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The effect of climate change on the productivity of agrocenoses

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This paper analyses the variation of some physical characteristics of the atmosphere during a 60-year period (1947–2007). The precipitation and temperature data were compared with those of the last decade (1998–2007). The findings suggest that compared with the 60-year period, the last decade witnessed an increase in air temperatures during the vegetation season in West Lithuania. The highest rise in the air temperature (1.1 °C) occurred in July, while the lowest increase (0.3 °C) was recorded in June. During the decade between 1998 and 2007 an increase in the amount of rainfall occurred in June and August (by 12.9–13.4 mm, respectively), and a reduction in May and September (by 8.6–12.7 mm, respectively).

The indicator of the totality of meteorological factors correlates with crop yield during the growing season, this correlation, however, is rather varied. Herbage growth rate and development intensity highly depends on the time of resumption of vegetation. The annual herbage dry matter yield strongly correlates (r = 0.77) with the sum of positive temperatures. In May, the dry matter yield of herbage is most markedly influenced by the warmth, on which duration of herbage re-growth depends (r = 0.88), while in June and July the greatest effect is exerted by rainfall (r = 0.83).

The data from the Vėžaičiai and Vokė weather stations were used for the description of the meteorological conditions.

Key words: climatic factors, agrocenoses, correlations, the hydrothermal coefficient

INTRODUCTION

The production and the quality of herbage will be affected by climatic variation and by the frequency of extreme climatic events (Porter and Semenov, 2005). Global environment change: rising temperatures, changing precipitation and rising atmospheric CO_2 concentrations, will become a major driver of changes in plant diversity and loss in the 21st century. A recent modelling study of 1350 European plant species predicted that half of these species will become classified as 'vulnerable' or 'endangered' by the year 2080 due to rising temperatures and changes in precipitation (Thuiller et al., 2005). Global warming took place between about 900 and about 1200 or 1300, just before the Little Ice Age (1550–1700 AD). In southern Europe land abandonment will result in much more increased wild fires, loss of biodiversity and desertification (Mannetje, 2007).

Increasingly evident climate changes occurring during the last decades pose a threat to the environment, agricultural activities and to the development of global economy (Bubnienė et al., 2006). The key factor responsible for these changes is a rise in global air temperature. The average annual temperature in Lithuania is 6.2 °C (from 6.5–7.1 °C in the littoral zone to 5.5 °C in the north-east). The air temperature in Lithuania is by 2–4 °C higher than that in the respective latitude (55° north latitude) (Bukantis et al., 2001; Galvonaitė et al., 2007).

The total annual precipitation in Lithuania is about 700 mm. In general, there is a shortage of soil moisture during April and May and surplus of moisture during July and August. Extremely dry periods occur occasionally, particularly in spring. In Lithuania, there are on average 179 days with precipitation. A close correlation was determined between the number of days with precipitation (≥ 10 mm) and monthly amount of precipitation. In the littoral zone, the maximum of precipitation moves towards the autumn, September and November being the months with the greatest amount of precipitation, while in South-east Lithuania it shifts to June and July (Galvonaitė et al., 2007). Lithuania's climate is favourable for herbage production. Precipitation and

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warmth have the greatest impact on the yield of the 2nd and 3rd grazing. The highest pasture yield and the proportion of white clover in the sward is achieved when herbage has a re-growth interval of between 35–40 days, and the percentage of sunny and cloudy days during this period is almost identical, with the mean daily precipitation rate of 3.1 mm (Gutauskas, Daugėlienė, 2005).

The development and yield of plants depend a great deal on the climate, edaphic and biotic factors. Water deficit influences the basic processes connected with grass productivity (Jones, 1988; Assuero et al., 2002). The portion of legumes and grasses in dry matter yield is in the relationship of cyclic fluctuation. The representation of legumes in grasslands is markedly affected by a mutual interaction of environmental conditions and the management practices applied to the grassland (Klimeš, 1999; Hopkins et al., 2001; Pacurar et al., 2004). Annual rye-grass (*Lolium multiflorum* Lam.) yield in southern Portugal is strongly affected by soil water availability in early autumn and especially late spring. Rye-grass is usually cultivated under rain-fed condition allowing usually two harvests. Lourenço and Palma (2001) reported total dry matter yield values ranging from 5.247 to 6.790 kg ha^{-1}. This shows the great variability of forage production of the region depending mostly on total amount and rainfall distribution along the year. In Mediterranean regions *Dactylis glomerata* seemed more adapted to severe water deficit conditions since it maintained a high photosynthetic rate longer even at the most severe drought treatment (Salis et al., 2006). If global temperatures increase, soil from high altitude will require higher water content to maintain characteristic vegetation, and if global temperatures eventually decrease, plants associated with higher altitudes will get favourable conditions also in lower altitudes, which would result in uniform vegetation along the altitudinal gradient (Sánchez-Jardón et al., 2006).

