ForestGrid - A Powerful Tool for Integrating, Displaying, Querying and Analyzing Theme Maps

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ABASTRACT

Species distribution maps, habitat maps and human-induced effect maps are important bases of natural resource management and conservation. For decision-making easily, we developed an ecological habitat suitability program in doing data processing and analysis on grid map layers with Visual C++ and Net. In the paper, the distribution of some tree species and habitat factors in Taiwan with 22,501,993 40m*40m grids were used to demonstrate the function of the program. A user-friendly software –ForestGrid - was developed to aid the researchers in habitat suitability analysis and forest management. The contributions of the developed software include (1) the integrating, displaying and querying for the theme maps; (2) calculating the ecological amplitudes for different species; (3) investigating the relationship of the different theme maps via scatter diagrams; and (4) evaluating the importance (weighting) of habitat suitability indices by using the neural network. Forest-Grid was used to do habitat studies of comparing among different spatial scale and temporal scale. Different classification levels and the relationship of different habitat factors could be checked by Forest-Grid, also. To do analyzing the results of ecological assessment in ecological site quality (ESQ) and habitat suitability index (HSI) by Forest-Grid. The spatial variation of different scenarios in climate change could be checked easily by the Forest-Grid.

【Keywords】 grid、species distribution、habitat factor、ecological amplitude、habitat suitability index, (HSI)、scatter plot、neural network

INTRODUCTION

In the last years it was observed in the literature a growing number of works concerned with forest management and natural resource conservation in spatial informatics. But there is little software designed for spatial data processing and analysis. In this paper, an user-friendly software was developed to aid the researchers in the study of habitat suitability analysis and forest management. The contributions of the developed software include (1) the integrating, displaying and querying for the theme maps; (2) calculating the ecological amplitudes for different species; (3) investigating the relationship of the different theme maps via scatter diagrams; and (4) evaluating the importance (weighting) of habitat suitability indices by using the neural network.

MATERIALS AND METHODS

For observing and comparing the different theme map easily, ForestGrid can display and query the multiple theme maps simultaneously, it is useful to verify and compare the value in each grid point. For better visualization, we transfer the gray-scale intensity map to the pseudocolor image. The R, G, and B component images have the horizontal intensity profiles shown in Fig. 1.

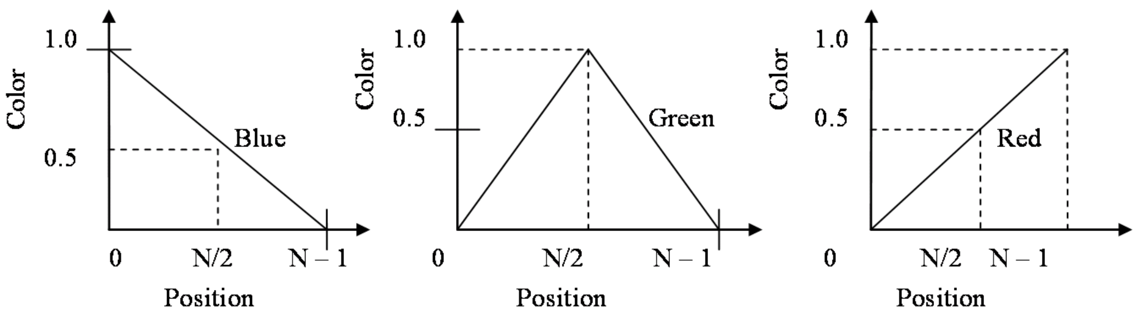

Figure 1 The horizontal intensity profiles of the R, G, and B components for the pseudcolor images.

The result of the average temperature, soil moisture and elevation of 40mx40m grid theme maps in Taiwan is shown in Fig. 2. Values toward the blues signify low values of the grid dataset, with the opposite being true for red. Obviously, the results are much easier to interpret.

