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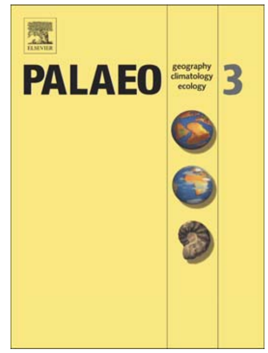

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Refining CLAMP – investigations towards improving the Climate Leaf Analysis Multivariate Program

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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.

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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.

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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, Přívlaky, 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

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

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

where X means a random variable, μ means a mean value of this variable and σ means a standard deviation.

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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 *Xi*, *Yi* are converted to ranks *xi*, *yi,* and the differences *di* = *xi* − *yi* 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

<u>3.1. CLAMP Robustness</u>

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,

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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

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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).

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

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

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

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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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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 meterological 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).

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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.

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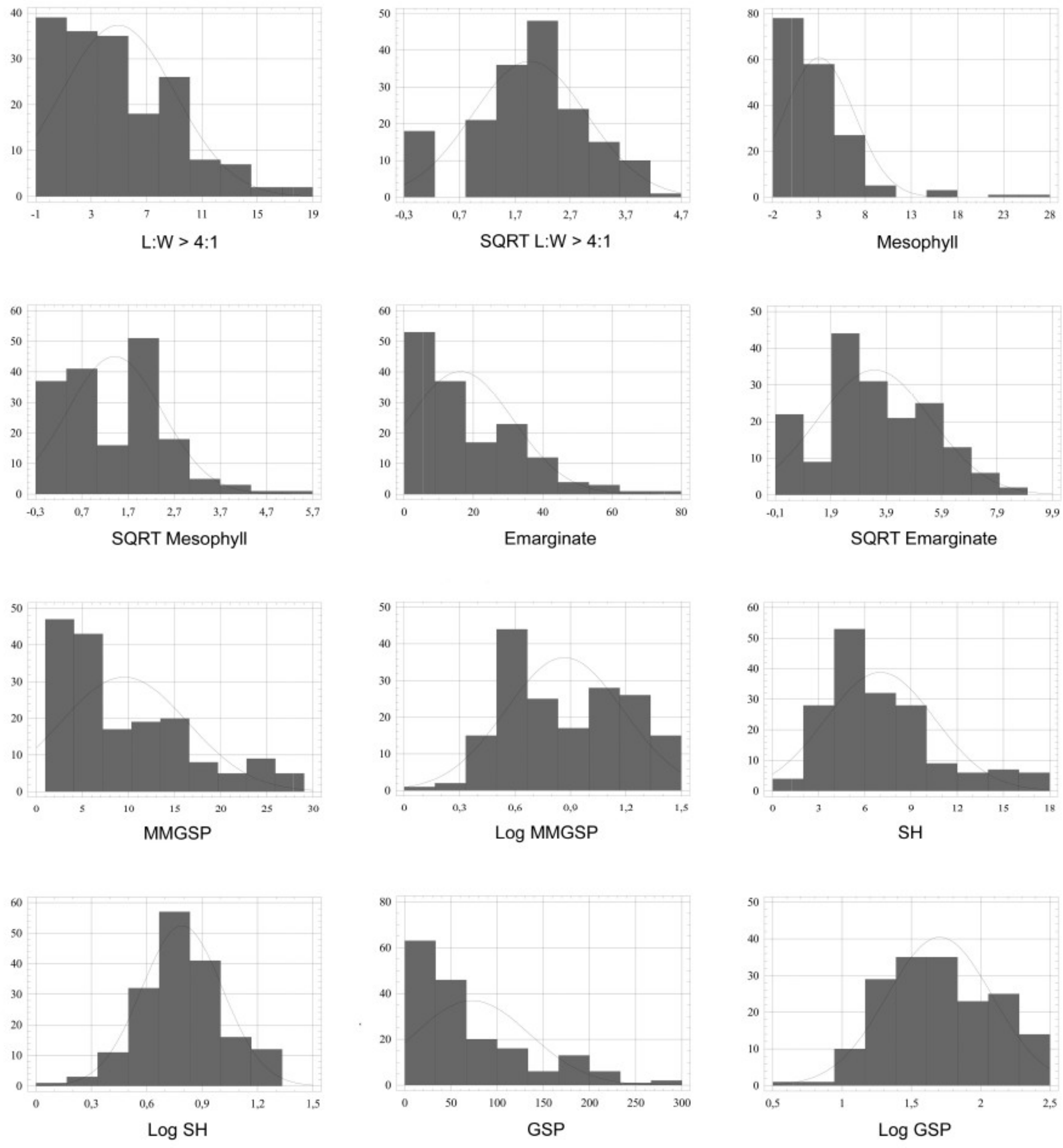

