Rural landscape planning——case study of Nanhua State Farm

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Abstract—Research work on rural landscape planning was conducted at Nanhua State Farm, which is located in the south of the Leizhou Peninsula, Guangdong Province. Based on its soil nutrient status, rainfall and mean yield of major crops, the soil suitability and land adaptability were evaluated. An artificial neural network was introduced as an alternative for modeling the landscape planning. A model was developed using back-propagation as the learning procedure, the sigmoid function as the transfer function and 6 patch types and its number of three phases as input factors. Three optimum planning schemes were selected by using the model. Strategies were proposed for improving diversity and heterogeneity, productivity and sustainability within the system through the planning scheme.

Keywords: rural landscape, planning, neural networks, back-propagation, modeling.

1 Introduction

Highly productive land use results in a continuous change of landscapes in rural areas. Under the impact of crop product markets, land use policy and economic development, great attention is paid to obtain of the economic benefit of land use in the short term. In the planning and design of land, the main regulation to conform to is the level of expected economic income. An extremely important principle is generally ignored-that of rural sustainable development. Without maintaining the productive capacity of the earth, we cannot sustain communities, therefore, the sustainability of communities requires planers to focus on sustaining landscape structure and function and change the traditional planning approach (Grant, 1996).

At present, in the study of land utilization or landscape planning, a linear programming approach from operations research is often employed. However, it is difficult to set the beneficial coefficient correctly because of the constant changeable price of products on the market, so a planning scheme based on this approach is seldom cogent. In general, a linear programming approach is inefficient in dealing with the problem of landscape planning, since due to landscape planning is characteristically multi-factorial and nonlinear.

In this paper, a theory of artificial neural network (Jones, 1989; Weigned, 1989) was used to conduct rural landscape planning with the aim of proposing an optimum planning scheme, and probing a new and practical approach to process landscape planning problem. Because the neural network system has superior ability in solving nonlinear problems, in recent years, it has been widely applied into the field of classification (Sobey, 1991), model identification (Widow, 1990) and prediction (Bing, 1991).

2 Materials and methods

2.1 Study site

Overlooking Hainan Island, the study site (Nanhua State Farm, 20°20′58″—20°28′47″N, 110°08′32″—110°16′10″E) is located in the south of the Leizhou Peninsular, the center of Xuwen County, Guangdong Province. Its topography is relatively smooth and is part of a gently sloping platform. The slope is less than 5 degrees.

The site has a monsoonal climate, with rainy season beginning in May and lasting until October, bringing 80% of total annual rainfall. Mean annual rainfall is approximately 1600 mm.

Temperature averages 22.7℃. Relative humidity and evaporation per year average 86% and 1563.5 mm respectively. The typhoon (over 10 force) frequently hits the area from June to October, averaging 0.76 times per year.

The total area of the site is near 6000 hm^2, cropped with cash crops such as sugarcane, tea, coffee, *Amomum longiligulare*, banana, pineapple and so on. Tree species such as rubber, eucalyptus and acacia have been planted by 27 production teams. The total population in the area is 5100 (Wang, 1991).

2.2 Landscape pattern characteristics

During the 1950s'—1970s', the farmers planted rubber trees and surrounded each plantation with a belt of other species, as a protection against typhoon and other adverse weather conditions. At this time the landscape dominance index was high, and the landscape diversity and landscape evenness indices were low.

In the early 1980s', the farm formulated the policy to take planting rubber as the key crop, to plant protective belts around the rubber and to adopt diversified management systems. The main part of the diversification drive was to intercrop the rubber trees and protective belts with agricultural crops. The result of this was to decrease the landscape dominance index and increase the landscape diversity index and heterogeneity index. There was also an increase in the stability and productivity of the system.

During the early 1990s', market influences meant there was a reduced demand for rubber and some farm-product. The farm thus formulated an alternative management strategy to obtain more short-term benefits. At this time a large proportion of the trees (including rubber trees and trees for protective forest-belts) at the farm were felled. The intercropping patch type and the mono-cultivated orchard patch type disappeared from the landscape. The landscape matrix was thus greatly altered. Meanwhile the heterogeneity index and the diversity index were evidently decreased. From the point of view of landscape, reconciliation of long-term benefits with short-term gains should be carried out through landscape planning. This will increase the diversity and heterogeneity indices and will have a positive effect on productivity and sustainable development at the farm.