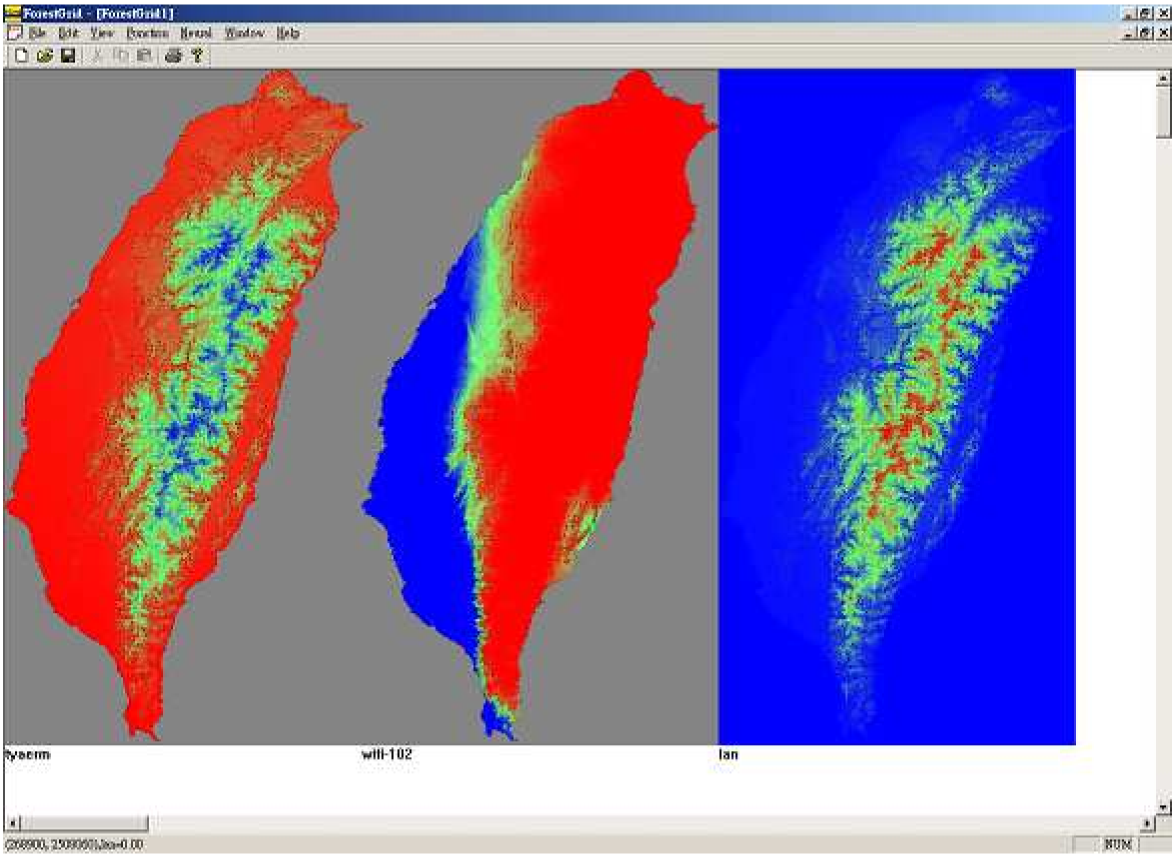

Figure 2 The representation of three theme maps, the average temperature, soil moisture and elevation in Taiwan.

For investigating the possible relationship between two variables that both relate to the same event, the developed software use the scatter plot to analyze it. Scatter plot is a useful and powerful tool for investigating the possible relationship between two variables that both relate to the same event. For example, if we want to study the correlation between the elevation and the temperature, we can plot its scatter diagram, the results is shown in Fig. 3. Here, for understanding the relationship between the variables in the scatter plot and geographical location in detail, we assign the color to the points in the scatter plot by using the same color component profiles in Fig.1. Points with the color toward blues signify they are from the south area of Taiwan, with the opposite being true for red. From Fig. 3, it is obvious to know the temperature is an inverse proportion to elevation. And we also find the slopes for the south, center and north Taiwan are different slightly.