Fig. 1

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

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

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

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

Table 2

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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 Physiognomic Characters [%]		Studied Localities																
		Arjuzanx	Auenheim	Břešťany	Černíky	Enspel	Frechen 7o	Garzweiler 8o	Hambach 7f	Hambach 8u	Hambach 9A	Hammerunter-wiesenthal	Hlavačov Gravel and Sand	Holedeč	Kleinsaubernitz	Přívlaky	Schrotzburg	Wackerdorf
Margin Character States	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 Regular	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 Round	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 Compound	8	7	0	14	13	30	36	18	29	28	0	17	20	8	17	17	0

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Size Character States	Nanophyll	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leptophyll I	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Leptophyll II	5	2	4	1	2	0	0	0	0	0	11	0	2	0	2	2	0
	Microphyll I	11	7	13	9	8	0	15	7	12	17	19	3	8	3	11	15	8
	Microphyll II	40	23	17	26	49	33	41	34	41	46	46	18	24	48	22	46	36
	Microphyll III	33	43	18	40	27	36	36	40	31	39	14	44	38	43	27	23	40
	Mesophyll I	9	21	19	15	9	28	7	19	12	0	9	31	22	11	35	13	11
	Mesophyll II	0	4	17	5	4	4	0	0	4	0	0	4	5	0	2	0	5
	Mesophyll III	0	0	11	4	0	0	0	0	0	0	0	0	2	0	0	0	0
Apex Character States	Apex Emargnate	5	5	6	0	6	4	0	0	0	0	0	0	0	0	0	0	0
	Apex Round	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 Attenuate	22	11	17	11	34	38	36	21	29	36	33	10	11	40	7	32	5

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Base Character States	Base Cordate	8	26	10	17	20	37	27	22	16	21	54	20	17	13	12	6	0
	Base Round	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
Length to Width Character States	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
Shape Character States	Obovate	13	31	17	9	0	15	3	13	12	7	0	2	3	8	8	10	13
	Elliptic	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

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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

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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

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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	Přívlaky				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

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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
Guanica, 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

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o Rico																					
Cabo Rojo, Puerto Rico	25.87	24.61	27.32	27.61	24.01	20.10	12.00	12.20	161.53	75.54	13.46	5.09	54.86	38.56	21.16	11.39	75.48	74.29	15.34	12.37	35.83	34.66
Mocuzari A, Sonora	25.30	22.03	31.30	28.71	18.37	14.02	12.00	11.71	63.57	85.58	5.30	8.54	44.91	36.67	1.86	8.09	52.80	57.37	9.96	8.95	33.76	33.09
Mocuzari-B, Sonora	25.11	21.46	31.10	27.64	18.18	14.58	12.00	11.42	63.57	79.37	5.30	7.07	44.91	36.01	1.86	7.40	52.80	57.04	9.96	8.95	33.74	33.03
Natua, Fiji	24.72	24.25	26.48	26.15	22.76	20.79	12.00	12.20	249.86	201.65	20.82	17.87	98.75	86.79	33.33	29.20	75.98	81.43	14.37	15.50	35.35	35.84
Borinquen, Puerto Rico	25.37	24.18	26.83	26.16	23.61	21.18	12.00	11.88	180.31	76.40	15.03	4.38	61.26	41.93	24.47	12.69	75.37	77.10	15.46	13.10	35.83	34.91
Cambalache, Puerto Rico	24.92	24.24	26.46	27.27	22.79	19.56	12.00	12.49	201.07	174.79	16.76	15.50	72.32	70.99	25.37	20.98	94.69	76.47	16.35	13.53	36.11	35.07
Tres Hermanos, Sonora	24.72	21.22	30.54	27.29	17.83	14.57	12.00	11.12	58.92	76.45	4.91	6.95	42.14	37.74	1.63	9.09	53.72	64.41	10.19	9.61	33.78	33.26
Keka, Fiji	24.04	26.41	25.58	26.97	22.28	23.42	12.00	13.27	276.24	224.55	23.02	18.68	116.41	89.31	34.03	28.98	78.56	81.04	14.76	16.14	35.42	36.29
Guajatica, Puerto Rico	24.09	23.87	25.43	26.82	22.23	19.36	12.00	12.15	207.38	189.44	17.28	17.56	79.51	80.28	20.52	26.22	91.39	80.35	16.81	14.52	36.19	35.42
Susua Alta, Puerto Rico	24.66	24.72	26.06	27.60	22.83	20.28	12.00	12.25	194.23	80.75	16.19	5.56	70.16	40.44	22.94	12.08	83.41	74.85	16.02	12.57	35.96	34.75
Cabo San	24.17	23.96	29.31	30.96	19.06	13.99	12.00	12.38	40.81	33.13	3.40	3.49	28.64	15.39	0.53	2.39	73.87	47.14	13.14	7.52	34.83	32.73

