Application of the grey system theory in deciding climatic regions suitable to introduce *Panax quinquefolium*

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Abstract. Climatic ecoconditions were analysed of *Panax quinquefolium* (P.q.) growing indigenously and as introductions. Four climatic indices, namely annual precipitation, annual mean relative humidity, and mean monthly temperature in July and January, respectively were selected as the judge index for introducing P.q. Through applying the methods of grey gather and grey relative analysis in grey system theory, the four climatic indices of 43 counties for typical classification in the Qinba Mountain Regions (QMR), and climatic similarity was calculated of about 43 counties with that of the state of Wisconsin, USA. According to the results and conditions of topography, geomorphology, vegetation, soil etc. in the QMR, a map was drawn of climatic regions suitable for introducing P.q., and the climatic features of each region are discussed.

Key words: Grey system theory – Introducing *Panax quinquefolium*

Introduction

*Panax quinquefolium* (P.q.) is a medicinal plant, indigenous to the broadleaf forest belt of North America, 30°–48° N, 67°–95° W. P.q. has been widely distributed in the 22 states of northeastern and southeastern USA. The state of Wisconsin, where the quality of P.q. is the best in America with a P.q. production of 90% is the major centre of commercial planting.

The wild P.q. grows in broadleaf hybrid forest regions with liana and herbs, in moist brown forest soil which is rich in humus and of pH values between 5.5 and 6.5. The state of Wisconsin is situated southwest of the Five Lakes in North America; because of the effect of the Lakes on climatic regulation, there are clearer maritime features – warm in winter and pleasantly cool in summer, higher humidity, with plenty of rain fairly well distributed over the four seasons.

P.q. was introduced into China in 1975 in large quantities, but first met with success in 1980. The planting area in fields developed to 40 ha in 1986. P.q. had been also introduced into Shaanxi Province from 1975 and was especially successful in the Qinba Mountain Regions (QMR) in 1980.

According to investigations of P.q. growth in the QMR, similar ecoconditions of vegetation and soil occur between the regions where P.q. is introduced and the area to which P.q. is indigenous. Analysing data of P.q. introduced at the test stations from 1978 to 1986 in the QMR and climatic ecoconditions of the area of indigenous growth. Four climatic indices were found to be the most suitable determinants of climatic ecoconditions: annual precipitation between 900 mm and 1000 mm, annual mean relative humidity between 65% and 75%, mean monthly temperature between 20° and 22° C in July and between –1° and 1° C in January.

Grey system theory and methods

The grey system theory was proposed in 1982 by a well-known Chinese scientist, Professor Deng Jiulong (Deng Jiulong, 1982). The grey system theory includes about eight components: the mathematical problems of grey systems, relative analysis of grey factors, model of grey systems, pre-estimate of grey systems, policy decision and plan of grey systems, system analysis of grey systems, control of grey systems, and processing of grey systems.

The system that includes not only known information but also unknown information is called the grey system. Therefore the system that includes only known information or only unknown information is called the white system or black system respectively. Since 1982, the grey system theory, as a new theory and method, has been widely applied in the fields of sociology, economy, science and technology in China. At the same time, some scientists from other countries, namely Professor Brockett and Y.C. Ho (Harvard University, USA), Professor...
T.J. Tarn (University of Washington, USA), Professor Wegner (Professor of Mathematics, Germany), have also contributed to the grey system theory.

The investigation for deciding climatic regions suitable to introduce P.q. can be considered as a problem of grey systems. Because this research includes not only known information – the growth capacity of P.q., observational data of effects of climatic factors in every growth period, etc., but also unknown information – how the climatic ecoconditions influence P.q. growth, the mechanisms that are affected, how P.q. is adapted to the climatic ecoconditions, etc. This research is thus particularly suitable for application of the grey system theory.

There are many methods in the grey system theory, two of which are the methods of grey gather and grey relative analysis.

**Method of grey gather**

The method of grey gather can be used to judge a gather factor by selecting a classification according to a gather factor suitable for the gather index. Some effect functions in this method need to be defined. The effect function quantitatively describes the possibility of a gather factor for selecting a typical classification; every effect function always corresponds to a typical classification. The basic kinds of effect function are the kind of left boundary, the kind of centre, and the kind of right boundary respectively.

**Defining effect function**

**Definition.** \( i = 1, 2, 3, \ldots, L \) is the gather index
\( j = 1, 2, 3, \ldots, M \) is the gather factor
\( k = 1, 2, 3, \ldots, N \) is a typical classification.

The gather index is selected as the judge index from gather factors by methods of experience or statistical analysis. The gather factor is really meteorological elements or other data. The typical classification given depends on the needs and aims of man.

**Definition.** When a gather factor \( X_{ij} \) is bigger than a threshold of gather index \( g_{i1}(2) \), the effect function \( Y_{i1}(X_{ij}) \) is the kind of left boundary and can be expressed as:

\[
Y_{i1}(X_{ij}) = \begin{cases} 
X_{ij}/g_{i1}(2) & \text{if } X_{ij} \in [0, g_{i1}(2)] \\
Y_{i1}(s) & \text{if } X_{ij} \in [g_{i1}(2), +\infty)
\end{cases}
\]

where \( Y_{i1}(s) \) is the maximum value of effect function when \( X_{ij} \) equates to \( s \).

**Definition.** When a gather factor \( X_{ij} \) is between two thresholds of gather indices \( g_{i2}(1) \) and \( g_{i2}(3) \), the effect function \( Y_{i2}(X_{ij}) \) is the kind of centre and can be expressed as:

\[
Y_{i2}(X_{ij}) = \begin{cases} 
X_{ij} - g_{i2}(1) & \text{if } X_{ij} \in [g_{i2}(1), g_{i2}(2)] \\
Y_{i2}(s) & \text{if } X_{ij} \in [g_{i2}(2), g_{i2}(3)]
\end{cases}
\]

where \( g_{i2}(2) \) is a mean threshold of gather index, i.e. \( g_{i2}(2) = (g_{i2}(1) + g_{i2}(3))/2 \).

**Definition.** When a gather factor \( X_{ij} \) is smaller than a threshold of gather index \( g_{i3}(2) \), the effect function \( Y_{i3}(X_{ij}) \) is the kind of right boundary and can be expressed as:

\[
Y_{i3}(X_{ij}) = \begin{cases} 
Y_{i3}(s) & \text{if } X_{ij} \in (-\infty, g_{i3}(2)] \\
Y_{i3}(s) - X_{ij} & \text{if } X_{ij} \in [g_{i3}(2), g_{i3}(3)]
\end{cases}
\]

where \( g_{i3}(3) \) is a threshold of gather index in relation to \( g_{i3}(2) \). Generally, the relationship is expressed by:

\[
g_{i3}(3) = ag_{i3}(2) + b
\]

where
\[
a=2, \quad b=0 \quad \text{when } g_{i3}(2)>0
\]
\[
a=0, \quad b=1 \quad \text{when } g_{i3}(2)=0
\]
\[
a=0.5, \quad b=0 \quad \text{when } g_{i3}(2)<0.
\]

Three effect functions are shown in Fig. 1.