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# Research on Carbon Distribution in Natural Scenic Area

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By calculating carbon sink of vegetation in a natural scenic area and tourist carbon footprint, carbon distribution load rate, carbon distribution equilibrium degree and carbon distribution order degree were introduced to study the carbon distribution order in a scenic area quantitatively. Then Simulink was used to simulate the scenic area model to get the value of carbon distribution load rate, carbon distribution equilibrium degree and carbon distribution order degree. On the basis of the carbon distribution situation, managerial staffs of the scenic area could modify tourists' touring routes to realize an equilibrium state of carbon distribution order and ultimately make sustainable development come true.

## 1. Introduction

Carbon emission during travel mostly took place in a scenic area. In recent years, researches on low carbon tourism emerged in endlessly. researches in this field mainly focused on the connection and interplay between tourism and global climate change (Li et al., 2012),including quantitative measurement of tourism carbon emission (James et al., 2004; Dalton et al., 2008; Hares et al., 2010; Dong et al., 2013) strategies on low carbon tourism (Kuang et al., 2012; Farsari et al., 2007) ,tourism carbon footprint (Walmsley et al., 2015),and carbon distribution (Zhou, et al., 2016).

Due to the fact that it was hard to have a clear cut of tourism system spectrum and there existed various measurement methods, the comparability and precision of the measured carbon footprint were to some degree being impacted. This paper drawn on forest carbon sink and calculate vegetation's carbon absorption ability of CO2 and tourists' carbon footprint within the natural scenic area by complying with the life cycle principle. On the basis of the scenic area's carbon sink and tourists' carbon footprint, the concept of carbon distribution order (namely carbon distribution situation in a scenic area) was initiated. By measuring the carbon distribution order, it was possible to prevent partial long-term CO2 overload state in a scenic area caused by unbalanced tourist distribution. In this way, ecological environment deterioration in the scenic area could be eased and sustainable development could be realized.

## 2. Basic concepts

According to the definition in UNFCCC, carbon sink refers to the process, activity and mechanism to remove CO2 from the air, and it mainly indicates how much CO2 has the forest absorbed and saved, or in other words, it exemplifies the forest's ability to absorb and save CO2. Drawing on the definition of forest carbon sink, in a natural scenic area, carbon sink means vegetation's ability to absorb and fix CO2 in itself.

The volume of forest carbon sink (volume of the absorbed CO2) in a time unit reflects the forest's carbon sink ability. The total carbon sink volume in a time unit is the sum of products of vegetation area multiplies per unit vegetation's absorbed CO2 volume in a time unit. Specifically, if there are $m$ kinds of vegetation in a scenic area, and the fixed carbon sink of each vegetation in a time unit is $\mathrm{q_k}(1,2,\dots,\mathrm{m})$, the plantation area of each vegetation is $s_k(1,2,\dots,m)$, then the total carbon sink volume in a time unit is recorded as C, and C is Eq(1)

$$C = \sum_{k=1}^{m} s_k . q_k \tag{1}$$

Carbon footprint is also known as carbon fingerprint or carbon emissions, and it firstly became popular in Britain. To vividly and precisely measure the effect of greenhouse emission to mankind's daily life,

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environment organizations and scholars initiate a figurative notion “carbon footprint” when conducting relevant researches(Wang et al., 2009). It means the total greenhouse emission released by individuals, families, groups (companies) or products (equipment) during the whole life cycle. According to the life cycle method of carbon footprint evaluation, tourists’ carbon footprint refers to the consumed carbon volume during the whole trip either produced by a traveling group or individual tourist.

In a natural scenic area, the major influential element for carbon distribution changes is tourists’ carbon emission during the travel, and it includes two aspects: carbon emission from the transportation as well as from the tourists’ breath.