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Lucas, Baja California Sur																						
Quiriego, Sonora	24.07	20.25	30.18	28.18	17.11	11.52	12.00	11.05	62.73	85.63	5.23	9.32	44.37	37.47	1.72	7.73	51.17	53.56	9.35	7.91	33.40	32.51
Seqaqa, Fiji	22.99	23.22	24.49	25.68	21.25	19.42	12.00	11.90	279.11	246.47	23.26	23.50	119.44	103.22	33.74	34.75	79.17	81.63	14.73	15.69	35.30	35.82
Nuri, Sonora	22.29	17.69	28.70	27.23	15.30	8.06	12.00	9.83	67.09	65.82	5.59	8.26	44.85	34.29	2.25	7.20	47.66	54.87	7.98	6.80	32.71	31.81
Santiago, Baja California Sur	23.94	22.13	29.25	28.59	18.29	14.55	12.00	11.47	44.52	48.88	3.71	4.31	33.30	25.69	0.29	5.50	62.30	58.68	9.64	8.75	33.49	33.02
Alamos, Sonora	23.74	20.40	29.81	27.30	16.88	12.91	12.00	10.81	66.31	96.01	5.53	10.09	46.35	45.74	1.99	12.16	53.09	67.78	10.00	9.77	33.61	33.24
Empalme, Sonora	24.47	22.03	31.09	30.59	17.40	11.15	12.00	11.82	34.73	36.94	2.89	4.49	23.63	15.99	0.91	1.45	50.73	35.05	9.82	5.89	33.62	31.91
Baie d'Magenta, New Caledonia	22.31	22.27	25.42	23.36	18.87	20.83	12.00	11.35	124.43	138.94	10.37	9.52	46.14	66.92	19.33	18.90	77.46	78.24	12.04	13.77	34.22	34.98
Avon Park, Florida	22.53	22.10	27.76	26.11	16.12	17.45	12.00	11.48	121.45	127.45	10.12	10.93	53.57	57.87	15.42	16.02	75.22	73.62	13.00	12.03	34.61	34.28
Orlando, Florida	22.30	19.87	27.92	24.28	15.41	15.70	12.00	10.55	121.85	115.94	10.15	9.70	53.05	56.72	16.97	14.52	74.39	71.67	12.76	11.09	34.49	33.70

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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 Bartolo, 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

