 125/4:* 365-374.
HANTKE R. (1982): Floreninhalt, biostratigraphische Gliederung und Paläoklima der mittelmiozänen Oberen Süßwassermolasse (OSM) der Schweiz und ihrer nördlichen Nachbargebiete. *Günzburger Hefte 11, Weissenhorn:* 47-53.
HEER O. (1865): Die Urwelt der Schweiz. Verlag Friedrich Schultheß, Zürich: 622 p.
MEUSEL H. & JÄGER E. (1965, 1978, 1992): Vergleichende Chorologie der zentraleuropäischen Flora. I, II, III. Jena: G. Fischer Verlag.
MOSBRUGGER V. & UTESCHER T. (1997): The coexistence approach a method for quantitative reconstructions of tertiary terrestrial palaeoclimate data using plant fossils. *- Paleogeography, Paleoclimatology, Paleoecology 134:* 61-86.
NEW M., HULME M. & JONES P. (1999): Representing 20th century space-time climate variability. Part I: Development of a 1961-1990 mean monthly terrestrial climatology. *- Journal of Climate 12:* 829-856.
WOLFE J.A. (1993): A method of obtaining climatic parameters from leaf assemblages. *- U.S. Geological Survey Bulletin 2040:* 71p.