THE EFFECT OF ENVIRONMENTAL FACTORS ON THE PHYTOMASS PRODUCTION OF SANDY MEADOWS

by

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The examinations of the authors were begun in 1968 within the IBP, and aimed at acquiring information on the production conditions of natural sandy meadow associations, as well as cultivated stands, further at disclosing the effect of factors influencing production.

With this in view, in the years 1968 and 1969, the authors examined the monthly changes of the phytomass in the various ecosystems during the vegetation period, and followed with attention the values of the climatic factors – monthly mean temperature, relative atmospheric humidity, monthly total precipitation, global insolation, as well as soil moisture – of the examined associations. In their paper (Kovács–Láng – Szabó, 1971) they dealt with the production conditions of the examined meadow associations and with the trend of the moisture content of their soils. In the present work – a continuation of the said paper – they strove to throw light upon the role of the examined environmental factors in the production of the sandy meadows by applying mathematical methods.

Material and methods

The examinations took place in Csévharaszt (Hungarian Plain), a region with wooded steppe vegetation of the sandy area between the rivers Danube and Tisza, in meadow associations forming a natural succession series. The initial stage of the succession series is formed by a *Brometum tectorum* sandy meadow which gradually yields ground to an association of a perennial open sandy meadow: *Festucetum vaginatae danubiale*. The latter one is found in the widest range within the area of the examination. The closing of the grassland cover begins with the association *Festucetum sulcatae*, which – in places – leads to the formation of closed *Festucetum wagneri*. The present examinations were centred upon the perennial sandy meadows *Festucetum vaginatae* and

Festucetum wagneri. For comparison, the authors determined the production values of rye, cultivated in a near-by field. A detailed description of the meadow associations is to be found in earlier papers of the authors (Kovács – Láng, 1970, Kovács – Láng – Szabó, 1971, Verseghy – Kovács – Láng, 1971). The phytomass was weighed every month, by taking 11, 20×20×20 cm. monoliths from each of the associations and separating the cryptogamic (moss, lichen) and floral living and non-living parts to be found on the surface of each monolith, as well as the underground parts in it.

Simultaneously with sampling, humidity was measured by means of a neutron-scattering moisture-meter in the soil of the examined associations, at depths of 20, 40, 60, 100, 140 and 200 cm. (Kovács – Láng – Szabó, 1971). From among the climatic factors, the values of precipitation were founded on the measurements of the Csévharaszt station, those of temperature and relative atmospheric humidity on the ones of the Monor station, while those of global insolation on the ones of the Pestlőrinc Observatory. The said values can be adapted to the examined area. (As regards the problems of adaptation, see Précsényi, 1971).

When elaborating the data, the authors did calculations for determining the depth of soil in the various associations, of which the change in moisture content correlated most with the change in phytomass production.

The change of production is expressed most expediently by productivity – i. e. the value of production to the time unit (1 day) and to the space unit – in this way the values of the examined factors also reflect the extent of the changes ensued between the dates at which the samples were taken. So that information can be acquired on the role of the factors, on their weight as compared with one another, as well as on other factors – not examined by them – the authors did path analysis (Osváth, 1961, Précsényi, 1971).

Results of the examination

The data on the productivity of the overground floral living parts of the meadows selected for assessment are summarized in *Table I*.

In the natural meadows *Festucetum vaginatae* and *Festucetum wagneri* two production maximums are to be observed, in early summer and in autumn.

Table II. includes the values of the changes of the examined environmental factors.

The preliminary correlation analysis conducted by the authors concerning the relationship between the change in moisture content as measured at various depths and productivity indicates, that at the deeper levels (140 cm.) of the soil of the open sandy meadow – *Festucetum vaginatae* – it is the change in the humidity content, which is

Table I.

Productivity of overground living parts of grassland communities (g/4 dm²/day)

Festucetum vaginatae		*Festucetum wagneri*		*Secaletum cultum*	
Day of sampling 1968		Day of sampling 1969		Day of sampling 1969	
V. 23.		IV. 10.		IV. 10.	
	−0.050		+0.008		+0.204
VI. 21		V. 19		V. 19	
	+0.020		+.0026		+0.323
VII. 22		VI. 16		VI. 16.	
	−0.027		+0.037		−0.445
VIII. 30		VII. 22		VII. 22	
	+0.108		−0.106		−0.075
IX. 12		VIII. 13		VIII. 13	
	−0.058		+0.044		
X. 10		XI. 11			
			−0.034		
		X. 13			

positively correlated with productivity (correlation coefficient: +0.60). Owing to the desiccating effect of intensive insolation acting on the surface of the soil, the upper levels of same dry up rather rapidly, and thus moisture can be stored but in the deeper levels.