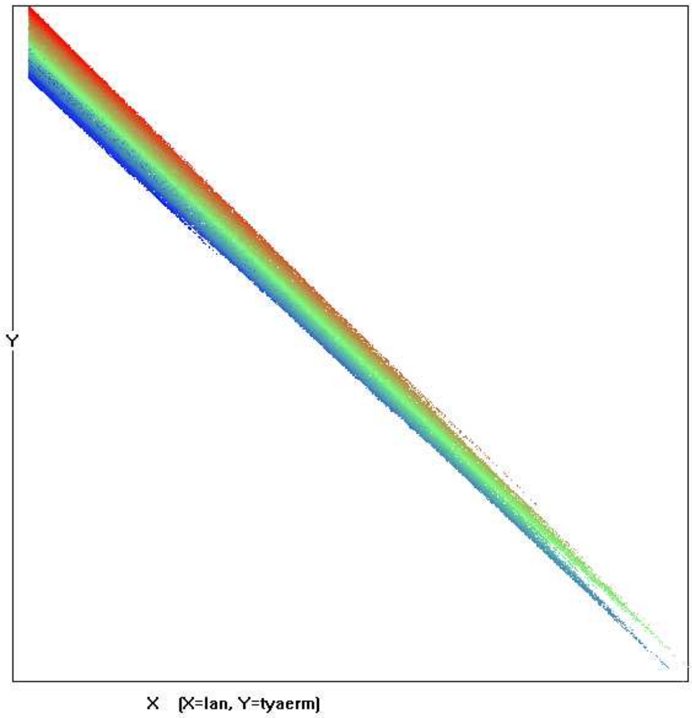

Figure 3 The scatter plot for elevation and the temperature.

Feng and Wu (2003) developed the ecological site quality (*ESQi*) of forest with environmental factors (climate and soil factors) in spatial modeling to evaluate the planting trees in the right places? Those environmental factors are light *fi* (AL), temperature responded function *fi* (TF) of climate, dry tolerance *fi* (WiF), wet *fi* (WeF) and N contents *fi* (NF) responded function of soil in the paper. Spatial interpolation method and spatial analysis were used to estimate the climate and environment factors of Taiwan in 40m x 40m grids (Kao and Feng 2001). These factors of relative light radiation, temperature, precipitation, ground water level, potential evapotranspiration and available N contents in soil were normalized in the scale of 0~1, except the shade intolerance tree species . The model $Qi = fi(AL) \times fi(TF) \times fi(WiF) \times fi(WeF) \times fi(NF)$, were used to evaluate site quality of forest (Feng and Wu, 2003) . Fig. 4 is the scatter plot for the degree day "degd" of temperature responded function *fi* (TF) of climate in Taiwan and the ecological site quality of *Cinnamomun camphora* (*ESQ*301), we obtain an interesting Gaussian shape pattern.

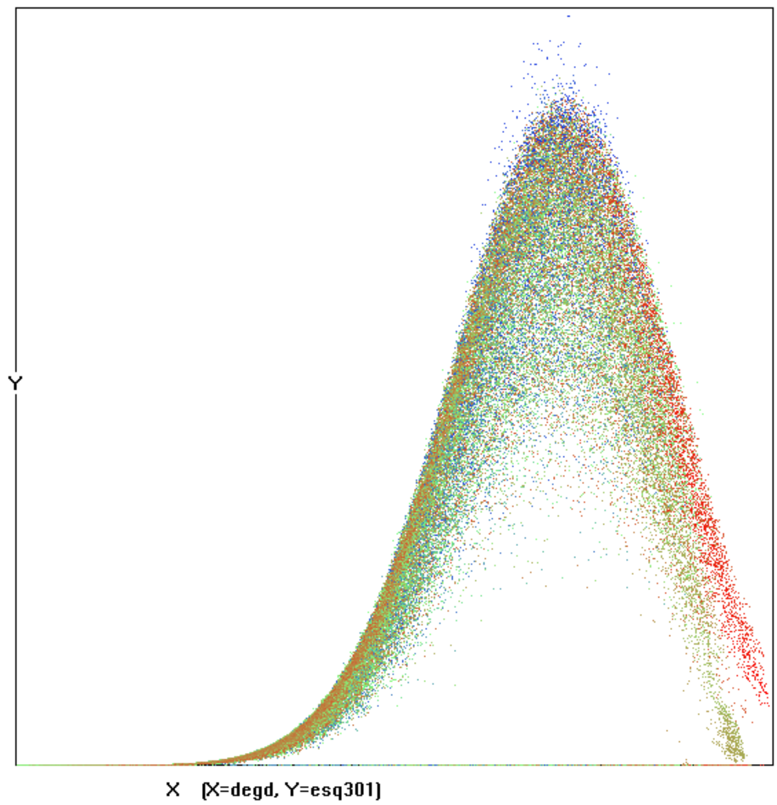

Figure 4 The scatter plot for the “degd”of temperature responded function *fi* (TF) of climate in Taiwan and the ecological site quality of *Cinnamomun camphora* (*ESQ*301).

