THE PHENOLOGICAL FLUCTUATIONS AS A POSSIBLE SIGNAL OF CLIMATIC CHANGES

Višnja Vučetić, Marko Vučetić

Meteorological and Hydrological Service, Grič 3, Zagreb, Croatia
E-mail: *visnja.vucetic@cirus.dhz.hr*

Abstract: The development (phenological) stages of some perennial plants and herbaceous plants as well stages of field work operation have been analysed at the mountain station Gospić during the available periods (mainly 1954–2004). The results of the linear trend analysis indicate a significant earlier blooming for plants which bloom in the second half of April and May. Those variations are the consequence of a significant increase in winter and spring insolation and air temperature.

Key words – phenological observations, linear trend, climatic variations, the mountain Gospić station

1. INTRODUCTION

Phenology is the science which studies the regularity of periodical occurrences in plant development from the beginning to the end of the vegetation period. In order to identify the climatic variations in specific regions according to phenological data, plants that grow freely in the nature without any agro-technical practice added or the long-term observations of the same phenological object should be analysed. The wild herbaceous plants satisfy the first condition; the fruit trees the second condition and the forests trees and bushes both conditions.

The meteorological station with the longest series of observations in the Croatian mountain area is the Gospić station (564 a.s.l.) which was established in November 1872. Therefore, the measurement at Gospić has an important role in detecting the climatic changes. In spite of the fact that development stages of forest trees and bushes and herbaceous plants have been observed at Gospić mainly since 1954 and fruit trees since 1968, there are not any phenological analyses for this station. Thus, the aim of this paper is to study linear trends of development stages of the wild herbaceous plants (snow drop, saffron, dandelion and oxeye daisy), the forests trees and bushes (buckeye, locus-tree, weeping ash, birch, lilac, bour tree, white thorn, black thorn, hazel and cornel tree), fruit trees (apple, peach and plum) and field work operation in Gospić during the available periods (mainly 1954–2004) as to detect a possible signal of climate changes.

Generally, the connection between phenological and meteorological characteristics in Croatian area has not yet been researched sufficiently. A comparative analysis of phenological and meteorological data for the Zavižan region in the northern part of Mount Velebit at an altitude of about 1600 m shows that not only accumulated heat during the vegetation period but also weather conditions in the cold season play an important role (Vučetić and Vučetić, 1992 and 2003). Linear trend analysis indicate a significant prolongation of the vegetation period over the Zavižan area the autumn.

2. RESULTS AND DISCUSSION

In forest plants six development stages are observed: the commencement of leafing, blooming and ripening, the full blooming, the yellowing and falling of leaves and in fruit trees are added the end of blooming and the harvest. In herbaceous plants only blooming is observed. The first flowers occur on snow drop, hazel, saffron and cornel tree in the middle or the end of March (Tab. 1). Dandelion, black torn, birch, pear and plum trees bloom a month later. Apple tree, lilac, buckeye, oxeye daisy, locus-tree and bour tree bloom up the latest, during May or beginning of June. The yellowing and falling of leaves of the observed forest and fruit trees ended already on October. As plants quickly react to temperature and precipitation fluctuations, the commencement and the duration of the growing stages vary greatly. Interannual differences in the commencement of some growth stages of the same kind of plants can reach up 3 weeks (example for oxeye daisy, hazel and birch).

The results of linear trend analysis and the Mann-Kendall rank test (Mitchell et all, 1966) indicate the significant earlier blooming for the plants which bloom in the second half of April and May (Tab. 1 and Fig. 1). The trend analysis of the leafing of peach trees and lilac and the yellowing of leaves of weeping ash have been shown significant trend at the 0.05 level in sense of earlier commencement of leafing and later yellowing. Those fluctuations are the consequence of significant increase in winter and spring insolation duration what cause increase in the mean spring maximum and winter minimum temperature and decrease in number of the freezing days (Tab. 2 and Fig. 2). It is also noticed that the cutting of winter crop is earlier in summer.

