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Research Note

The effect of climate change on the fall foliage vacation in China

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ABSTRACT

Fall foliage season has been a favorite time for sightseeing activity for centuries around the world. The dates of fall foliage coloration for Acer mono maxim at two stations (Beijing and Xi'an) with more than 30 years of records were collected. Time-series analysis showed a strong overall delay of the timing of the fall foliage vacation season. The trend for later fall foliage vacation season averaged 4–5 days/decade. Regression analysis revealed that the air temperature in September or October is decisive for the annual timing of the fall foliage vacation season. A warming of 1 °C led to a delayed beginning, best date and the end of fall foliage vacation of 5.3 days, 3.5 days and 3.7 days respectively. The beginning of fall foliage vacation season started to delay in the 1990s. Sudden delay in the best date of fall foliage vacation season of Beijing and Xi'an took place in the early 2000s and 1990s respectively. For the end of fall foliage vacation season, an abrupt delay occurred in the early 2000s. This has implications for tourists and the tourism industry with reference to the timing of trips and their promotion.

1. Introduction

Seasonal changes in vegetation appearance are generally appreciated by tourists (Bender, Schumacher & Stein, 2007). During the fall, some destinations become particularly attractive when Acer species start changing color, such as in most of southern Canada; much of the eastern part of the United States; Northern, and Western Europe; most of northern China, as well as Korea, and Japan (Daniel & Edward, 1993; William, 1999, pp. 4–19). This fall foliage vacation season occurs between the onset of leaf coloration and the end of leaf fall. There is usually a period of a week or so when the fall foliage in a particular area is at its best (Daniel & Donald, 2007).

The autumnal foliage season has become a favorite time for weekend recreation and week-long vacations (Christine & Daniel, 1995). The spectacular colors of autumn mean more than just pretty scenery to travel and tourism industry. In China, red leaf viewing has been a quite popular recreation activity for centuries and today draws large numbers of travelers to famous spots. The Fragrant Hill Park Red Leaf Festival attracted 1.36 million of tourists in 2011 (http://www.xiangshanpark.com/cn).

The fall foliage vacation is sensitive to climate change as climate-driven changes in phenology are becoming more apparent (Daniel, 2003; Zheng, Ge, Hao, & Wang, 2006). The average annual length of the growing season has lengthened by 4.8 days in autumn since early 1960 (Menzel & Peter, 1999). Leaf coloring has been delayed by 4.8 days since the early 1960s, and autumnal senescence has been delayed by between 1.3 and 1.8 days per decade during the last 30 years (Menzel et al., 2006).

Phenological change is one of the most readily observable ecosystem reactions to climate change. Phenology therefore offers promise as a tool for estimating the impact of climate change on leaf viewing tourism. We present a quantitative study where the contribution that climate change makes to Chinese fall foliage vacation is assessed. This analysis can be used to help policy makers to design mitigation strategies and adaptation approaches that enhance the adaptive capacity of the tourism industry of China to climate change.

2. Materials and method

2.1. Materials

Analysis was undertaken for Acer mono maxim, widespread and typical red leaf specie in China. The leaf coloration records were obtained from the Chinese Phenological Observation Network (CPON) consisting of a total of 25 observation stations with the

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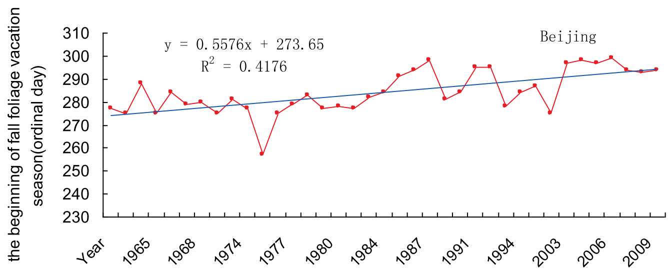

Fig. 1. Trend of the dates of the beginning of fall foliage vacation season in Beijing, 1963–2010.

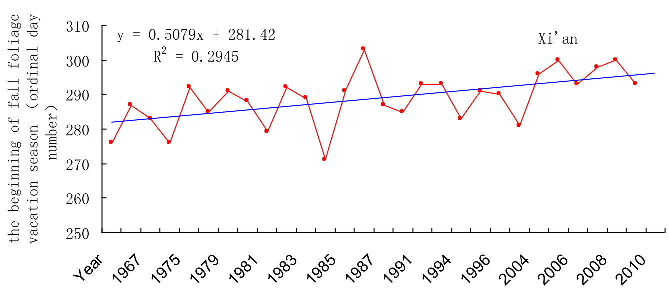

Fig. 2. Trend of the dates of the beginning of fall foliage vacation season in Xi'an, 1966–2010.

longest series recorded since 1963. The dates of onset of coloration, peak coloration and last defoliation date of Acer mono maxim at two stations (Beijing and Xi'an) with more than 30 years of records were included.

The Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Science (CAS) guide to phenology observation (IGSNRR 1965–1992) defines the start coloring date as the first day when more than 5% of the leaves on the specified observation tree appear red or yellow. The full coloration is decided to occur when 90% of the crowns of the relevant trees are completely red. The leaf fall day occurs when 95% of the leaves fall off from the same tree.

We defined the beginning, best and the end of the fall foliage vacation season as the dates of start coloring, full coloration and leaf fall, respectively.

Monthly air temperature data were collected from China Meteorological Data Sharing Service System.

2.2. Method

Firstly, we checked the synchronization and ordering of the records (Bai, Ge, & Dai, 2011).

Secondly, the standard error test was used to identify the outliers of the records. The extreme outliers, whose value exceeds

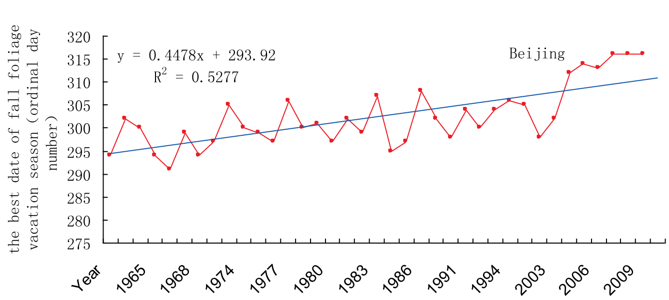

Fig. 3. Trend of the best date of fall foliage vacation season in Beijing, 1963–2010.

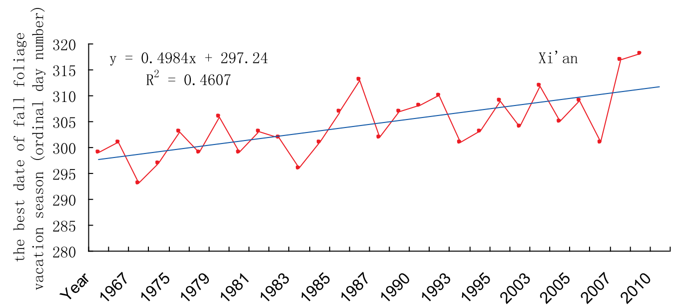

Fig. 4. Trend of the best date of fall foliage vacation season in Xi'an, 1966–2010.

three times of the standard error, were removed from the dataset (Erik, Anders, Magnus & Andersson, 2006).

Thirdly, an abrupt change and shift in the timing of the fall foliage vacation was examined and identified using the Mann–Kendall test (Adina, Iulian, Catalin, Florin, & Alexandru, 2012; Mahyoub, 2012).

The null hypothesis H_0 is that the data come from a population where the random variables are independent and identically distributed. The alternative hypothesis H_1 is that the data follows a monotonic trend. The Mann–Kendall test statistic can be calculated by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \tag{1}$$

$$\operatorname{sgn}(x) = \begin{cases} +1, & x > 0 \\ 0, & x = 0 \\ -1, & x < 0 \end{cases} \tag{2}$$

where x_i and x_j are observations from years i to j, n is the length of the dataset. The mean $E(s)$ and the variance $Var(s)$ are as follows:

$$E(s) = 0 \tag{3}$$

$$Var(s) = \frac{\left[n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_j - 1)(2t_j + 5)\right]}{18} \tag{4}$$

where p is the number of the tied value, t_j is the number of the data points in the jth tied group.

The standard normal variable is given by:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 & S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \tag{5}$$

The H_0 should be rejected if $|Z| \geq Z_{1-a/2}$ is at the a level of significance in a two-sided trend test. The Z value is used to evaluate the statistically significant change trend. A positive Z indicates a delayed trend while a negative Z means an advanced trend.

Table 1
The distribution of fall foliage vacation season across the week.

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Beijing	0	16.22	8.11	18.92	13.51	35.14	8.11
Xi'an	13.79	31.03	3.45	10.34	0	17.24	24.14