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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
Anbo-west, 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 260 m, 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, Arizon	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 420 m, 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.	25.75	22.	4.69	7.8	8.39	8.3	87.65	139	10.45	15.	37.89	72.	23.52	20.	73.12	74.	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
Toga-take, 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 800 m, 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
Zozu-san, 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, Arizona	7	51	2	84		1		0	9	78		6	1	20		1	0	92		1	1	2
Canelo, Arizona	14.74	13.48	24.16	22.65	6.34	5.80	7.97	7.91	30.62	43.07	3.84	4.75	23.22	32.26	2.53	5.26	39.20	52.83	4.59	5.49	30.66	30.86
Lakeport, California	13.92	12.60	21.23	20.66	7.44	6.11	8.11	7.35	35.02	54.43	4.31	5.77	54.07	41.41	2.16	8.79	66.37	64.17	6.02	6.77	31.10	31.27
Santa Cruz, California	13.84	12.83	17.92	19.52	9.23	7.64	10.78	7.26	30.24	65.91	2.86	6.57	20.31	49.62	0.31	12.56	74.59	72.75	7.54	8.37	31.66	31.92
Placerville, California	14.47	9.97	24.35	17.09	6.05	4.42	7.79	6.15	31.70	56.67	4.06	5.88	46.05	47.96	1.92	10.52	61.13	68.13	5.84	6.69	31.09	30.96
Kiyosumi, Honshu	14.03	12.12	24.63	21.65	4.52	3.66	7.83	7.47	135.61	128.33	17.30	16.32	58.76	68.87	24.01	17.59	74.15	69.42	8.90	7.66	32.19	31.56
Nekko 1, Honshu	12.93	14.56	23.68	23.91	2.91	5.69	7.32	8.79	151.64	193.24	20.73	24.09	68.32	85.61	22.88	22.74	76.20	70.20	8.46	8.97	31.92	32.33
Nekko 2, Honshu	13.03	9.52	23.78	22.89	3.01	-3.29	7.37	6.22	152.20	105.08	20.68	18.05	68.30	63.52	22.87	18.34	76.22	71.43	8.46	5.98	31.92	30.62
S.I.E.R.C., Maryland	13.57	9.60	25.47	20.70	0.77	-0.41	7.37	5.94	68.93	78.17	9.36	12.32	30.24	57.35	24.40	16.82	66.93	74.84	7.42	6.84	31.60	30.98
Yakusugi 1080 m, Yakushima	10.43	10.55	19.24	21.34	1.61	0.64	6.25	6.91	172.43	154.30	27.61	21.27	104.21	79.93	26.06	21.16	81.79	70.69	8.86	7.31	31.80	31.26

ACCEPTED MANUSCRIPT

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
Sanno-dake, 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

ACCEPTED MANUSCRIPT

Sanze, Honshu	11.94	11.69	25.24	23.94	0.29	-0.13	6.64	6.89	96.87	108.48	14.60	17.94	52.87	65.73	29.03	21.74	75.59	77.56	7.06	7.93	31.29	31.62
Crown King, Arizona	11.20	12.19	22.54	19.52	1.71	6.49	6.16	7.12	21.05	56.63	3.42	5.66	16.44	44.14	3.70	9.67	41.59	66.74	4.61	7.15	30.30	31.38
Amagi-toge , Honshu	11.47	7.69	22.19	21.58	1.50	-5.60	6.70	5.27	142.85	83.89	21.36	15.94	68.88	59.57	22.90	17.72	76.37	73.11	8.44	5.37	31.75	30.18
Powers, Oregon	12.65	10.48	19.24	19.46	7.09	2.97	7.47	6.02	46.56	43.99	6.28	6.15	64.98	44.80	7.21	12.97	75.05	75.69	5.88	7.35	30.92	31.28
Troutdale, Oregon	12.03	9.15	20.54	19.53	4.29	0.10	6.80	5.59	55.11	50.58	8.07	8.06	78.15	47.65	13.21	13.54	75.71	74.24	5.73	6.46	30.80	30.78
Yakusugi 1350, Yakushima	9.06	9.20	17.86	20.64	0.30	-1.30	5.50	6.24	158.32	126.86	28.79	18.54	104.12	72.13	26.06	18.83	81.73	69.67	8.85	6.39	31.65	30.75
Kidogawa 2, Honshu	11.40	9.51	23.51	22.28	0.66	-2.51	6.58	6.08	100.00	91.85	15.23	15.69	51.81	60.16	14.06	17.67	75.87	72.94	7.12	6.23	31.26	30.72
Kannami 2, Honshu	10.62	7.61	22.76	20.86	-0.98	-4.84	6.30	5.43	118.88	89.79	18.83	15.63	73.54	59.95	15.96	15.87	72.81	68.38	8.06	4.92	31.53	29.99
Port Orford, Oregon	12.06	10.75	17.01	19.64	7.81	3.26	7.30	6.41	50.70	68.04	6.91	8.78	71.25	52.26	7.02	13.94	78.99	73.02	6.48	7.31	31.08	31.28
Frederick, Maryland	12.47	9.93	24.37	20.41	-0.54	0.65	6.98	5.96	64.47	68.23	9.23	10.53	29.72	54.26	22.06	16.26	70.37	75.98	7.09	7.18	31.36	31.15
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