This paper has studied the carbon footprint in transportation, and the volume of the produced CO2, by tourist transportation was recorded as $Q_t$, $Q_t$is Eq(2)

$$Q_t = \sum D_i . n_i . \beta_i . \alpha_i \tag{2}$$

$Q_t$ refers to CO2 emission volume of transportation tool i; $D_t$ refers to the driving distance of the transportation tool i; $n_i$ refers to the number of i; $\alpha_t$ is the CO2 emission coefficient(kg/MJ) of i’s consumed energy; and $\beta_i$ (MJ/ unit.km) is the energy consumption of per unit i.

In line with the carbon footprint study of transportation, a formula to show an individual tourist’s transportation carbon emission volume $Q_t$’ in a time unit could be gained, $Q_t$’ is Eq(3)

$$Q_t' = \sum_{i=1}^{m} \frac{W_i . V_i . \alpha_i . \beta_i}{C_i} \tag{3}$$

In this formula, the meaning of $\alpha_i$ and $\beta_i$ are the same with those in formula (2), $W_i$=0 or 1, $\sum_{i=1}^{m} W_i = 1$; $W_i$=0 means tourists do not choose i as their transportation tools, while $W_i$=1 means the contrary; $V_i$ means the speed of i; $C_t$ means the passengers carrying capacity of the transportation tool I (Kang., 2012).

CO2 emitted by tourist breath per day can be recorded as 0.9kg per person. Carbon emission volume from tourist breath in a time unit is $Q_b$, $Q_b$ is Eq(4)

$$Q_b = \frac{0.9}{t} \tag{4}$$

If t=24, then $Q_b$ is the carbon emission volume from tourist breath in one hour; if t=24×60, then $Q_b$ is the carbon emission volume from tourist breath in one minute.

## 3. Measurement of carbon distribution order in a natural scenic area

Tourist touring system of a scenic area is a carrier to provide service to the tourists. Tourist distribution in the system directly influences the carbon distribution of the scenic area. Normally, the tourist touring system is made up of scenic spots and road networks, just as Figure 1.shows.

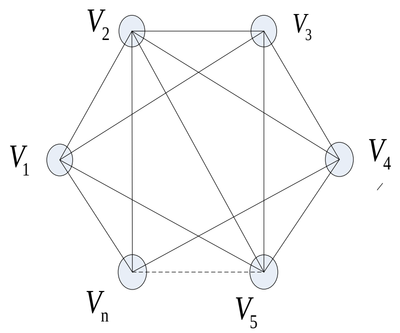


*Figure 1: The tourist sightseeing system*

Suppose altogether there are n scenic spots in a scenic area, and there are recorded as $V_1$, $V_2$ ,..., $V_n$. The total tourist number of each scenic spot at moment t is x (t) = {$x_1$(t), $x_2$(t), … , $x_n$(t)}. The time needed for a tourist to arrive and leave the scenic spot is T= {$T_1$, $T_2$,…, $T_n$}, and the time spend in each scenic spot is $\tau = \{\tau_1, \tau_2, ...\tau_n\}$ . In this case, tourist carbon emission in each scenic area is Eq(5) :

$$q_k = \frac{Q_t' \times t_k + Q_b \times (\tau_k + t_k)}{\tau_k}, \text{ k=1,2,...n.} \quad (5)$$

As the tourist number of each scenic spot at moment t is x (t) = {$x_1$(t), $x_2$(t), … , $x_n$(t)}, then the carbon load of scenic spot i at moment t is Eq(6):

$$l_i(t) = x_i(t) \cdot q_i,\ i = 1, 2, \ldots n. \quad (6)$$

Because the carbon sink volume of each scenic spot in a time unit is C= {$C_1$, $C_2$,…, $C_n$}, then the carbon load rate of scenic spot i at moment t is:

$$r_i(t) = \frac{l_i(t)}{c_i} = \frac{x_i(t) \cdot q_i}{c_i},\ i = 1, 2, \ldots n. \quad (7)$$

And the scenic area's carbon load rate at moment t is Eq(8):

$$\mathrm{R}(t) = \frac{\sum_{i=1}^{n} x_i(t) \cdot q_i}{\sum_{i=1}^{n} c_i}. \quad (8)$$

The scenic area's equilibrium degree of carbon distribution at moment t is Eq(9):

$$B(t) = \sqrt{\frac{\sum_{i=1}^{n} (r_i(t) - r(t))^2}{4}}. \quad (9)$$

In formula (9), B(t) represents deviation degree of the scenic area's actual carbon load rate and the most optimal load rate. The bigger the B(t) value is, the further the scenic area is from being equilibrium, and the smaller the the B(t) value is, the closer the scenic area is from being equilibrium.

