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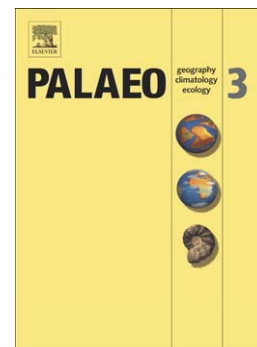
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Vasilis Teodoridis, Petr Mazouch, Robert A. Spicer, Dieter Uhl

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**Refining CLAMP – investigations towards improving the Climate Leaf Analysis  
Multivariate Program**

Vasilis Teodoridis <sup>1</sup>, Petr Mazouch <sup>2</sup>, Robert A. Spicer <sup>3,4</sup>, Dieter Uhl <sup>5,6</sup>

<sup>1</sup> Department of Biology and Environmental Studies, Faculty of Education, Charles University in Prague, M.D. Rettigová 4, 116 39 Prague 1, Czech Republic,

e-mail: vasilis.teodoridis@pedf.cuni.cz., phone: +420 221 900 173, fax: +420 221 900 172

<sup>2</sup> Faculty of Informatics and Statistics, University of Economics, Prague, Winston Churchill sq. 4, 130 67 Prague 3, Czech Republic, e-mail: mazouchp@vse.cz.

<sup>3</sup> Department of Earth and Environmental Sciences, Centre for Earth, Planetary, Space and Astronomical Research, The Open University, Milton Keynes, MK7 6AA, UK, e-mail: r.a.spicer@open.ac.uk.

<sup>4</sup> Institute of Botany Chinese Academy of Sciences, No.20 Nanxincun, Xiangshan, Beijing 100093, China.

<sup>5</sup> Senckenberg Forschungsinstitut und Naturmuseum Frankfurt, Senckenberganlage 25, 60325 Frankfurt am Main, Germany, e-mail: dieter.uhl@senckenberg.de.

<sup>6</sup> Eberhard Karls Universität Tübingen, Institut für Geowissenschaften, Sigwartstraße 10, 72076 Tübingen, Germany.

**Abstract:**

CLAMP (Climate Leaf Analysis Multivariate Program) has been used for the past 17 years to estimate palaeoclimatic conditions. The reliability and applicability of this method, based on leaf physiognomic characters of fossil woody dicots, has been widely discussed over the same period. The present study focuses on some technical aspects of CLAMP, mainly on its robustness in the context of the theoretical unimodal requirements of Canonical Correspondence Analysis, and introduces “correction coefficients” for these aspects of the statistical approach as a new way of interpreting and improving on CLAMP estimates. This tool was tested on datasets derived from 17 European fossil floras ranging in age from the Late Oligocene to the Pliocene. Additionally, an objective statistical method for the selection of the best-suited modern vegetation dataset from 144 site (Physg3br) or 173 (Physg3ar) extant biotopes is proposed.

Key words: CLAMP, palaeoclimate, Palaeogene, Neogene, Czech Republic, France, Germany.

## 1. Introduction

Fossil plants provide excellent proxies for the reconstruction of non-marine palaeoenvironmental conditions. In recent decades several different techniques have been developed to reconstruct such conditions. Techniques for the quantitative reconstruction of palaeoclimatic conditions during the Cenozoic and the Cretaceous, in particular, have attracted a considerable amount of scientific interest. Although much work has been devoted to this kind of research, it has to be kept in mind that so far all methods and approaches have their own limitations and shortcomings and that perhaps there will never be an optimal, universally applicable and absolutely reliable technique for the quantitative estimation of palaeoclimatic parameters from fossil plants (e.g., Mosbrugger and Utescher, 1997; Wilf, 1997; Wilf et al., 1998; Wiemann et al., 1998; Uhl et al., 2007a, 2007b; Traiser et al., 2005, 2007; Spicer et al., 2004; Spicer, 2000, 2007; Yang et al., 2007). This is largely due to complex spatial and temporal variations in the natural environment and plant adaptations that require finite time to equilibrate, and ultimately are compromise solutions to often conflicting environmental constraints (Spicer, 2007; Spicer et al., 2009). Nevertheless the development of a wide variety of different approaches and techniques is desirable, and as well as developing new techniques attempts should be made to improve existing methodologies.

The present study focuses on potential improvements to the Climate Leaf Analysis Multivariate Program (CLAMP) – a multivariate leaf physiognomic technique first introduced by J. A. Wolfe (1990, 1993, 1995) and subsequently refined by various authors (e.g., Kovach and Spicer, 1995; Stranks and England, 1997; Wolfe and Spicer, 1999; Spicer et al., 2004; Spicer 2000, 2007; Spicer et al., 2009). Methodologically, CLAMP is a development of Leaf Margin Analysis (LMA). LMA is a method based on the observations of Bailey and Sinnott (1915, 1916), which were subsequently expanded by others (e.g., Wolfe 1971, 1978, 1979). Unlike the univariate LMA that yields only a single climate variable (mean annual temperature), CLAMP is based on a multivariate statistical technique for determining, quantitatively, a range of palaeoclimate parameters utilizing the physiognomic characteristics of the fossilised leaves of woody dicots.

This technique has been investigated by many authors, mainly in respect of the “validity” of input datasets, its methodological approach and the comparability of its results with the results derived from other palaeobotanical techniques as well as independent proxies (e.g., Wilf, 1997; Kowalski, 2002; Traiser, 2004; Traiser et al., 2005, Green, 2006; Greenwood et al., 2004; Greenwood, 2005, 2007; Uhl, 2006; Peppe et al. 2010). In some cases evaluations have been rendered invalid because they have been based on test sites scored in such a way that they do not conform to CLAMP protocols and in others the inappropriate use of calibration (training) datasets derived from one biogeographic region being applied to other regions that are characterized by foliar physiognomies that lie outside the physiognomic space defined by the calibration set(s). At present the commonly used calibration sets do not comprehensively incorporate foliar physiognomies from tropical climates or the southern hemisphere where it is well known that the univariate relationship between leaf margin type and temperature is markedly different to that in the Northern Hemisphere (e.g. Greenwood et al., 2004). The biogeographic component in CLAMP was highlighted by Kennedy et al. (2002) in the context of New Zealand, but could equally apply to elsewhere..

Here we focus on some technical aspects of CLAMP and try to show which innovations have the potential to be used to improve the reliability of estimates (at least for European palaeofloras). In this European context we attempt to find answers to three crucial questions: a) Is the CLAMP method robust? ; b) Which modern reference dataset is more appropriate for specific fossil assemblages? (in this case we examine Physg3ar, here designated dataset ‘A’ and Physg3br here designated dataset ‘B’) and c) Is it possible to improve the precision and accuracy of CLAMP?

## 2. Material and Methods

Seventeen leaf floras of different ages (Late Oligocene – Pliocene) from the Czech Republic (Čermníky, Přívklady, Břešťany, “Hlavačov Gravel and Sand” and Holedeč), France (Arjuzanx, Auenheim) and Germany (Hambach 9A, Garzweiler 8o, Hambach 8u, Hambach 7f, Frechen 7o, Enspel, Schrotzburg, Kleinsaubernitz, Hammerunterwiesenthal and Wackersdorf) were analyzed. The floras were selected according to qualitative criteria, i.e. taxonomic and/or floristic diversity, reliable taxonomic treatment, good preservation, completeness of the studied material (autochthonous or parautochthonous taphocoenoses) and the assumed environments in which these floras were growing (i.e., basin vs delta and/or

riparian vegetations) . For detailed accounts of these floras and their contexts see the references in Table 1. These floras were analysed using CLAMP.

In the standard configuration the Climate Leaf Analysis Multivariate Program (CLAMP) utilizes 31 different leaf physiognomic characteristics to estimate 11 climatic parameters (Table 2). Variants on this are possible (Spicer et al., 2009) but this requires recalibration of the results spreadsheet.

The CLAMP technique is based on the observed quantitative relationship between foliar physiognomic characters of living woody dicots and the relevant climatic parameters at a given locality. These datasets can then be compared to the foliar physiognomic characters of a fossil flora in order to obtain palaeoclimate estimates. Mathematically, this method is based on Canonical Correspondence Analysis (CCA) – see Ter Braak (1986). For our study the spreadsheets and modern calibration data available on the CLAMP website (<http://www.open.ac.uk/earth-research/spicer/CLAMP/Clampset1.html>.) were used. These include physiognomic and gridded meteorological data for 173 modern sample sites (Physg3ar and GRIDMet3ar – marked as CLAMP data A in the following text) and for 144 modern sample sites (Physg3br and GRIDMet3br – marked as CLAMP data B in the following text) – Spicer et al. (2009). The datasets for CLAMP data A-B are mostly located in Northern America and Eastern Asia. All modern analogue materials have been downloaded from the CLAMP website. For this analysis CANOCO for Windows Version 4.5 was used.

Additional statistical methods were used for this study, namely:

a) Test of Normality. We calculate Skewness Normality and Kurtosis Normality following the below mentioned equations (1, 2). Values of the Skewness and Kurtosis Normality should be about 0 and 3 respectively to reach the Gaussian ordination.

$$(1) \textit{skewness} = E \left[ \left( \frac{X-\mu}{\sigma} \right)^3 \right],$$

$$(2) \textit{kurtosis} = E \left[ \left( \frac{X-\mu}{\sigma} \right)^4 \right],$$

where  $X$  means a random variable,  $\mu$  means a mean value of this variable and  $\sigma$  means a standard deviation.

b) Spearman correlation coefficient (Spearman Correlations Section - Pair-Wise Deletion) was calculated by following equation (3):

$$(3) r_s = 1 - \frac{6 \sum d_i^2}{n(n^2-1)},$$

where  $n$  raw scores  $X_i, Y_i$  are converted to ranks  $x_i, y_i$ , and the differences  $d_i = x_i - y_i$  between the ranks of each observation on the two variables are calculated.

c) Cluster Analysis. Hierarchical tree clustering analysis was processed by STATGRAPHICS. We used single linkage (nearest neighbour) as a linkage tree clustering method. In this method the Euclidean distance (4) between two clusters ( $x, y$ ) is determined by the distance of the two closest objects (nearest neighbours) in the different clusters. This rule will, in a sense, string objects together to form clusters, and the resulting clusters tend to represent long "chains."

$$(4) d_{(x,y)} = \sqrt{\sum_{i=1}^n (x_i - y_i)^2}$$

### 3. Results and Discussion

#### 3.1. CLAMP Robustness

The forerunner of CCA, Correspondence Analysis (CA) (Benzecri, 1973; Hill, 1973, 1974) has been shown by Ter Braak (1986) to approximate the maximum likelihood solution of the Gaussian ordination if the sampling distribution of the species abundances is Poisson, and if the following conditions (C1-C4) are met:

C1 - the species' tolerances (in CLAMP substitute species with physiognomic character states) are equal,

C2 - the species' maxima are equal,

C3 - the species' optima are homogeneously distributed over an interval A (range of the environmental gradient) that is large compared to tolerance,

C4 - the site scores are homogeneously distributed over a large interval B that is contained in A.

According to Ter Braak (1986, p. 1168) “conditions C1 and C2 are not likely to hold in most natural communities, but the usefulness of correspondence analysis in practice relies on its robustness against violations of these conditions (Hill and Gauch, 1980)” and concludes that CCA “derives its theoretical strength from its relation to maximum likelihood Gaussian canonical ordination under conditions C1-C4 and furthermore seems extremely robust in practice when these assumptions do not hold” (Ter Braak, 1986, p. 1177). In respect of unimodality Ter Braak (1986, p. 1177) stated “the model would not work if a large number of species were distributed in a more complex way, e.g. bimodally; the restriction to a unimodal model is necessary for practical solubility”. Clearly Ter Braak’s concern is with the extent to which bimodality is present in the data set. This assertion of robustness was tested by Palmer (1993) who demonstrated by the use of simulation studies that CCA performs well even in the face of skew and noise, and by Hill (1991) who used CCA to predict spatial distributions using only binary data. The CLAMP categorical unitary scoring process tends to force compliance with conditions C1-C4 and especially C1 and C2, even when converted to the percentage scores for each site, but it does not eliminate bimodality.

Despite these demonstrations of robustness when data do not conform to the theoretical underpinnings of CCA, it is possible that improvement in CLAMP precision and accuracy might be achieved if transformations were applied to the data such that there was better compliance with CCA’s theoretical requirements. Here we investigate the effects of physiognomical and meteorological dataset transformations by taking square roots to down-weight high abundances; or by taking logarithms for those with very skewed distribution. Non-transformed and transformed datasets of CLAMP data A (173 modern sites) were employed to test for normality and find their distribution – see table 2, figure 1. Table 2 shows values of the two parameters, i.e. skewness normality and kurtosis normality.

Our analyses show the most significant parameters of normal distribution are the values of skewness and kurtosis normality. Focusing on the results indicated in table 2 (last column “Recommended Transformation”), it is obvious the input dataset transformation, i.e. taking square roots or taking logarithms, improves values of skewness normality and/or kurtosis normality. This operation resulted in a distribution closer to the Gaussian ordination. After application of the recommended transformation 18 of 31 physiognomical and 7 of 11 meteorological variables show distinct improvement of their normality (i.e. value of the

Skewness Normality is getting close to 0 and value of the Kurtosis Normality to 3). Figure 1 shows these results displayed in histograms based on the selected original and transformed variables of 173 modern sites.

An additional issue is the degree to which variables are correlated. Although CCA does not assume independence of variables, strongly correlated environmental variables can lead to complex species/environment relationships and the risk of poor CCA results. A good choice of environmental variables should mean that this problem is largely avoided. (Ter Braak, 1986). In respect of climate all variables are of course correlated by the physics of the atmosphere. For example temperature affects evaporation, which affects humidity and ultimately precipitation. Moisture condensing from the vapour phase yields latent heat, which in turn increases temperature. Nevertheless in CLAMP the extent of correlations could easily be reduced. Two variables were removed for this reason (GROWSEAS and MMGSP). This reduction was carried out to obtain climate estimates derived from non-transformed datasets with correlated climatic parameters (see below and Table 5). Based on Ter Braak 1986, p. (1771) and our findings, some climate variables could be removed from CCA and/or CLAMP because they are strongly correlated with one of the remaining variables – the absolute value of the Spearman correlation coefficient is equal or higher than 0.95 (see Table 3). The prediction of the removed climate variables was calculated using a linear regression with correlated variables, i.e. MAT for CMMT and GROWSEAS; and SH for ENTHAL (Table 3). Partial results indicate that the MMGSP parameter is best removed due to the weak relationship between the vector score and the observed values of this parameter for both the 144 and 173 reference datasets and because there is the obvious linear correlation with the GSP variable. Ter Braak (1986, p. 1173) used the same procedure to remove two environmental variables because of their strong correlation with another of the remaining variables in his test data relating to hunting spiders.