ACCEPTED MANUSCRIPT

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, Honsh	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.	19.1	20.	1.23	5.4	5.16	6.7	13.9	34.	2.73	3.9	65.9	36.	3.90	9.2	56.3	71.	3.97	7.1	29.8	31.3

ACCEPTED MANUSCRIPT

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

ACCEPTED MANUSCRIPT

m Bay, Washington		8	6	19		6		7	0	44	1	1	55	46	9	08	3	58		0	1	4
Parkdale, Oregon	10.87	7.46	20.90	19.29	2.16	-3.10	6.03	4.67	27.39	21.29	4.53	5.36	47.90	36.88	8.96	10.88	73.65	74.00	4.63	5.14	30.28	30.07
Trout Lake, Washington	9.09	8.31	18.69	19.04	0.54	-1.09	5.26	5.04	25.52	33.22	4.81	6.27	73.40	42.46	9.74	12.77	73.24	75.82	4.67	6.17	30.11	30.57
Sierraville, California	9.39	8.27	20.11	18.24	0.88	-0.05	5.37	5.26	12.15	19.90	2.26	3.36	39.37	32.86	4.17	6.97	52.58	65.25	3.36	4.64	29.66	29.97
Toya-ko, Hokkaido	7.06	8.58	20.61	23.52	-5.59	-6.14	5.10	5.29	64.12	62.44	12.58	14.60	44.17	52.63	23.13	19.05	80.17	78.16	5.39	6.02	30.18	30.54
Flagstaff AP, Arizona	8.89	8.94	20.45	20.06	-1.16	-0.49	5.32	5.75	21.55	17.25	4.11	3.26	17.43	27.70	5.77	4.57	43.35	55.62	3.36	3.54	29.61	29.60
Ketchikan, Alaska	7.37	8.98	14.74	22.29	0.51	-3.18	4.37	5.69	59.01	22.73	13.51	5.83	77.22	30.32	31.23	7.04	81.47	61.91	5.08	3.67	30.08	29.66
Satus Pass 2 SSW, Washington	7.19	7.72	17.77	18.70	-2.77	-1.90	4.57	4.76	5.07	23.33	1.12	5.07	16.58	38.20	2.97	11.14	65.36	74.59	4.76	5.56	29.95	30.27
Red Fleet, Utah	7.87	9.88	22.29	19.83	-7.18	1.71	5.46	6.43	12.48	34.05	2.28	4.24	7.14	32.01	4.92	4.26	56.47	47.89	3.25	3.73	29.47	29.78
Mt. Pocono, Pennsylvania	7.75	4.62	20.24	18.87	-5.63	-8.94	5.33	3.83	53.40	36.56	10.02	9.33	31.29	43.34	21.61	11.37	71.29	68.09	5.73	3.05	30.37	28.92
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