A histogram is a specialized type of bar chart. Individual data points are grouped together in classes, so that we can get an idea of how frequently data in each class occur in the data set. The strength of a histogram is that it provides an easy-to-read picture of the location and variation in a data set. For easy-to-read the ecological amplitudes, the developed software is able to plot the histogram distribution for each habitats for a species.

Artificial Intelligence (AI) can be defined as the study of mental capabilities through the use of computational models. There are a growing number of applications that employ AI technologies such as Expert system (ES) and Artificial Neural Network (ANN) to solve the problems in specialized domains of the forest management. ANN is a non-linear computational system that models network of neurons in the brain to perform problem-solving tasks. In many applications, the performance of ANN was shown to be superior to classical linear approaches, and has been widely used as a pattern and statistical classifiers or estimators in many fields. Advantage about this approach is providing good results when dealing with problems where there are complex relationships between inputs and outputs, and where the input data maybe is distorted by high noise levels.

In this paper, the methodology used for the evaluating the importance of the habitat suitability indices is the back-propagation network ( ). Its architecture is shown in Fig. 5. We apply Artificial Neural Network (ANN) to derive the generalized associations between habitats and the species. ANN imitates the structure of biological nervous system. It consists of a set of nodes. Input nodes to receive the input signals, output nodes to give the output signals and unlimited number of intermediate layers contain the intermediate nodes. There are various different architectures for ANN and they each utilize different learning algorithms to perform tasks. Back-Propagation Network (BPN) architecture consists of a three-layered network with input unit, intermediate unit and output unit. Back-Propagation Algorithm is a gradient descent method of optimization executed iteratively, with implicit bounds on the distance moved in the search direction in weight space. This is achieved by incorporating a learning rate and the momentum term in the model. The structure of BPN is simple but it can be used to perform many classification or prediction tasks. And BPN are the most studied and arguably the most successful ANN in many fields [1, 2]. In this paper, we use BPN for calculating the weighting of different habitats to the ESQ and estimating the hot area for each tree.

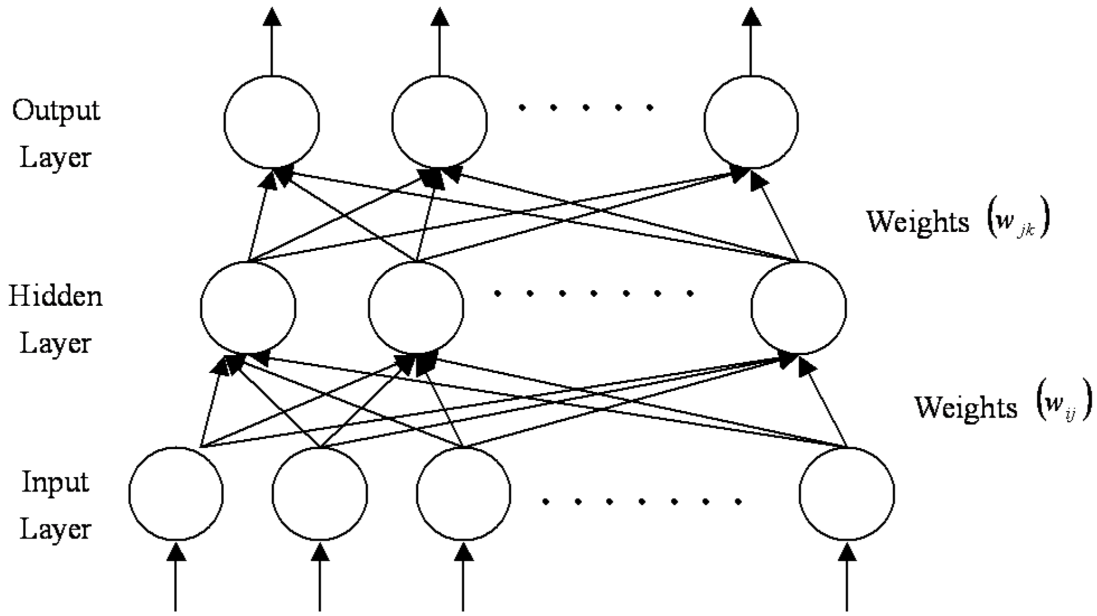

Figure 5 The architecture of an ANN.

When the ANN trained, we are able to calculate the importance (weight) of each input features by

$$W_i = \sum_{j=0}^{J-1}\left(W_{ij}\cdot\sum_{k=0}^{K-1}W_{jk}\right) \quad i = 0,1,2,\cdots,I-1 \qquad (1)$$

where W_{ij} is the weight from input and hidden layer, W_{jk} is the weight from hidden and input layer..

