Short Communication

Quantitative risk analysis and prediction of potential distribution areas of common lantana (*Lantana Camara*) in China

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Abstract
The ornamental hybrid shrub, *Lantana camara* L. (lantana), is a serious environmental weed and has been targeted for the biologist. This paper used such approaches as Analytic Hierarchy Process (AHP), fuzzy decision, etc., to analyze and predict potential distribution areas of common lantana in 147 sites of China. Based on ecological properties of common lantana, we chose 5 climate ecological factors, i.e., mean annual temperature, mean temperature from March to May in a year, elevation, days with temperature greater than 25℃ and annual precipitation. The results showed that common lantana will continue to spread forward north China (Hunan, Hubei, etc.).

Keywords *Lantana camara*; AHP; suitability analysis; distribution.

1 Introduction

Biological invasion, defined as the entry, establishment and spread of non-indigenous species (NIS) into a new region (Vitousek, 1990). Invasive species alter the biogeochemical cycles and act as competitors, predators, parasites or pathogens of the native species placing their survival at risk (Diamond and Case, 1986; Vitousek, 1990; Usher, 1991). At the international level, there is a growing agreement that invasion by exotic species is one of the greatest threats to biodiversity conservation (Coblentz, 1990; Wilcove et al., 1998). In many areas, it causes enormous economical losses and biodiversity losses, and wrecked function of sensitive and delicately balanced ecosystems in the forest. Because of the deep impacts of biological invasions and the difficulty of eradicating an exotic species once it has established, it is important to develop prospective work that allows the detection of invasions in their initial stages (Macdonald and Frame, 1988; Richardson et al., 1989; Waage and Berks, 1997).

Lantana camara is a species of flowering plant of verbena family, and Verbenaceae is native to the American tropics. It has been introduced into other parts of the world as an ornamental plant and is considered an invasive species in many tropical areas (Wang et al., 2008). The native areas of *Lantana camara* include Mexico, Central America, the Greater Antilles, The Bahamas, Colombia, Australia, the east of Africa, Hawaii, India, the south of Africa, Zimbabwe and Zambia, etc. It was reported to impair agriculture and meadow in 47 states, and has become one of the malignant weeds around the world (Holm et al., 1997). The whole and remnant plant can produce intense allelochemical substances that can seriously destroy wood resource and ecosystem function (Leak, 1999). Parts of lantana are also toxic (Li and Xie, 2002). It is mostly distributed in Guangdong, Hainan, Fujian, Taiwan, Guangxi, Hong Kong, Yunnan (Ma et al. 2003; Zhang and Chen, 2006).

It was regarded as an ornamental flower widely planted.

Numerous models have been utilized by some ecologists and environmentalists to predict the risk and the distribution (Peterson and Robins, 2003). There are some familiar models, e.g., BIOCLIM, DOMAIN, GARP, MAXENT, MD (Busby, 1991; Phillips, 2004).

The aim of this study was to explore the use of an Analytic Hierarchy Process (AHP) and fuzzy decision model to evaluate the risk of invasion of *Lantana camara.* Meanwhile, we used Entropy-Weight coefficient to evaluate synthesized value of each factor for overcoming the subjectivity of weighting.

An invasive species must respond quickly and efficiently to new environmental conditions. Because of the absence of coevolved natural enemies, main factors to influence the invasive species include soil PH, salt content, the organic matter in the soil, the luminosity of community, nitrogen content of soil, phosphor content of soil, etc. Other factors include altitude, precipitation, temperature, humidity (Meyer et al., 2008).

Lantana camara lives better around 38°C. Its survival becomes worse for temperatures less than 5℃ (Guo et al., 2002). It grows in many areas with minimal amount of rainfall. It can be seen in the wild and along footpaths, deserted fields, and farms from 80 to 2,200 meters of elevation. The optimum temperature for this plant is from 20°C to 32°C. If the soil is wet, it will sprout after about 30 to 40 days later. It can be planted when the temperature16°C to 20°C is keeping. In the budding period, it grows quickly when the temperature falls in 25 °C to 28 °C. About 10 to 15 days later the seed planted will germinate. In Xiamen, it can grow in the whole year (Ma et al., 2003).

Based on ecological properties of *Lantana camara*, we chose 5 climate ecological factors, i.e., mean annual temperature, mean temperature from March to May, elevation, days with temperature greater than 25°C and annual precipitation. This original data in this study were from the World Weather Information Service (http://www.worldweather.cn/) and China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn/index.jsp).