Seventeen different fossil floras and/or their physiognomical characters were used (see table 4) to the effect on estimates in the results when using non-transformed datasets with correlated climatic parameters (marked as “original”) and transformed input datasets without correlated climatic parameters (marked as “adapted”) for both CLAMP data A and CLAMP data B sets. A comparison of these results (Table 5) shows notable differences in estimates of the most important palaeoclimate parameters such as MAT, WMMT and CMMT. For example, the average value of MAT increases by 2.5 °C, WMMT and CMMT increase by 2 °C. There are also some minor value increases in the STDEV Residuals (see table 5).



Results demonstrate (Table 5), agreement with Yang et al. (2007) that the use of CCA for CLAMP is a robust tool. However further improvement can be made using transformed datasets and excluding strongly correlated meteorological parameters (both *sensu* Ter Braak, 1986) to obtain more precise and accurate results.

### **3.2. Which reference dataset is more appropriate 144 (CLAMP data B) or 173 (CLAMP data A) modern sites, for specific fossil assemblages?**

CLAMP often produces different results depending on whether the 144 site (Physg3br) or the 173 site (Physg3ar) dataset (see Table 8) is applied. The larger reference set contains the same 144 modern vegetation sites (here referred to as CLAMP data B) plus an additional set of 29 modern sites, which include sites from areas that experience pronounced winter cold. The 173 dataset (CLAMP data A) is recommended for use when estimating the climate of cooler fossil floras. In some cases it is hard to say by simple inspection of the fossil leaf assemblage which data set is the more appropriate. It is true that obtaining CLAMP results from both modern datasets takes only few minutes and inspection of where the fossil flora is positioned in physiognomic space should indicate which dataset is likely to yield the more reliable results. However, this inspection still remains subjective and a better approach would be to devise a set of objective mathematical rules to assist in such decision-making.

The following statistically objective steps were carried out:

- 1) Calculate means for all foliar physiognomic parameters for the 144 modern sites included in both datasets (Mean144).
- 2) Calculate means for the remaining 29 modern sites (Mean29).
- 3) Take the foliar physiognomic parameters of the studied fossil flora (OUR).

For each foliar physiognomic parameter:

$$a) 144_i = \frac{ABS(OUR-MEAN144)}{[MAX(ABS(OUR-MEAN 144),ABS(OUR-MEAN 29))]},$$

$$b) \text{ } ^{29}_i = \frac{ABS(OUR-MEAN29)}{[MAX(ABS(OUR-MEAN 144),ABS(OUR-MEAN 29))]} ,$$

where  $i=1$  to 31 is a foliar physiognomic parameter.

If  $\sum(DIFF144)_i < \sum(DIFF29)_i$  then OUR site is closer to the mean calculated from 144 sites and we should use the 144 dataset; otherwise we should use the 173 dataset. The final results of this analysis for the floras studied are presented in table 8.

Generally, the above-given statistically objective steps are not straightforward and can discourage people applying them. Therefore a simple application in Excel with “copy and paste” mode which is freely downloadable from the CLAMP website has been prepared.

### **3.3. Is it possible to improve the precision and accuracy of CLAMP?**

The answer to this question comes from the basic and crucial premise behind CLAMP that a relationship exists between foliar physiognomic parameters of woody angiosperm vegetation and their relevant climatic parameters. We focused on the analysis of the predicted (derived from the CLAMP) and observed meteorological values in the modern calibration datasets (GRIDMet3ar and GRIDMet3br). The predicted climatic values are calculated during the CCA/CLAMP procedure and are indicated for each reference modern site used in the relevant result files (i.e. Res3arcGRID and Res3brcGRID – see the CLAMP website). Table 6 shows predicted and observed values for each meteorological parameter on 173 modern site. Those differences vary from tens to tenths of unit of the measurement (e.g., °C, cm, g/kg) depending on which variable is involved as is demonstrated in Table 6.

These meteorological differences are unavoidable products of the CCA procedure, when multi-dimensional space (31 physiognomical and up to 11 meteorological parameters) is simplified to 4 dimensional space characterized by axes 1 to 4 (AX1-AX4). Predicted climatic values are calculated based on regression analysis. If the above-mentioned statement of CLAMP is valid, a fossil flora/site defined by the specific physiognomical pattern should have a similar palaeoclimatic and/or meteorological character as modern sites with the most similar/closest physiognomical character. To test this, Cluster Analysis was used to identify modern floras (from Physg3ar /CLAMP data A/ and Physg3br /CLAMP data B/) whose

physiognomic characters corresponded best to an individual palaeoflora (approximately 4 to 8 recent analogues for each fossil flora). Then the means of differences between the observed and the predicted values were calculated for each climate parameter of these “nearest” recent sites and “correction coefficients” were created (see Table 7). This approach is similar to, but distinct from, that of Stranks and England (1997). By adding these coefficients to the original CLAMP results, a value for the relevant palaeoclimatic parameter that corresponded best to living vegetations defined in the CLAMP data A or data B files (Table 8) was obtained.

Calculation of these coefficients can help to make CLAMP palaeoclimate estimates more reliable because it automatically corrects for differences between the observed climate and that predicted by CLAMP. The reasons for these differences are complex and include the simplification in the current methodology from 11 dimensional climate space to 4, and the fact that the conditions within and below the vegetation canopy are inevitably different to those measured regionally by meteorological stations. Our proposed adjustment, derived directly from the physiognomical and meteorological characters of calibration datasets, goes some way towards correcting for these effects.

#### **4. Conclusions.**

Since CLAMP was first published by Wolfe (1993), a number of improvements to this method have been proposed (e.g., Kovach and Spicer, 1995; Stranks and England, 1997; Yang et al. (2007), but not all of these improvements have been widely accepted. Stranks and England (1997) proposed the use of only ~20 modern sites that are physiognomically most similar to the fossil flora under investigation (nearest neighbours based on the Euclidean distance to determine temperature), in general an approach that is very similar to the procedure proposed by us, but based on different and more complicated mathematics. A “resemblance function” (i.e., linear regression) was used to predict climatic parameters of the studied sites based on the nearest neighbour values. This methodology was used only for MAT estimation by Stranks and England (1997) and employed Canonical Analysis (CA), but can be applied to any climate variable as demonstrated by Velasco-de León et al. (2010). Here we also use all characters of the modern reference datasets (CLAMP data A and B).

CLAMP data A as well as CLAMP data B might be thought of as “global” i.e., Northern American and Eastern Asian, however they only represent a small fraction of possible physiognomic/climate space. As more sites are added to fill and quantify physiognomic/climate space it is hoped that CLAMP accuracy and precision can be improved

through the use of datasets more specific to any given fossil site. The “correction coefficients” proposed here are tools allowing the CLAMP reference datasets to be adapted to more specific conditions relating to the individual fossil sites and/or their peculiar physiognomic characters. These coefficients define the mean of the difference between observed and predicted climatic parameters from the nearest neighbours (approximately only 8 to 10 that should show more specific “local” aspect from CLAMP data A and/or B datasets). These neighbours are selected by the use of cluster analysis and express “regional” or appropriate local calibration for fossil sites. So adding their values to the original results derived from CLAMP (“global aspect”) shifts the points from the regression line (derived from the CCA/CLAMP) into a space towards values, that are more typical of those of the nearest neighbour sites. Similarly, applying the other two suggested improvements, i.e. transformation of the modern calibration datasets (CLAMP data A and B) and the statistically objective selection of the calibration dataset to be used throughout the CLAMP procedure, allows more precise and accurate results from CLAMP to be obtained, as suggested by the use of these modifications on the 17 different palaeofloras studied here.

These two improvements to CLAMP, i.e. transformations of the extant reference datasets and their objective selection, represent refinements to CLAMP that will be incorporated into the technique it develops further with the expansions of the calibration datasets into other geographic regions and climate regimes. Finally, our analysis demonstrates that there is still some as yet undiscovered potential for improving existing palaeoclimate proxies such as CLAMP.

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**References**

- Bailey, I.W., Sinnott, E.W., 1915. A botanical index of Cretaceous and Tertiary climates. *Science* 41, 831-834.
- Bailey, I.W., Sinnott, E.W., 1916. The climatic distribution of certain types of angiosperm leaves. *Am. J. of Bot.* 3, 24-39.
- Benzecri, J.P., 1973. *L'analyse des données: L'analyse des correspondances*. Dunod, Paris.
- Bůžek, Č., 1971. Tertiary flora from the northern part of the Pětipsy area (North-Bohemian basin). *Rozp. Ústř. Úst. Geol.* 36, 1-118.
- Green, W.A., 2006. Loosening the CLAMP: An Exploratory Graphical Approach to the Climate Leaf Analysis Multivariate Program. *Palaeo. Electronica* 9 (2, 9A), 1-17.
- Greenwood, D.R., 2005. Leaf form and the reconstruction of past climates. *New Phytolog.* 166, 355–357.
- Greenwood, D.R. 2007. Fossil angiosperm leaves and climate: from Wolfe and Dilcher to Burnham and Wilf. *Cour. Forsch.-Inst. Senckenberg* 258, 95-108.
- Greenwood, D.R., Wilf, P., Wing, S.L., and Christophel, D.C., 2004. Paleotemperature estimation using leaf-margin analysis: Is Australia different? *Palaios* 19, 129-142.
- Hantke, R. 1954. Die fossile Flora der obermiozänen Oehninger-Fundstelle Schrotzburg. *Denkschr. d. Schweiz. Naturf. Gsll.* 80, 27-118.
- Hill, M.O., 1973. Reciprocal Averaging: an eigenvector method of ordination, *J. Ecol.* 61, 237-249.
- Hill, M.O., 1974. Correspondence Analysis: a neglected multivariate method. *Appl. Statist.* 23, 340-354.

- Hill, M.O. 1991. Patterns of species distributions in Britain elucidated by canonical correspondence analysis. *J. Biog.* 18, 247-255.
- Hill, M.O., Gauch, H.G., 1980. Detrended correspondence analysis: An improved ordination technique. *Vegetatio*, 42, 47-58.
- Kennedy, E.M., Spicer, R.A., Rees, P.M. 2002. Quantitative palaeoclimate estimates from Late Cretaceous and Paleocene leaf floras in the northwest of the South Island, New Zealand. *Palaeogeog., Palaeoclimatol., Palaeoecol.* 184, 321-345.
- Knobloch, E., Kvaček, Z., 1976. Miozäne Blätterflore vom Westrand der Böhmischen Masse. *Rozp. Ústř. Geol. Úst.* 42, 1-129.
- Köhler, J., 1998. Die Fossilagerstätte Enspel– Vegetation, Vegetationsdynamik und Klima im Oberoligozän. Ph.D. University of Tübingen, Germany.
- Kovach, W.L., Spicer, R.A., 1995. Canonical Correspondence Analysis of Leaf Physiognomy: a Contribution to the Development of a New palaeoclimatological Tool. *Palaeoclimates* 1, 125-138.
- Kowalski, E.A., 2002, Mean annual temperature estimate based on leaf morphology: a test from tropical South America. *Palaeog. Palaeoclim. Palaeoecol.* 188, 141-165.
- Kvaček, Z., Teodoridis, V. 2007. Tertiary macrofloras of the Bohemian Massif: a review with correlations within Boreal and Central Europe. *Bull. Geosci.* 82(4), 383–408.
- Kvaček, Z., Teodoridis, V., Gregor, H.J. (2008): The Pliocene leaf flora of Auenheim, Northern Alsace (France). *Doc. natur.* 155 (10), 1-108.
- Kvaček, Z., Teodoridis, V., Roiron, P. (in press): A forgotten Miocene mastixioid flora of Arjuzanx (Landes, SW France) – leaf remains. *Palaeontog., Abt. B.*
- Mosbrugger, V., Utescher, T., 1997. The coexistence approach – a method for quantitative reconstructions of Tertiary terrestrial palaeoclimate data using plant fossils. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 134, 61-86.
- Palmer, M. 1993. Putting things in even better order: the advantages of canonical

correspondence analysis. *Ecology* 74, 2215-2230.

Peppe, D.J., Royer, D.L. Wilf P. and Kowalski, E.A., 2010. Quantification of Large Uncertainties in Fossil Leaf Paleoaltimetry, *Tectonics* 29, TC3015, doi: 10.1029/2009TC002549

Spicer, R.A., 2000. Leaf physiognomy and climate change. In: Culver, S.J., Rawson, P., (Eds.), *Biotic Response to Global change. The Last 145 Million Years*. Cambridge University Press, Cambridge.

Spicer, R.A., 2007. Recent and Future of CLAMP: Building on the Legacy of Jack A. Wolfe. *Cour. Forsch. Inst. Senckenberg*. 258, 109-118.

Spicer, R.A., Herman, A.B., Kennedy, E.M., 2004. Foliar Physiognomic Record of Climatic Conditions during Dormancy: Climate Leaf Analysis Multivariate Program (CLAMP) and the Cold Month Mean Temperature. *J. Geol.* 112, 685-702.

Spicer, R. A., Valdes, P. J., Spicer, T. E. V. Craggs, H. J., Srivastava, G., Mehrotra, R. C., Yang, J. (2009): New developments in CLAMP: Calibration using global gridded meteorological data. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 283 (1-2), 91-98

Stranks, L., England, P., 1997. The use of a resemblance function in the measurement of climatic parameters from the physiognomy of woody dicotyledons. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 131, 15-28.

Teodoridis, V., 2002. Tertiary flora and vegetation of the Hlavačov gravel and sand and the surroundings of Holedeč in the Most Basin (Czech Republic). *Acta Musei Nat. Pragae, B, hist-nat.* 57 (3-4), 103-140.

Teodoridis, V., 2004. Floras and vegetation of Tertiary fluvial sediments of Central and Northern Bohemia and their equivalents in deposits of the Most Basin (Czech Republic). *Acta Musei Nat. Pragae, B, hist-nat* 60 (3-4), 113-142.