The variable effect of the totality of the meteorological factors within the same year and each subsequent year is one-to-many. The data of meteorological observations, the study of which will enable preparation of long-term forecasts and development of adjustment measures, are of vital importance for climate analysis. One of the key adjustment measures is the choice of suitable plant species and development of growth technologies designed for specific regions of Lithuania.

Assessments of meteorological conditions at a specific plant growth stage on a daily basis were done using the data of day and night length (photoperiodism) and duration of sunshine (h), mean daily temperature (°C), and amount of precipitation (mm). A relationship was identified between plant yield and the level of some physical characteristics of the atmosphere during the entire growing season and during individual months. The hydrothermal coefficient (HTC) was used to describe the conditions of plant growing period.

MATERIALS AND METHODS

The data from the long-term experiments conducted in East and West Lithuania were used for the estimation of meteorological conditions. In West Lithuania (the Lithuanian Institute of Agriculture (LIA) Vėžaičiai Branch), the soil of the experiment was a sod podzolic *Endocalcaric Gleysol* (GLk2) light loam on medium loam with top soil pH_{KCl} 5.5–6.0, available P_2O_5 132 mg kg^{-1} and K_2O 104 mg kg^{-1}. Experiments were done for 20 years in legume / grass swards that were re-sown every 5 years. In the spring of each year of use the swards were fertilised with P50K60-90. The species that dominated in the swards were red clover (*Trifolium pratense* L.) or white clover (*Trifolium repens* L.), common timothy (*Phleum pratense* L.), perennial rye-grass (*Lolium perrene* L.), meadow fescue (*Festuca pratensis* Huds.), and in the last year – smooth-stalked meadow grass (*Poa pratensis* L.) (Dailidė, 1998; Daugėlienė, 2002).

In East Lithuania (LIA Vokė Branch) the long-term (18 years) experiments were conducted in six, six-course crop rotations expanded over time and space. The experimental soil was sandy *Skeleti–Calcaric Arenosols*, with pH_{KCl} 4.5–5.3, available P_2O_5 111–254 mg kg^{-1} and K_2O 163–277 mg kg^{-1}. The area of cereals in the crop rotation was increased from 50 to 100%. The plots were laid out in three bands, in blocks of crop rotation-sequence, and in them in groups according to perennial grasses included and non-included in the rotation (Žekonienė, 1991; Žekonienė, 1994).

The beginning of resumption of vegetation of the swards in these experiments was determined according to the regulations of observation of the weather stations. During the vegetation period, the date of grazing or cutting is considered to be the beginning of re-growth of the grass (aftermath) intended for various purposes. Cutting of herbage was started when it was 15–20 cm in height, and was repeated every 7 days during the period of 10 weeks. Dry matter yield was determined at each cutting date.

The distribution of rainfall within each month of vegetation period was described on the basis of perennial average of precipitation. The data were grouped in four variants (5 years in each variant) according to similar intervals of the amount of precipitation of a respective month. Each variant was distributed over a period of two months, which, according to extreme conditions, can be respectively longer or shorter. The next month's amount of precipitation was added to the amount of precipitation of the period. Yield data grouped with regard to precipitation according to the years were used for correlation and regression analysis.

The conditions of plant vegetation period were described using the agrometeorological indicator – G. Selianinov hydrothermal coefficient (Багров, 1983; Bukantis, et al., 1997), which was calculated according to the formula:

$$HTK = \Sigma p / 0.1 \Sigma t, \quad (1)$$

where Σ p represents sum of precipitation (mm) during the test period, when average daily air temperature is higher than 10 °C, and Σ t stands for the sum of active temperatures (°C) during the same period.

Analysis of the weather conditions was based on the data obtained from the weather station. The data of meteorological conditions were statistically analysed by the ANOVA and STAT-ENG according to Tarakanovas et al. (2003).