In a scenic area, the whole carbon distribution load rate and carbon distribution equilibrium degree are important factors for its sustainable development. According to WAA operator and taking the scenic area's carbon load rate and carbon distribution equilibrium degree, the scenic area's carbon distribution order can be obtained by Eq(10):

$$O(t) = \omega \cdot \mathrm{R}(t) + (1 - \omega) \cdot B(t) \quad \omega \in [0, 1]. \quad (10)$$

When $\omega$=0, O (t) =B (t), and formula (10) is for the convenience of the primary level managerial staffs of the scenic area to adjust their responsible areas. When $\omega$=1, O (t) =R (t), and formula (10) is for the convenience of senior level managers to have a macro control of the scenic area.

## 4. Simulation study of carbon distribution

Suppose that a scenic area is a closed system, and then the scenic area model can be shown as Figure 2. Altogether there are four scenic spots representing by 1, 2, 3, and 4. I is the entrance and O is the exit. I→1, I→2 means from entrance to scenic spot 1 and scenic spot 2; 0.8 and 0.2 represent the two scenic spot's tourist shunting rate respectively; 20 represents the distance between I and 1, while 15 represents the distance between I and 2(km). In the scenic area, sightseeing bus and bus are the major transportation tools. Set $q_i$ = ( 0.02, 0.03, 0.04, 0.05 ) , C= ( 0.2, 0.3, 0.4, 0.5 ) and $\omega$=0.5. In the model, the time unit is one minute.

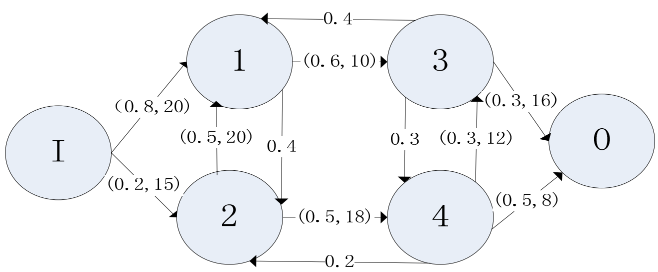


*Figure 2: A Scenic Area System*

Simulink uses a graphic system module to describe the dynamic system thus offering a graphical interactive environment for the users. Besides, the computing engine of MATLAB is applied to work on the dynamic system in a certain time span and a certain space. The Simulink simulation model for the above scenic area model is shown as Figure 3. The simulation is done by following the above mentioned measurement process to analyse the carbon distribution order of the scenic area.

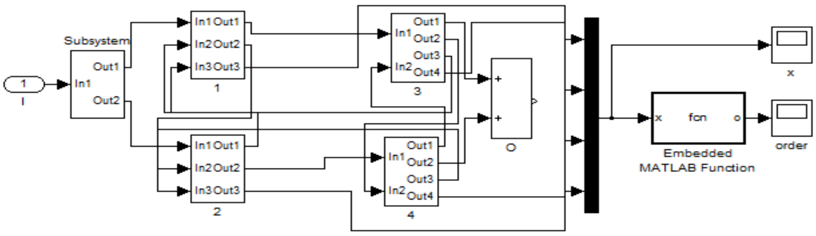


*Figure 3: The Simulation Model of the Scenic Area*

In the model, the output of X represents each scenic spot's tourist number at a certain time, and the output of order represents the scenic area's carbon distribution order.