2 Methods

2.1 Analytic hierarchy process (AHP) and fuzzy decision

Fuzzy decision considers relational impacts of things judged in various factors, so the overall evaluation can be elicited. The steps for the judgement include: (1) determine the object of hierarchy process; (2) determine each factor and compare the power of factors with standard of 1-9 (included in Table 1); (3) test consistency. The formula used is $CI=(\lambda-n)/(n-1)$. The Ratio of Consistency (CR) is divided by the maximal eigenvalue (RI), and if the value is less than 0.1, the variance is admitted, the eigenvectors will be regarded as the vectors of power; (4) establish subjected function; (5) calculate the synthesized value (Z): $Z= TV_1+NV_2+DV_3+WV_4+HV_5$, ($V_1$-$V_5$ is the representation of each factorial weights); (6) determine the scope through comparisons. Relative comparisons of probability were conducted according to the approach of Zhang and Gu (1996).

The established subjected functions are:

$$T=1,\ X\geq 20;\ T=(X-5)/15,\ 5<X<20;\ T=,\ X\leq 5,$$
$$H=1,\ X\leq 140;\ H=1-(X-140)/2060,\ 140<X<2200;\ H=0,\ X\geq 2200,$$
$$N=1,\ X=18;\ N=e^{-((18-X)/5)\char`^2},\ X\neq 18,$$
$$D=1,\ X\geq 60;\ D=X/60,\ X<60,$$
$$W=\mathrm{e}^{-0.0001X},$$

where T: mean annual temperature), N: mean temperature from March to May, H: elevation, D: days above 25℃, and W: annual precipitation.

In this study, 20℃ is a representation of the minimum of optimum temperature for the growth of plants. 5℃ is a representation of the ill-fitted temperature to the *Lantana camara*, 140 is a representation of height in Xiamen; 2,200 is maximum height for the growth of the *Lantana camara;* 18℃ is a representation of the average temperature in room; 60 is a representation of growing days in 20℃.

Table 1 Judging matrix for factors and their weights

factors	*T*	*N*	*D*	*W*	*H*	Weights
T	1	1/2	3	5	2	0.281
N	2	1	3	5	4	0.365
D	1/3	1/3	1	5	2	0.212
W	1/5	1/7	1/5	1	1/2	0.050
H	1/2	1/4	1/2	2	1	0.092

2.2 Entropy-weight coefficient

The main steps to calculate entropy-weight coefficient are:

(1) Standardization on the basis of the formula of the positive direction and standardization of data for coincident dimension.

The formula of the positive direction:

$$1/X_{ij}\ (X_{ij}>0) \text{ or } 1/(\max|X_{ij}|+X_j+1)\ (X_{ij}\le 0).$$

The formula of standardization of data:

$$Y_{ij}=(X_{ij}-X_j)/((\sum X_i^{\ 2}-(\sum X_i)^2/n)^{1/2}/n),\quad i=1,2,\ldots,n;\ j=1,2,\ldots,m.$$

We made calculation using Matlab function ZSCORE().

(2) Calculate the proportion of the evaluated sites (j) of the factors (i), the following formula was used:

$$P_{ij} = X'_{ij} / \sum_{j=1}^{n} X'_{ij}\ .$$

(3) Calculate the entropy of the factors (i):

$$e_i = -\frac{1}{mn}\sum_{j=1}^{n} p_{ij} \ln p_{ij}\ .$$

(4) Calculate the weight of the factors (i):

$$a_i = \left(1-e_i\right) / \sum_{i=1}^{n}\left(1-e_i\right).$$

(5) Calculate the synthesized value,

$$W_j = \sum_{i=1}^{m} a_i p_{ij}\ .$$

2.3 The climate distance

Based on the standardized data, we choose the distributed site, Xiamen, for basic point and educed the various value with each area by the formula $D_{ij}=(\sum(X_{i1}-X_{i2})^2)^{1/2}$, we judged the survival based on the sphere of influence of distributing to *Lantana camara*.

2.4 Principal component analysis (PCA)

PCA is a coordinate transformation to reduce dimensionality (Zhang, 2007).

3 Results

3.1 Results of analytic hierarchy process and fuzzy decision

It was calculated that in consistency test the maximal eigenvalue is λ_{max}=5.2079, *CI*=0.05178, and *CR*=0.0463<0.1. So the power is $V=(0.281\ 0.365\ 0.212\ 0.050\ 0.092)^T$. Details are indicated in Table 1.