RESULTS AND DISCUSSION

The data from the 1947–2007 period obtained from the Vėžaičiai weather station were used for the comparison of some physical characteristics of the atmosphere. The most vivid description of the meteorological conditions is exhibited by the variation in precipitation amount and air temperature, which is very high in the course of years. The amount of yield is the outcome of plant adaptation in the course of time. As a result, retrospective analysis of meteorological conditions is of special relevance for the precision of yield prediction.

The data from the 1947–2007 period include a 30-year period that started in 1961 (1961–1990), with which the past and future climate periods of the same length (1931–1960 and 1991–2020) are compared, and whose mean values are considered the world climate norm (Gentvilienė, 1997). In the world's meteorological research practice there exist universally accepted climate periods covering a 30-year period. At the end of the 20th century Estonian researchers determined a statistically significant 27.1-year cycle of annual precipitation amount in the long-term variation (Jaagus, Tarand, 1998).

During the period 1947–1998, the amount of precipitation tended to increase during the months of active growth season (Table 1). It represents a very favourable distribution of precipitation for sward growth, since in spring there is generally sufficient amount of moisture in the soil for herbage to grow. However, in summer, especially in July and August there is a shortage of moisture for perennial grass growth. During the last decade (1998–2007), a significant reduction in the amount of precipitation (8.6–12.7 mm) was recorded in May and September. In summer the amount of precipitation was higher, and the highest increase (12.9–13.4) occurred in June and August. The greatest variation in precipitation (54.2–78.3%) was identified in July and August, which is determined by downpours that occur in these months. For example, in July of 2005 and 2007 the amount of precipitation was 2.2–2.9 times higher than the long-term mean. An extremely rainy period that lasted for a longer span occurred in August of 2005. It is rather difficult to discern a general trend for precipitation, since in some parts of Lithuania the amount of precipitation declines and in others increases, and the changes are not high – several or several tenths of a millimetre. However, a trend has been noted suggesting that in the greater part of the country the amount of precipitation increases during the cold period of the year and declines during the warm period (Galvonaitė et al., 2005; Galvonaitė et al., 2007). The key factor determining annual variations of the precipitation amount is large and moderate-scale atmospheric circulation characteristics (Bukantis et al., 1998).

The air temperature during the growth season did not exhibit any consistent trend of increasing (Table 1). In both periods, the dynamics of air temperature during the period of active vegetation season was similar, however, during the last decade an increase in the air temperature was recorded for all months. The highest increase in the

Table 1. **Variation of meteorological indices**
Vėžaičiai, 1947–2007 average data

Indices	Total (January–December)	Growing season (April–October)	Including months of active vegetative growth				
			May	June	July	August	September
1947–1997							
Precipitation mm							
Mean	839.2	468.7	45.5	61.6	86.8	89.4	95.8
Error of the mean	23.7	18.9	3.3	4.3	6.5	8.0	6.8
Coefficient of variation %	20.2	26.3	52.6	49.5	54.2	63.6	51.2
1998–2007							
Precipitation mm							
Mean	902.8	425.5	36.9	74.5	96.9	102.8	83.1
Error of the mean	55.8	42.3	3.85	11.5	24.0	22.9	18.4
Coefficient of variation %	19.5	25.6	33.0	49.0	78.3	70.5	70.0
Average monthly air temperature °C							
1947–1997							
Mean	79.3	76.5	11.1	14.7	16.7	16.4	12.3
Error of the mean	1.5	0.6	0.2	0.2	0.2	0.2	0.2
Coefficient of variation %	13.8	5.4	15.6	10.1	8.5	7.7	11.7
1998–2007							
Mean	72.1	81.3	11.8	15.0	17.8	17.0	12.9
Error of the mean	0.24	0.16	1.28	0.42	0.63	0.5	0.41
Coefficient of variation %	10.2	4.02	32.6	8.84	11.2	9.19	10.1

air temperature (1.1 °C) was identified in July and the lowest increase (0.3 °C) in June. For the rest of the months the air temperature increase was very similar (0.6–0.7 °C). The greatest variation in the air temperature was noted in May (variation coefficient of 15.6–32.6%). These data do not negate the proposition about global air warming (Bukantis et al., 1997; Galvonaitė et al., 2007). In all probability, they describe the cyclic nature of natural phenomena balance. It is rare that the mean daily air temperature of a specific day coincides with the long-term mean monthly temperature. Only 15–20% of it coincides or differs by not more than 1 °C (Galvonaitė et al., 2007).