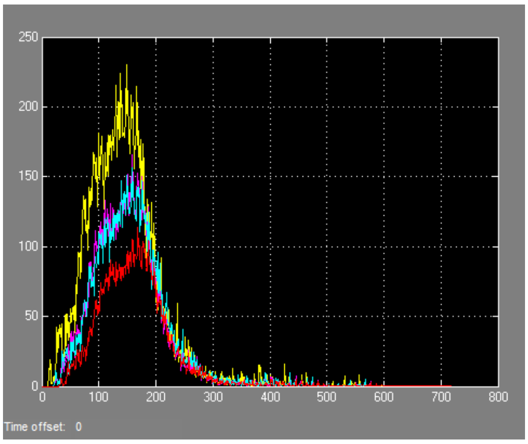


*Figure 4: Tourist number of each scenic spot*

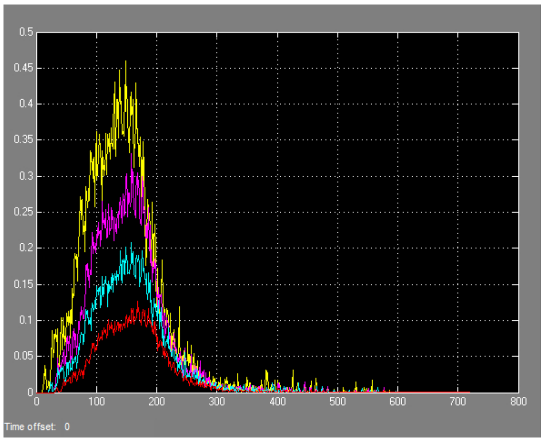


*Figure 5: Carbon distribution load rate of each scenic spot*

Yellow, purple, blue and red represented scenic spot 1, 2, 3 and 4 respectively.
The tourist data was sourced from Jiuzhai Valley in 30th July, 2012, and it was the number of newly entered tourist in each minute for each scenic spot, recording as $x_t(t)$, just as Figure 4 presented. Seeing from Figure 4, in time dimension, whatever scenic spot it was, tourist number differed in different time span. And tourist number of the four scenic spots all reached their peaks during the time span of 100-200 minutes. In space dimension, tourist number differed in different scenic spots even in the same time span. Seeing from Figure 4, it could be seen that tourist number of scenic spot 1 was the biggest while in scenic spot 4, tourist number was the smallest.
The carbon distribution rate ($R_t(t)$) of the four scenic spot in a day was shown in Figure 5. It could be observed that the carbon distribution load rate was in strong conformity with tourist distribution of the scenic spot, illustrating that carbon distribution load rate could well reflect the scenic area's tourist distribution.
The scenic area's carbon distribution load rate R(t) was shown in Figure 6. Seeing from the Fig, it could be told that during the time span of 80-200 minutes, the scenic area's carbon distribution load rate was beyond 1, and it was less than 1 in other time span. Therefore, it was necessary to guide tourists to different scenic spot at different time of a day.
The scenic area's carbon distribution equilibrium degree B(t) was shown in Figure 7. Judging from Figure 7, it could be told that during the time span of 80-200 minutes, the equilibrium degree B(t) was relatively high, indicating that in other time spans, the equilibrium degree was not that good.
Therefore, it was necessary to adjust tourist distribution by guiding tourists move from high load rate scenic spot to those with lower load rate.