The trend analysis of the secular time series of other meteorological data show significant increase in the annual values of mean air pressure, mean and absolute minimum temperature, insolation duration and number of dry days, and decrease in annual precipitation amount, mean and minimum relative humidity and number of days with precipitation ≥ 10 mm (but increase in number of rainy days ≥ 0.1 mm). Such progressive growth in stability of the dry weather depends on recent prevailing meridional circulation rather than zonal over the Atlantic and Europe (Čapka, 1998). A slight decrease is evident in other element as the maximum height of snow cover and the numbers of days with snow cover over 1 cm, 20 cm, 30 cm and 50 cm.

Finally, it should be mentioned that the absolute minimum temperature of -36.0°C in Croatia was measured at Gospić on 4 February 1929.

Table 1. Mean dates and linear trends for different phenological stages of plants and field work operation (day/10 years) for Gospić. The trend with the 0.05 significant level is marked by green.

HERBACEOUS PLANTS			FRUIT TREES 1968–2004								
Period	Pheno-phases	1		1	2	3	4	5	6	7	8
1953–2004	Snow drop	10-Mar -1.04	Apple-tree	25-Apr -2.15	2-May -3.31	8-May -3.92	15-May -5.11	21-Sep 1.72	3-Oct 0.86	19-Oct -3.25	29-Oct -2.32
1961–2004	Saffran	16-Mar -2.07	Pear-tree	21-Apr -2.32	24-Apr -2.26	30-Apr -2.11	7-May -3.18	11-Sep 4.88	22-Sep -3.80	18-Oct -1.81	24-Oct -1.67
1954–2004	Dandelion	19-Apr 0.11	Plum-tree	27-Apr -0.62	28-Apr -1.21	2-May -1.26	11-May -2.39	7-Sep -0.34	21-Sep 0.17	17-Oct -1.20	24-Oct -0.07
1964–2004	Oxeye daisy	19-May -5.59									

FOREST TREES AND BUSHES						
Period	1954–2004					
Pheno-phases	1	2	3	5	7	8
Buckeye	21-Apr -0.05	10-May -1.65	15-May -1.17	25-Sep -0.70	12-Oct -3.22	21-Oct -1.60
Locus-tree	–	29-May -5.76	4-Jun -4.41	–	–	–
Weepening ash 1958-2004	3-May -2.80	–	–	–	15-Oct 2.75	22-Oct 1.52
Birch 1959-2004	21-Apr -1.82	23-Apr -1.83	–	–	13-Oct -4.13	27-Oct 1.42
Lilac 1953–2004	14-Apr -1.77	8-May -1.57	13-May -2.00	–	–	–
Bour tree	–	1-Jun -2.43	7-Jun -1.36	26-Aug 0.85	–	–
White torn	–	22-May -3.30	–	10-Sep -1.90	–	–
Black torn	29-Apr -1.40	22-Apr -2.05	–	–	–	–
Hazel 1962–2004	–	12-Mar 5.11	18-Mar 3.66	11-Sep 6.29	–	–
Cornel tree	–	23-Mar -0.90	1-Apr -2.00	7-Sep 0.60	–	–

FIELD WORK OPERATION			
	1954–2004	1962–2004	
	1	2	3
Spring field work	19-Mar 2.30	14-Apr 1.47	10-May 1.38
Haying	17-Jun -1.30	27-Jun -2.30	15-Jul -0.88
Cutting of winter crop	24-Jul -2.70	31-Jul -6.07	9-Aug -3.20

Phenological stages:
1 – the commencement of leafing
2 – the commencement of blooming
3 – the full blooming
4 – the end of blooming
5 – the commencement of ripening
6 – the harvest
7 – the full yellowing
8 – the full leaves falling