Research on grass growth dynamics was conducted during 1978–1995; it covered the rainy period of 1974–1990 and the forecasted drier period of 1991–2001. During the rainy and droughty years there occurred drier (1982) and rainier (1993) vegetation periods. The August of 1989 was very rainy and the July of 1994 was with no rainfall at all. In this case correlations of precipitation and air temperature dynamics were characteristic of the months of the vegetation period.

Plant cultivation agrotechnical research was estimated as fragmentary expression of the effects of meteorological conditions during the vegetation period that is characterized by the amount of plant produce obtained, which varies from year to year. Phytomass growth in the sward is unequally proportional to different years' vegetation period (Table 2). Different calendar time of the resumption of vegetation was noted (e. g. 1981 and 1991). Herbage growth and development rate depend on the variation level of the air temperature, amount of precipitation, light and other factors. Consequently, herbaceous or any other vegetation is considered as an indicator of variation of meteorological factors.

In terms of phytomass growth and its utilisation, the vegetation period is divided into 3–4 herbage growth periods. These periods differ considerably in meteorological conditions of each year. The main, the first period of grass growth and development takes place in May and June, and when the weather is extremely wet, this period can extend to the greater part of July. The amount of precipitation and its uneven distribution within separate vegetation periods is a dominating factor responsible for uneven plant growth and development. Similar or the same plants grow and develop very differently in the same soil even if identical agrotechnical practices are used. This is determined by the unequal impact of different meteorological factors, which directly does not depend on the role of vegetation. The totality of these factors, related to the duration of sunny and cloudy days and nights, correspondingly affects the development of vegetation. Hence, the effect of precipitation on various plants is indefinite and very varied. The effect of air humidity and temperature is relative (Dailidė, 1998; Daugėlienė et al., 2002).

The correlations between meteorological factors and dry matter yield for individual months of growth suggest that in May dry matter yield mostly depended on herbage re-growth duration (r = 0.88) and was least dependent on the amount of precipitation (r = 0.29), since during this period the soil contained enough moisture for the plants to grow (Table 3).

Table 2. **Increase of herbage yield, depending on the beginning of growing season in different years**
Vėžaičiai, 1978–1995

Year	Beginning of growing season (month, day)	First date of mowing (month, day)	Number of days			Dry matter yield t ha–1		
1978	04 19	05 22	34	41	48	1.02	1.57	1.96
1979	04 22	05 28	37	44	51	0.20	0.53	0.86
		05 28	37	44	51	0.46	1.27	1.78
1980	04 22	05 19	28	35	42	0.29	0.62	1.22
1981	05 05	05 18	14	21	28	0.65	1.98	3.36
1982	04 29	05 17	19	26	33	0.25	1.05	2.29
1983	04 17	05 03	17	24	31	0.08	0.41	0.91
		05 03	17	24	31	0.19	0.60	1.55
1984	04 03	05 07	35	42	49	0.43	0.89	1.70
1985	05 04	05 20	17	24	31	0.97	2.16	3.09
1986	04 22	05 12	21	28	35	0.40	1.10	2.84
1987	04 29	05 18	20	27	34	1.10	2.13	2.91
1988	04 16	05 16	31	38	45	1.03	2.33	3.18
1989	04 11	05 13	23	30	37	0.84	1.70	2.04
1990	04 14	05 28	15	22	29	0.42	1.02	2.02
1991	04 02	05 06	35	42	49	0.40	0.87	1.64
1992	04 26	05 18	23	30	37	0.76	1.65	3.06
1993	04 02	05 10	39	46	53	1.00	1.68	2.12
1994	04 10	05 16	37	44	51	1.03	1.68	2.22
1995	04 19	05 15	27	34	41	0.55	1.15	1.91
LSD_{05}						0.08	0.18	0.17

Table 3. **The correlation between meteorological factors (x) and (y) herbage yield (dry matter)**
Vėžaičiai, 1981–1989

Meteorological factors	Correlation coefficient r				
	Growing season				annual yield t ha–1
	May	June	July	August	
Herbage growth duration (days)	0.88	0.77	0.69	0.41	0.65
Sunny days %	0.57	0.63	0.83	0.12	0.62
Cloudy days %	0.46	0.65	0.76	0.34	0.56
Sum of positive temperatures °C	0.53	0.70	0.44	0.37	0.77
Precipitation mm	0.29	0.83	0.80	0.54	0.69

In June, the yield was most considerably influenced by precipitation (r = 0.83) and the sum of positive temperatures (r = 0.77), in July – by precipitation (r = 0.80) and percentage of sunny and cloudy days (r = 0.83–0.76), and in August, when herbage growth slows down, the effect of meteorological factors on the herbage dry matter yield is weak or moderate. Even in the brightest months, solar radiation duration accounted for only 50–55% of the theoretically possible. The number of cloudy days is usually the highest in November and the lowest in May–August (Galvonaitė et al., 2007). The effect of meteorological factors on annual yield of sward showed a strong correlation (r = 0.77) between dry matter yield and sum of positive temperatures. This indicates that there is insufficient amount of not only moisture but also warmth in order to produce a high yield of sward.