2.3 Landscape planning targets

Market demand should be the leading factor in choice of crop as the economic benefits to the farm must be productive. However the ecological aspects should be used as a foundation for any planning, and the aim should be to increase landscape diversity and heterogeneity.

The targets should therefore be to establish a system that is both economically and ecologically sound, involving more complex planting patterns of intercropping to replace mono-cultivation systems, and to improve the productivity and sustainability of the system.

2.4 Method of assessment of soil resource suitability and land adaptability

2.4.1 Soil resource suitability

From soil resource-wise, certain land utilizing manner or crop's adaptability were appraised in terms of soil's specific use, such as the soil's suitability for crops, forests, irrigation and so on (Chen, 1997). Based on different soil type, nutrient content and long-term of production practice of the farm, soil resource suitability were initially appraised.

2.4.2 Land adaptability

From the point of view of the crops, the economic properties of crop were taken as the core, the crop's requirement for soil and environment condition is assessed (Chen, 1997). Land adaptability of 5 districts in the farm was identified based on the soil nutrient, rainfall and mean economic yield of major crops.

2.5 Modeling the landscape planning scheme

A back-propagation algorithm of artificial neural network was used for modeling the landscape-planning scheme. Optimum planning schemes were determined by applying the model. A neural network is a parallel system of highly interconnected, interacting processing elements, or nodes, which is analogous to a brain's neuron. The processing elements are usually grouped into layers, as depicted in Fig. 1. Neural networks process information through the interaction of a large number of these processing elements or nodes. Knowledge is stored in the strengths of the connections between elements.

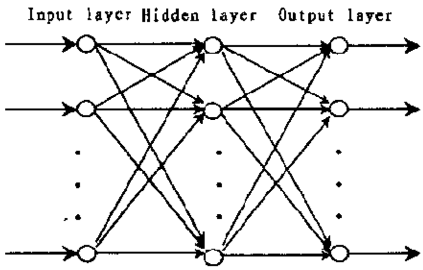

Fig. 1 Multilayer feedforward network

Much of the interest in neural networks arises from their ability to learn, which can be viewed as the process of developing a function that maps input vectors to output vectors. The learning or training process is comprised of forward and back-propagation processes, as described by Rumelhart *et al*. (Rumelhart, 1986). The forward pass through the network begins as the input layer receives information from the environment and passes it to the hidden layer. Each processing element calculates an activation value by summing the weighted inputs. This sum is then used by the activation function to determine the activity level of that processing element. The generated output value is compared to the known target value. If there is no error, then no learning will take place, i.e. weights will not be changed. Otherwise errors will be back-propagated from the output layer through the hidden layers to the input layer, and the connection weights will be adjusted according to the errors.

2.6 B-P learning rule

Let: $x_i (i = 1, 2, \cdots, m)$ be the input value of input layer; y_k the output value of hidden layer $(k = 1, 2, \cdots n)$; y_j the output value of output layer $(j = 1, 2, \cdots l)$; T_j the target output for pattern $(j = 1, 2, \cdots p)$; W_{ih} the weight connecting the input layer unit and hidden layer unit; W_{hj} the weight connecting the hidden layer unit and output layer unit; θ_j, ϕ_k the threshold value of hidden layer and output layer unit respectively.