Field work operation:
1 – the beginning
2 – the full work
3 – the end

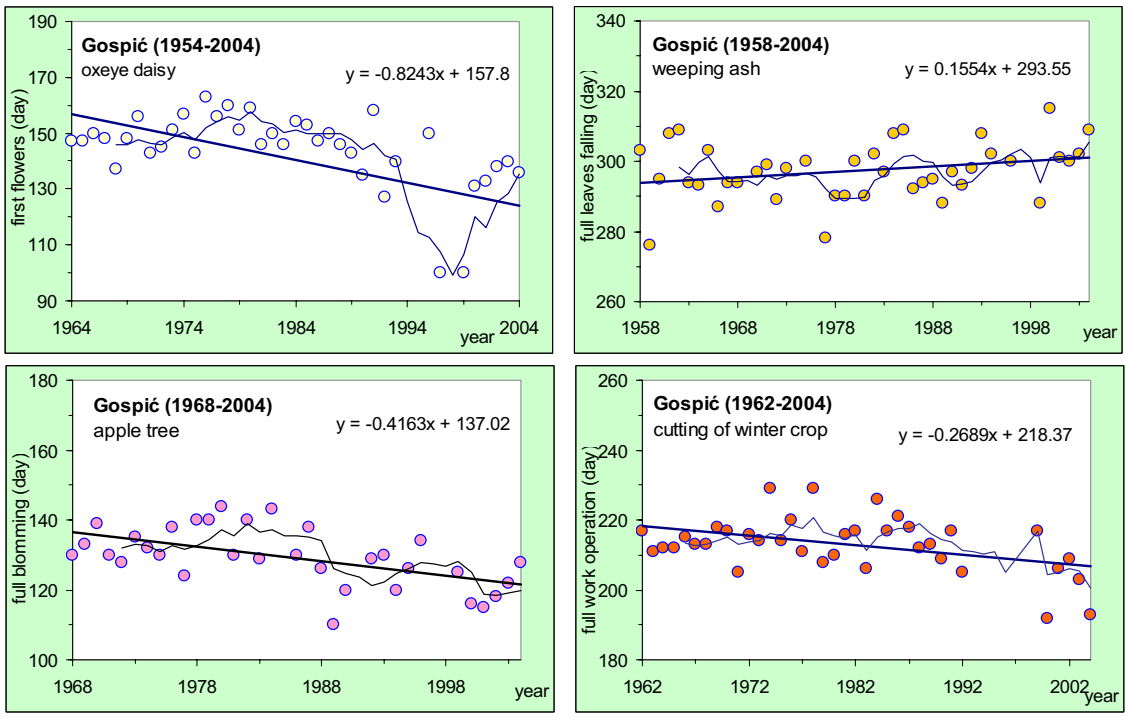

Figure 1. Time series (dots) of phenological stages (days), the curves of a 5-year series of moving average and the linear trends for Gospić. x is number of years (1, 2, 3….n).