In agrometeorology, beside other indicators, G. Salianinov hydrothermal coefficient (HTC), based on the ratio of precipitation and warmth, is often used for general estimation of moisture. The differences of the hydrothermal coefficient are determined by the differences of precipitation amount. While analysing dynamics of the hydrothermal coefficient it is possible to distinguish 29–33-year cycles. HTC reduction trend was noted all over Lithuania, which is linked to droughty summers. This trend is most distinct in West Lithuania (Bukantis et al., 1997).

The hydrothermal coefficient is also used to explain or foresee the causes of variation in the results of swards research. Calculations based on long-term data made it possible to determine that the curvilinear correlation ($\eta^2 - r^2 > 0.1$) between HTC of the same vegetation stages and dry matter content of growing grasses per area unit is of inconsistent direction and of greatly varying level (Table 4). It is natural that with extension of plant growth duration dry matter yield of herbage increases, therefore the correlation between these indicators is strong. However, when compared with the duration of vegetation in days, HTC does not show actual role of meteorological conditions in grass growth and development. It is likely that the herbage growing period in our experiment was too short to describe meteorological conditions using HTC. Some literature sources indicate that HTC is an adequate indicator for the description of various climate zones or longer vegetation periods according to the amount of precipitation (Bukantis et al., 1997; Galvonaitė et al., 2007).

Average daily increment of sward yield is influenced by the biological characteristics of grasses, meteorological conditions and soil productivity. However, yield increment is determined by meteorological conditions that exert a diverse effect on sward re-growth stages. Unlike the correlation between duration of vegetation and herbage increment, the effect of the total hydrothermal coefficient on the dry matter yield of the herbage of the first cut was very high (Fig. 1). Although no linear correlation was established, the curvilinear correlation between the mentioned indicators was strong. This is explained by the fact that herbage growth occurred within a 10-week period (cuts were taken weekly) and plants copied meteorological conditions more precisely.

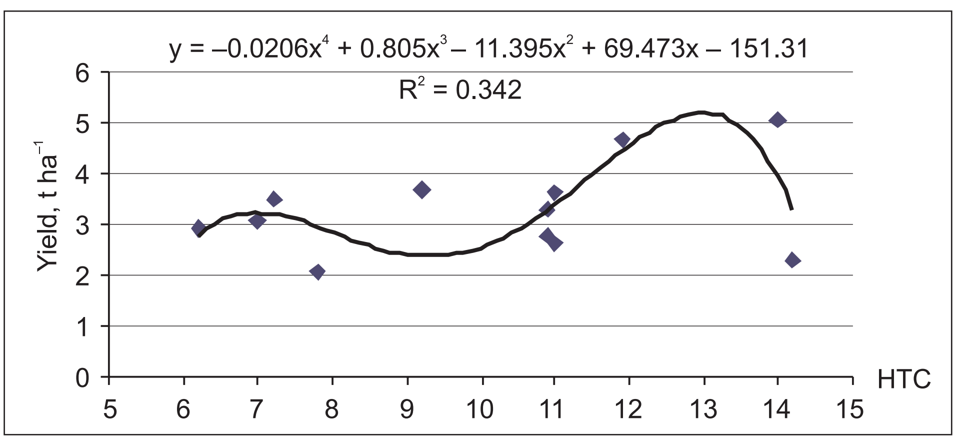

Fig. 1. The relationship between the increment of the first herbage yield and the hydrothermal coefficient (HTC was added). Vėžaičiai, 1978–1994

Table 4. **The correlation between the length of vegetation, HTC and phytomass increment**
Vėžaičiai, 1978–1994