- Teodoridis, V., 2006. Tertiary flora and vegetation of the locality Přívklady near Žatec (Most Basin). *Acta Univers. Carolinae, Geol.* 47 (2003, 1-4), 165-177.
- Teodoridis, V., Kvaček, Z., 2006. Palaeobotanical research of the Early Miocene deposits overlying the main coal seam (Libkovice and Lom Mbs.) in the Most Basin (Czech Republic). *Bull. Geosci.* 81 (2), 93-113.
- Teodoridis, V., Kvaček, Z., Uhl, D., 2009. Late Neogene palaeoenvironment and correlation of the Sessenheim-Auenheim floral complex. *Palaeodiversity*. 2, 1-17.
- Ter Braak, C.J.F., 1986. Canonical correspondence Analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology* 67, 1167-1179.
- Traiser, C., 2004. Blattphysiognomie Als Indikator für Umweltparameter: Eine Analyse Rezenten und Fossiler Floren, PhD Thesis, Eberhard-Karls-University, Germany.
- Traiser, C., Klotz, S., Uhl, D., Mosbrugger, V., 2005. Environmental signals from leaves - a physiognomic analysis of European vegetation. *New Phytol.* 166, 465-484.
- Traiser, C., Uhl, D., Klotz, S., Mosbrugger, V., 2007. Leaf physiognomy and palaeoenvironmental estimates – an alternative technique based on an European calibration. *Acta Palaeobot.* 47, 183-201.
- Uhl, D., 2006. Fossil plants as palaeoenvironmental proxies – some remarks on selected approaches. *Acta Palaeobot.* 46, 87-100.
- Uhl, D., Bruch, A.A., Traiser, Ch., Klotz, S. 2006. Palaeoclimate estimates for the Middle Miocene Schrotzburg flora (S Germany): a multi-method approach. *Int. J. Earth Sci. (Geol Rundsch)* (2006) 95, 1071–1085.
- Uhl, D., Herrmann, M. 2010. Palaeoclimate estimates for the Late Oligocene taphoflora of Enspel (Westerwald, West Germany) based on palaeobotanical proxies., in: Wuttke, M., Uhl, D., Schindler, T. (Eds.), *Fossil-Lagerstätte Enspel – exceptional preservation in an Upper Oligocene maar. Palaeobiodiversity and Palaeoenvironment*, 90, Springer Berlin, Heidelberg, pp. 39-47.
- Uhl, D., Klotz, S., Traiser, C., Thiel, C., Utescher, T., Kowalski, E.A., Dilcher, D.L., 2007b. Paleotemperatures from fossil leaves – a european perspective. *Palaeog. Palaeoclim. Palaeoecol.* 248, 24-31.



- Uhl, D., Traiser, C., Griebner, U., Denk, T., 2007a. Fossil leaves as palaeoclimate proxies in the Palaeogene of Spitsbergen (Svalbard). *Acta Palaeobot.* 47, 89-107.
- Utescher, T., Mosbrugger, V., Ashraf, A. R., 2000. Terrestrial climate evolution in Northwest Germany over the last 25 million years. *Palaios* 15, 430-449.
- Velasco-de León, M.P., Spicer, R.A., Steart, D.C., 2010, Climatic reconstruction of two Pliocene floras from Mexico. *Palaeobio. Palaeoenv.* 90, 99-110.
- Walther, H. 1998. Die Tertiärflora von Hammerunterwiesenthal (Freistaat Sachsen). *Abh. Staatl. Mus. Mineral. Geol.* 43-44, 239-264.
- Walther, H. 1999. Die Tertiärflora von Kleinsaubernitz bei Bautzen. *Palaeontog., Abt. B.* 249, 63-174.
- Wiemann, M.C., Manchester, S.R., Dilcher, D.L., Hinojosa, L.F., Wheeler, R.A., 1998. Estimation of temperature and precipitation from morphological characters of dicotyledonous leaves. *Am. J. Bot.* 85 (12), 1796-1802.
- Wilf, P., 1997. When are leaves good thermometers? A new case for leaf margin analysis. *Paleobiol.* 23, 373-390.
- Wilf, P., Wing, S.L., Greenwood, D.R., Greenwood, C.L., 1998. Using fossil leaves as paleoprecipitation indicators: An Eocene example. *Geology* 26(3), 203-206.
- Wolfe, J.A., 1971. Tertiary climatic fluctuations and methods of analysis of Tertiary floras. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 9, 27-57.
- Wolfe, J. A., 1978. Paleobotanical interpretation of tertiary climates in Northern Hemisphere. *Am. Scient.* 66 (6), 694-703.
- Wolfe, J. A., 1979. Temperature parameters of the humid to mesic forests of eastern Asia and their relation to forests of other regions of the Northern Hemisphere and Australasia. *US Geol. Surv. Prof. Pap.* 1106, 1-37.
- Wolfe J.A., 1990. Palaeobotanical evidence for a marked temperature increase following the Cretaceous/Tertiary boundary. *Nature* 343, 153-156.

Wolfe, J. A. 1993. A method of obtaining climatic parameters from leaf assemblages. U.S. Geol. Surv. Bull. 2040, 1-73. Wolfe, J.A., 1995, Paleoclimatic estimates from Tertiary leaf assemblages. *Annu. Rev. Earth Planet. Sci.* 23, 119-142.

Wolfe, J. A., Spicer, R. A., 1999. Fossil Leaf Character States: Multivariate Analysis, in: Jones, T.P., Rowe, N.P. (Eds.), *Fossil Plants and Spores: Modern Techniques*. Geological Society, London, pp. 233-239.

Yang, J., Wang, Y.F., Spicer, R.A., Mosbrugger, V., Li, C. S., Sun, Q.G., 2007. Climate reconstruction at the Miocene Shanwang Basin, China, using Leaf Margin Analysis, CLAMP, coexistence approach, and overlapping distribution analysis. *Amer. J. Bot.* 94 (4), 599-608.

### **Explanation of figure and tables**

Figure 1. Selected histograms showing original and transformed variables of the CLAMP 3A dataset. SQRT – taking square roots, and Log – taking logarithms for the transformations.

Table 1. Palaeofloras considered in the present study.

Table 2. Results of the normality test (Skewness normality and Kurtosis normality) of non-transformed and transformed physiognomical and meteorological values in CLAMP data A dataset including recommended transformation. Symbols: MAT (Mean Annual Temperature), WMMT (Warm Month Mean Temperature), CMMT (Cold Month Mean Temperature), GROWSEAS (Length of the Growing Season), GSP (Growing Season Precipitation), MMGSP (Mean Monthly Growing Season Precipitation), 3-WET (Precipitation during 3 Consecutive Wettest Months), 3-DRY (Precipitation during 3 Consecutive Driest Months), RH (Relative Humidity), SH (Specific Humidity) and ENTHAL (Enthalpy).

Table 3. Linear relationship among meteorological parameters of the CLAMP data A dataset checked by the Spearman correlation coefficient (Spearman Correlations Section - Pair-Wise Deletion).

Table 4. Percentage scores for the foliar physiognomic characters of the studied fossil floras.

Table 5. CLAMP estimates from the studied floras using original (non-transformed) and adapted (transformed) input datasets of CLAMP data A and CLAMP data B including values of the STDEV Residuals for each climatic parameter.

Table 6. Differences of the CLAMP predicted and real observed values for each climatic parameters in CLAMP data A dataset.

Table 7. Values of correction coefficients calculated for each climatic parameters for the studied floras.

Table 8. Final palaeoclimate estimates derived from the CLAMP using the results of the the input datasets selection method to determine whether the 144 or 173 site datesets was used, and the addition of “correction coefficients” to resulting base CLAMP estimate for each flora that was analyzed.

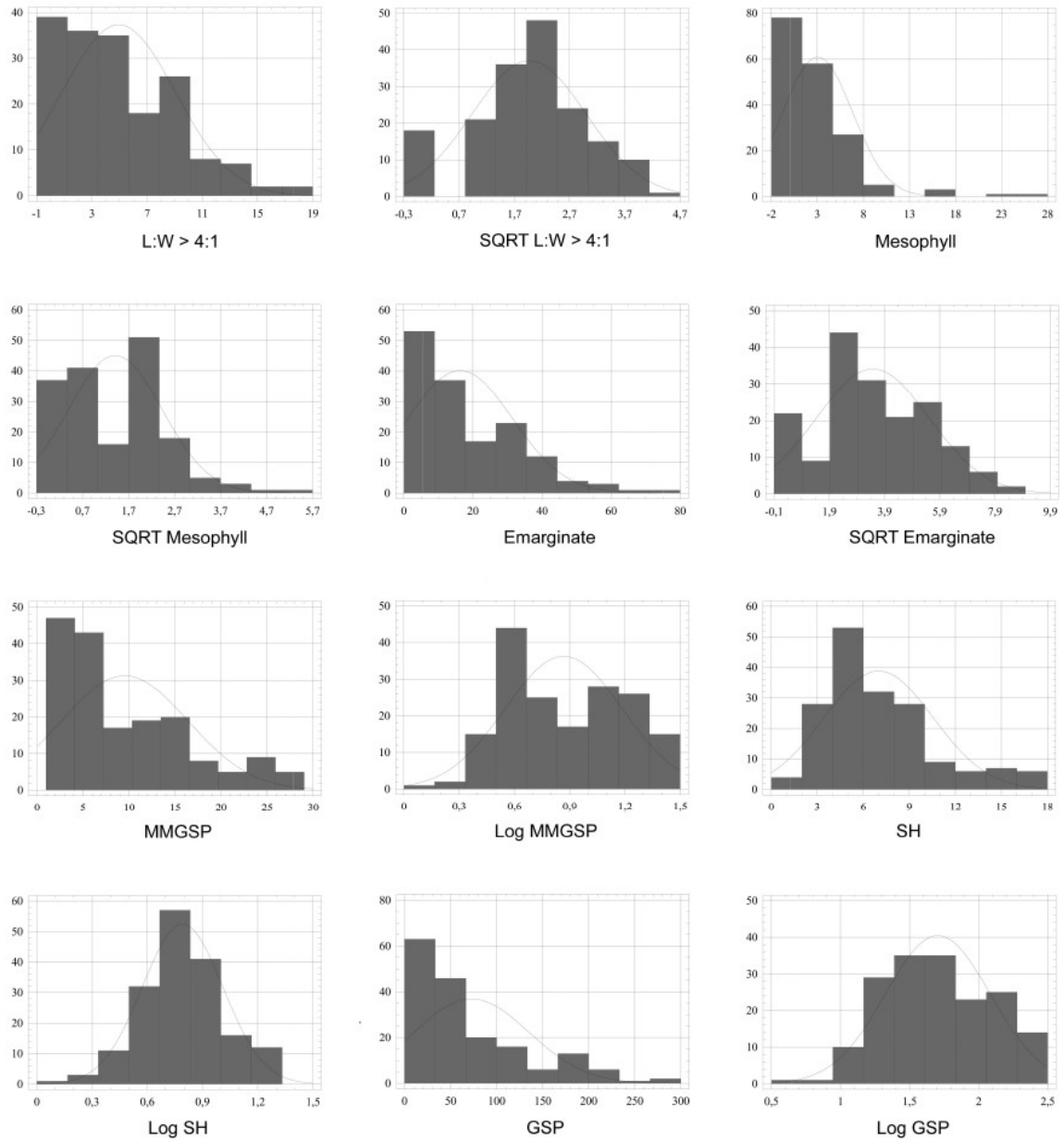


Fig. 1

Locality (Country)	Age	Environment	References
Arjuzanx (France)	Late Miocene	lacustrine	Kvaček et al. (in press)
Auenheim (France)	Pliocene	fluvatile–lacustrine	Kvaček et al. (2008), Teodoridis et al. 2009)
Břešťany (Czech Republic)	Early Miocene	delta-lacustrine	Teodoridis and Kvaček (2006), Kvaček and Teodoridis (2007)
Čermníky (Czech Republic)	Early Miocene	fluvatile/delta	Bůžek (1971)
Enspel (Germany)	Late Oligocene	lacustrine (maar lake)	Köhler (1998), Uhl and Herrmann, (2010)
Frechen 7o	Late Miocene	fluvatile	Utescher et al. (2000)
Garzweiler 8o (Germany)	Late Miocene	fluvatile	Utescher et al. (2000)
Hambach 7f (Germany)	Late Miocene	fluvatile	Utescher et al. (2000)
Hambach 8u (Germany)	Late Miocene	fluvatile	Utescher et al. (2000)
Hambach 9A (Germany)	Late Miocene	fluvatile	Utescher et al. (2000)
Hammerunterwiesenthal (Germany)	Early Oligocene	lacustrine (maar lake)	Walther (1998)
Hlavačov Gravel and Sand (Czech Republic)	Early Miocene/Late Oligocene	fluvatile	Teodoridis (2002, 2004)
Holedeč (Czech Republic)	Early Miocene	oxbow lake	Teodoridis (2002, 2004)
Kleinsaubernitz (Germany)	Late Oligocene	lacustrine (maar lake)	Walther (1999)
Přívklady (Czech Republic)	Early Miocene	fluvatile	Teodoridis (2006)
Schrotzburg (Germany)	Middle Miocene	fluvatile	Hantke (1954), Uhl et al. (2006)
Wackersdorf (Germany)	Early Miocene	fluvatile–lacustrine	Knobloch and Kvaček (1976)

Table 1

Studied physiognomic and climate variables (CLAMP 3A 173)	Value and Use Recommendation for non-transformed datasets		Value and Use Recommendation for transformed datasets		Recommended Transformation
	Skewness Normality	Kurtosis Normality	Skewness Normality	Kurtosis Normality	

<b>Lobed</b>	0.31	Cannot reject normality	2.20	Rejected normality	-0.68	Rejected normality	2.81	Cannot reject normality	NO
<b>No Teeth</b>	0.44	Rejected normality	2.03	Rejected normality	-0.11	Cannot reject normality	2.70	Cannot reject normality	SQ R
<b>Regular teeth</b>	0.04	Cannot reject normality	2.01	Rejected normality	-0.41	Rejected normality	2.05	Rejected normality	NO
<b>Close teeth</b>	0.09	Cannot reject normality	2.01	Rejected normality	-0.37	Rejected normality	2.03	Rejected normality	NO
<b>Round teeth</b>	0.08	Cannot reject normality	2.54	Cannot reject normality	-0.36	Cannot reject normality	2.77	Cannot reject normality	NO
<b>Acuteteeth</b>	0.47	Rejected normality	2.40	Cannot reject normality	-0.29	Cannot reject normality	2.26	Rejected normality	SQ R
<b>Compound teeth</b>	0.62	Rejected normality	2.65	Cannot reject normality	-0.12	Cannot reject normality	2.09	Rejected normality	SQ R
<b>Nanophyll</b>	2.53	Rejected normality	9.50	Rejected normality	1.28	Rejected normality	3.68	Cannot reject normality	SQ R
<b>Leptophyll 1</b>	1.66	Rejected normality	5.52	Rejected normality	0.37	Rejected normality	2.43	Cannot reject normality	SQ R
<b>Leptophyll 2</b>	0.28	Cannot reject normality	1.99	Rejected normality	-0.49	Rejected normality	2.53	Cannot reject normality	NO
<b>Microphyll 1</b>	-0.14	Cannot reject normality	2.46	Cannot reject normality	-0.71	Rejected normality	3.41	Cannot reject normality	NO
<b>Microphyll 2</b>	-0.38	Rejected normality	2.86	Cannot reject normality	-0.89	Rejected normality	3.63	Cannot reject normality	NO
<b>Microphyll 3</b>	0.01	Cannot reject normality	2.12	Rejected normality	-0.74	Rejected normality	3.35	Cannot reject normality	NO
<b>Mesophyll 1</b>	0.67	Rejected normality	2.68	Cannot reject normality	-0.27	Cannot reject normality	2.56	Cannot reject normality	SQ R

