APPLICATION OF REMOTE SENSING AND GIS ON THE DISPERSAL OF *LEUCAENA LEUCOCEPHALA* IN HENGCHUN PENINSULA

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ABSTRACT: The issue of invasive species has been growing concerns recently. In Taiwan, *Leucaena Leucocephala* has invaded the native ecosystems and caused a serious problem in Hengchun Peninsula. Therefore, this study focuses on applying remote sensing and GIS to study the dispersal of *Leucaena Leucocephala* in Hengchun Peninsula. The research process includes (1) generating the land use map and the distribution map of *Leucaena Leucocephala* in 1994 and 2006 based on the integration of remote sensing and GIS; (2) investigating the effect of *Leucaena Leucocephala* dispersal on the landscape of Hengchun Peninsula via landscape structure indices and Shannon diversity t-test; (3) analyzing the significant landscape factors which are related to the dispersal of *Leucaena Leucocephala* through the logit model. The result is as follows. The land use map and the distribution map of *Leucaena Leucocephala* in 1994 and 2006 generated by remote sensing and GIS are acceptable after the accuracy assessment of test area. The result of Shannon diversity t-test indicates that the dispersal of *Leucaena Leucocephala* from 1994 to 2006 has significant effect on the landscape of Hengchun Peninsula. As for the selection of significant landscape factors using the logit model, the result shows that the dispersal of *Leucaena Leucocephala* are strongly related to four landscape factors such as slope, the distance from the seashore, the distance from the road, and the distance from *Leucaena Leucocephala*. Those factors are very important for the occurrence of *Leucaena Leucocephala.* The above results can be extended to the related forest units and National Park for a reference of the dispersal of *Leucaena Leucocephala* in Hengchun Peninsula.

1.INTRODUCTION

The world is a global village after the industrial revolution. Due to the existence of different species whose life cycle impact Earth's ecological balance, there are so many researches begin to promote the maintenance of biodiversity issues when the natural resources are being rapidly developed. Invasive species have been regarded as one of the important reasons to cause the damage of biodiversity in the study for maintaining ecological diversity of the world. The advancement of technology and increasing of human activity result in species invade other species habitat and destruct biodiversity and ecological balance. Invasive species is a hazard for biodiversity after disturbing habitat. Therefore, the international has started to pay attention to issues related to invasive species. In the past five years International Union for Conservation of Nature (IUCN) established a global invasive species database (GISD), and it is expected to be completed before the end of 2011. This database is created in order to raise awareness of invasive alien species-related knowledge. For this purpose, research of invasive species has become an important issue in the world.

The most serious hazard of invasive species in Taiwan is *Leucaena leucocephala*. It is ranked 100 of the World's Worst Invasive Alien Species, and it is on the list of invasive species in Taiwan. *Leucaena leucocephala* will change the local natural ecosystem, crowd out native species, and threat the diversity of native species. It is in the whole island of Taiwan, Penghu and Kinmen. The larger pure woodland is in Hengchun Peninsula, Penghu islands and the coastal area of Taitung (Wu, 2007). The worst invasion places are Hengchun Peninsula and Penghu islands.

In many domestic study of *Leucaena leucocephala* which is the most difficult in Kenting National Park. The reason is that the National Park was established to protect the rich and varied ecology appearance, but the ecological damage caused by invasion of *Leucaena leucocephala.* Therefore, there are many papers related to the landscape change of *Leucaena leucocephala* in the Hengchun Peninsula (Li, 2003; Chung and Lu, 2006; Chung and Lu, 2007; Kuo, 2008; Lu, Huang, and Chung, 2009). According to those studies, the spatial structure of *Leucaena leucocephala* for the spread speed and diffusion area was focused. The study area is mostly located in Kenting National Park which is inside the Hengchun Peninsula. In addition, Chen (2010) studied the distribution of *Leucaena leucocephala* using

remote sensing technique. Therefore, this study focuses on applying remote sensing and GIS capability to firstly generate the maps of *Leucaena leucocephala* in the Hengchun Peninsula, then to explore the invasion of *Leucaena leucocephala* and finally suggest the prevention of spread and intrusion for *Leucaena leucocephala*.

2. MATERIALS AND METHODS

2.1 Study Area and Materials

2.1.1 Study Area: Henchun peninsula is located in the south of Taiwan. The study area includes the land scope of Kenting National Park and the National Forest of Hengchun managed by Pingtung Forest District Office (Figure 1). The total area is about 314.2712 square kilometers. The area of low mountains, hills or terraces are above 600 meters and the coastal plains divided from sporadic hills in the west of the peninsula are the population distribution center.

