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THE INFLUENCE OF METEOROLOGICAL INDICES ON THE MOUNTAINOUS AND WATER HABITAT IN THE BASIN OF THE RIVER HORYN (UKRAINE)

Abstract. This paper is devoted to the investigation of pecularities of basic meteorological indices in the basin of the river Horyn. The results of long-term observation of the main meteorological indices at Rivne meteorological station are given. The causes and probable consequences of climate change have been discovered. Global warming as a factor of impact on land and water habitat is considered. The availability of changes of the main elements of meteorological conditions on the territory of the basin (precipitation, air temperature, the value of active and effective temperatures) and their influence on the soil temperature, soil freezing, moisture conditions, hydrothermical coefficient, soil heating and river drainage have been reliably confirmed.

Key words: air and soil temperature, precipitation, active and effective temperatures, freezing, moisture, heating, river drainage, greenhouse gases.

INTRODUCTION

In recent years we have been observing global warming. Summer is getting hotter and winter milder. Scientists have noticed that over the past 100-130 years our atmosphere has become noticeably warmer and this process is steadily growing. The average temperature is constantly growing as well. As shown in Figure 1, only over the past 100 years the average annual temperature has increased at least by 0,3-0,6^{0}C [Ліпінський В.М., Дячук В.А., Бабіченко В.М. 2003].

Global warming is caused by the greenhouse effect. Its nature is that the Earth receives solar energy mainly in the visible part of the spectrum and being much colder object it radiates mainly infra-red rays into space. But many gases that the atmosphere contains, such as water vapour, carbon dioxide, methane, nitrogen oxides and others are transparent for visible rays and actively absorb infra-red ones, therefore, keeping the heat, which could be delivered to space, in the atmosphere. Thus, the Earth surface temperature is kept on the level suitable for life. Keeping heat in the Earth atmosphere these gases make an effect called "greenhouse" [Старченко В.Ф., Канєвський О. П., Рудницький П. В., Луценко Ф. Г. 1946].

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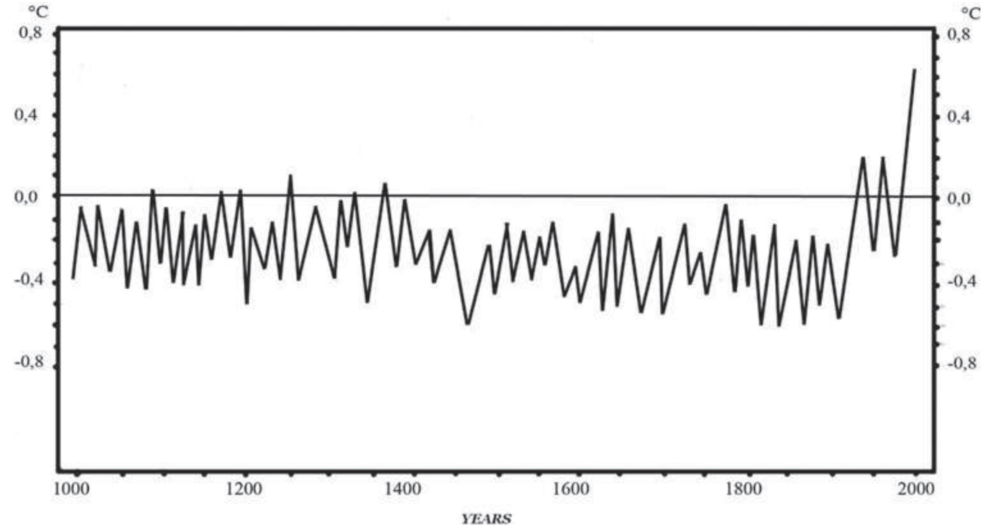

Fig. 1. The air temperature changes in the northern hemisphere over the past 1000 years (compared with the average temperature value for the period 1961-1990) US NASA Agency.
Rys. 1. Zmiany temperatury powietrza na półkuli północnej w ciągu ostatniego 1000 lat (w porównianiu ze średnią wartością temperatury w okresie 1961–1990) USA Agencja NASA

The main greenhouse gases on the Earth are water vapour (responsible for about 36-70 % greenhouse effect, not including clouds), carbon dioxide (CO_2) – 9-26%, methane (CH_4) – 4-9% and ozone – 3-7%. Atmospheric concentration of CO_2 and CH_2 has increased by 31% and 149% respectively in comparison with the beginning of the industrial Revolution in the middle of the 18th century.

