INVESTIGATING THE LOW TEMPERATURE EFFECT ON VEGETATION COVER DURING EARLY SPRING AT LIEN-HUA-CHI EXPERIMENT FOREST IN TAIWAN

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ABSTRACT: Temperature is an important environmental factor affecting plant growth and geographical distribution. Early spring is the most crucial period for plants to burst. It is also the period that plants are very sensitive to the temperature changes. In low temperature events which exceed the tolerance range, the growth pattern of the plants can be disturbed.

In order to investigate the temperature effect on plant growth, this study selects the area of Lien-Hua-Chi experimental forest as the case and uses the daily data of temperatures in March from 2000 to 2010. The normalized difference vegetation index (NDVI) is calculated based on the SPOT images before and after the low temperature events. The low temperature effects on the vegetation cover can be quantified by analyzing the changes of NDVI, which provide valuable information on cold resistance of different topographic sites by comparing the results between different elevations and aspects in this area.

The results show that the natural forest is more sensitive to the low temperature during early spring, and the change of NDVI change ratio is related to the topographic positions. The NDVI is lower while the decrease of NDVI is larger at the higher elevations and the windward aspects.

1. INTRODUCTION

Climate change is a global issue and has been observed to cause varied effects worldwide. There are increasing attentions paid on how climate change can possibly alter weather patterns and affect ecosystem. Notably, climate change has great impacts on forest ecosystems, including primary productivity, plant growth, migration of various tree species, biodiversity, and regime disturbances such as forest fire (Boisvenue and Running, 2006; Goldblum and Rigg, 2005; Reinhard et al., 2005; Wotton et al., 2003; Scheller and Mladenoff, 2005; Miles et al., 2004).

As a result of global climate change, it is expected that the average weather conditions will change and the extreme conditions probability will increase. The low temperature effect on plant growth is needed to be investigated because the global temperature is changing and becoming extremely.

In this research, Lien-Hua-Chi experimental forest was selected as the case study area. The daily temperatures data in March from 2000 to 2010 were analyzed to get the low temperature events. The normalized difference vegetation index (NDVI) is calculated based on the SPOT images before and after these events. The low temperature effects on the vegetation cover can be quantified by analyzing the changes of NDVI, which provide valuable information on cold resistance of different topographic sites by comparing the results between different elevations and aspects in this area.

2. METHODS

2.1 Study area

The Lien-Hus-Chih Experimental Forest of Taiwan Forestry Research Institute, located in central Taiwan (Figure 1), was selected as the study site. The total area is about 548 ha. It situates 576 to 925 meters above the sea level with an average altitude of 701 meters. The site is characterized as a humid subtropical forest with an annual mean temperature of 21.1℃ and mean annual rainfall of 2,211 mm. The major forest type is natural hardwood evergreen forest intermixed with artificial plantations.

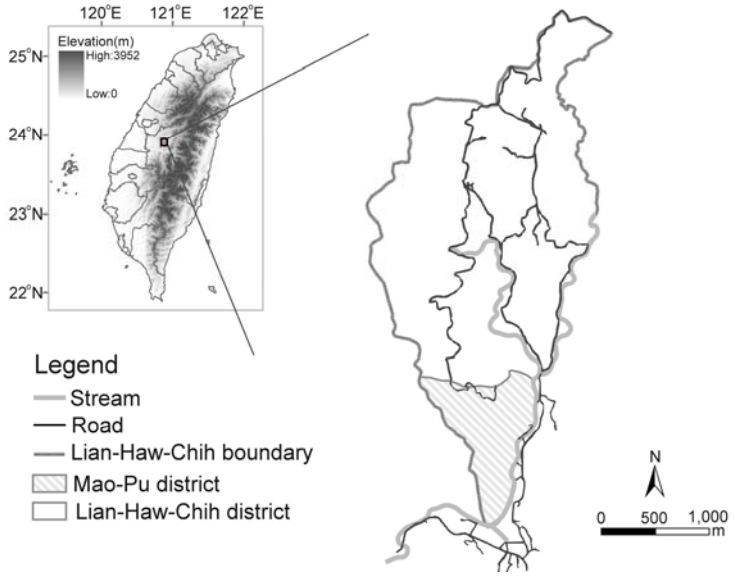

Fig.1 Study area

2.2 Study materials

2.2.1 Low temperature data

We used meteorological data including daily temperature recorded in Sun Moon Lake weather station during early spring in March from 2000 to 2010. The definition of low temperature event in this study is relative low temperature, but not absolute low temperature. The largest decrease of temperature was selected as low temperature event in each year.