<b>Mesophyll 2</b>	2.91	Rejected normality	14.79	Rejected normality	0.52	Rejected normality	3.63	Cannot reject normality	SQ R
<b>Mesophyll 3</b>	3.05	Rejected normality	14.85	Rejected normality	0.93	Rejected normality	3.52	Cannot reject normality	SQ R
<b>Emarginate apex</b>	1.22	Rejected normality	4.35	Rejected normality	0.05	Cannot reject normality	2.43	Cannot reject normality	SQ R
<b>Round apex</b>	-0.21	Cannot reject normality	2.16	Rejected normality	-0.61	Rejected normality	2.50	Cannot reject normality	NO
<b>Acute apex</b>	0.33	Cannot reject normality	3.08	Cannot reject normality	-0.24	Cannot reject normality	2.88	Cannot reject normality	SQ R
<b>Attenuate apex</b>	0.82	Rejected normality	2.42	Cannot reject normality	0.24	Cannot reject normality	2.12	Rejected normality	SQ R
<b>Cordate base</b>	0.39	Rejected normality	2.67	Cannot reject normality	-0.38	Rejected normality	3.19	Cannot reject normality	SQ R
<b>Round base</b>	-0.36	Cannot reject normality	3.42	Cannot reject normality	-0.79	Rejected normality	4.35	Rejected normality	NO
<b>Acute base</b>	0.86	Rejected normality	3.76	Rejected normality	0.15	Cannot reject normality	3.34	Cannot reject normality	SQ R
<b>L:W &lt;1:1</b>	0.51	Rejected normality	2.40	Cannot reject normality	-0.45	Rejected normality	2.43	Cannot reject normality	SQ R
<b>L:W 1-2:1</b>	0.03	Cannot reject normality	2.77	Cannot reject normality	-0.29	Cannot reject normality	2.96	Cannot reject normality	NO
<b>L:W 2-3:1</b>	0.70	Rejected normality	3.34	Cannot reject normality	0.25	Cannot reject normality	2.87	Cannot reject normality	SQ R
<b>L:W 3-4:1</b>	0.55	Rejected normality	3.21	Cannot reject normality	-0.39	Rejected normality	3.07	Cannot reject normality	SQ R
<b>L:W &gt;4:1</b>	0.93	Rejected normality	3.23	Cannot reject normality	-0.17	Cannot reject normality	2.53	Cannot reject normality	SQ R
<b>Obovate</b>	0.15	Cannot	2.25	Rejected	-0.5	Rejected	2.93	Cannot reject	NO

		reject normality		normality	8	normality		normality	
<b>Elliptic</b>	0.88	Rejected normality	3.47	Cannot reject normality	0.22	Cannot reject normality	3.13	Cannot reject normality	LOG
<b>Ovate</b>	-0.18	Cannot reject normality	2.65	Cannot reject normality	-0.55	Rejected normality	3.01	Cannot reject normality	NO
<b>MAT</b>	0.24	Cannot reject normality	2.22	Rejected normality	-	No recommendation	-	No recommendation	NO
<b>WMMT</b>	0.03	Cannot reject normality	2.22	Rejected normality	-0.39	Rejected normality	2.42	Cannot reject normality	NO
<b>CMMT</b>	0.40	Rejected normality	2.53	Cannot reject normality	-	No recommendation	-	No recommendation	NO
<b>GROWSEAS</b>	0.34	Cannot reject normality	1.91	Rejected normality	0.06	Cannot reject normality	2.01	Reject normality	SQ R
<b>GSP</b>	1.24	Rejected normality	3.69	Cannot reject normality	0.02	Cannot reject normality	2.16	Rejected normality	LOG
<b>MMGSP</b>	0.99	Rejected normality	2.98	Cannot reject normality	0.08	Cannot reject normality	1.96	Rejected normality	LOG
<b>3-WET</b>	0.83	Rejected normality	3.08	Cannot reject normality	-0.19	Cannot reject normality	2.01	Rejected normality	LOG
<b>3-DRY</b>	0.39	Rejected normality	1.84	Rejected normality	-1.08	Rejected normality	3.89	Rejected normality	NO
<b>RH</b>	-0.60	Rejected normality	1.88	Rejected normality	-0.79	Rejected normality	2.07	Rejected normality	NO
<b>SH</b>	1.04	Rejected normality	3.53	Cannot reject normality	-0.14	Cannot reject normality	2.93	Cannot reject normality	LOG
<b>ENTHAL</b>	0.81	Rejected normality	3.05	Cannot reject normality	0.68	Rejected normality	2.88	Cannot reject normality	LOG

Table 2



Climate parameter	MAT	WMMT	CMMT	GROWSEAS	GSP	MMGSP	3-WET	3-DRY	RH	SH	ENTHAL
MAT	1.00	0.87	0.95	0.99	0.52	0.04	0.14	-0.06	-0.07	0.74	0.90
WMMT		1.00	0.70	0.84	0.40	-0.04	-0.10	-0.11	-0.30	0.55	0.73
CMMT			1.00	0.94	0.46	-0.01	0.23	-0.10	0.02	0.72	0.86
GROWSEAS				1.00	0.55	0.06	0.13	-0.06	-0.04	0.76	0.91
GSP					1.00	0.85	0.68	0.69	0.59	0.85	0.77
MMGSP						1.00	0.72	0.85	0.73	0.55	0.37
3-WET							1.00	0.60	0.74	0.57	0.41
3-DRY								1.00	0.69	0.39	0.23
RH									1.00	0.45	0.24
SH										1.00	0.95
ENTHAL											1.00

Table 3

Foliar Physiognom ic Characters [%]	Studied Localities																	
	Arju zanx	Auen heim	Břeš ťany	Čer mník y	Ensel pel	Frec hen 7o	Garz weile r 8o	Ham bach 7f	Ham bach 8u	Ham bach 9A	Hamme runter- wiesent hal	Hlav ačov Gravel and Sand	Hol edeč	Kleinsa ubernit z	Přív laky	Schrot zburg	Wacke rdorf	
Marg in Char acter State s	Lobed	6	31	12	20	14	18	18	24	32	14	20	26	28	10	19	17	6
	No Teeth	47	36	55	33	36	23	0	24	32	14	54	20	32	57	31	38	69
	Tth Regul ar	26	49	39	46	38	54	82	60	64	71	23	65	57	26	48	26	21
	Teeth Close	27	20	34	33	28	61	86	68	68	79	27	43	39	19	52	26	15
	Teeth Roun d	20	42	24	17	39	13	18	15	11	0	0	22	13	11	24	24	15
	Teeth Acute	35	31	26	50	31	64	82	62	68	86	38	61	55	32	40	36	9
	Tth Comp ound	8	7	0	14	13	30	36	18	29	28	0	17	20	8	17	17	0

Size Char acter State s	Nano phyll	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lepto phyll I	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Lepto phyll II	5	2	4	1	2	0	0	0	0	0	11	0	2	0	2	2	0
	Micro phyll I	11	7	13	9	8	0	15	7	12	17	19	3	8	3	11	15	8
	Micro phyll II	40	23	17	26	49	33	41	34	41	46	46	18	24	48	22	46	36
	Micro phyll III	33	43	18	40	27	36	36	40	31	39	14	44	38	43	27	23	40
	Meso phyll I	9	21	19	15	9	28	7	19	12	0	9	31	22	11	35	13	11
	Meso phyll II	0	4	17	5	4	4	0	0	4	0	0	4	5	0	2	0	5
	Meso phyll III	0	0	11	4	0	0	0	0	0	0	0	0	2	0	0	0	0
Apex Char acter State s	Apex Emar gnate	5	5	6	0	6	4	0	0	0	0	0	0	0	0	0	0	
	Apex Roun d	34	47	32	21	9	11	9	24	32	7	0	6	17	4	21	13	57
	Apex Acute	39	37	46	68	51	45	45	50	50	57	67	84	72	56	71	55	38
	Apex Atten uate	22	11	17	11	34	38	36	21	29	36	33	10	11	40	7	32	5

Base Char acter State s	Base Corda te	8	26	10	17	20	37	27	22	16	21	54	20	17	13	12	6	0
	Base Roun d	30	42	42	40	26	23	32	37	33	28	13	37	38	24	38	39	50
	Base Acute	62	32	46	43	54	39	41	37	36	50	33	43	45	64	50	56	50
Lengt h to Widt h Char acter State s	L:W< 1:1	3	12	11	8	9	14	23	12	11	0	5	7	9	2	10	10	4
	L:W 1-2:1	16	59	24	31	26	35	45	46	49	47	44	28	27	24	30	39	13
	L:W 2-3:1	38	21	31	29	31	30	23	25	24	33	17	32	31	28	32	27	15
	L:W 3-4:1	33	5	16	16	27	15	0	16	9	4	35	10	14	20	9	6	20
	L:W> 4:1	10	3	19	17	7	5	9	0	8	14	0	23	20	26	19	18	18
Shap e Char acter State s	Obov ate	13	31	17	9	0	15	3	13	12	7	0	2	3	8	8	10	13
	Ellipti c	50	39	50	40	61	35	44	39	48	64	83	50	48	68	35	51	63
	Ovate	37	30	35	51	39	49	53	45	41	28	17	48	48	24	58	39	25

Table 4

Climate parameters	STDEV Residuals				Arjuzanx				Auenheim			
	ORIGINAL		ADAPTED		ORIGINAL		ADAPTED		ORIGINAL		ADAPTED	
	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B
MAT [°C]	1.64	1.13	1.73	1.20	13.35	13.69	14.12	15.81	11.35	11.80	15.04	15.03
WMMT [°C]	1.82	1.41	2.02	1.67	23.58	23.25	22.63	24.52	20.21	20.24	21.24	20.97
CMMT [°C]	2.18	1.86	1.46	1.47	3.91	5.32	5.51	7.61	3.81	4.34	6.71	6.53
GROWSEAS [month]	0.78	0.71	0.09	0.09	8.37	8.12	7.69	8.52	6.53	6.85	8.11	8.17
GSP [cm]	18.55	19.62	36.94	36.10	150.14	137.84	73.80	92.87	69.31	74.00	94.34	111.24
MMGSP [cm]	2.44	2.56	3.45	3.49	19.04	17.80	19.43	16.12	9.17	9.10	9.20	7.54
3-WET [cm]	13.07	13.78	15.98	16.39	69.13	82.78	60.77	62.95	53.84	55.36	65.26	69.98
3-DRY [cm]	3.51	3.20	3.84	3.47	15.76	16.48	24.60	22.96	15.84	14.90	17.44	21.22
RH [%]	6.22	5.22	6.72	5.51	59.90	67.20	74.99	76.50	76.40	74.00	80.01	80.96
SH [g/kg]	1.01	1.03	0.20	0.17	6.95	7.26	15.81	9.72	8.07	7.67	4.62	5.70
ENTHAL [kJ/kg]	0.45	0.46	1.22	0.82	31.41	31.53	35.18	33.19	31.65	31.51	30.21	30.80
Climate parameters	Břešťany				Čermníky				Enspel			
	ORIGINAL		ADAPTED		ORIGINAL		ADAPTED		ORIGINAL		ADAPTED	
	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B
MAT [°C]	13.70	14.80	12.34	13.70	9.49	9.87	12.29	11.91	10.87	11.01	8.41	10.07
WMMT [°C]	20.44	21.94	19.12	21.13	21.27	20.86	21.26	21.76	22.85	22.10	19.59	21.68
CMMT [°C]	8.12	8.58	3.17	4.70	-1.26	-0.07	3.11	2.23	-0.35	1.07	-1.98	-0.30
GROWSEAS [month]	7.92	8.28	6.91	7.59	6.10	6.21	6.89	6.85	7.17	6.90	5.34	6.12
GSP [cm]	128.64	125.74	60.02	82.58	83.41	81.46	112.86	114.73	136.07	126.48	60.27	58.61
MMGSP [cm]	13.81	13.75	11.11	8.45	13.25	12.75	11.88	9.89	19.77	18.50	26.08	23.39
3-WET [cm]	71.27	71.69	63.54	63.60	56.49	62.94	65.54	65.90	69.22	82.02	62.22	60.54
3-DRY [cm]	19.05	19.00	17.17	18.29	15.20	14.51	21.23	22.87	17.09	17.28	25.94	21.02