Years	Indices	Variation range	Correlation					
			r^2	t_r	P%	η^2	$t\eta^2$	P%
1978	Number of days	34–69	0.98	17.1	>99.9	0.99	19.7	>99.9
	HTC	0–3.63	0.42	1.90	88.4	0.86	5.64	99.8
	DM t ha–1	1.23–3.96	–	–	–	–	–	–
1981	Number of days	14–70	0.94	11.2	>99.9	0.99	58.8	>99.9
	HTC	0–5.34	0.02	0.35	26.2	0.50	2.64	96.5
	DM t ha–1	0.65–7.20	–	–	–	–	–	–
1983	Number of days	17–73	0.98	22.92	>99.9	0.99	54.0	>99.9
	HTC	5.4–0	0.12	0.96	65.3	0.82	5.61	99.9
	DM t ha–1	0.08–7.01	–	–	–	–	–	–
1984	Number of days	35–98	0.97	10.0	>99.9	0.99	41.7	>99.9
	HTC	0–3.08	0.23	1.57	85.2	0.47	2.68	97.3
	DM t ha–1	0.30–6.15	–	–	–	–	–	–
1986	Number of days	21–77	0.78	5.03	99.8	0.98	18.7	>99.9
	HTC	2.72–0.14	0.14	1.05	67.1	0.49	2.62	96.5
	DM t ha–1	0.40–4.55	–	–	–	–	–	–
1990	Number of days	17–80	0.98	19.0	>99.9	0.99	28.4	>99.9
	HTC	0.01–5.28	0.20	1.44	80.1	0.44	2.49	96.3
	DM t ha–1	0.42–6.22	–	–	–	–	–	–
1991	Number of days	33–96	0.99	28.4	>99.9	0.99	45.4	>99.9
	HTC	3.61–7.32	0.00	0.07	8.0	0.35	2.06	93.1
	DM t ha–1	0.40–7.33	–	–	–	–	–	–
1993	Number of days	39–102	0.97	15.2	>99.9	0.99	45.4	>99.9
	HTC	0.07–3.88	0.29	1.80	89.1	0.40	2.30	94.9
	DM t ha–1	1.03–4.92	–	–	–	–	–	–
1994	Number of days	26–82	0.97	15.2	>99.9	0.99	34.4	>99.9
	HTC	3.06–0	0.16	1.15	71.1	0.43	2.30	94.5
	DM t ha–1	1.04–5.47	–	–	–	–	–	–

r – correlation coefficient; η – determination index; t_r – deviation; P – probability.

Having calculated the relationship between the dry matter yield of the long-term test sward and meteorological conditions in separate months of growth, we established a curvilinear correlation, however always non-significant, between herbage yield and the hydrothermal coefficient (Table 5). The absence of such correlation is shown by a very great variation of the hydrothermal coefficient. Therefore, in terms of meteorological conditions, it is important to identify the level of variation of the dominating factor in relation to phytomass increment. When estimating the differences between the months of the vegetation period, it is rather difficult to discern any general trend, since the amount of precipitation may differ during the months of a specific year. The greatest precipitation variation range is specific to July–August, however, the yield may be influenced by the occurring anomalies. On August 8–11, 2005 there was heavy rainfall and the amount of precipitation that fell nearly equalled three months' rate. This was the longest rainy period within the whole observation period (Galvonaitė et al., 2007). In July 1992, the amount of rainfall was only 6.7 mm (that was the longest drought which lasted from the second ten-day period of May to the end of August), and in 1995 the total of rainfall amounted to 108.4 mm.

Table 5. **The correlation between the hydrothermal coefficient (x) and phytomass (y) growth during the vegetation period**
Vėžaičiai, 1992–2006

Indices		Linear correlation		Linear regression		Coefficient of variation V %
Month	HTC variation range	r	Sr t_{05}	Y = A+	Bx	
May	0.3–4.2	0.165 n	± 0.312	3.113	0.091	86
June	0.9–4.5	0.42 n	± 0.287	2.606	0.39	55
July	0.0–3.4	0.353 n	± 0.296	2.758	0.376	60
August	0.3–3.7	–0.014 n	± 0.316	3.302	–0.009	70
September	0.4–5.6	–0.031 n	± 0.316	3.326	–0.013	67

n – nonlinear correlation.

In July 1994 the was no rainfall at all (the drought continued until mid August), and in 2002 the amount of precipitation was 132.4 mm. When herbage is cut during a droughty period, it re-grows poorly, and either does not form yield during that period or it is 4–5 times lower (Daugėlienė, 2002). Although torrential rainfall equilibrates monthly precipitation balance, it has a lesser effect on plant growth than constantly recurring rainfall. In West Lithuania the rainfall of torrential intensity increases in August–September (Misiūnienė, 1998).