According to the data of certain studies, such concentration levels have been achieved for the first time over the past 650000 years, the period for which the reliable data have been obtained by investigating samples of polar ice. The rapid growth of greenhouse gas concentration started after the 1950-ies and the 1970-ies [Ліпінський В.М., Дячук В.А., Бабіченко В.М. 2003].

It is ascertained that since 1990 with the increase of concentration of greenhouse gases on the Earth, their radioactive impact has increased by 29% mostly because of the increase of carbon dioxide (CO_2) volume in the air. Since the industrial Revolution of the 18th century the fraction of CO_2 in the atmosphere has increased by 39%. According to scientific research, it is the result of emissions from burning fossil fuels, deforestation and the introduction of new technologies in agriculture.

The concentration of methane in the atmosphere has increased by 158%, 40% of methane is released from natural resources, such as swamps and ponds, and 60% - as a result of human activities, such as cattle farming, rice cultivation, the use of fossil fuels and the formation of landfills. The volume of nitric oxide in the atmosphere has increased by 20% in comparison with pre-industrial period. It is exuded both from natural sources and because of the use of fertilizers, biomass burning and other industrial processes.

Excessive emissions of nitric oxide cause the destruction of ozone layer which protects the Earth from ultraviolet radiation [Чуб В.Е. 2007].

According to the UN data only for the period of 2000-2006, emissions of greenhouse gases in the leading industrialized countries have grown by 2.3%. It is prognosticated that global emissions of greenhouse gases will double within the next 40 years. It will increase the average global temperature at the end of the century by 3-6^{0}C.

The combination of energy technologies won't be considerably changed by 2050, while the share of fossil fuels for energy still remains at 85%. By 2050 the concentration of greenhouse gases in the atmosphere may reach 685 parts per million (pm). This is considerably above the level of 450 parts, which according to the calculations of scientists is necessary to have at least 50% - chance to maintain the temperature rising on the Earth at 2°C.

Climate change is perhaps the most important and complicated problem in environmental protection that befell humanity in the last century [Ліпінський В.М., Дячук В.А., Бабіченко В.М. 2003].

Till now the potential consequences of increased carbon dioxide and other greenhouse gases concentration in the atmosphere have not been reliably identified, but global temperature changes are most likely of them.

Rising of temperatures may cause a number of phenomena, such as rising sea levels and changes in local climate conditions, which in their turn can affect socio-economic development of many countries. There is no doubt that global warming may cause unexpected changes in the environment. Even a slight change of radiation balance components may cause changes in wind direction and currents of the ocean, which can greatly alter the existing climatic conditions and lead to unpredictable consequences. As a resut, the world's population and most of its ecosystems may be seriously damaged [Старченко В.Ф., Канєвський О. П., Рудницький П. В., Луценко Ф. Г. 1946].

Computer models have shown that if the contents of greenhouse gases in the atmosphere continue to grow, at the end of the 21st century the average temperature will increase by 1.4-5.8 degrees Celsius. At the same time the sea levels will rise by several tens of centimeters, not only because of the polar ice melting but as a result of thermal expansion of the upper layer warming up. Some coastal regions may completely disappear in the sea [IPCC, 2001 Climate Change 2001: Synthesis report].

Soil erosion will grow, landslides and flooding of coastal lands will become more frequent, the number of waterlogged lands will increase. The risk of natural disasters, such as cyclones, droughts, fires, floods, hurricanes will grow up. The number of natural disasters on our planet in the 80ies of the 20th century is known to be doubled comparing with the 70ies. In agriculture the need for meliorative activities will increase, yielding capacity and crop quality will change and this in its turn, will impact cattle breeding. In the energy sphere hydropower stations will be the most vulnerable.

Blood-sucker insects and forest pests will massively multiply. Many tropical and subtropical species of insects will spread to the north carrying such diseases as malaria, tropical virus fevers, etc, with them. There might be sharp deviation of temperature to both sides of the average one. For example, in January, there will be more days with temperature 25 degrees below zero and also with temperature above zero in Kiev.

The same can be observed with precipitation, winds, etc. Not only their average values will be changed but also deviation from them and the amplitudes of annual fluctuations. The increase of industrial emissions and the emissions of vehicles, besides the intensification of greenhouse effect, leads to worsening of air quality in cities more and more.

MATERIALS AND METHODS

The research was conducted in the territory of Rivne region (in the basin of the river Horyn), the type of soil under research is turphy-podzolic and dark grey podzolic light-loamy one. Field observations were carried out in the research field of the meliorative system "Pechalivka" and at seven observation sites of Rivne Agrometeorological Station.

All field studies were conducted according to current standards and methods of agrometeorological observations and in accordance with instructions [Наставление гидрометеорологическим станциям и постам. 1974; 2000].