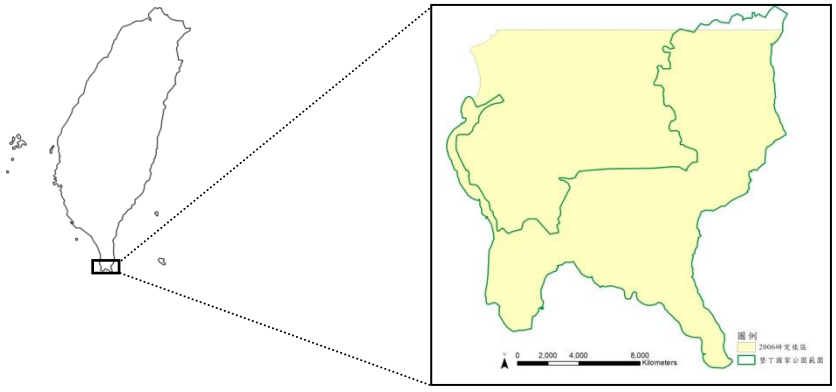


Figure 1. Study area.

2.1.2 Materials: In this study, the first and second national land-use survey data produced by Taiwan Survey and Mapping Center in 1994 and 2006 are used as the basic data (Figure 2).

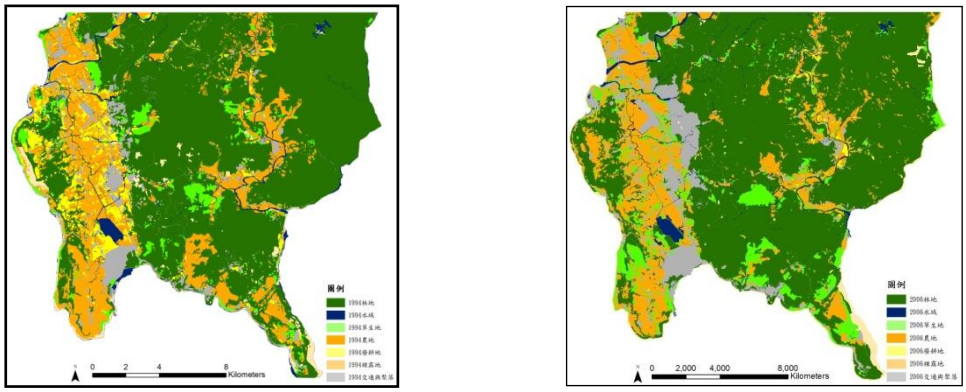
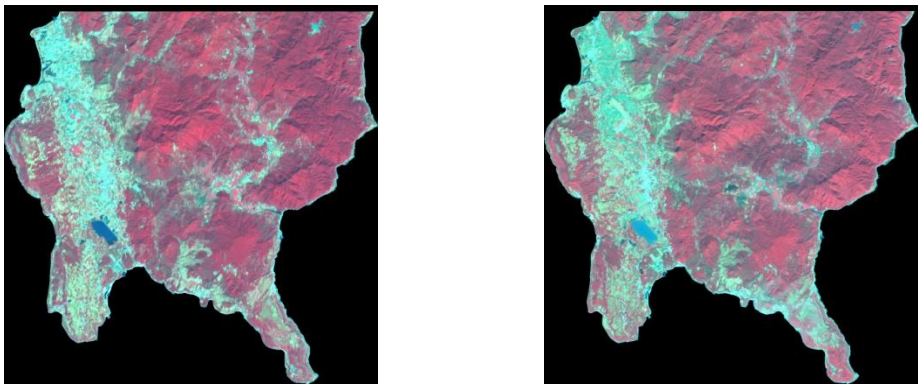


Figure 2. National land-use survey data produced by Taiwan Survey and Mapping Center.
(a) First land-use survey data in 1994. (b) Second land-use survey data in 2006.