If we can determine that the synthesized value (*Z*) of a site is greater for the growth of *Lantana camara*, the site is more suitable to this plant. The suitable areas include Jiangxi, Chongqing, Sichuan, Hubei, Anhui, Hunan, Zhejiang, Henan, Shandong, Shanghai, Jiangsu, Beijing, Shanxi, Liaoning, Tianjin, Shaanxi, Guizhou, Hebei , Ningxia (Yinchuan), Gansu (Wudu, Dunhuang, Lanzhou, Minqin, Jiuquan), Xinjiang (Tulufan, Hetian, Lushi, Ruoqiang, Shache, Kuche, Keshi, Kelamayi, Wulumuqi, Aletai, Yining), Neimeng(Chifeng, Tongliao, Zhaluteqi, Bayanmaodao, Qianguoeduosi, Huhehaote , Zhurihe), and Jilin (Changchun,Yanji, Fujin).

3.2 Results of entropy-weight coefficient

The suitable areas, calculated by entropy-weight coefficient are Jiangxi, Liaoning, Tianjin, Shanghai, Anhui, Sichuan, Hunan, Zhejiang, Yunnan, Chongqing, Henan, Shandong, Beijing, Guizhou, Shanxi, Shaanxi (Hanzhong, Xi'an), Hebei, Gansu (Wudu), Xinjiang (Tulufan, Lushi, Hetian, Ruoqiang), Jilin (Changchun)

Different areas in the comparison of the two methods include Ningxia (Yinchuan), Gansu (Dunhuang, Lanzhou, Minqin, Jiuquan), Xinjiang (Shache, Kuche, Keshi, Kelamayi, Wulumuqi, Aletai, Yining), Neimeng (Chifeng, Tongliao, Zhaluteqi, Bayanmaodao, Qianguoeduosi, Huhehaote , Zhurihe) and Jilin (Yanji,Fujin).

3.3 Results of climate distance

The suitable areas, calculated by climate distance (with Xiamen as basic point) are Jiangxi , Hunan, Chongqing, Hubei, Sichuan, Zhejiang , Anhui , Shanghai, Jiangsu, Guizhou, Shandong, Henan, Shanxi, Shaanxi (the south of Yanan), Gansu (Wudu), Tianjin, Beijing ,Liaoning, Xinjiang(Tulufan, Ruoqiang, Shache , Kuche)

3.4 Results of PCA

The two principal components calculated by PCA are:

$$y_1=0.5236x_1+0.5157x_2+0.4908x_3+0.4373\,x_4+0.1668\,x_5,$$
$$y_2=0.0912x_1+0.1226\,x_2+0.0317x_3+0.0861\,x_4-0.984\,x_5,$$

We calculated the synthesized value and ranked the values by size.

It is concluded from influence sphere analysis of *Lantana camara*, we know that the suitable areas are Jiangxi, Shanghai, Zhejiang, Chongqing, Hubei, Hunan, Sichuan, Anhui, Henan, Guizhou, Shandong, Jiangsu, Shanxi, Beijing, Tianjin, Hebei, Gansu (Wudu), Shaanxi (Hanzhong, Xian), XinJiang (Tulufan, Hetian, Lushi, Ruoqiang, Kuche).

4 Discussion

Because of the uncertainty of risk for invasion species, it is hard to measure the risk if we have not established the model of the Analytic Hierarchy Process (AHP) and fuzzy decision. However, the subjectivity of weighting affects results. How to reduce subjectivity of models should be noted. The validity of models needs to be tested in the practical application.

Our results indicate that the *Lantana camara* will continue to spread to the north China. Many studies have showed *Lantana camara* are photosynthetic plants (like masculine plants). It has stronger capability to capture the CO_2, and utilize the water and light. We thus inferred that *Lantana camara* possesses wider flexibility in distribution.

Up till now the prediction methods have been established by considering the steady states that the species are only survival under definite climate conditions. But some study demonstrated the species possessed the eco-physiological tolerance or plasticity in non-adaptive environment. Only five factors were included in this paper. We did not take into account agro-type and vegetation features affecting its distribution. This study indicated the demand of eco-location for species has been well reflected by temperature and precipitation on which the natural distribution depend (Wang et al., 2008). This is the foundation for risk prediction in this paper.

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