RESULTS AND DISCUSSION

For investigating the relationship of the rainfall of each month to the average yearly rainfall of the winter and summer (Feng, 2003), we plot their scatter diagram as shown in Fig. 6.

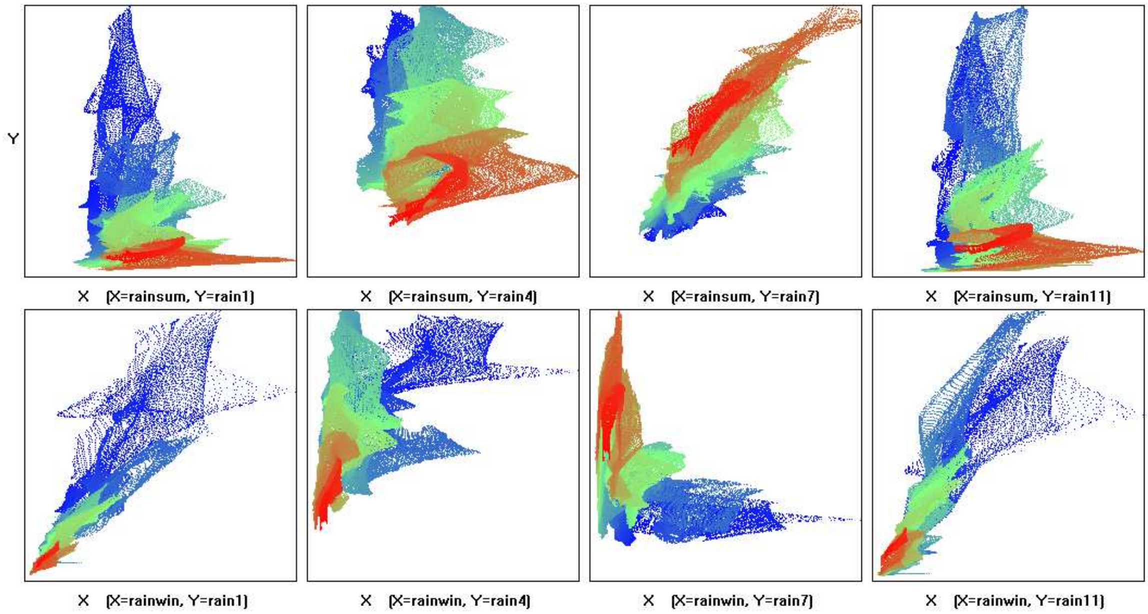

Figure 6. The spatial relationship diagrams of summer /winter rainfall with different month rainfall in Taiwan

It showed the ecological amplitudes (temperature, rainfall and elevation) for the *Chamaecyparis formosensis*.in Fig.7. The green curve is the estimated Gaussian probability density function for each distribution. From the result, we can say the area suited for the living of *Chamaecyparis formosensis* (or the ecological Amplitude) is where the elevation is 2226m and the average temperature is 10.35 degree.

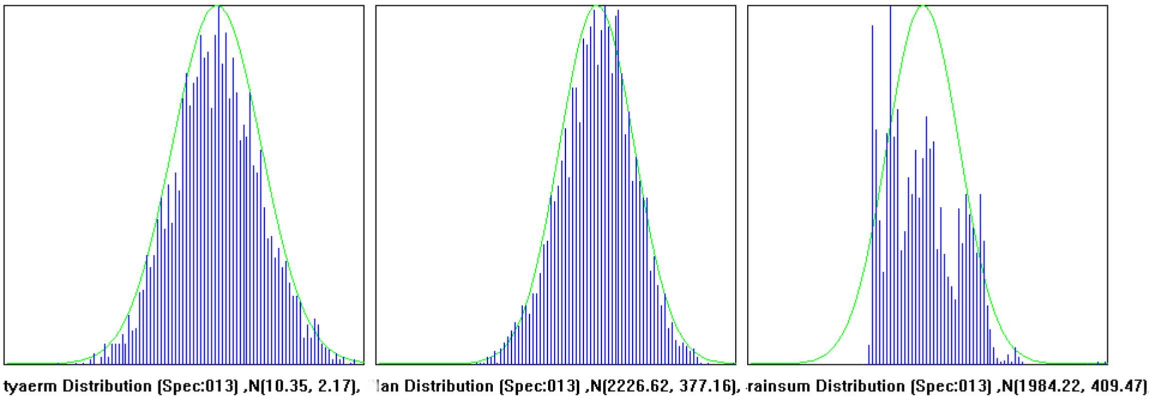

Figure 7. The histogram distribution of the habitat variables temperature, rainfall and elevation for *Chamaecyparis formosensis*.