However, there is no information about *Leucaena leucocephala* in the national land-use survey data. Therefore, SPOT satellite image is then used to extract the spatial distribution map of *Leucaena leucocephala*. To coincide with the date of national land-use survey data, two kinds of SPOT images are collected. One is SPOT-2 image on 11/12/1994 including three spectral bands: green (XS1: 0.50 - 0 .59 μm), red (XS2: 0.61 - 0 .68 μm), and near infrared (XS3: 0.79 - 0.89 μm). The other is SPOT-4 image on 11/22/2006 including four spectral bands: green (XI1: 0.50 - 0 .59 μm), red (XI2: 0.61 - 0.69 μm), near-infrared light (XI3: 0.79 - 0 .90 μm), and shortwave infrared (SWIR: 1.58 - 1.75 μm). The spatial resolution of each pixel for both images is 20 m × 20 m.



(a) (b)

Figure 3. SPOT image of Henchun peninsula. (a) In 1994. (b) In 2006.

2.2 Methods

To achieve the objective of analyzing the spread of *Leucaena leucocephala* in Hengchun Peninsula from 1994 to 2006, firstly the classification maps of *Leucaena leucocephala* in 1994 and 2006 have to be generated. However, the generation steps of *Leucaena leucocephala* classification map are similar, no matter the SPOT image in 1994 or 2006. Thus, the following research process about the generation of *Leucaena leucocephala* classification map is only focused on the year of 1994.

2.2.1 The Generation of *Leucaena leucocephala* Classification Map: According to the first national land-use survey data produced by Taiwan Survey and Mapping Center in 1994 (Figure 2a), the land-use types include seven categories. They are forest land, water, grassland, agricultural land, waste land, bare land, transport and settlement. As mentioned above, there is no information about *Leucaena leucocephala* in the national land-use survey data. To acquire the spatial distribution map of *Leucaena leucocephala,* the forested area in the national land-use survey data is firstly extracted and then used to cut the SPOT image of 1994 (Figure 3a) for the classification map of *Leucaena leucocephala.* As for image classification, there are two basic approaches (i.e., supervised and unsupervised). The fundamental difference between these techniques is that supervised classification involves a training step followed by a classification step. In the unsupervised classification the image data are first classified by aggregating them into the natural spectral groupings, or clusters, present in the scene. Then the image analyst determines the land cover identity of these spectral groups by comparing the classified image data to ground reference data. It is known that there are advantages and disadvantages for supervised classification and unsupervised classification. Therefore, this study adopts the integration of supervised and unsupervised classification. The step is as follows. Firstly, produce uniform spectral value group by using unsupervised classification. Secondly, select the train areas with the assistance of color ortho-photo (scale 1/5000) produced by Taiwan Aerial Survey Office, and then use the Gaussian maximum likelihood classifier to accomplish the classification map of forested areas, which includes the spatial distribution of *Leucaena leucocephala* and non-*Leucaena leucocephala.* In the assessment of classification accuracy, the test areas for each land-type are selected from the classification map. Then, the overall classification accuracy is obtained from a classification error matrix.

After the generation of *Leucaena leucocephala* and non-*Leucaena leucocephala* classification map in 1994, the classification map is then converted into vector data and overlaid together with the first land-use survey data in 1994 (Figure 2a) to form a new land-use map. Similarly, the above research processes is applied to generate a new land-use map in 2006.

2.2.2 Monitoring of Landscape Change using Shannon Diversity t-test: To investigate the landscape diversity of Hengchun Peninsula, the Shannon diversity t–test is applied to examine if there is a significant landscape change due to *Leucaena leucocephala* dispersal. The method was presented by Magurran (1988) and derived by Hutcheson (Cheng, 1999). The formula is as follows.

$$t = \frac{(H_1 - H_2)}{(\mathrm{Var}H_1 + \mathrm{Var}H_2)^{1/2}}$$

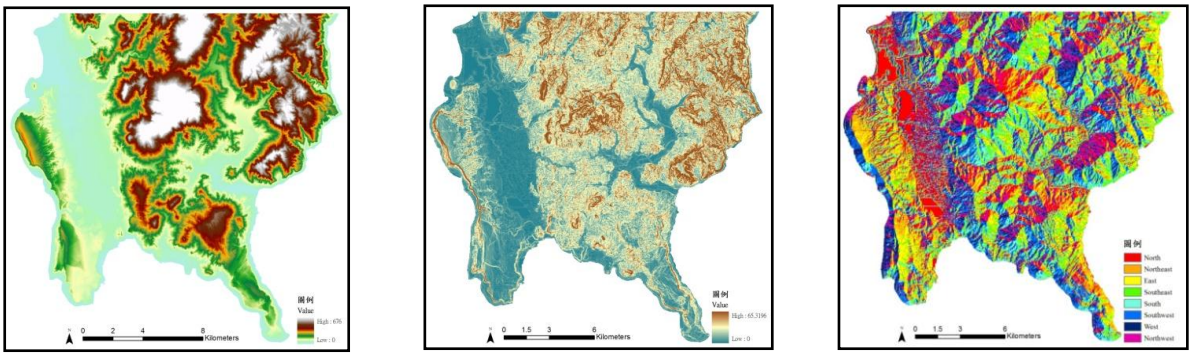
The hypothesis of Shannon diversity t-test is that under the significance level of 5% or 1%, the landscape change of Hengchun Peninsula is significant from 1994 to 2006 if the calculated t-value is greater than the look-up value. Otherwise, there is no significant change. In the following formula, H_i is the Shannon diversity index at i time; $VarH_i$ is the variance; and df is the degree of freedom.