(1) For W_{ih}, W_{hj}, θ_h, ϕ_j initial value is given;

(2) Put one sample and target value vector into network;

(3) To calculate the output of hidden layer and output layer. Let S_h be the weighted sum of inputs to the hth units in hidden layer, i.e.,

$$S_h = \sum_{i=1}^{m} w_{ih} x_i . \tag{1}$$

Outputs of hidden layer,

$$y_h = F(S_h) = F(\sum_{i=1}^{m} w_{ih} x_i + \theta_h). \tag{2}$$

S_j be the weighted sum of outputs to the jth units in output layer.

$$S_j = \sum_{h=1}^{n} w_{hj} y_h . \tag{3}$$

Outputs of output layer,

$$y_j = F\Big(\sum_{i=1}^{m} w_{hj} F\Big(\sum_{i=1}^{m} w_{ih} x_i + \phi_j\Big)\Big). \tag{4}$$

Where $F(x)$ is activation function,

$$F(x) = \frac{1}{1 + e^{-x}}. \tag{5}$$

(4) To measure an error for unit j in output layer (δ_j) and an error for h in hidden layer (δ_h)

$$\delta_j = F'(\delta_j)(T_j - y_i), \tag{6}$$

$$\delta_h = F'(S_h)\sum_{j=1}^{l} w_{hj}\delta_j \tag{7}$$

(5) To adjust connection weight and threshold value according to error (Rumelhart, 1986; Shi, 1993).

$$\Delta w_{ih} = \beta\delta_h x_i, \tag{8}$$

$$\Delta w_{hj} = \beta\delta_j y_h, \tag{9}$$

$$\Delta\theta_h = \eta\delta_h, \tag{10}$$

$$\Delta\phi_j = \eta\delta_j. \tag{11}$$

Where β is a learning rate which is a positive number smaller than 1. η is learning coefficient, commonly between 0.1 and 0.5.

(6) Put the other training samples into the network in turn, go back to (3)—(5). Then measure the sum of mean squared errors (E-value).

$$E = \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{p}(y_j - T_j)^2. \tag{12}$$

The training process is stopped when E-value is less than the given precise ε-value, otherwise, turn to (2) step and continue training until less than the ϵ -value.

3 Results and discussion

3.1 Soil resource suitability

According to the soil survey of 1981 for the entire state farm, 95.2% of the soils were brick clays derived from basalt, and 4.8% were clays derived from coastal marine deposits.

In terms of biological features of tropical crops and nutrient contents of soil types (Table 1), it has been shown that the hydrous ferrallitic brick clay and hydrous ferrallitic cultivated soil are more productive, and are highly suitable for growing all kinds of tropical crops. The soils derived from coastal marine deposits are of lower fertility, and not suitable for tropical crops. They are most suited to growing forest trees. The brick clay of thicker organic matter and cultivated soil derived from basalt is intermediate in fertility levels, and is suitable for growing most tropical crops.

Table 1 Nutrient status of different soil types

Soil parent materials	Soil category	Proportion, %	O.M., %	Total N, %	N*, ppm	Available P, ppm	Available K, ppm	pH
Basalt	1 Brick clays of thicker O.M.	82.13	3.2	0.154	140.3	3.86	29.92	5.01
	2 Cultivated soils	11.6	2.9	0.134	125.7	13.1	57.6	5.46
	3 Hydrous ferrallitic brick clay	1.0	4.13	0.149	151.3	13.7	31.9	4.90
	4 Hydrous ferrallitic cultivated soils	0.47	3.76	0.173	140.9	11.3	22.0	4.78
Coastal marine deposits	5 Brick clays of thicker O.M.	4.5	1.28	0.084	68.7	2.05	16.5	5.67
	6 Cultivated soils	0.3	1.38	–	66.3	1.45	10.0	4.93

* N from alkali hydrolysis

3.2 Assessment of land adaptability

The brick clay derived from basalt is the major soil type in Nanhua State Farm. On this soil type, research was carried for the adaptability of major crop types, as this soil type will be the major source of production at the farm. The farm was divided into 5 districts: the east, west, north, south and central for the purposes of this study. For each of these districts, the paper concentrates on research work on the adaptability of the major crops with regard to soil fertility, rainfall and the average yields for these major crop types.

3.3 Soil fertility

Soil nutrient status of 5 districts and land distribution is shown in Table 2.