In this paper, we use the neural network to evaluate the importance (weighting) of habitat suitability indices. The inputs of BPN are the habitat suitability indices for *Chamaecyparis formosensis*, and the output is its ESQ. The number of nodes in the hidden layer is simply the arithmetic average of the numbers of nodes in the input and output layers. The learning curve for the ESQ estimation of *Chamaecyparis formosensis* with the learning rate $\eta = 0.5$, moment $\alpha = 0.8$ is shown in Fig. 8. The number of training samples is 5266 and the number of iterations is 3000. The weight calculated by ANN for temperature, elevation, summer rainfall, winter rainfall are 970, 684, -167 and -410 respectively.

CONCLUSTIONS

In this paper, a user-friendly software was developed to aid the researchers in the study of habitat suitability analysis and forest management. The contributions of the developed software include (1) the integrating, displaying and querying for the theme maps; (2) calculating the ecological amplitudes for different species; (3) investigating the relationship of the different theme maps via scatter diagrams; and (4) evaluating the importance (weighting) of habitat suitability indices by using the neural network.

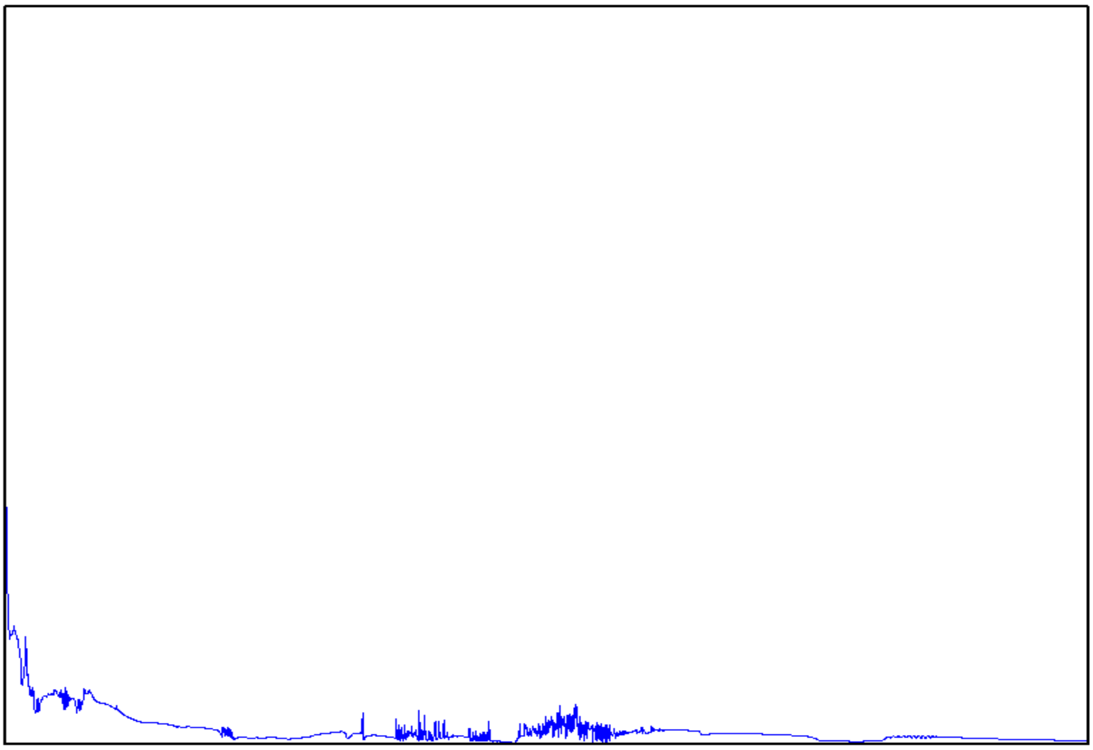

Figure 8 The learning curve for the ESQ estimation of Chamaecyparis formosensis.

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