2.2.2 Satellite image data

This study used level 10 SPOT multi-spectral images with DTM geometric corrections. Twenty images acquired before and after low temperature events were selected for analysis between 2000 and 2010 (2006 was excluded because of the poor image quality). The time intervals were limited in one month to minimize the vegetation growth effect. The dates of images acquisition were listed in Table 1.

Table.1 Dates of images and low temperature

Year	Image before low temperature event	Date of low temperature (the relative lowest temperature ℃)	Image after low temperature event	Time interval
2000	03/10	3/17(15.2)	03/21	11
2001	03/05	3/8(12.7)	03/17	12
2002	02/14	3/6(13.5)	03/11	25
2003	02/27	3/8;3/10(11.2)	03/15	16
2004	02/26	3/4(9.7)	03/13	15
2005	03/07	3/13(8.0)	03/17	10
2007	02/28	3/7(11.6)	03/15	15
2008	03/09	3/24(14.8)	03/25	19
2009	03/13	3/14(12.5)	03/18	5
2010	03/06	3/10(7.7)	03/19	13

2.3 Methods

2.3.1 Multi-temporal satellite images relative radiometric correction

Different sun elevation, incidence, atmospheric radiation effects and terrain effects may lead to different reflection in the images acquired in different timing. The weather conditions of images acquisition also make un-isometric deviation in the images reflection. Therefore, the histogram match enhancement approach was applied as the relative radiometric correction in order to compare multi-period satellite images. Human disturbed area was excluded for analysis to avoid interferences of vegetation changes directly resulted from human activities.

2.3.2 Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) takes the difference between near-infrared (NIR) and red channel reflectance values normalized by the sum of these two channels: NDVI= (NIR-R)/(NIR+R). The range of NDVI is from -1 to 1. The index often corresponds to non-vegetated area such as cloud, water, roads, and buildings with values near or below zero. NDVI may eliminate sun incidence influenced by slope and aspect, and decrease spectrum reflection difference between area and season. It is widely used vegetation indices for studies on changes in vegetation condition and phytophenology (Birky, 2001; Scanlon et al., 2002; Li et al., 2004). NDVI was calculated to analyze vegetation greenness before and after the low temperature in this study. It has been proofed as a suitable method to evaluate the vegetation change.

2.3.3 Change Ratio of Vegetation

The low temperature effects on the vegetation cover can be quantified by analyzing the NDVI changes ratio. The change ratio (CR) can be calculated as $CR = (NDVI_{after} - NDVI_{before}) / NDVI_{before}$ which provide valuable information on cold resistance. The CR values of nature forest and plantation were calculated to examine the cold resistance in different forest phase. Meanwhile, the CR values of different elevations and aspects were calculated and compared to find the spatial variety of low temperature effect.

3.RESULT

3.1 Vegetation Change in Different Forest Phase

The NDVI of natural forest is higher then that of plantation before and after low temperature disturbance. The average NDVI value decreases in natural forest but increases in plantation after low temperature event in last 11 years. The plantation is made of coniferous tree species in this study area, so it shows that the plantation is more resistive to the cold weather because the conifer is originated from the frigid zone. In the other hand, the natural forest made of broadleaf tree species is more sensitive to the low temperature.

Table 2. The NDVI in different forest phase before and after low temperature events

year	NDVI of total forest			NDVI of natural forest			NDVI of plantation		
	before LT	after LT	CR(%)	before LT	after LT	CR(%)	before LT	after LT	CR(%)
2000	0.5176	0.5139	-0.72	0.5442	0.5360	-1.51	0.4929	0.4934	0.10
2001	0.5148	0.5125	-0.45	0.5402	0.5296	-1.96	0.4912	0.4966	1.09
2002	0.5178	0.5168	-0.19	0.543	0.5436	0.11	0.4939	0.4914	-0.50
2003	0.5131	0.5139	0.15	0.5314	0.5283	-0.59	0.4964	0.5007	0.87
2004	0.5166	0.5138	-0.54	0.5361	0.5269	-1.71	0.4988	0.5019	0.62
2005	0.5191	0.5178	-0.26	0.5352	0.5362	0.18	0.5041	0.5006	-0.69
2007	0.5186	0.5154	-0.62	0.5342	0.5243	-1.85	0.5041	0.5071	0.60
2008	0.519	0.5197	0.12	0.5383	0.5421	0.71	0.5012	0.4988	-0.47
2009	0.5215	0.5213	-0.03	0.5396	0.5382	-0.25	0.5046	0.5056	0.19
2010	0.5162	0.5169	0.14	0.535	0.534	-0.20	0.4987	0.5011	0.48
Ave.	0.5174	0.5162	-0.24	0.5377	0.5339	-0.71	0.4986	0.4997	0.23