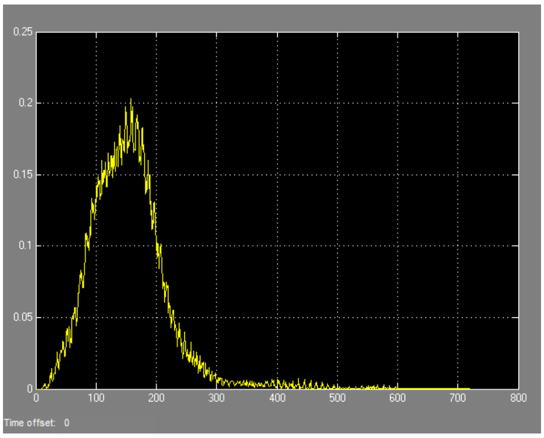


*Figure 6: Carbon distribution load rate*

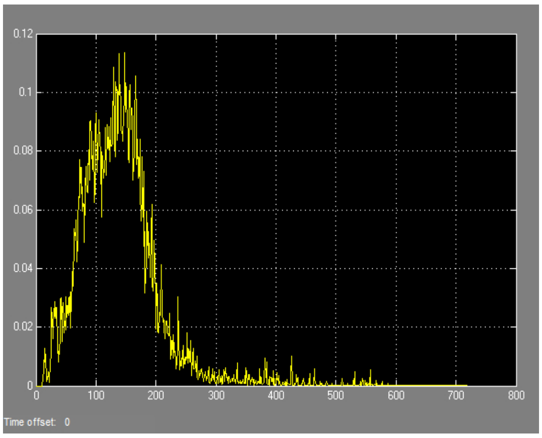


*Figure 7: Carbon distribution equilibrium degree*

When $\omega$=0.5, carbon distribution order degree O(t) was presented in Figure 8. O(t) took full account of tourist distribution order in both time and space dimensions. A bigger $\omega$ meant the carbon distribution load rate of a scenic spot was in a prominent state and the tourist scale was too large for the scenic area to carry. In this case, the senior managerial staffs would take macro measures to control the total tourist number or guide tourists to enter the scenic area at a different time. A bigger $\omega$ meant carbon distribution equilibrium degree dominated the scenic area and tourist distribution in different scenic spot was quite unbalanced. In this case, the primary level managerial staffs could carry out real-time adjustment to guide tourists move from high load rate scenic spot to those with lower load rate. By doing so, a balanced tourist distribution could be realized.

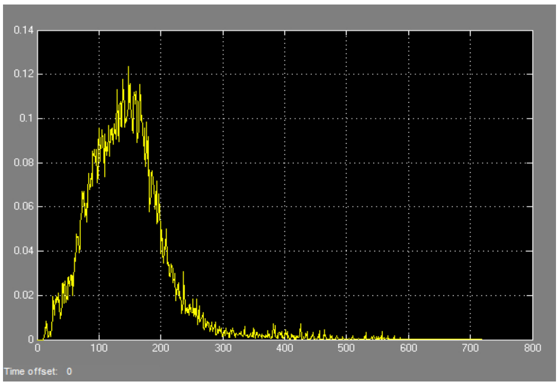


*Figure 8: Carbon distribution order degree of the scenic area*

Judging from Figure 8, carbon distribution order degree was obviously higher during the time span of 100-200 minutes, as a result, managerial staffs should take correspondent adjustment measures to balance the scenic area's carbon distribution order. On one hand, senior managerial staff should control the ceiling of tourist numbers and launch decisions to guide tourists entering the scenic area at a different time. On the other hand, the primary level managerial staffs should adopt appropriate measures to adjust touring routes, guiding tourists move from high load rate scenic spot to those with lower load rate. With macro and micro measures, the carbon distribution order would become balanced and so would tourist distribution in time and space dimension. Finally, the scenic area's ecological environment could be protected and sustainable development could be realized.

## 5. Conclusions

Low carbon tourism is still in its infancy. Although scholars at home and abroad have already done some related researches, on the whole the development of theory lags behind practical development, which greatly restricts the execution of low carbon tourism. This paper, by calculating tourist carbon footprint(mainly came from tourists' breath and the transportation) and the scenic area's carbon sink ability(vegetation's ability to absorb CO2), successfully got the carbon distribution load rate and carbon distribution equilibrium degree of the scenic area, making the measurement of carbon distribution order of the scenic area a possible thing. In the end, Simulink was used to do a simulation study of the natural scenic area's carbon distribution. Thanks to this simulation, the managerial staffs could get direct data, have a better understanding of the scenic area's carbon distribution situation and make timely measures to adjust tourist distribution. In this case, no scenic spot would suffer from a long-term overload burden which would definitely damage partial ecological environment, and eventually the ecological environment of the whole scenic spot could be protected. However, the measurement method for carbon distribution is not good, it is necessary to explore better methods.

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