$$H_i = -\Sigma\, Pi \times \ln Pi - \frac{m_i - 1}{n_i}$$

$$VarH_i = -\frac{\Sigma_{i=1}^{n}\, Pi\,(\ln Pi)^2 - (\Sigma Pi \times \ln Pi)^2}{n_i} + \frac{m_i - 1}{2n_i^2}$$

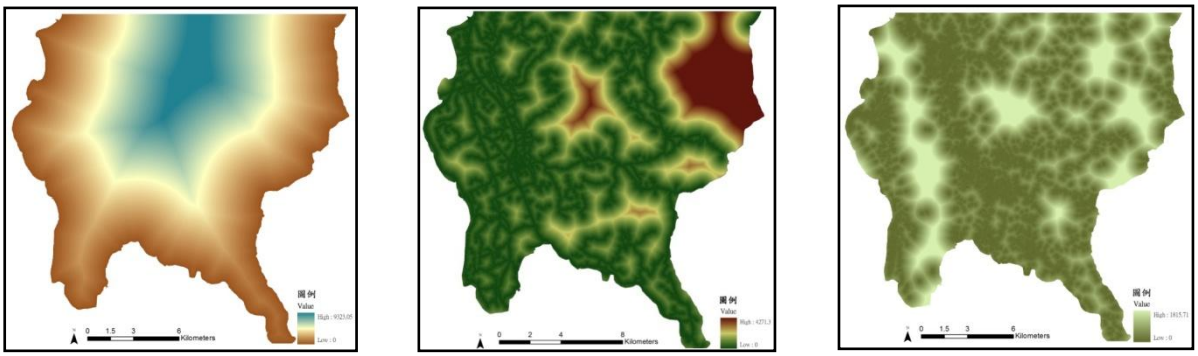
$$df = \frac{(VarH_1 + VarH_2)^2}{(VarH_1)^2/n_1 + (VarH_2)^2/n_2}$$

2.2.3 Analysis of *Leucaena Leucocephala* Dispersal: To analyze the correlation between landscape factors and the distribution of *Leucaena leucocephala*, the logit model is applied (Cao, 2009). The step is as follows. First of all, establish the maps of altitude, slope, the distance from the coast line, the distance to roads, and the distance to original *Leucaena leucocephala* according to the actual values, except the aspect map is set to eight levels. Those six parameters are regarded as the independent variable of logit model. Next, 8020 sample points are randomly selected among six maps and then determine the dependent variable according to the occurrence of *Leucaena leucocephala*. Finally, analyze the correlation between landscape factors and the distribution of *Leucaena leucocephala* using the SAS logit model.



(a) (b) (c)

Figure 4. Topographic conditions within the possible dispersal range. (a) Altitude. (b) Slope. (c) Aspect.



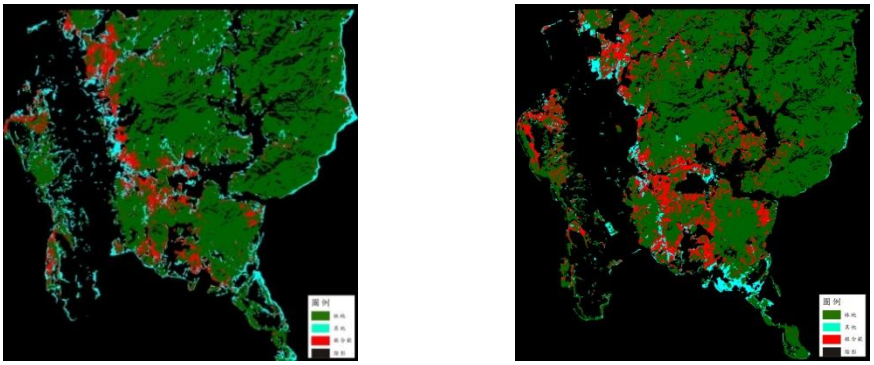
(a) (b) (c)

Figure 5. Proximity factors within the possible dispersal range. (a) The distance to coast line. (b) The distance to roads. (c) The distance to original *Leucaena leucocephala*.