Table 2 Soil nutrient status of the districts and land distribution

District name	O.M., %	Total N, %	N*, ppm	Available P, ppm	Available K, ppm	pH	Land area, hm^2	Production team
East	3.51	0.151	154.4	4.14	25.0	4.95	1252.6	7, 8, 9, 20, 21, 27
South	3.0	0.135	122.0	3.55	33.78	5.0	1087.5	6, 13, 17, 18, 19
West	3.03	0.13	127.0	4.2	26.05	4.97	1331.0	3, 4, 5, 15, 22, 24, 25
North	3.53	0.147	142.35	6.77	29.03	4.93	402.1	1, 14, 16, 26
Central	3.3	0.163	147.35	3.76	41.67	5.14	1149.8	2, 10, 11, 12, 23

From Table 2 we can see that the total N and that obtained from alkali hydrolysis is high in all districts. Available P and K are generally lower in all districts. Organic matter content is higher in the east and north districts, but for total N content, the east and central districts are the highest.

3.4 Rainfall and crop yields

The crop growth is closely related to the soil type and soil nutrient levels, and also to variations in rainfall across the site. Since there were no climate monitoring stations in four of the five districts, rainfall data were estimated from the dates of tapping the rubber trees for latex in each planting district. If the district is dry with low rainfall, the tapping date is earlier, whereas, where rainfall is high, the opposite is true. The data from two years, 1995 and 1996 are shown to express the level of rainfall in each district (Table 3). It is assumed that more rain had fallen in the east, north and central than in the west and south. On the other hand, the level of rainfall of 5 districts can be estimated by the yield of sugarcane and tea, which is positively correlated with rainfall.

To describe the adaptability of crops to the site, yield data of the major crops were collected in the 5 districts from 1994 to 1996. The average yield were calculated and listed in Table 3.

Table 3 Average yields of the major crops and latex tapping dates

District name	Sugarcane, t/hm^2	Coffee, kg/hm^2	Fresh tea, kg/hm^2	Pepper, kg/hm^2	Latex, t/plant	Tapping date, 1995a	Tapping date, 1996a
East	61.155	151.5	14.45	280.5	2.128	22/5	16/6
South	43.995	339.0	0.188	372.0	2.933	29/4	18/5
West	35.595	–	1.177	481.5	2.824	02/5	18/5
North	56.655	432.0	6.035	–	2.245	24/5	17/6
Central	55.350	822.0	7.587	–	2.370	22/5	15/6

From Table 3 it can be seen that the latex yields per tree are higher in the west and south than in the east, north, and central. The table indicates that the mean yield of sugarcane and tea per hectare in the east, north, and central are higher than in the west and south. The yield of coffee is the highest in the central. In the west and south, pepper has higher yield. Consequently, the land adaptability of the 5 districts is appraised. The east district is suitable for developing sugarcane and tea. The south is suitable for developing rubber and pepper. The west is suitable for developing rubber, pepper and mango. The north and central are suitable for developing sugarcane, tea and coffee. The management unit should manage crops according to the land adaptability, and might adjust crop variety for market-orientation. When the varieties are grown on the soils, derived from basalt, the suitable growing district should be determined by the crop requirements for water and nutrients.

3.5 Landscape neural network architecture

In view of the studies of landscape pattern for 1972, 1987 and 1995, a training data set for establishing a back-propagation network, consisting of 3 examples of area and number of patch type, was constructed. The network was comprised of three layers, an input layer of 12 nodes, one hidden layer and an output layer. The inputs to the network included 6 patch types, namely the rubber-protective forest networks (in short, rubber), timber plantations, sugarcane-protective forest networks (in short, sugarcane), land for tropical crops (including mono-cropping and inter cropping model), fruit orchard and garden land.

A pattern of (0.9, 0.1, 0.1) represent a value of landscape pattern level that was higher; (0.1, 0.9, 0.1) represent a value of landscape pattern level that was within the uppers and lowers; and (0.1, 0.1, 0.9) represent a value of landscape pattern level that was lower. The mean squared errors for training was smaller than 1% by 2159 times of iterative calculation on PC.