Summing of the indicators of hydrothermal coefficient of the whole vegetation period (May–September) and calculation of their effects on herbage dry matter yield resulted in a greater correlation than for individual months of the year (Fig. 2). However, even the sum total of hydrothermal coefficient does not highlight the role of meteorological conditions in plants since the amount of precipitation is determined not only by its seasonal variation but also by great variation in the course of individual summer months. During this experimental period there were three droughts that had a decisive effect on herbage yield. In 1994 the drought was shorter and started within the first days of July and continued until mid August; it was very hot during the drought in 2002. On estimating the productivity of long-term swards (used for more than 40 years) in relation to non-meteorological and meteorological factors, trends and deviations from trend line proved precipitation and its distribution over the vegetation period to have the greatest effect on sward productivity (Рябчиков, 1968).

Application of the hydrothermal coefficient for the assessment of the meteorological conditions during cereal growing period provided evidence that in none of the cases there was a strong correlation between spring cereals grain yield and the hydrothermal coefficient (Table 6). In most cases there existed

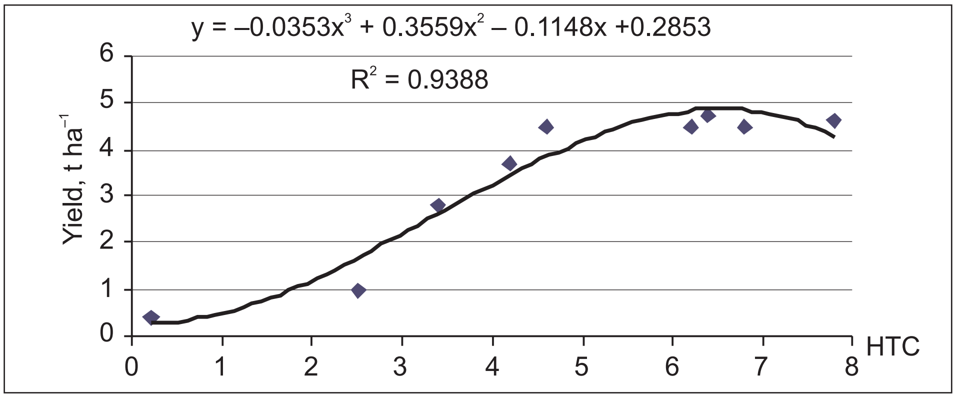

Fig. 2. The relationship between herbage dry matter yield and the hydrothermal coefficient (sum of HTC). Vėžaičiai, 1992–2006

Table 6. **The influence of the hydrothermal coefficient (x) on the yield of barley and oats (y) t ha^{-1}**
Vokė, 1979–1996 data average

Indices		Linear correlation		Linear regression		Coefficient of variation V %
Month / ten-day period	HTC variation range	r	Sr t_{05}	Y = A+	Bx	
			Barley			
May 1st ten days	0–5.34	0.023 n	± 0.25	3.134	0.013	90
2nd ten days	0.67–9.19	0.058 n	± 0.25	3.113	0.027	121
3rd ten days	0.12–6.07	0.36 n	± 0.233	2.764	0.21	87
June 1st ten days	0–2.88	0.61**l	± 0.198	2.326	0.642	74
2nd ten days	0.39–6.18	0.444 n	± 0.224	2.623	0.241	79
3rd ten days	0–3.71	0.398 n	± 0.229	2.548	0.393	62
July 1st ten days	0.02–3.07	0.05 n	± 0.25	3.106	0.038	92
2nd ten days	0.09–6.36	0.087 n	± 0.249	3.061	0.045	86
3rd ten days	0.01–3.63	–0.065 n	± 0.249	3.237	–0.053	79
			Oats			
May 1st ten days	0–5.34	–0.104 n	± .249	3.265	–0.064	90
2nd ten days	0.67–9.19	0.121 n	± 0.248	3.033	0.064	121
3rd ten days	0.12–6.07	0.237 n	± 0.243	2.849	0.156	87
June 1st ten days	0–2.88	0.475*l	± 0 .22	2.446	0.56	74
2nd ten days	0.39–6.18	0.39 n	± 0.23	2.611	0.239	79
3rd ten days	0–3.71	0.346 n	± 0.235	2.545	0.385	62
July 1st ten days	0.02–3.07	0.149 n	± 0.247	2.966	0.128	92
2nd ten days	0.09–6.36	0.257 n	± 0.242	2.819	0.15	86
3rd ten days	0.01–3.63	0.109 n	± 0.249	2.992	0.102	79