RH [%]	74.60	76.06	78.50	79.62	70.16	69.66	80.44	80.52	63.94	68.93	76.22	73.65
SH [g/kg]	9.52	9.59	4.73	6.35	6.00	5.76	5.67	7.26	6.11	6.24	12.29	9.59
ENTHAL [kJ/kg]	32.47	32.55	30.30	31.26	30.63	30.58	30.98	31.86	30.82	30.88	34.10	33.12
Climate parameters	Frechen 7o				Garzweiler 8o				Hambach 7f			
	ORIGINAL		ADAPTED		ORIGINAL		ADAPTED		ORIGINAL		ADAPTED	
	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B
MAT [°C]	9.72	9.28	10.75	10.05	4.86	5.86	3.87	4.10	8.25	8.45	9.39	9.00
WMMT [°C]	22.93	23.33	22.67	22.45	21.14	21.88	20.40	20.63	21.70	21.75	22.30	22.09
CMMT [°C]	-2.96	-3.64	1.09	-0.32	-11.25	-9.46	-7.94	-8.53	-4.46	-3.82	-0.70	-1.77
GROWSEAS [month]	5.77	5.83	6.25	6.12	3.71	4.33	3.78	4.05	5.27	5.49	5.71	5.72
GSP [cm]	74.53	85.37	154.22	173.17	36.49	42.31	89.04	87.10	61.30	66.77	116.70	125.08
MMGSP [cm]	14.61	15.84	8.46	6.61	11.67	12.48	8.15	7.73	12.47	12.94	8.11	7.11
3-WET [cm]	57.60	53.34	57.64	63.34	44.86	42.69	43.62	47.08	51.78	52.44	50.54	56.77
3-DRY [cm]	20.52	20.63	19.44	24.50	14.97	15.86	16.36	17.29	16.40	16.39	17.66	20.93
RH [%]	79.19	77.49	80.58	80.96	74.92	73.06	76.89	76.91	75.29	73.17	78.56	79.97
SH [g/kg]	7.21	6.93	4.27	5.77	3.61	3.93	3.54	5.18	5.73	5.55	4.61	5.91
ENTHAL [kJ/kg]	31.13	30.97	29.92	30.85	29.17	29.49	29.23	30.39	30.39	30.36	30.21	30.95
Climate parameters	Hambach 8u				Hambach 9A				Hammerunterwiesenthal			
	ORIGINAL		ADAPTED		ORIGINAL		ADAPTED		ORIGINAL		ADAPTED	
	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B
MAT [°C]	8.02	8.47	8.00	8.16	8.16	8.04	7.48	7.66	12.11	11.34	9.79	10.25
WMMT [°C]	21.63	21.96	21.03	21.19	24.48	24.66	25.16	25.17	25.97	25.39	26.12	26.55
CMMT [°C]	-4.83	-3.95	-2.52	-2.93	-8.29	-7.44	-3.21	-3.62	-1.87	-1.46	-0.17	-0.05
GROWSEAS [month]	5.19	5.49	5.19	5.41	5.40	5.42	5.00	5.24	7.56	7.06	5.87	6.19
GSP [cm]	57.94	62.62	87.96	98.12	67.67	75.71	148.06	171.15	114.25	114.13	94.25	91.85
MMGSP [cm]	12.05	12.47	8.10	7.13	16.37	17.31	8.68	7.90	19.62	19.53	10.41	12.89

3-WET [cm]	50.22	50.08	48.45	53.97	50.98	50.36	38.88	47.90	58.90	66.37	33.36	38.22
3-DRY [cm]	15.63	16.04	16.16	18.30	16.83	18.83	20.57	24.07	16.33	18.01	20.72	19.49
RH [%]	74.43	72.95	77.28	78.93	73.05	73.15	75.08	78.17	65.38	68.66	65.39	64.98
SH [g/kg]	5.44	5.49	4.10	5.34	4.60	5.10	8.81	8.22	5.79	6.08	17.07	9.75
ENTHAL [kJ/kg]	30.25	30.34	29.76	30.52	29.93	30.16	32.72	32.42	30.83	30.86	35.52	33.20
Climate parameters	Hlavačov Gravel and Sand				Holedeč				Kleinsaubernitz			
	ORIGINAL		ADAPTED		ORIGINAL		ADAPTED		ORIGINAL		ADAPTED	
	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B
MAT [°C]	7.68	7.91	7.59	7.72	8.50	8.94	8.73	9.03	14.75	13.84	16.72	17.32
WMMT [°C]	21.60	21.00	20.89	21.54	21.28	21.04	20.46	21.42	27.20	26.39	28.30	28.83
CMMT [°C]	-5.55	-4.30	-3.05	-3.53	-3.37	-2.14	-1.56	-1.73	1.69	2.18	8.92	9.69
GROWSEAS [month]	5.24	5.36	5.04	5.26	5.65	5.80	5.46	5.73	9.08	8.30	8.90	9.21
GSP [cm]	70.74	71.70	114.97	124.31	76.35	75.59	95.96	105.74	175.62	166.65	231.12	267.15
MMGSP [cm]	13.94	13.82	10.73	8.88	13.40	13.15	11.21	9.21	25.95	24.57	31.45	22.77
3-WET [cm]	53.91	59.53	56.77	59.79	54.97	60.37	58.23	59.80	72.71	83.93	65.80	71.30
3-DRY [cm]	15.65	15.02	20.45	22.67	15.19	14.75	19.90	21.17	18.87	21.24	37.18	36.62
RH [%]	71.58	69.88	79.83	80.22	70.51	69.84	79.31	79.66	61.25	70.08	78.94	80.68
SH [g/kg]	4.98	4.66	4.65	6.47	5.43	5.25	4.98	6.65	6.92	7.62	33.25	8.04
ENTHAL [kJ/kg]	30.02	29.97	30.23	31.35	30.29	30.30	30.49	31.47	31.54	31.69	38.58	32.31
Climate parameters	Přívlačky				Schrotzburg				Wackerdorf			
	ORIGINAL		ADAPTED		ORIGINAL		ADAPTED		ORIGINAL		ADAPTED	
	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B	CLAMP data A	CLAMP data B
MAT [°C]	8.48	9.24	8.16	8.15	10.84	11.04	11.63	11.83	15.48	16.32	18.59	20.34
WMMT [°C]	20.09	19.68	19.41	20.00	23.40	22.68	22.91	23.46	22.56	22.11	24.14	25.89
CMMT [°C]	-1.98	-0.35	-2.31	-2.95	-1.01	0.68	2.24	2.12	9.33	11.38	11.38	13.84
GROWSEAS [month]	5.61	5.89	5.25	5.41	7.02	6.84	6.61	6.81	9.44	9.29	9.83	10.68

GSP [cm]	70.01	67.26	67.50	63.43	108.18	101.99	77.69	66.73	180.88	159.82	94.36	125.77
MMGSP [cm]	11.35	10.67	8.27	8.13	16.80	15.68	13.45	15.84	18.59	16.56	28.10	20.02
3-WET [cm]	53.02	59.69	51.85	52.25	59.39	68.86	51.04	53.30	76.44	94.12	71.30	71.87
3-DRY [cm]	13.82	12.66	14.85	14.81	14.77	15.49	21.43	19.09	15.80	15.96	29.41	27.89
RH [%]	69.56	68.52	77.45	76.52	63.32	67.94	73.47	71.49	57.49	67.22	77.26	79.46
SH [g/kg]	5.52	5.25	3.28	5.24	5.60	5.99	12.15	9.51	8.38	8.67	23.44	9.47
ENTHAL [kJ/kg]	30.33	30.33	28.96	30.44	30.61	30.79	34.05	33.08	32.20	32.32	36.94	33.06

Table 5

Name and location of the modern site (CLAMP data A)	Climate parameters																							
	MAT [°C]		WMMT [°C]		CMMT [°C]		GROWSEAS [month]		GSP [mm]		MMGSP [mm]		3-WET [mm]		3-DRY [mm]		RH [%]		SH [g/kg]		ENTHAL [kJ/kg]			
	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted		
Guani ca, Puert	26.03	25.42	27.53	26.82	24.21	22.43	12.00	12.30	178.34	78.74	14.86	4.48	60.57	42.65	24.14	14.01	75.40	79.00	15.44	13.92	35.89	35.34		





Lucas, Baja Califor nia Sur																						
Quirie go, Sonor a	24.0 7	20.2 5	30.1 8	28.1 8	17.1 1	11.5 2	12.0 0	11.0 5	62.7 3	85.6 3	5.23	9.32	44.3 7	37.4 7	1.72	7.73	51.1 7	53.5 6	9.35	7.91	33.4 0	32.5 1
Seqaq a, Fiji	22.9 9	23.2 2	24.4 9	25.6 8	21.2 5	19.4 2	12.0 0	11.9 0	279. 11	246. 47	23.2 6	23.5 0	119. 44	103. 22	33.7 4	34.7 5	79.1 7	81.6 3	14.7 3	15.6 9	35.3 0	35.8 2
Nuri, Sonor a	22.2 9	17.6 9	28.7 0	27.2 3	15.3 0	8.06	12.0 0	9.83	67.0 9	65.8 2	5.59	8.26	44.8 5	34.2 9	2.25	7.20	47.6 6	54.8 7	7.98	6.80	32.7 1	31.8 1
Santia go, Baja Califor nia Sur	23.9 4	22.1 3	29.2 5	28.5 9	18.2 9	14.5 5	12.0 0	11.4 7	44.5 2	48.8 8	3.71	4.31	33.3 0	25.6 9	0.29	5.50	62.3 0	58.6 8	9.64	8.75	33.4 9	33.0 2
Alamo s, Sonor a	23.7 4	20.4 0	29.8 1	27.3 0	16.8 8	12.9 1	12.0 0	10.8 1	66.3 1	96.0 1	5.53	10.0 9	46.3 5	45.7 4	1.99	12.1 6	53.0 9	67.7 8	10.0 0	9.77	33.6 1	33.2 4
Empal me, Sonor a	24.4 7	22.0 3	31.0 9	30.5 9	17.4 0	11.1 5	12.0 0	11.8 2	34.7 3	36.9 4	2.89	4.49	23.6 3	15.9 9	0.91	1.45	50.7 3	35.0 5	9.82	5.89	33.6 2	31.9 1
Baie d'Mag enta, New Caled onia	22.3 1	22.2 7	25.4 2	23.3 6	18.8 7	20.8 3	12.0 0	11.3 5	124. 43	138. 94	10.3 7	9.52	46.1 4	66.9 2	19.3 3	18.9 0	77.4 6	78.2 4	12.0 4	13.7 7	34.2 2	34.9 8
Avon Park, Florid a	22.5 3	22.1 0	27.7 6	26.1 1	16.1 2	17.4 5	12.0 0	11.4 8	121. 45	127. 45	10.1 2	10.9 3	53.5 7	57.8 7	15.4 2	16.0 0	75.2 2	73.6 2	13.0 0	12.0 3	34.6 1	34.2 8
Orlan do, Florid a	22.3 0	19.8 7	27.9 2	24.2 8	15.4 1	15.7 0	12.0 0	10.5 5	121. 85	115. 94	10.1 5	9.70	53.0 5	56.7 2	16.9 7	14.5 2	74.3 9	71.6 7	12.7 6	11.0 9	34.4 9	33.7 0

Todos Santos, Baja California Sur	22.96	23.28	28.35	31.09	18.32	12.58	12.00	12.10	27.19	21.76	2.27	2.62	19.35	11.34	0.16	1.06	68.76	41.85	11.40	6.55	34.05	32.30
Buena Vista, Puerto Rico	22.14	24.26	23.37	25.82	20.51	21.58	12.00	12.15	195.45	117.75	16.29	7.98	72.20	55.49	21.53	16.18	85.51	77.18	16.33	13.64	35.80	35.12
San Bartolomeo, Baja California Sur	22.06	19.07	27.71	28.68	16.50	8.78	12.00	10.34	34.02	30.60	2.83	4.06	25.25	18.87	0.41	2.68	65.03	45.34	10.65	5.76	33.68	31.56
Canyon Lake, Arizona	20.52	22.10	31.95	32.92	10.21	6.14	11.41	12.25	40.88	18.97	3.58	4.77	17.55	4.72	2.95	-1.99	42.25	-0.30	4.95	2.25	31.39	30.54
Los Divisaderos, Baja California Sur	20.47	24.12	26.11	29.40	15.24	16.84	12.00	12.22	35.53	49.89	2.96	4.00	26.86	24.99	0.27	5.99	66.22	62.27	10.58	9.78	33.48	33.62
Maricao, Puerto Rico	21.11	25.06	22.28	26.27	19.56	22.23	12.00	12.41	194.93	146.94	16.24	11.14	71.71	66.84	21.75	21.78	85.08	80.47	16.27	14.95	35.67	35.70
Riv. Bleue, New Caledonia	22.13	26.12	25.19	25.89	18.88	24.18	12.00	12.60	119.90	190.70	9.99	15.13	45.83	87.04	18.49	32.41	79.46	80.80	12.49	17.40	34.37	36.75
Bartlett Resvr., Arizona	20.20	22.59	32.44	31.61	9.35	10.24	10.59	11.99	37.43	20.65	3.53	3.32	14.14	9.50	3.37	0.12	40.58	31.43	5.27	5.19	31.48	31.71
Mt.	20.1	24.	23.1	26.	16.9	21.	12.0	12.	124.	184	10.4	15.	46.1	81.	19.4	27.	77.2	81.	11.9	15.	33.9	35.8

Koghis, New Caledonia	1	38	9	05	7	17	0	16	87	.83	1	88	8	98	2	98	7	51	9	54	7	7
Lake George, Florida	21.56	16.37	27.77	21.56	14.01	12.15	12.00	9.15	128.21	128.53	10.68	11.78	52.50	66.02	19.44	16.33	74.66	71.53	12.29	10.15	34.24	32.99
Castle Cr., Arizona	19.73	21.07	31.92	30.46	9.21	9.68	10.59	11.46	24.66	28.52	2.33	3.81	10.02	13.11	1.87	0.32	39.73	28.05	5.74	4.87	31.60	31.43
Silver Bell, Arizona	20.30	22.42	30.96	32.99	10.34	6.57	12.06	12.32	27.26	16.24	2.26	4.33	12.42	4.01	1.51	-2.02	37.95	2.23	6.16	2.47	31.82	30.65
Saguaro Lake, Arizona	21.41	20.28	32.90	29.75	10.96	9.47	12.00	10.85	30.32	15.25	2.53	2.22	10.89	11.21	1.79	0.46	38.39	37.61	5.92	5.17	31.84	31.46
Superior, Arizona	18.45	19.38	30.07	30.68	8.09	6.06	9.72	10.95	31.87	23.46	3.28	4.26	14.63	10.39	2.59	-0.96	40.35	12.09	5.38	2.82	31.34	30.46
Roosevelt Lk., Arizona	19.75	19.89	31.95	30.31	8.89	7.72	10.38	10.94	39.96	20.49	3.85	3.41	16.13	11.06	3.54	-0.21	41.40	25.40	5.05	4.01	31.35	30.97
Brunswick, Georgia	19.51	19.29	27.55	24.36	10.31	14.46	11.99	10.33	126.58	130.86	10.56	12.08	44.72	62.71	21.74	16.79	74.36	73.14	11.04	11.12	33.56	33.66
Anbwest, Yakushima	20.14	17.93	27.12	23.26	13.31	12.90	12.00	10.40	209.95	244.83	17.50	24.53	67.85	98.02	29.91	24.29	80.67	70.01	11.97	11.19	33.97	33.54
Nagakubo, Yakus	15.84	18.60	24.70	24.07	6.82	13.20	8.83	10.42	208.71	225.27	23.63	23.18	104.46	93.92	26.06	25.72	81.97	74.93	8.87	11.86	32.37	33.87