Table 3. Percentage of decrease, unchanged, and increase in natural forest and plantation

year	Natural forest			Plantation		
	CR<0	CR=0	CR>0	CR<0	CR=0	CR>0
2000	65.44%	1.07%	33.48%	50.13%	1.23%	48.63%
2001	62.81%	0.47%	36.72%	47.22%	0.33%	52.45%
2002	52.06%	0.97%	46.98%	66.12%	0.55%	33.34%
2003	49.27%	1.86%	48.86%	41.44%	1.50%	57.07%
2004	52.55%	0.13%	47.32%	45.37%	0.11%	54.52%

2005	50.01%	0.55%	49.45%	55.88%	0.40%	43.72%
2007	69.15%	1.27%	29.58%	48.18%	1.16%	50.67%
2008	39.05%	1.86%	59.09%	55.77%	1.60%	42.64%
2009	53.34%	2.46%	44.20%	47.26%	2.75%	49.99%
2010	51.65%	0.54%	47.81%	47.88%	0.55%	51.57%
Ave.	**54.53%**	**1.12%**	**44.35%**	**50.52%**	**1.02%**	**48.46%**

3.2 The relationship between vegetation change and topographic condition

There are two important results related to the topographic effects. Firstly, the correlation between natural forest vegetation change and elevation is negative. In the other words, the NDVI is decreasing with the elevation, shown in Table 4 (The plantation is absent over 800m). Secondly, the NDVI is lower windward then leeward, and the decrease of NDVI is larger windward then leeward. The low temperature causes the major impacts on west and west-south aspects in all kinds of forest (shows in Table 5). It is evidence that the terrain provide a natural protection for the vegetation against the cold pressure caused by the cold front from west side.

Table 4. The average NDVI changes in different elevations

Elevation (m)	NDVI of total forest			NDVI of natural forest			NDVI of plantation		
	before LT	after LT	CR(%)	before LT	after LT	CR(%)	before LT	after LT	CR(%)
500~600	0.4762	0.4885	2.58	0.5442	0.5506	1.18	0.4698	0.4826	2.73
600~700	0.5058	0.5049	-0.18	0.5304	0.5278	-0.48	0.4996	0.4991	-0.10
700~800	0.5319	0.5288	-0.58	0.5374	0.5338	-0.67	0.5147	0.5133	-0.27
800~900	0.5444	0.5401	-0.80	0.5440	0.5392	-0.87	No data	No data	No data
>900	0.5397	0.5267	-2.37	0.5397	0.5267	-2.41	No data	No data	No data

Table 5. The average NDVI changes in different aspects.

aspect	NDVI of total forest			NDVI of natural forest			NDVI of plantation		
	before LT	after LT	CR(%)	before LT	after LT	CR(%)	before LT	after LT	CR(%)
W	0.4873	0.4756	-2.37	0.5044	0.4960	-1.65	0.4817	0.4689	-2.62
WS	0.5086	0.5009	-1.52	0.5245	0.5172	-1.38	0.4997	0.4917	-1.60
WN	0.4644	0.4632	-0.23	0.4947	0.4894	-1.04	0.4526	0.4529	0.12
ES	0.5318	0.5309	-0.18	0.5534	0.5484	-0.90	0.5124	0.5151	0.53
S	0.5330	0.5295	-0.66	0.5518	0.5469	-0.89	0.5086	0.5069	-0.33
N	0.4883	0.4882	-0.01	0.4975	0.4945	-0.59	0.4772	0.4807	0.73
E	0.5270	0.5292	0.41	0.5487	0.5459	-0.51	0.5056	0.5125	1.39
F	0.5069	0.5056	-0.25	0.5284	0.5269	-0.27	0.4870	0.4859	-0.21
EN	0.5107	0.5131	0.47	0.5255	0.5244	-0.22	0.4901	0.4974	1.48

4. DISCUSSION

The radiometric correction method may affect the NDVI value so that a relative method was selected to minimize the error. Histogram match has been proofed as an effective radiometric correction approach in multi- period issues in many literatures and not include in this study.

Although the time interval is not the same as a result of images quality control which may lead to some error of absolute CR value, the change trend can be discovered in this study. After low temperature event, the NDVI of Lien-Hua-Chi Experimental Forest shows decrease insignificant might be the trade off between the decrease of disturbance and increase of growth in spring.

5. CONCLUSION

Temperature is an important environmental factor affecting plant growth and geographical distribution. The impact of low temperature between natural forest and plantation is different, i.e., the decrease of greenness in natural forest is larger than in plantation. The change of NDVI caused by spatial variation was closely related to geomorphology at a finer scale. The decrease of NDVI is significant at higher elevation and windward than in other terrain condition. When the elevation increases and the temperature decreases, the low temperature impact to the vegetation becomes observable.

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