ACCEPTED MANUSCRIPT

man Resvr., Colorado		5	3	42	7	6		0	3	4		8	4	85		1	1	70		3	4	7
River Falls, Wisconsin	6.76	6.23	22.17	19.90	-11.33	-6.69	5.54	4.41	49.56	50.87	8.95	11.20	28.99	49.82	6.78	14.96	71.26	73.89	5.24	4.72	30.09	29.76
Namarikawa, Hokkaido	7.12	9.77	20.43	23.15	-4.74	-3.13	4.98	5.80	63.33	75.84	12.71	14.98	44.61	57.88	22.36	20.73	78.75	79.20	5.69	7.19	30.29	31.13
Laurel Mtn., Oregon	5.43	6.78	12.49	18.16	-0.53	-3.25	2.96	4.65	9.85	26.09	3.36	5.34	69.23	37.25	9.63	8.75	82.08	67.04	6.30	4.15	30.33	29.60
Rimrock Lake, Washington	8.11	6.59	18.08	18.54	-0.84	-4.12	4.89	4.29	17.40	15.82	3.59	4.70	52.67	35.12	8.53	10.04	71.60	73.17	4.10	4.62	29.80	29.77
Chuzenji-ko, Honshu	6.42	7.79	19.00	23.53	-5.13	-7.91	4.66	4.92	103.80	59.47	22.32	15.14	73.99	52.68	13.61	19.71	76.40	78.75	6.26	5.70	30.43	30.33
Greer, Arizona	6.87	6.59	17.45	16.42	-2.43	-1.79	4.45	4.84	20.41	34.94	4.60	5.10	18.61	39.29	3.48	6.98	44.09	58.49	3.45	3.66	29.43	29.39
Dannemora, New York	4.74	5.05	18.54	19.85	-10.43	-9.09	4.60	3.68	43.81	18.47	9.51	7.35	30.00	36.98	17.31	11.62	76.82	73.63	4.97	3.55	29.78	29.17
Akagawa Spa, Honshu	6.14	9.92	19.81	22.91	-6.43	-2.52	4.69	6.02	77.32	89.35	16.47	16.22	56.48	61.73	24.52	20.75	77.88	77.92	5.92	7.16	30.28	31.13
Tierra Amarilla, New Mexic	6.45	7.39	18.63	17.86	-5.77	-1.40	4.74	5.23	21.92	22.07	4.62	3.48	17.19	30.85	7.97	4.27	46.79	51.17	2.78	2.91	29.15	29.18

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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

ACCEPTED MANUSCRIPT

Park, Colorado		0	1	40	8	8		6	9	16		2	9	76		5	3	38		1	9	5
Tadenoumi, Honshu	4.35	5.55	16.97	22.25	-7.24	-11.21	3.80	3.94	95.25	46.20	25.07	13.99	79.58	49.47	15.13	18.11	78.22	77.84	5.91	4.43	30.09	29.57
Soda Springs, California	6.42	7.26	16.59	17.34	-1.36	-1.20	4.03	4.82	7.62	10.52	1.89	2.23	49.16	29.08	4.40	5.42	51.94	62.36	3.27	3.81	29.32	29.52
Lake Placid, New York	4.33	5.22	17.74	20.97	-10.43	-10.08	4.45	3.88	43.40	26.09	9.76	9.20	30.49	38.84	18.32	12.07	75.91	72.06	4.69	3.23	29.64	29.06
Seward, Alaska	3.16	7.38	13.66	19.96	-6.22	-4.02	3.16	4.81	22.85	27.33	7.29	6.53	26.40	37.75	13.50	10.42	82.12	70.81	3.31	4.54	29.01	29.82
Nederland, Colorado	3.77	5.47	15.62	17.34	-6.88	-5.12	3.52	4.05	16.58	11.96	4.71	3.74	15.12	31.55	6.40	6.74	38.93	64.25	2.42	3.04	28.74	29.02
Suganuma, Honshu	3.78	3.98	16.38	21.61	-7.81	-13.86	3.58	3.27	92.81	28.81	25.93	11.82	81.63	42.32	15.56	14.96	78.76	75.50	5.78	2.98	29.98	28.81
Red River, New Mexico	5.20	5.45	17.21	15.77	-7.05	-3.52	4.26	4.21	18.38	17.93	4.31	3.43	14.78	33.50	4.90	5.77	46.01	59.04	2.97	2.95	29.09	28.98
Nukabira, Hokkaido	3.53	6.72	17.29	22.61	-10.57	-9.02	3.97	4.33	49.47	43.25	12.46	12.80	39.49	47.99	15.36	18.28	80.74	79.01	4.61	5.24	29.53	30.02
Wolf Creek, Colorado	0.34	6.55	12.35	17.20	-11.79	-2.76	2.13	4.91	14.52	47.55	6.55	7.27	19.53	44.07	9.00	8.47	38.40	59.06	1.42	3.70	28.03	29.39
Tahosa	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, Colorado		8	6	38	3	4		2	3	79		9	2	91		4	4	36		8	6	1
Homer, Alaska	3.61	8.24	12.73	21.44	-4.62	-3.77	2.95	5.40	16.93	26.45	5.73	6.32	24.88	32.98	11.85	7.62	80.15	62.36	3.84	3.60	29.25	29.55
Alyeska, Alaska	3.26	8.04	15.48	20.55	-8.14	-3.27	3.82	5.20	23.64	35.20	6.16	7.40	20.88	39.43	8.92	10.47	82.89	69.06	3.45	4.64	29.07	29.93
Grand Lake, Colorado	3.22	6.37	15.37	16.96	-7.89	-2.78	3.41	4.72	14.79	28.64	4.33	4.77	13.36	36.34	7.68	6.36	40.51	57.51	1.91	3.22	28.50	29.19
Lake Granby, Colorado	3.55	10.01	15.74	20.68	-7.69	1.11	3.56	6.46	15.45	25.09	4.33	3.53	13.43	27.51	8.08	3.22	39.86	45.30	1.87	3.24	28.52	29.60
Dillon, Colorado	1.62	7.30	13.50	17.74	-9.51	-1.47	2.65	4.98	12.72	11.87	4.77	2.38	14.38	27.98	8.85	4.38	33.17	56.74	1.49	3.21	28.18	29.29
Kenai, Alaska	2.55	6.53	13.57	20.01	-7.70	-5.81	3.09	4.65	16.39	22.74	5.31	6.15	22.29	33.64	9.14	7.69	78.16	62.78	3.76	3.00	29.11	29.12
Talkeetna, Alaska	0.58	8.90	14.67	21.33	-12.38	-2.28	3.11	5.65	23.25	32.87	7.48	6.72	25.30	36.00	8.22	8.77	78.26	65.17	3.43	4.40	28.79	29.93
Eklutna Lake, Alaska	1.90	8.37	14.61	19.70	-9.53	-1.49	3.29	5.47	20.53	31.42	6.24	5.62	19.81	36.06	7.15	7.81	84.91	62.97	3.04	4.27	28.78	29.82
Sheep Mtn., Alaska	-0.64	9.51	13.59	21.19	-13.97	-0.70	2.68	5.91	19.26	24.33	7.16	4.80	21.49	31.27	8.57	6.78	89.23	62.13	2.71	4.31	28.40	29.97