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Monte Guilarte, Puerto Rico	19.84	21.41	20.99	24.85	18.33	17.57	12.00	11.15	202.41	162.89	16.87	14.42	73.78	73.80	23.66	21.81	86.10	78.05	16.03	13.12	35.45	34.64			
Beaufort, South Carolina	18.96	17.69	27.59	23.22	9.20	12.73	11.01	9.29	120.01	113.40	10.90	11.28	51.01	63.63	19.86	19.77	72.34	78.95	10.55	11.54	33.32	33.67			
Punkin Center, Arizona	19.26	17.27	31.60	28.12	8.35	6.26	10.03	9.91	39.98	32.08	3.98	4.44	16.52	17.83	3.89	0.79	41.66	26.69	4.96	3.76	31.26	30.60			
Yakusugi 260m, Yakushima	14.58	15.09	23.43	22.76	5.61	8.03	8.27	9.15	201.81	232.74	24.41	26.48	104.34	98.48	26.06	25.29	81.88	70.73	8.86	9.91	32.23	32.76			
Toro Negro, Puerto Rico	18.53	19.72	19.66	23.89	17.06	15.64	12.00	10.52	197.65	162.79	16.47	14.94	68.81	75.13	26.66	21.26	87.21	76.70	15.99	12.29	35.29	34.16			
Childs, Arizona	18.33	17.93	30.69	28.66	7.33	6.60	9.46	9.93	40.44	28.84	4.27	4.53	18.97	18.27	4.79	2.28	42.96	41.18	4.32	4.83	30.93	31.08			
Simmonsville, South Carolina	18.09	19.52	27.25	22.98	7.91	16.50	9.77	10.04	107.46	97.54	11.00	7.42	46.15	55.37	22.18	15.85	73.00	77.27	10.16	11.98	33.08	34.02			
Santa Rita, Arizona	15.74	16.08	25.54	25.64	7.20	7.33	8.58	9.02	31.64	34.97	3.69	4.11	22.19	25.07	2.27	3.84	40.88	49.62	4.81	5.63	30.84	31.19			
Miami, Arizona	15.81	15.56	27.36	24.61	5.70	7.63	8.11	8.85	28.41	40.34	3.51	4.24	17.18	27.71	2.93	4.02	41.67	48.66	4.97	5.67	30.91	31.16			

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Yakusugi, Yakushima	13.77	14.98	22.61	22.84	4.83	7.75	7.88	9.13	197.01	227.69	25.02	26.00	104.34	96.17	26.06	24.25	81.88	69.30	8.86	9.62	32.15	32.63				
New Bern, North Carolina	16.44	14.70	26.02	22.81	5.98	7.40	8.91	8.48	99.76	143.90	11.19	16.91	43.00	72.80	25.80	20.02	74.05	73.56	9.36	9.40	32.61	32.52				
Kure Beach, North Carolina	17.38	17.63	26.75	21.56	7.16	14.47	9.46	9.52	105.72	128.00	11.18	10.80	45.43	66.79	24.23	17.58	73.30	75.15	9.75	11.31	32.86	33.57				
Pamlico Sound, North Carolina	16.00	13.31	25.94	20.59	5.43	7.31	8.72	7.88	92.04	113.65	10.56	12.14	37.55	63.43	27.20	15.22	73.05	69.01	9.01	8.36	32.44	31.97				
Camp Pardee, California	15.81	14.28	25.39	21.17	6.77	8.92	8.96	8.11	35.52	57.02	3.94	5.02	34.33	40.22	1.11	8.02	62.86	62.65	6.60	7.40	31.52	31.70				
Portal, Arizona	15.00	16.41	24.94	24.35	5.61	9.46	7.99	9.19	26.43	57.72	3.31	5.59	19.08	34.72	2.66	6.29	39.84	55.27	4.30	6.97	30.58	31.75				
Tatsuta-yama, Kyushu	15.25	12.32	26.71	21.33	3.83	4.34	8.05	7.68	189.27	153.61	23.53	18.79	110.16	77.18	19.51	19.44	75.87	69.34	8.84	8.06	32.30	31.74				
Auburn, California	14.80	14.51	24.57	20.93	6.08	9.52	8.21	7.96	33.26	58.43	3.93	5.30	38.44	43.94	1.71	10.87	62.45	71.35	6.29	8.61	31.30	32.20				
Edenton, North	15.61	14.5	25.75	22.5	4.69	7.8	8.39	8.3	87.65	139	10.45	15.5	37.89	72.2	23.52	20.2	73.12	74.8	8.85	9.6	32.34	32.5				

Carolina		50		09		2		2		.06		89		78		19		77		3		9
Arakawa Dam, Yakushima	12.35	13.21	21.18	22.43	3.46	4.83	7.24	8.19	188.33	176.04	26.00	21.62	104.27	82.09	26.06	20.75	81.84	68.51	8.86	8.33	32.00	31.94
Jerome, Arizona	14.09	14.54	26.05	24.13	3.65	6.17	7.38	8.22	24.94	31.52	3.38	3.82	15.39	27.05	5.21	4.76	42.59	55.25	4.48	5.68	30.55	31.05
Togatake, Kyushu	14.52	13.43	25.84	20.77	3.42	7.05	7.84	8.57	187.14	224.89	23.86	24.70	107.15	96.90	19.74	22.39	74.55	65.47	8.99	8.89	32.28	32.18
Yakusugi 800m, Yakushima	11.85	13.31	20.67	23.26	2.98	3.90	6.98	8.28	184.46	203.16	26.43	26.23	104.24	91.16	26.06	24.51	81.81	71.13	8.86	8.70	31.95	32.09
Zozusan, Shikoku	14.27	14.08	26.20	22.83	3.56	6.13	7.62	8.09	113.62	135.27	14.90	16.88	53.48	71.96	11.91	20.97	73.14	75.67	8.44	9.35	32.05	32.44
Sierra Ancha, Arizona	13.68	13.67	25.38	22.07	3.43	6.73	7.24	8.03	26.21	62.11	3.62	6.51	17.30	40.24	3.76	7.48	42.37	57.00	4.76	6.36	30.62	31.22
Colfax, California	13.60	14.11	23.52	20.48	5.13	9.15	7.30	7.79	30.83	68.05	4.16	6.49	53.24	48.99	2.35	12.68	60.46	73.28	5.64	8.90	30.93	32.27
Yava, Arizona	17.22	15.07	29.20	26.73	7.04	3.97	9.11	8.75	27.19	18.29	2.99	3.22	14.09	16.44	3.19	0.87	41.47	33.61	4.64	3.28	30.94	30.17
Jasper Ridge, California	15.57	13.64	20.13	20.60	10.52	8.22	11.93	7.65	55.11	54.19	4.62	5.12	30.90	42.19	0.45	9.77	71.72	68.73	7.20	7.85	31.71	31.81
Natur	14.7	12.	26.8	20.	4.13	5.7	7.65	7.3	30.6	57.	4.01	6.4	18.6	43.	4.78	9.7	43.3	65.	4.18	6.9	30.5	31.3

al Bridge , Arizon a	7	51	2	84		1		0	9	78		6	1	20		1	0	92		1	1	2
Canel o, Arizon a	14.7 4	13. 48	24.1 6	22. 65	6.34	5.8 0	7.97	7.9 1	30.6 2	43. 07	3.84	4.7 5	23.2 2	32. 26	2.53	5.2 6	39.2 0	52. 83	4.59	5.4 9	30.6 6	30.8 6
Lakep ort, Califor nia	13.9 2	12. 60	21.2 3	20. 66	7.44	6.1 1	8.11	7.3 5	35.0 2	54. 43	4.31	5.7 7	54.0 7	41. 41	2.16	8.7 9	66.3 7	64. 17	6.02	6.7 7	31.1 0	31.2 7
Santa Cruz, Califor nia	13.8 4	12. 83	17.9 2	19. 52	9.23	7.6 4	10.7 8	7.2 6	30.2 4	65. 91	2.86	6.5 7	20.3 1	49. 62	0.31	12. 56	74.5 9	72. 75	7.54	8.3 7	31.6 6	31.9 2
Placer ville, Califor nia	14.4 7	9.9 7	24.3 5	17. 09	6.05	4.4 2	7.79	6.1 5	31.7 0	56. 67	4.06	5.8 8	46.0 5	47. 96	1.92	10. 52	61.1 3	68. 13	5.84	6.6 9	31.0 9	30.9 6
Kiyosu mi, Honsh u	14.0 3	12. 12	24.6 3	21. 65	4.52	3.6 6	7.83	7.4 7	135. 61	128. .33	17.3 0	16. 32	58.7 6	68. 87	24.0 1	17. 59	74.1 5	69. 42	8.90	7.6 6	32.1 9	31.5 6
Nekko 1, Honsh u	12.9 3	14. 56	23.6 8	23. 91	2.91	5.6 9	7.32	8.7 9	151. 64	193. .24	20.7 3	24. 09	68.3 2	85. 61	22.8 8	22. 74	76.2 0	70. 20	8.46	8.9 7	31.9 2	32.3 3
Nekko 2, Honsh u	13.0 3	9.5 2	23.7 8	22. 89	3.01	-3.2 9	7.37	6.2 2	152. 20	105. .08	20.6 8	18. 05	68.3 0	63. 52	22.8 7	18. 34	76.2 2	71. 43	8.46	5.9 8	31.9 2	30.6 2
S.I.E.R .C., Maryl and	13.5 7	9.6 0	25.4 7	20. 70	0.77	-0.4 1	7.37	5.9 4	68.9 3	78. 17	9.36	12. 32	30.2 4	57. 35	24.4 0	16. 82	66.9 3	74. 84	7.42	6.8 4	31.6 0	30.9 8
Yakus ugi 1080 m, Yakus hima	10.4 3	10. 55	19.2 4	21. 34	1.61	0.6 4	6.25	6.9 1	172. 43	154. .30	27.6 1	21. 27	104. 21	79. 93	26.0 6	21. 16	81.7 9	70. 69	8.86	7.3 1	31.8 0	31.2 6



Umedaira, Honshu	12.70	10.61	24.54	22.77	2.42	-0.82	7.10	6.58	98.24	103.25	13.87	16.57	45.97	63.10	9.99	18.65	74.68	73.53	7.37	6.90	31.49	31.10
Battle Cr., Maryland	13.85	8.33	25.53	19.32	1.32	-1.55	7.44	5.49	66.73	81.58	8.97	12.65	28.67	59.80	24.16	16.52	68.29	73.28	7.64	6.29	31.71	30.62
Junipine, Arizona	12.91	9.58	24.87	19.98	2.35	0.60	6.91	5.95	26.18	49.99	3.83	7.53	17.30	44.19	5.66	10.96	43.16	68.59	3.64	5.77	30.12	30.55
Payson, Arizona	14.24	13.37	26.24	22.07	3.63	6.20	7.41	7.72	29.31	43.83	3.95	4.77	18.33	34.72	4.71	6.70	43.36	59.65	4.17	6.22	30.45	31.14
Sannoda, Kyushu	12.86	13.49	24.20	21.82	1.69	5.99	7.19	8.40	179.27	206.47	24.95	24.22	108.78	92.41	19.88	23.27	75.43	69.59	8.93	9.00	32.08	32.23
Prescott AP, Arizona	14.13	12.03	25.89	21.76	4.07	3.88	7.40	6.85	24.25	23.55	3.28	3.40	15.48	29.93	4.70	6.84	41.95	65.74	4.42	5.92	30.53	30.88
Kitt Peak, Arizona	10.55	13.66	20.20	20.93	2.18	7.96	5.94	7.59	22.88	42.82	3.84	4.04	19.09	37.52	2.13	8.60	40.08	68.16	5.22	7.56	30.46	31.69
Half Moon Bay, California	15.41	11.95	19.77	20.12	10.54	5.32	12.00	6.82	58.50	49.96	4.87	5.84	31.94	43.56	0.52	11.20	72.14	71.87	7.23	7.44	31.71	31.47
Kannami 1, Honshu	11.02	13.01	23.15	22.11	-0.61	4.91	6.47	7.78	121.22	129.61	18.69	16.15	73.82	69.11	15.93	18.35	72.79	71.45	8.06	8.29	31.57	31.91
Kidogawa 1, Honshu	11.68	8.38	23.79	22.45	0.92	-5.19	6.67	5.41	100.75	77.07	15.13	15.45	51.71	57.49	13.55	18.66	75.77	75.94	7.11	5.91	31.29	30.47

Sanze, Honshu	11.9 4	11. 69	25.2 4	23. 94	0.29	-0.1 3	6.64	6.8 9	96.8 7	108 .48	14.6 0	17. 94	52.8 7	65. 73	29.0 3	21. 74	75.5 9	77. 56	7.06	7.9 3	31.2 9	31.6 2
Crown King, Arizona	11.2 0	12. 19	22.5 4	19. 52	1.71	6.4 9	6.16	7.1 2	21.0 5	56. 63	3.42	5.6 6	16.4 4	44. 14	3.70	9.6 7	41.5 9	66. 74	4.61	7.1 5	30.3 0	31.3 8
Amagi- toge, Honshu	11.4 7	7.6 9	22.1 9	21. 58	1.50	-5.6 0	6.70	5.2 7	142. 85	83. 89	21.3 6	15. 94	68.8 8	59. 57	22.9 0	17. 72	76.3 7	73. 11	8.44	5.3 7	31.7 5	30.1 8
Power s, Oregon	12.6 5	10. 48	19.2 4	19. 46	7.09	2.9 7	7.47	6.0 2	46.5 6	43. 99	6.28	6.1 5	64.9 8	44. 80	7.21	12. 97	75.0 5	75. 69	5.88	7.3 5	30.9 2	31.2 8
Troutdale, Oregon	12.0 3	9.1 5	20.5 4	19. 53	4.29	0.1 0	6.80	5.5 9	55.1 1	50. 58	8.07	8.0 6	78.1 5	47. 65	13.2 1	13. 54	75.7 1	74. 24	5.73	6.4 6	30.8 0	30.7 8
Yakusugi 1350, Yakushima	9.06	9.2 0	17.8 6	20. 64	0.30	-1.3 0	5.50	6.2 4	158. 32	126 .86	28.7 9	18. 54	104. 12	72. 13	26.0 6	18. 83	81.7 3	69. 67	8.85	6.3 9	31.6 5	30.7 5
Kidogawa 2, Honshu	11.4 0	9.5 1	23.5 1	22. 28	0.66	-2.5 1	6.58	6.0 8	100. 00	91. 85	15.2 3	15. 69	51.8 1	60. 16	14.0 6	17. 67	75.8 7	72. 94	7.12	6.2 3	31.2 6	30.7 2
Kannami 2, Honshu	10.6 2	7.6 1	22.7 6	20. 86	-0.9 8	-4.8 4	6.30	5.4 3	118. 88	89. 79	18.8 3	15. 63	73.5 4	59. 95	15.9 6	15. 87	72.8 1	68. 38	8.06	4.9 2	31.5 3	29.9 9
Port Orford, Oregon	12.0 6	10. 75	17.0 1	19. 64	7.81	3.2 6	7.30	6.4 1	50.7 0	68. 04	6.91	8.7 8	71.2 5	52. 26	7.02	13. 94	78.9 9	73. 02	6.48	7.3 1	31.0 8	31.2 8
Frederick, Maryland	12.4 7	9.9 3	24.3 7	20. 41	-0.5 4	0.6 5	6.98	5.9 6	64.4 7	68. 23	9.23	10. 53	29.7 2	54. 26	22.0 6	16. 26	70.3 7	75. 98	7.09	7.1 8	31.3 6	31.1 5
Mt.	11.0	11.	23.8	23.	-0.5	-0.3	6.42	6.8	83.7	107	13.0	17.	48.1	64.	10.6	20.	73.2	76.	6.81	7.6	31.1	31.5