During warm season soil temperature was taken with the help of mercury thermometer installed at the depth of 5, 10, 20, 30, 40, 50, 80, 100, 120, 140 cm, accuracy of measuring was 0,1 ^{0}C.

Precipitation was measured by the field rain gauge M-99 at the height of 150 cm over the soil, registration was done within 1 mm accuracy. Reception area of the rain gauge was 30 cm^2. Soil dampness was defined by thermostatical-weight method every decade, soil samples were selected in the field on the eighth day of the decade.

During winter period in order to observe temperature, the depth of freezing and soil thawing, the snow cover thickness, the following devices and equipment were used:

- manometrical thermometer AM-17;
- the Box of Nizyenkov;
- electric thermometer AM-2M;
- electric thermometer AM-29a;
- weight snowmeter AC-43;
- portable snowmetrical rail M-104;
- measuring instruments for the depth freezing measurement AM-21-I (AM-21-II).

Observation of the temperature, the depth of freezing and soil thawing, the height of snow cover were carried out in observation plots of winter crops and perennial grasses. The aim of our research was to reveal meteorological change factors on the local level, compare them with global warming processes and define their impact on mountainous and water habitat.

The results of numerous studies affirm that air temperature is a specific factor which affects all major biological processes on the earth [Старченко В.Ф. та ін. 1946; Димо В.Н. 1972; Веремеєнко С.І. 1997; Ліпінський В.М. та ін. 2003; Чуб В.Е. 2007]. The results of temperature in close-to-soil air layer in Rivne region are given in Table 1 and Figure 2.

Table 1. Temperatures of the decade, for the period 1961–2009 (According to data of Rivne meteorological station) [Веремеєнко С.И., Фурманец О.А. 2011]

Tabela 1. Temperatury w ciągu dekady, dla okresu 1961–2009 (według danych stacji meteorologicznej Rivne) [Веремеєнко С.И., Фурманец О.А. 2011]

Period Okres	**Months** Miesiące						**Annual** Rocznie
	I	II	III	IV	V	VI	
	VII	VIII	IX	X	XI	XII	
1961-1970	-6,4	-4,9	-1,5	8	13,5	17,2	6,8
	18,1	17,1	13,4	8,1	3,0	-4,1	
1971-1980	-5,2	-3,4	0,7	7,3	13,2	16,4	7,0
	17,5	17,1	12,7	7,0	1,9	-1,3	
1981-1990	-4	-3,7	3	7,9	14,4	16,1	7,3
	17,6	17,4	12,0	7,9	1,5	-1,8	
1991-2000	-2,8	-2	1,4	8,4	13,9	17,4	7,6
	18,5	18,0	12,8	7,6	1,4	-2,5	
2001-2009	-3,9	-2,1	1,4	8,8	15,7	17,1	8,3
	20,6	19,1	13,3	8,9	4,1	-3,7	

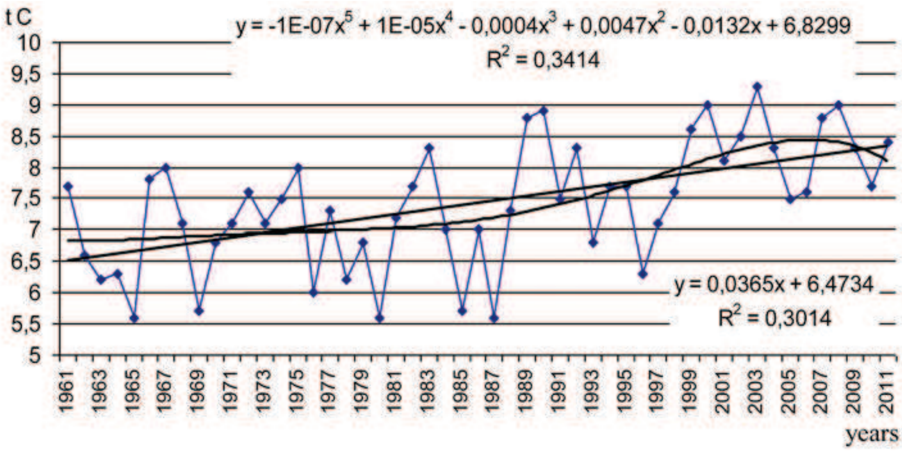

Fig. 2. The dynamics of air temperature change in Rivne: 1 – actual data; 2 – trend line (polynomial); 3 – trend line (straight line)

Rys. 2. Dynamika zmian temperatury powietrza w Rivne: 1 – faktyczne dane; 2 – linia trendu (wielomian) 3- linia trendu (linia prosta)

As Table 1 shows, average temperature over the past 50 years has risen by over 2 ^{0}C, that considerably exceeds average rate of global warming on the planet. It can be the result of the total effect of global climate changes and uncontrolled environmental changes on the local level. Such rising of annual average temperature points out at significant irreversible changes of thermal conditions of all ecosystem components.