3.6 Stimulation of the optimum planning scheme

Firstly, 9 random numbers (λ) between 0 and 1 at 0.1 intervals are derived. They are 0.121, 0.211, 0.321, 0.436, 0.576, 0.657, 0.749, 0.852 and 0.927. Secondly, the upper and lower limit of each input factor is set. Thirdly, 9 random planning schemes are created based on the following formula $x_i = x_{min} + \lambda(x_{max} - x_{min})$.

The input factors (x_i) are standardized and put into the stable networks. The optimum planing schemes are appraised according to the output value of the network (Y_1 more than 0.8), and landscape diversity index. Table 4 shows the results of optimum planning schemes and output values.

Table 4 Output values of the network and optimum planing schemes

Patch type	Area and number	Schemes 1	2	3	4	5	6	7*	8*	9*
Rubber-forests network	Area, hm²	2121	2211	2321	2436	2576	2657	2749	2852	2927
	Number	113	119	125	132	141	145	151	157	162
Pure timber plantation	Area, hm²	259.4	273.8	291.4	309.8	332.2	345.1	359.8	376.3	388.3
	Number	26	29	33	38	43	46	49	53	56
Sugarcane-forests network	Area, hm²	1060.5	1105.5	1160.5	1218	1288	1328.5	1374.5	1426	1463.5
	Number	81	82	83	84	86	87	87	89	89
Land for crops	Area, hm²	44.5	55.3	68.5	82.3	99.1	108.8	119.9	132.2	141.2
	Number	31	46	63	81	104	117	131	148.3	160
Fruit garden	Area, hm²	38.5	44.8	52.5	60.5	70.3	76.0	82.4	89.6	94.9
	Number	10	11	11	12	12	13	13	13	14
Garden land	Area, hm²	106.1	110.6	116.1	121.8	128.8	132.9	137.5	142.6	146.4
	Number	33	38	45	52	60	65	70	76	81
Output value Y_1		0.399	0.490	0.595	0.683	0.754	0.780	0.801	0.817	0.824
Output value Y_2		0.389	0.368	0.341	0.317	0.299	0.293	0.290	0.290	0.291
Output value Y_3		0.237	0.188	0.143	0.110	0.085	0.076	0.068	0.062	0.059
H, %		46.36	47.37	47.52	47.60	47.69	47.73	47.77	47.81	47.84

* the optimum planing scheme; H, %: landscape diversity index

From the point of view of the stimulation effect of 9 planing schemes, schemes 7, 8 and 9 give output values greater than 0.8. Moreover, the landscape diversity index will be more than 47%. It is no doubt that the three schemes are the optimum.

4 Conclusion and suggestion

The paper demonstrates the promising future of using artificial neural networks as an alternative for modeling rural landscape planning. Three optimum landscape-planing schemes were selected by stimulation method of the stable neural network. According to the existing state of land utilization, the management units (the farm) of the site may choose any one scheme from among the three optimum schemes to carry out. In the process of implementation, the area and number of each patch type should be ensured. Moreover, with the view of improving diversity, heterogeneity and productivity of the system, and maintaining rural sustainable development, the following strategies or principles should be adhered to.

(1) The land adaptability of crops should be considered in the growing of crops. According to the research on land adaptability, the east district is suitable for developing sugarcane and tea; the south is suitable for developing rubber and pepper; the west is suitable for developing rubber, pepper and mango; the north and central regions are suitable for developing sugarcane, tea and coffee.

(2) The diversification of spatial configuration of patch type should be emphasized. In management of tropical crops, great attention should not only be paid to selection of crop variety to fit with market price fluctuation, but also to the spatial planting structure. Agroforestry models, Intercropping and Alley cropping way are suggested systems.

(3) One should endeavor to avoid connecting of dominant patch types. The dominant patch types of the site are rubber and sugarcane. For these two patch types, the connections between patches should be gradually decreased.

(4) One should also endeavor to protect and increase the number of corridor (protective forest belts). At the site, the protective forest belts, which had previously been cut for planting sugarcane, should be recovered quickly.

(5) In order to maintain the land fertility and rural sustainable development, a rotation cropping system should be utilized.

Acknowledgement—— Thanks are given to IDRC and CIFOR for financial support.

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