In the closing meadow *Festucetum wagneri*, the water economy of the soil is modified by the shadowing effect of vegetation. The fluctuations of the moisture content of the upper levels are less, and show a positive correlation with the productivity of the phytomass (correlation coefficient: +0.75). Table III. comprises the results of the analysis of the correlation of the examined factors with one another and with the productivity of the natural meadows.

The productivity of the *Festucetum vaginatae* perennial open sandy meadow shows positive but not close correlation with relative atmospheric humidity (correlation coefficient: +0.46). A negative connection of negligible measure appeared with the other factors.

In the closing perennial sandy meadow – *Festucetum wagneri* – it is the moisture of the soil measured at 40 cm. depth and the global insolation, which are positively correlated (correlation coefficient: +0,75 and +0,56. With the other factors, the connection is not so expressed. Path analysis *(Table IV.)* gives a nearly similar result regarding the natural meadows.

Table II.

a) **Changes of weather elements**

Year and month	*a*	*b*	*c*	*d*
1968 V.				
	+0.133	+0.766	−0.133	+40.000
VI.				
	+0.010	+0.354	−0.096	− 9.300
VII.				
	−0.022	+0.387	+0.541	−66.200
VIII.				
	−0.106	−0.900	+0.290	−39.200
IX.				
	−0.161	−1.119	+0.032	−21.900
X.				
1969 IV.				
	+0.251	+1.741	+0.129	+40.900
V.				
	−0.010	+1.666	+0.433	−20.800
VI.				
	+0.096	−2.709	−0.225	+25.500
VII.				
	−0.025	+0.741	+0.193	−45.700
VIII.				
	−0.080	−1.466	+0.066	−29.000
IX.				
	−0.142	+0.483	+0.032	−36.800
X.				

Symbols:
a = monthly mean temperature (C)
b = amount of monthly precipitation (mm)
c = relative humidity (%)
d = sum of monthly global insolation (cal/4 dm²/day)

It is relative atmospheric humidity and global insolation, which exert the most decided effect on the variability of productivity, the third place is taken by the effect of the other non-examined factors. However, in the closing meadow the relative effect of the other factors is substantially smaller than in the open meadow. According to the calculations of the authors, in both associations the changes in the monthly mean temperature, in the monthly total precipitation and in soil humidity affect the variability of productivity of the phytomass in a rather slight measure.

Table II/b

b) **Changes of soil moisture content (%)**

Year and month 1968	*Festucetum vaginatae*	Year and month 1969	*Festucetum wagneri*	Year and month 1969	*Secaletum cultum*
V.		IV.		IV.	
	+0.107		−0.023		−0.041
VI.		V.		V.	
	−0.019		−0.018		+0.007
VII.		VI.		VI.	
	−0.013		+0.014		+0.011
VIII.		VII.		VII.	
	+0.008		−0.036		−0.054
IX.		VIII.		VIII.	
	+0.017		+0.028		
X.		IX.			
			−0.013		
		X.			

Table III.

Correlation coefficients (r) between the change of phytobiomass weights and the change of studied factors

Studied elements	b	c	d	e	*Festucetum vaginatae*
a	+0.65	−0.31	+0.45	+0.13	−0.24
b		−0.24	+0.39	+0.26	−0.30
c			−0.89	−0.16	+0.46
d				+0.26	−0.32
e					−0.40

Studied elements	b	c	d	e	*Festucetum wagneri*
a	+0.14	−0.08	+0.90	+0.40	+0.24
b		+0.89	−0.14	−0.81	−0.40
c			−0.34	−0.57	−0.26
d				+0.55	+0.56
e					+0.75

For the symbols a, b, c, d, see Table 2.
e = soil moisture content

Table IV.

Path coefficients between the phytobiomass weight of the ecosystems (a) and the percentual rate of the different factors (b)

Ecosystem	Direct effects					Indirect	Other
	a	b	c	d	e		
a) *Festucetum vaginatae*	−0.1164	−0.2126	+1.1352	+0.9266	−0.3889		0,7264
Festucetum wagneri ...	−1.3555	−1.3160	+1.4651	+2.1716	−0.1296		0.2392
b) *Festucetum vaginatae* .	1.35	4.51	128.86	85.85	15.12	−188.46	52,77
Festucetum wagneri ...	183.73	173.13	214.65	471.58	188.56	−950.53	5.72

For the symbols a, b, c, d, e see Table 2 and Table 3.