Table 6

ACCEPTED MANUSCRIPT

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	-1.05	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	-0.01	-3.37	-5.94	-0.05	-0.01
Břešťany	-0.18	0.97	2.71	0.04	0.01	0.00	-0.02	-6.40	1.11	-0.04	0.00
Čermníky	2.06	2.90	-1.72	0.00	-0.01	-0.05	-0.15	-0.95	-4.55	0.00	-0.01
Enspel	-1.12	0.09	-1.08	0.01	0.01	0.04	0.14	3.28	10.33	0.00	-0.01
Frechen 7o	-1.28	-0.98	-2.86	0.08	0.05	0.08	-0.10	-3.56	-0.55	-0.11	-0.01
Garzweiler 8o	0.86	-0.15	-3.33	0.09	0.13	0.11	-0.06	0.61	-0.40	0.01	-0.01
Hambach 7f	1.56	2.88	-4.46	0.05	0.07	0.03	-0.22	0.73	-7.59	-0.03	-0.01
Hambach 8u	1.83	2.52	-4.45	0.05	0.08	0.02	-0.21	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	-1.49	-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	-0.16	-0.92	-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

ACCEPTED MANUSCRIPT

							3				
Kleinsaubernitz	-2.32	-0.39	-0.62	0.02	-0.06	-0.03	0.14	2.99	14.88	-0.02	-0.01
Přívlaky	1.94	2.03	-1.58	0.01	0.04	0.00	-0.11	2.37	-3.76	0.01	-0.01
Schrotzburg	1.80	3.37	-2.81	-0.01	0.00	-0.03	-0.03	3.82	3.37	0.04	0.00
Wackerdorf	-2.90	0.76	-0.64	0.08	-0.08	-0.10	0.11	5.70	18.41	-0.05	0.00

Table 7

ACCEPTED MANUSCRIPT

Studied localities	Dataset selection: CLAMP data A or CLAMP data B	Climate characters										
		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	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

ACCEPTED MANUSCRIPT

Přívlaky	A	10.10	21.44	-3.89	5.26	67.54	8.27	51.74	17.22	73.70	3.29	28.95
Schrotzburg	B	13.63	26.83	-0.69	6.80	66.74	15.81	53.27	22.91	74.87	9.54	33.08
Wackerdorf	B	17.44	26.65	13.20	10.76	125.69	19.92	71.98	33.59	97.87	9.42	33.06

Table 8