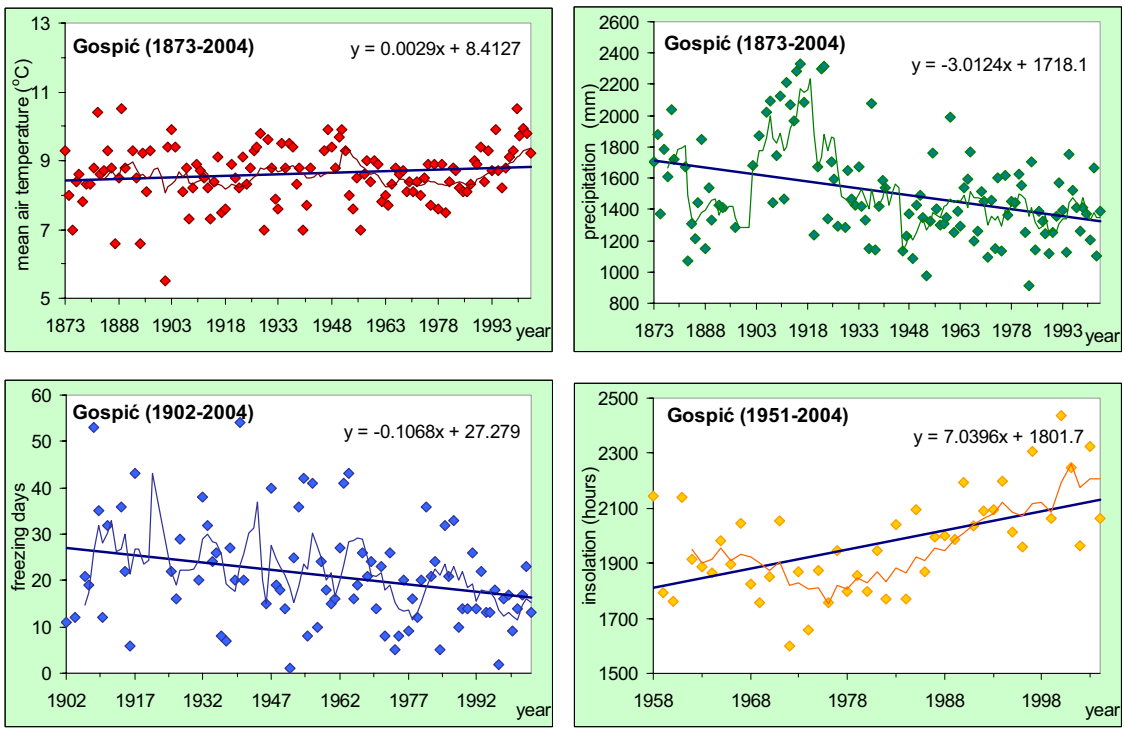

Figure 2. Time series (dots) of mean annual air temperature (°C), freezing days, precipitation amount (mm) and insolation duration (h), the curves of a 11-year series of the moving average and the linear trends for Gospić. x is a number of years (1,2,3…n).

Table 2. Mean or extreme values and linear trends for different meteorological elements (/100 years except for insolation h/10 years) for Gospić. The trend with the 0.05 significant level is marked by yellow.

Mean or extreme Trend	Air temperature (°C)					Air relative humidity (%)		Precipitation (mm)		Cloudiness (1/10)	Air pressure (hPa)	Snow cover (cm)	Insolation (h)
1873–2004		1902–2004				1873–2004					1875-2004	1925-2004	1958-2004
	MEAN	MMAX	MMIN	MAX	MIN	MEAN	MIN	SUM	dMAX	MEAN	MEAN	MAX	SUM
Winter	-0.8 2.03	3.7 0.93	-5.1 1.75	20.1 1.61	-36.0 3.71	85 -5.97	18 -2.13	131.3 -23.43	129.7 -8.17	6.9 0.28	950.4 0.35	285 -17.66	215.5 21.50
Spring	8.4 0.17	13.9 1.04	2.6 0.33	30.3 0.01	-23.5 0.94	76 -5.59	11 -10.99	117.8 -31.68	126.2 -10.14	6.0 0.57	948.3 1.61	110 -7.57	311.3 24.10
Summer	17.9 0.61	24.7 -026	10.4 0.06	38.7 0.08	-1.8 0.85	71 0.07	13 -6.51	86.0 -15.16	120.9 -5.09	4.2 0.79	950.7 0.52	–	828.6 23.96
Autmn	9.1 0.0	15.2 -0.10	4.1 0.30	33.3 1.57	-23.2 0.23	82 -3.28	14 -15.60	171.9 -32.43	313.6 -11.58	6.0 0.38	951.5 0.98	95 13.85	392.4 2.02
Year	8.6 0.29	14.4 0.30	2.9 0.89	38.7 0.48	-36.0 4.12	79 -3.22	11 -8.22	1503.1 -298.96	313.6 -15.79	5.8 0.49	950.3 0.75	285 -11.94	1968.1 70.40

Period	Days	Mean value Trend	Period	Days	Mean value Trend	Period	Days	Mean value Trend
1902–2004	freezing	21 -10.53	1873–2004	R≥ 0.1mm	138 12.67	1925–2004	SC ≥ 1 cm	66 -6.00
	icy	26 -5.55		R≥ 10 mm	50 -9.13		SC ≥ 20cm	39 -8.93
	cold	117 0.92		R≥ 20 mm	25 -5.97		SC ≥ 30cm	16 -3.56
	warm	55.6 -7.58		R≥ 50 mm	3 -1.96		SC ≥ 50cm	5 -4.68
	hot	11 -0.38		rainy	118 18.34	1873-2004	snowy	33 1.54
1873–2004	clear	68 -32.02		RH ≤ 30%	11 24.10	MMAX and MMIN – mean maximum and minimum air temperatures dMAX – daily maximum precipitation of amount		
	overcast	124 4.61		RH ≥ 80%	103 -49.95			

CONCLUSION

The results of the current analysis for Gospić present that the great fluctuations of development stages of forest trees and bushes, herbaceous plants and fruit trees were noticed in spring when the vegetation started. A climate change in this region is being indicated which the linear trend analysis of secular time series of meteorological data of the Gospić station confirm.

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