The subsequent summary shows the order of the intensity of the effects of the examined factors, relying on the path coefficients:

	a	b	c	d	e	other
Festucetum vaginatae	4	5	1	2	6	3
Festucetum wagneri	6	5	2	1	4	3

(The meaning of a, b, c, d and e see in Tables 2 and 3).

In certain cases, e. g. with *Festucetum vaginatae*, the correlation coefficient between the changes of global insolation and productivity is negative (−0.32), while, as to be demonstrated by path analysis, global insolation exerts a marked direct influence on productivity (path coefficient: +0.9266). The same is to be observed with relative atmospheric humidity and productivity in the *Festucetum wagneri* meadow: the value of the correlation coefficient is: − 0.26, that of the path coefficient: +1.4651.

The reason for these phenomenons is that, besides the direct effect, also the indirect — mutual — effects come to be expressed, and the latter can exert an intensive modifying influence.

Thus e. g., in *Festucetum vaginatae*, the correlation between global insolation and the productivity of the green phytomass is: − 0.32.

The correlation can be resolved to the following components:

direct effect of global insolation	+0.9266
indirect effect through soil humidity	−0.1011
effect through relative atmospheric humidity	−1,0103
effect through the mothly total precipitation	−0.0829
effect through the monthly mean temperature	−0.0524
altogether	−0.3201

The examination of the cultivated stand – rye field – *Secaletum cultum* – gives a different result.

The productivity of the overground floral living parts *(Table 1)* shows a maximum in early summer (May and June), and the vegetation period of this association ends with the harvest in July.

As to be seen from the calculations of the correlation of the examined factors with one another and with productivity *(Table V.)*, the productivity of the overground living substance shows a marked positive correlation with the changes of relative athmospheric humidity and monthly total precipitation (correlation coefficients: +0.81 and +0.70). With the other factors, the correlation is negligible.

Table V.

Correlation coefficients (r) between the change of phytobiomass weight and the change of studied factores in arye-field

Studied elements	b	c	d	e	Rye field
a	+0.04	−0.28	+0.76	−0.48	+0.07
b		+0.89	−0.26	−0.47	+0.70
c			−0.56	−0.18	+0.81
d				+0.23	+0.08
e					−0.20

For the symbols a, b, c, d, e see Table 2 and Table 3.

The result of path analysis.

(Table VI.) shows that, differently from the natural meadows, the greatest effect on the productivity of rye is exerted by the changes of temperature. The changes of the values of monthly total precipitation and soil humidity influence the variability of the productivity of the phytomass in a nearly identical measure. In contrast with the natural meadows, the direct effect of the changes in global insolation and atmospheric humidity is rather slight.

Among the examined environmental factors, soil humidity takes a special place since, besides the climatic factors, it depends on quite a series of other soil factors and on vegetation.

For a trial, the authors carried out path analysis taking only the climatic factors into consideration and leaving out soil humidity. Hardly any change in the values of the other factors resulted from the omission of the moisture of the soil in the natural meadows, where its effect on productivity was small (it gave a low path coefficient). However, in the rye field, where the changes of soil humidity originally showed a marked influence on productivity, calculations brought a different result when this factor was left out. The intensity of the effects of the examined factors changed both absolute value and in order of succession (cf. Tables VI. and VII.).

Table VI.

Path coefficients between the phytobiomass weight of the rye-field (a) and the percentual rate of the different factors (b)

Rye field		Direct effects					Indirect	Other
		a	b	c	d	e		
With soil moisture	*a)*	+1.5653	+1.2469	−0.3355	−1.2894	+1.3752		0.8166
	b)	245.01	155.47	11.25	166.25	188.56	−733.23	66.69
Without soil moisture	*a)*	−0.1193	−1.5721	+2.9766	+1.4280	—		0.8184
	b)	1.42	247.14	886.01	203.91	—	−1310.51	72.03

Table VII.

Rank of correlation coefficients

	a	b	c	d	e	other
With soil moisture	1	3	5	6	2	4
Without soil moisture	4	5	1	2	—	3

For the symbols a, b, c, d, e see Table 2 and Table 3.

Summary

From among the environmental factors, the authors examined the effect of the changes of monthly mean temperature, global insolation, relative atmospheric humidity, monthly total precipitation and the soil moisture content upon the productivity of the overground living phytomass of sandy meadows *Festucetum vaginatae*, *Festucetum wagneri*, as well as of a rye field. The connections between the examined factors and productivity were approximated by means of correlation analysis and path analysis. The greatest direct effect on the productivity of the natural meadows is exerted in the first place by changes of relative atmospheric humidity and global insolation and, on that of the rye field, by the changes in temperature.

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