* – 05, ** – 01a level of probability; l – linear correlation; n – nonlinear correlation.

a curvilinear correlation between these indicators, and only in several cases this correlation was linear. Meteorological conditions had a greater effect on spring barley grain yield. In the first ten-day period of June, a moderately strong linear correlation of 99% significance was identified between HTC and barley grain yield. Meteorological conditions had a weaker (0.475*l), but also direct influence on oat grain yield during the same period. Plant biomass yield variations are related to the changes in warmth and moisture ratio. When there is a shortage of moisture, an inverse correlation is observed between plant cover productivity and solar energy amount. The law of minimum, optimum and maximum of values determines indirect correlation of yield with agrometeorological conditions (Федосеев, 1970). The obtained data are also reflected by the variation of the hydrothermal coefficient, which was very big.

Agrometeorological indicator, G. Selianinov hydrothermal coefficient, used for the assessment of agrotechnical test results, does not demonstrate the actual role of meteorological conditions in plant growth and development, since plant growth is determined not only by the fluctuations of physical characteristics of the atmosphere but also by soil cover, soil physical properties and other factors. As a result, it would be expedient either to modify the methodology for the hydrothermal coefficient calculation or to search for more appropriate calculation methods in order to assess the agricultural crops yield in relation to meteorological conditions.

CONCLUSIONS

The meteorological data of the last decade (1998–2007) indicate the climate warming. Having compared this period with the 1947–1997 period, we identified the highest increase in the air temperature (1.1 °C) in July, a lower increase (0.6–0.7 °C) during May, August and September, and the lowest temperature increase (0.3 °C) in June.

During the last decade, an increase in the amount of precipitation was recorded in summer in June and August (12.9–13.4 mm), while a reduction (8.6–12.7) was identified in May and September.

The annual herbage dry matter yield strongly correlates (r = 0.77) with the sum of positive temperatures. The herbage dry matter yield was most markedly affected by the warmth of May, on which the herbage re-growth rate (r = 0.88) depended. In June and July the yield most markedly depended on precipitation (r = 0.83), and in August, when herbage growth slows down, the effect of meteorological factors on the herbage dry matter yield is weak or moderate.

Agrometeorological indicator, G. Selianinov hydrothermal coefficient, does not demonstrate the actual role of meteorological conditions in plant growth. It would be expedient either to modify the methodology for calculation or to search for more appropriate calculation methods.

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KLIMATO KAITOS POVEIKIS AGROCENOZIŲ PRODUKTYVUMUI

Santrauka

Apibendrintais tyrimų duomenimis, atmosferos fizinių charakteristikų, nuo kurių priklauso augalų augimas ir vystymasis, kaita yra būdinga tam tikrai vietovei. Šiame darbe analizuojama atmosferos fizinių charakteristikų kaita per 60 metų (1947–2007 m.). Kritulių ir temperatūros duomenys palyginti su pastarojo dešimtmečio (1998–2007 m.) duomenimis. Nustatyta, kad pastarąjį dešimtmetį, palyginti su 60 metų laikotarpiu, Vakarų Lietuvoje nustatytas oro temperatūros padidėjimas vegetacijos laikotarpiu. Daugiausiai (1,1 °C) oro temperatūra pakilo liepą ir mažiausiai (0,3 °C) birželį. Taip pat kritulių padaugėjo birželį ir rugpjūtį (12,9–13,4 mm), o sumažėjo gegužę ir rugsėjį (8,6–12,7 mm).

Egzistuoja meteorologinių veiksnių visumos rodiklio ir augalų derliaus vegetacijos laikotarpiu skirtingo lygmens ryšiai. Nuo vegetacijos atsinaujinimo laiko priklauso žolių augimo ir vystymosi intensyvumas. Metinis žolės sausųjų medžiagų derlius stipriai ($r = 0,77$) koreliuoja su teigiamų temperatūrų suma. Gegužę žolės sausųjų medžiagų derliui didžiausią įtaką turi šiluma, nuo kurios priklauso žolės atžėlimo trukmė ($r = 0,88$), birželį ir liepą – krituliai ($r = 0,83$).

Meteorologinės sąlygos apibūdintos pasinaudojus Vėžaičių ir Vokės meteorologijos stočių duomenimis.

Raktažodžiai: klimato kaita, agrocenozė, koreliaciniai ryšiai, hidroterminis koeficientas