3. RESULTS AND DISCUSSIONS

3.1 Classification Map of *Leucaena leucocephala*

The classification maps of Hengchun Peninsula in 1994 and 2006 were generated from SPOT images and shown as Figure 6. From the classification map in 1994 and 2006, the overall classification accuracy was calculated according to the selected test area. The result in 1994 was 99.25% and the Kappa index was 0.9857, and the result in 2006 was 99.25% and the Kappa index was 0.9857.



(a) (b)

Figure 6. The classification map of Hengchun Peninsula. (a) In 1994. (b) In 2006.

3.2 Monitoring of Landscape Change using Shannon Diversity t-test

Table 1 and Table 2 are the result of Shannon diversity t-test obtained from eight and two land-use types, respectively. The Shannon diversity t-test is under the significance level of 5% and the probability of the calculated t value is less than the value of TINV. From Table 1 and Table 2, the result indicates that the landscape of Hengchun Peninsula has significant change from1994 to 2006 and the landscape change may be caused by the effect of *Leucaena leucocephala* dispersal.

Table 1. Shannon diversity t-test focused on the landscape of Hengchun Peninsula

Year	patch type	patch number	Hi	Var Hi	t value	d.f	Test result	TINV
1994	8	9973	1.2494	0.0001	1.8978	20704	0.0293	1.96
2006	8	11567	1.2224	8.9E-05				

Table 2. Shannon diversity t-test focused on the *Leucaena leucocephala* of Hengchun Peninsula

Year	patch type	patch number	Hi	Var Hi	t value	d.f	Test result	TINV
1994	2	1831	0.226248	0.000233	3.24172	3963	0.000603	1.9601
2006	2	2369	0.292585	0.000185				

3.3 Analyze the Dispersal of *Leucaena Leucocephala* in Hengchun Peninsula

The result of the logit model is shown as Table 3. The P value of constant, aspect, the distance to coast line, the distance to roads, the distance to original *Leucaena leucocephala* are significant ($p<0.005$).

Table 3. Result of the logit model

Variable	Coefficient	Wald Chi–Square	P Value
Constant	–1.3124	81.9407	0.0001*
Altitude	–0.00064	0.761	0.383
Slope	0.00903	1.9748	0.1599
Aspect	–0.0592	7.5098	0.0061*
The distance to coast line	0.000048	4.5156	0.0336*
The distance to roads	–0.00031	8.6581	0.0033*
The distance to original *Leucaena leucocephala*	–0.00535	206.8354	0.0001*

4. CONCLUSIONS

This study focuses on applying remote sensing and GIS techniques on the dispersal of *Leucaena leucocephala* in Hengchun Peninsula. The results can be concluded as follows:

(1) The high feasibility of remote sensing and GIS techniques in the area of large-scale land use classification and *Leucaena leucocephala* dispersal: The result can be a reference for the related forest units and the Kenting National Park to timely and quickly generate the land use map, and also understand the spatial distribution of invasive species -*Leucaena leucocephala*.

(2) The effect of *Leucaena leucocephala* dispersal on the landscape of Hengchun Peninsula: Based on the Shannon diversity t-test, obviously the landscape of Hengchun Peninsula has significant change from 1994 to 2006 and this change may be caused by the dispersal of *Leucaena leucocephala.* Therefore, the relevant forest units and the Kenting National Park should keep monitoring and preventing the dispersal of *Leucaena leucocephala*.

(3) The significant landscape factors related to the dispersal of *Leucaena Leucocephala*: The dispersal of *Leucaena Leucocephala* are strongly correlated with four landscape factors such as slope, the distance from the seashore, the distance from the road, and the distance from *Leucaena Leucocephala.* Those factors are very important for the occurrence of *Leucaena Leucocephala* in Hengchun Peninsula. However, still many other factors such as rainfall, temperature, or human activities are not used in this study. Therefore, further analysis is needed to apply more factors.

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