Tokura, Honshu	1	53	6	85	4	2		7	6	.96	8	79	3	97	1	93	1	54		5	0	0
North Bend, Oregon	12.06	10.50	18.37	18.87	6.59	3.56	7.17	6.25	43.28	67.04	6.07	8.36	65.92	53.14	6.84	14.26	74.89	74.04	6.57	7.51	31.11	31.34
Higane Shrine, Honshu	10.22	11.01	22.34	20.88	-1.28	2.37	6.14	6.89	119.73	100.41	19.46	13.23	75.29	60.48	16.50	15.02	73.16	68.23	8.12	6.85	31.51	31.13
Walnut Cr., Arizona	13.99	10.37	25.58	21.33	4.12	1.11	7.33	6.60	23.17	23.78	3.16	3.56	15.07	26.52	4.85	3.20	41.25	45.80	3.95	3.28	30.35	29.66
Arendtsville, Pennsylvania	11.44	7.53	23.67	20.34	-1.81	-4.28	6.59	4.84	56.21	41.03	8.53	8.97	26.43	44.96	22.99	13.82	72.06	74.77	6.87	5.34	31.17	30.16
Jemez Springs, New Mexico	9.12	11.07	20.51	19.18	-1.82	4.80	5.67	6.72	29.48	32.51	5.21	3.11	21.33	32.98	8.24	5.23	45.88	56.61	3.15	5.27	29.55	30.52
Bandon, Oregon	12.19	10.89	18.06	21.20	7.12	1.83	7.35	6.58	48.84	71.56	6.63	10.24	68.87	51.27	7.08	13.60	76.09	70.69	6.42	6.70	31.07	31.06
Aoba, Honshu	10.54	10.71	23.24	23.93	-0.83	-2.14	6.22	6.25	85.26	80.54	13.70	15.43	48.66	57.81	10.97	20.63	73.74	78.84	6.89	7.42	31.09	31.32
Nestucca River, Oregon	11.37	8.10	18.32	18.63	5.39	-1.20	6.43	5.11	34.92	54.07	5.43	8.91	63.15	51.31	8.61	14.97	80.44	75.65	6.23	6.40	30.92	30.64
Nibetsu, Honshu	10.01	9.81	23.40	22.81	-1.88	-2.62	5.96	5.85	91.65	79.36	15.37	15.01	55.35	59.17	29.58	20.69	76.22	78.95	6.61	7.28	30.93	31.17

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Hood River, Oregon	11.22	7.75	21.01	19.04	2.40	-2.27	6.29	4.88	33.35	33.89	5.26	6.71	68.10	42.40	8.86	12.33	72.63	74.38	4.88	5.62	30.41	30.29
Blue Canyon, California	8.90	10.29	18.67	18.50	1.24	3.72	5.13	6.08	12.63	37.02	2.46	4.40	63.54	40.04	3.08	9.55	58.99	70.16	4.87	6.53	30.16	30.93
Cape Blanco, Oregon	11.78	10.01	16.51	19.38	7.74	2.06	7.01	6.04	45.30	58.89	6.47	8.12	70.28	49.64	7.00	13.36	80.17	73.10	6.61	6.88	31.10	31.04
Hasayampa, Arizona	11.20	7.99	22.58	17.91	1.76	-0.45	6.15	5.32	23.77	42.26	3.88	6.18	18.61	42.37	4.35	9.20	42.52	65.07	4.13	4.88	30.13	30.03
Grayland 2 S, Washington	10.00	10.64	15.53	20.83	5.16	1.65	5.61	6.35	49.10	74.67	8.76	10.92	91.70	55.09	16.01	16.02	82.91	74.92	6.33	7.34	30.82	31.28
Three Lynx, Oregon	10.97	7.91	20.22	19.24	2.97	-2.12	6.06	4.95	41.01	30.54	6.80	6.19	70.29	40.27	12.91	11.47	75.93	73.43	5.08	5.45	30.45	30.24
Stroudsburg, Pennsylvania	9.59	8.86	22.34	21.71	-4.11	-3.07	5.95	5.38	61.90	45.42	10.39	9.66	32.02	45.45	24.67	14.76	72.37	75.95	6.08	5.98	30.69	30.55
Takinosawa, Honshu	10.27	11.57	23.67	24.00	-1.79	-0.44	6.08	6.80	96.14	99.90	15.79	16.97	56.67	62.67	30.30	20.86	76.73	77.41	6.42	7.72	30.89	31.53
Clearwater, Washington	9.99	7.42	15.23	18.58	5.27	-2.52	5.73	4.85	73.12	44.39	12.75	8.02	133.25	46.91	21.98	13.17	84.58	73.68	6.15	5.58	30.75	30.24
Bowman	8.95	12.19	19.11	20.10	1.23	5.4	5.16	6.7	13.9	34.27	2.73	3.9	65.9	36.3	3.90	9.2	56.3	71.3	3.97	7.1	29.8	31.3

Dam, California		03	2	23		5		6	9	06		3	9	92		9	7	10		3	4	5
Pt. Grenville, Washington	9.88	8.88	14.98	21.03	5.16	-2.18	5.68	5.57	70.92	53.12	12.49	9.78	131.21	47.13	21.88	13.61	83.63	72.70	6.28	5.73	30.78	30.46
Sta. Catalina Mts., Arizona	9.82	9.08	19.65	17.37	0.95	2.33	5.67	5.60	19.11	42.76	3.32	5.33	15.99	44.22	2.28	10.64	40.49	70.82	5.61	6.32	30.53	30.71
Tazawa-ko, Honshu	9.91	10.46	23.30	24.53	-2.37	-3.50	6.00	6.14	92.01	81.42	15.33	16.62	56.22	58.11	25.25	21.35	77.46	79.08	6.06	7.19	30.72	31.20
Forestdale, Arizona	12.13	9.29	23.56	17.05	1.81	3.17	6.64	6.06	23.48	54.61	3.54	5.75	17.08	44.94	3.68	8.19	44.24	60.10	3.91	5.44	30.14	30.39
Los Alamos, New Mexico	7.21	10.22	18.63	18.40	-3.95	3.70	4.91	6.27	24.13	47.16	4.92	5.30	18.66	42.27	7.13	8.88	45.55	65.22	3.39	6.06	29.45	30.74
Wind River, Washington	10.10	8.96	19.11	20.36	1.92	-1.26	5.74	5.29	39.20	38.24	6.82	7.55	93.22	44.11	12.23	14.29	74.45	77.20	5.27	6.53	30.44	30.79
Lake Spaulding, California	9.30	10.73	19.44	21.21	1.47	1.81	5.29	6.30	14.07	23.62	2.67	3.99	61.46	31.30	3.73	7.31	56.40	66.06	4.10	5.40	29.92	30.53
Tunkhannock, Pennsylvania	9.22	6.61	21.89	20.45	-4.47	-6.40	5.89	4.31	53.14	28.29	9.02	8.17	28.71	41.03	18.70	13.56	72.11	76.07	5.70	4.86	30.51	29.86
Clalla	9.64	7.5	15.3	19.	4.47	-2.9	5.45	4.7	62.2	48.	11.4	9.3	128.	50.	20.1	16.	85.8	77.	5.89	6.3	30.6	30.5

m Bay, Washi ngton		8	6	19		6		7	0	44	1	1	55	46	9	08	3	58		0	1	4
Parkd ale, Orego n	10.8 7	7.4 6	20.9 0	19. 29	2.16	-3.1 0	6.03	4.6 7	27.3 9	21. 29	4.53	5.3 6	47.9 0	36. 88	8.96	10. 88	73.6 5	74. 00	4.63	5.1 4	30.2 8	30.0 7
Trout Lake, Washi ngton	9.09	8.3 1	18.6 9	19. 04	0.54	-1.0 9	5.26	5.0 4	25.5 2	33. 22	4.81	6.2 7	73.4 0	42. 46	9.74	12. 77	73.2 4	75. 82	4.67	6.1 7	30.1 1	30.5 7
Sierra ville, Califor nia	9.39	8.2 7	20.1 1	18. 24	0.88	-0.0 5	5.37	5.2 6	12.1 5	19. 90	2.26	3.3 6	39.3 7	32. 86	4.17	6.9 7	52.5 8	65. 25	3.36	4.6 4	29.6 6	29.9 7
Toya- ko, Hokka ido	7.06	8.5 8	20.6 1	23. 52	-5.5 9	-6.1 4	5.10	5.2 9	64.1 2	62. 44	12.5 8	14. 60	44.1 7	52. 63	23.1 3	19. 05	80.1 7	78. 16	5.39	6.0 2	30.1 8	30.5 4
Flagst aff AP, Arizon a	8.89	8.9 4	20.4 5	20. 06	-1.1 6	-0.4 9	5.32	5.7 5	21.5 5	17. 25	4.11	3.2 6	17.4 3	27. 70	5.77	4.5 7	43.3 5	55. 62	3.36	3.5 4	29.6 1	29.6 0
Ketchi kan, Alaska	7.37	8.9 8	14.7 4	22. 29	0.51	-3.1 8	4.37	5.6 9	59.0 1	22. 73	13.5 1	5.8 3	77.2 2	30. 32	31.2 3	7.0 4	81.4 7	61. 91	5.08	3.6 7	30.0 8	29.6 6
Satus Pass 2 SSW, Washi ngton	7.19	7.7 2	17.7 7	18. 70	-2.7 7	-1.9 0	4.57	4.7 6	5.07	23. 33	1.12	5.0 7	16.5 8	38. 20	2.97	11. 14	65.3 6	74. 59	4.76	5.5 6	29.9 5	30.2 7
Red Fleet, Utah	7.87	9.8 8	22.2 9	19. 83	-7.1 8	1.7 1	5.46	6.4 3	12.4 8	34. 05	2.28	4.2 4	7.14	32. 01	4.92	4.2 6	56.4 7	47. 89	3.25	3.7 3	29.4 7	29.7 8
Mt. Pocon o, Penns ylvani a	7.75	4.6 2	20.2 4	18. 87	-5.6 3	-8.9 4	5.33	3.8 3	53.4 0	36. 56	10.0 2	9.3 3	31.2 9	43. 34	21.6 1	11. 37	71.2 9	68. 09	5.73	3.0 5	30.3 7	28.9 2
Chees	7.00	3.6	18.8	14.	-3.8	-6.0	4.84	3.4	23.6	8.5	4.88	2.6	17.0	30.	4.86	4.9	44.6	57.	2.62	1.9	29.1	28.3

man Resvr., Colora do		5	3	42	7	6		0	3	4		8	4	85		1	1	70		3	4	7
River Falls, Wisco nsin	6.76	6.2 3	22.1 7	19. 90	-11. 33	-6.6 9	5.54	4.4 1	49.5 6	50. 87	8.95	11. 20	28.9 9	49. 82	6.78	14. 96	71.2 6	73. 89	5.24	4.7 2	30.0 9	29.7 6
Nama rikawa , Hokka ido	7.12	9.7 7	20.4 3	23. 15	-4.7 4	-3.1 3	4.98	5.8 0	63.3 3	75. 84	12.7 1	14. 98	44.6 1	57. 88	22.3 6	20. 73	78.7 5	79. 20	5.69	7.1 9	30.2 9	31.1 3
Laurel Mtn., Orego n	5.43	6.7 8	12.4 9	18. 16	-0.5 3	-3.2 5	2.96	4.6 5	9.85	26. 09	3.36	5.3 4	69.2 3	37. 25	9.63	8.7 5	82.0 8	67. 04	6.30	4.1 5	30.3 3	29.6 0
Rimro ck Lake, Washi ngton	8.11	6.5 9	18.0 8	18. 54	-0.8 4	-4.1 2	4.89	4.2 9	17.4 0	15. 82	3.59	4.7 0	52.6 7	35. 12	8.53	10. 04	71.6 0	73. 17	4.10	4.6 2	29.8 0	29.7 7
Chuze nji-ko, Honsh u	6.42	7.7 9	19.0 0	23. 53	-5.1 3	-7.9 1	4.66	4.9 2	103. 80	59. 47	22.3 2	15. 14	73.9 9	52. 68	13.6 1	19. 71	76.4 0	78. 75	6.26	5.7 0	30.4 3	30.3 3
Greer, Arizon a	6.87	6.5 9	17.4 5	16. 42	-2.4 3	-1.7 9	4.45	4.8 4	20.4 1	34. 94	4.60	5.1 0	18.6 1	39. 29	3.48	6.9 8	44.0 9	58. 49	3.45	3.6 6	29.4 3	29.3 9
Danne mora, New York	4.74	5.0 5	18.5 4	19. 85	-10. 43	-9.0 9	4.60	3.6 8	43.8 1	18. 47	9.51	7.3 5	30.0 0	36. 98	17.3 1	11. 62	76.8 2	73. 63	4.97	3.5 5	29.7 8	29.1 7
Akaga wa Spa, Honsh u	6.14	9.9 2	19.8 1	22. 91	-6.4 3	-2.5 2	4.69	6.0 2	77.3 2	89. 35	16.4 7	16. 22	56.4 8	61. 73	24.5 2	20. 75	77.8 8	77. 92	5.92	7.1 6	30.2 8	31.1 3
Tierra Amaril la, New Mexic	6.45	7.3 9	18.6 3	17. 86	-5.7 7	-1.4 0	4.74	5.2 3	21.9 2	22. 07	4.62	3.4 8	17.1 9	30. 85	7.97	4.2 7	46.7 9	51. 17	2.78	2.9 1	29.1 5	29.1 8

o																									
Estes Park, Colorado	4.88	5.72	17.10	16.32	-6.28	-3.51	4.03	4.17	17.25	14.01	4.29	3.25	14.61	32.81	6.29	6.66	46.06	64.29	2.68	3.46	28.95	29.21			
Republic, Washington	6.53	4.36	18.25	16.29	-5.36	-6.66	4.71	3.50	16.79	22.33	3.57	5.78	17.15	39.93	8.65	10.27	71.72	70.78	3.77	3.66	29.52	29.13			
Donner Lake, California	7.90	6.98	18.43	18.63	-0.29	-3.16	4.71	4.64	10.10	6.86	2.14	2.71	42.70	27.43	4.68	5.78	49.84	63.94	2.90	3.45	29.34	29.35			
Government Camp, Oregon	6.54	7.31	16.04	19.27	-1.49	-3.40	4.05	4.82	18.00	31.41	4.43	6.61	65.81	39.71	10.95	10.53	75.18	70.32	4.63	4.67	29.84	29.87			
Wanakena, New York	5.28	4.40	19.02	18.63	-9.90	-9.13	4.78	3.64	43.93	28.38	9.19	8.18	28.88	40.61	18.56	10.88	79.07	69.12	5.10	2.99	29.89	28.87			
Hanawa-Obono, Honshu	7.36	10.17	20.92	23.88	-5.15	-3.28	5.10	6.19	82.00	97.64	16.08	18.24	56.69	63.54	23.97	21.68	77.88	77.74	5.87	7.07	30.38	31.12			
Bumping Lake, Washington	7.08	7.41	16.71	18.59	-1.28	-2.31	4.33	4.96	19.88	23.16	4.58	4.59	66.77	34.30	11.43	7.38	73.81	63.99	3.87	3.99	29.61	29.61			
Teshio, Hokkaido	5.47	10.61	18.78	24.72	-7.34	-3.45	4.48	5.96	47.40	67.64	10.57	15.09	38.21	54.89	17.91	22.20	80.04	80.83	5.17	7.68	29.93	31.41			
Kogawa, Hokkaido	5.19	9.10	18.34	24.00	-8.27	-5.67	4.48	5.46	60.75	63.83	13.55	14.95	43.27	53.24	15.28	20.05	78.60	79.16	5.23	6.44	29.92	30.76			
Allens	3.46	7.6	15.4	17.	-7.3	-0.6	3.43	4.9	15.2	25.	4.46	4.1	14.9	36.	6.23	8.2	44.2	67.	2.62	4.8	28.7	29.9			



Park, Colora do		0	1	40	8	8		6	9	16		2	9	76		5	3	38		1	9	5
Taden oumi, Honsh u	4.35	5.5 5	16.9 7	22. 25	-7.2 4	-11. 21	3.80	3.9 4	95.2 5	46. 20	25.0 7	13. 99	79.5 8	49. 47	15.1 3	18. 11	78.2 2	77. 84	5.91	4.4 3	30.0 9	29.5 7
Soda Spring s, Califor nia	6.42	7.2 6	16.5 9	17. 34	-1.3 6	-1.2 0	4.03	4.8 2	7.62	10. 52	1.89	2.2 3	49.1 6	29. 08	4.40	5.4 2	51.9 4	62. 36	3.27	3.8 1	29.3 2	29.5 2
Lake Placid, New York	4.33	5.2 2	17.7 4	20. 97	-10. 43	-10. 08	4.45	3.8 8	43.4 0	26. 09	9.76	9.2 0	30.4 9	38. 84	18.3 2	12. 07	75.9 1	72. 06	4.69	3.2 3	29.6 4	29.0 6
Seward, Alaska	3.16	7.3 8	13.6 6	19. 96	-6.2 2	-4.0 2	3.16	4.8 1	22.8 5	27. 33	7.29	6.5 3	26.4 0	37. 75	13.5 0	10. 42	82.1 2	70. 81	3.31	4.5 4	29.0 1	29.8 2
Nederl and, Colora do	3.77	5.4 7	15.6 2	17. 34	-6.8 8	-5.1 2	3.52	4.0 5	16.5 8	11. 96	4.71	3.7 4	15.1 2	31. 55	6.40	6.7 4	38.9 3	64. 25	2.42	3.0 4	28.7 4	29.0 2
Sugan uma, Honsh u	3.78	3.9 8	16.3 8	21. 61	-7.8 1	-13. 86	3.58	3.2 7	92.8 1	28. 81	25.9 3	11. 82	81.6 3	42. 32	15.5 6	14. 96	78.7 6	75. 50	5.78	2.9 8	29.9 8	28.8 1
Red River, New Mexic o	5.20	5.4 5	17.2 1	15. 77	-7.0 5	-3.5 2	4.26	4.2 1	18.3 8	17. 93	4.31	3.4 3	14.7 8	33. 50	4.90	5.7 7	46.0 1	59. 04	2.97	2.9 5	29.0 9	28.9 8
Nukab ira, Hokka ido	3.53	6.7 2	17.2 9	22. 61	-10. 57	-9.0 2	3.97	4.3 3	49.4 7	43. 25	12.4 6	12. 80	39.4 9	47. 99	15.3 6	18. 28	80.7 4	79. 01	4.61	5.2 4	29.5 3	30.0 2
Wolf Creek, Colora do	0.34	6.5 5	12.3 5	17. 20	-11. 79	-2.7 6	2.13	4.9 1	14.5 2	47. 55	6.55	7.2 7	19.5 3	44. 07	9.00	8.4 7	38.4 0	59. 06	1.42	3.7 0	28.0 3	29.3 9
Tahos a	2.31	6.5	14.1	16.	-8.4	-1.7	2.90	4.8	12.8	29.	4.42	4.3	14.7	36.	6.33	6.2	44.6	57.	2.59	3.4	28.6	29.3

Creek, Colora do		8	6	38	3	4		2	3	79		9	2	91		4	4	36		8	6	1
Home r, Alaska	3.61	8.2 4	12.7 3	21. 44	-4.6 2	-3.7 7	2.95	5.4 0	16.9 3	26. 45	5.73	6.3 2	24.8 8	32. 98	11.8 5	7.6 2	80.1 5	62. 36	3.84	3.6 0	29.2 5	29.5 5
Alyesk a, Alaska	3.26	8.0 4	15.4 8	20. 55	-8.1 4	-3.2 7	3.82	5.2 0	23.6 4	35. 20	6.16	7.4 0	20.8 8	39. 43	8.92	10. 47	82.8 9	69. 06	3.45	4.6 4	29.0 7	29.9 3
Grand Lake, Colora do	3.22	6.3 7	15.3 7	16. 96	-7.8 9	-2.7 8	3.41	4.7 2	14.7 9	28. 64	4.33	4.7 7	13.3 6	36. 34	7.68	6.3 6	40.5 1	57. 51	1.91	3.2 2	28.5 0	29.1 9
Lake Granb y, Colora do	3.55	10. 01	15.7 4	20. 68	-7.6 9	1.1 1	3.56	6.4 6	15.4 5	25. 09	4.33	3.5 3	13.4 3	27. 51	8.08	3.2 2	39.8 6	45. 30	1.87	3.2 4	28.5 2	29.6 0
Dillon, Colora do	1.62	7.3 0	13.5 0	17. 74	-9.5 1	-1.4 7	2.65	4.9 8	12.7 2	11. 87	4.77	2.3 8	14.3 8	27. 98	8.85	4.3 8	33.1 7	56. 74	1.49	3.2 1	28.1 8	29.2 9
Kenai, Alaska	2.55	6.5 3	13.5 7	20. 01	-7.7 0	-5.8 1	3.09	4.6 5	16.3 9	22. 74	5.31	6.1 5	22.2 9	33. 64	9.14	7.6 9	78.1 6	62. 78	3.76	3.0 0	29.1 1	29.1 2
Talkee tna, Alaska	0.58	8.9 0	14.6 7	21. 33	-12. 38	-2.2 8	3.11	5.6 5	23.2 5	32. 87	7.48	6.7 2	25.3 0	36. 00	8.22	8.7 7	78.2 6	65. 17	3.43	4.4 0	28.7 9	29.9 3
Eklutn a Lake, Alaska	1.90	8.3 7	14.6 1	19. 70	-9.5 3	-1.4 9	3.29	5.4 7	20.5 3	31. 42	6.24	5.6 2	19.8 1	36. 06	7.15	7.8 1	84.9 1	62. 97	3.04	4.2 7	28.7 8	29.8 2
Sheep Mtn., Alaska	-0.6 4	9.5 1	13.5 9	21. 19	-13. 97	-0.7 0	2.68	5.9 1	19.2 6	24. 33	7.16	4.8 0	21.4 9	31. 27	8.57	6.7 8	89.2 3	62. 13	2.71	4.3 1	28.4 0	29.9 7

Table 6

Localities	Values of Correction coefficients										
	MAT [°C]	WMMT [°C]	CMMT [°C]	GROWSEAS [month]	GSP [cm]	MMGSP [cm]	3- WET [cm]	3- DRY [cm]	RH [%]	SH [g/kg]	ENTHAL [kJ/kg]
Arjuzanx	-1.0 5	1.09	-1.58	0.02	0.01	0.02	0.11	3.64	10.17	-0.01	-0.01
Auenheim	1.50	1.86	-0.16	-0.01	0.01	-0.02	-0.0 1	-3.3 7	-5.94	-0.05	-0.01
Břešťany	-0.1 8	0.97	2.71	0.04	0.01	0.00	-0.0 2	-6.4 0	1.11	-0.04	0.00
Čermníky	2.06	2.90	-1.72	0.00	-0.0 1	-0.05	-0.1 5	-0.9 5	-4.55	0.00	-0.01
Enspel	-1.1 2	0.09	-1.08	0.01	0.01	0.04	0.14	3.28	10.33	0.00	-0.01
Frechen 7o	-1.2 8	-0.98	-2.86	0.08	0.05	0.08	-0.1 0	-3.5 6	-0.55	-0.11	-0.01
Garzweiler 8o	0.86	-0.15	-3.33	0.09	0.13	0.11	-0.0 6	0.61	-0.40	0.01	-0.01
Hambach 7f	1.56	2.88	-4.46	0.05	0.07	0.03	-0.2 2	0.73	-7.59	-0.03	-0.01
Hambach 8u	1.83	2.52	-4.45	0.05	0.08	0.02	-0.2 1	1.66	-7.05	-0.01	-0.01
Hambach 9A	1.25	-0.65	-0.85	0.01	0.14	0.14	0.13	1.02	3.09	0.05	-0.01
Hammerunterwiesenthal	-1.4 9	-1.58	-0.34	0.01	0.05	0.11	0.23	6.42	16.64	0.11	-0.01
Hlavačov Gravel and Sand	0.55	1.72	-3.75	0.06	0.08	0.07	-0.1 6	-0.9 2	-4.61	-0.05	-0.01
Holedeč	2.23	3.62	-4.52	0.03	0.04	-0.01	-0.2	2.11	-7.19	0.00	-0.01

							3				
Kleinsaubernitz	-2.3 2	-0.39	-0.62	0.02	-0.0 6	-0.03	0.14	2.99	14.88	-0.02	-0.01
Přívlačky	1.94	2.03	-1.58	0.01	0.04	0.00	-0.1 1	2.37	-3.76	0.01	-0.01
Schrotzburg	1.80	3.37	-2.81	-0.01	0.00	-0.03	-0.0 3	3.82	3.37	0.04	0.00
Wackerdorf	-2.9 0	0.76	-0.64	0.08	-0.0 8	-0.10	0.11	5.70	18.41	-0.05	0.00

Table 7

Studied localities	Dataset selection : CLAMP data A or CLAMP data B	Climate characters										
		MAT [°C]	WMM T [°C]	CMM T [°C]	GROWSEA S [month]	GSP [cm]	MMGS P [cm]	3-WET [cm]	3-DRY [cm]	RH [%]	SH [g/kg]	ENTHAL [kJ/kg]
Arjuzanx	B	14.76	25.61	6.03	8.53	92.88	16.15	63.06	26.59	86.67	9.72	33.18
Auenheim	A	16.53	23.10	6.55	8.09	94.35	9.18	65.25	14.07	74.07	4.57	30.20
Břešťany	B	13.52	22.10	7.41	7.63	82.59	8.46	63.58	11.90	80.73	6.31	31.26
Čermníky	B	13.97	24.66	0.51	6.85	114.72	9.83	65.75	21.92	75.97	7.26	31.85
Enspel	B	8.95	21.77	-1.38	6.13	58.62	23.43	60.67	24.31	83.98	9.59	33.12
Frechen 7o	A	9.47	21.69	-1.78	6.33	154.27	8.54	57.54	15.88	80.03	4.16	29.91
Garzweiler 8o	A	4.73	20.24	-11.28	3.87	89.17	8.25	43.55	16.97	76.49	3.54	29.22
Hambach 7f	A	10.95	25.18	-5.16	5.76	116.78	8.13	50.32	18.39	70.97	4.58	30.20
Hambach 8u	B	9.99	23.71	-7.37	5.47	98.19	7.15	53.76	19.96	71.88	5.32	30.51
Hambach 9A	B	8.92	24.52	-4.47	5.24	171.29	8.04	48.03	25.09	81.26	8.27	32.41
Hammerunterwiesenthal	B	8.77	24.97	-0.39	6.20	91.90	13.00	38.45	25.91	81.63	9.85	33.19
Hlavačov Gravel and Sand	B	8.28	23.26	-7.28	5.31	124.38	8.95	59.63	21.74	75.62	6.42	31.34
Holedeč	B	11.27	25.04	-6.25	5.77	105.78	9.20	59.56	23.28	72.47	6.64	31.46
Kleinsaubernitz	B	15.00	28.44	9.07	9.23	267.09	22.73	71.44	39.62	95.57	8.02	32.31

Přívlačky	A	10.1 0	21.44	-3.89	5.26	67.54	8.27	51.7 4	17.2 2	73.7 0	3.29	28.95
Schrotzburg	B	13.6 3	26.83	-0.69	6.80	66.74	15.81	53.2 7	22.9 1	74.8 7	9.54	33.08
Wackerdorf	B	17.4 4	26.65	13.20	10.76	125.6 9	19.92	71.9 8	33.5 9	97.8 7	9.42	33.06

Table 8