It's worth noting that the dynamics of air temperature changes in the area of the river Horyn is described by equation of straight line or 5-grade polynomial with the determination coefficient R^2, 0,30 and 0,34 accordingly. The sum of effective temperatures is an important climate factor for agriculture.

As shown in Table 2 and Table 3 the sum of effective air temperatures over 5 ^{0}C has increased approximately by 10 per cent over the past 50 years while the sum of effective temperatures over 10 ^{0}C has increased almost by 22 per sent for the same period. Moreover, the determining point of this trend is the last decade.

Table 2. The sum of effective temperatures over 5 ºC for the period of 1961–2009 (According to data of Rivne meteorological station) [Веремеєнко С.И., Фурманец О.А. 2011]
Tabela 2. Suma temperatur efektywnych powyżej 5 ºC w okresie 1961–2009 (Według danych stacji meteorologicznej w Rivne)[Веремеєнко С.И., Фурманец О.А. 2011]

Period Okres	**Months** Miesiące												**Annual** Rocznie
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1961-1970	–	–	–	89	261	366	403	375	252	94	3	–	1843
1971-1980	–	–	–	68	254	342	386	375	231	62	–	–	1718
1981-1990	–	–	2	89	292	341	393	385	258	91	–	–	1851
1991-2000	–	–	–	104	276	371	420	403	234	83	3	–	1894
2001-2009	–	–	–	113	327	362	480	436	250	119	6	–	2093

Table 3. The sum of effective temperatures over 10 ºC for the period of 1961–2009 (According to data of Rivne meteorological station) [Веремеєнко С.И., Фурманец О.А. 2011]
Tabela 3. Suma temperatur efektywnych powyżej 10 ºC w okresie 1961–2009 (Według danych stacji meteorologicznej w Rivne)[Веремеєнко С.И., Фурманец О.А. 2011]

Period Okres	**Months** Miesiące												**Annual** Rocznie
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
1961-1970	–	–	–	–	107	215	265	220	101	8	–	–	916
1971-1980	–	–	–	–	100	192	232	220	96	–	–	–	840
1981-1990	–	–	–	1	136	186	238	230	96	–	–	–	887
1991-2000	–	–	–	7	120	222	265	223	84	–	–	–	921
2001-2009	–	–	–	–	178	212	329	281	100	8	–	–	1108

Effective influence of heat and light on biological and soil-forming processes is possible only when there is sufficient amount of moisture. Therefore, the value of precipitation in the soil is of great importance.

The precipitation coming into soil dissolves mineral organic compounds, removes them into lower horizons, removes the mobile forms of compounds and mechanical particles from higher elements of the relief to lower ones. These processes are carried out by surface waters and underground drains.

Precipitation brings silty soil particles, dissolved salts, acids, nitrogen, ammonia, toxic compounds to the soil surface, they directly and indirectly influence humification processes.

The soil moisture degree determines their chemical composition. In arid region soils with high content of carbonates and soluble salts, low in humus, with low absorption capacity are formed. In humid regions soil flushing, content of clay minerals and humus, absorbing capacity of soil are increased. In waterlogged conditions the acidity of soil is greatly increased, the humus content and absorption capacity are reduced.

The data of the precipitation observation of Rivne meteorological station prove that over the past 50 years average amount of precipitation has increased almost by 200 mm. Besides, clear tendency to annual precipitation growth is observed both during the whole period under analysis and also within past ten years.

It's important to note that the dynamics of changes in annual precipitation sum is described by the equation of the straight line or polynomial of the fifth grade with the determination coefficient R^2 0,27 and 0,42 accordingly (Figure 3).

In recent years the amount of precipitation during the period of January-March, May and July has significantly increased as well. Besides, the most important periods in agriculture concerning soil moisture content are periods of active vegetation and planting crops. Most of the rainfall increase refers to this period.

An important element of soil forming is evaporation of soil moisture which depends on temperature. Evaporation leads to increased concentration of soil solution and loss of salts in the sediment which causes the formation of secondary minerals and salt accumulation in soils.

Soil temperature affects the speed of chemical reactions. According to Van-Hoff's rule, with increasing temperature by 10 ^{0}C the speed of chemical reactions is increased

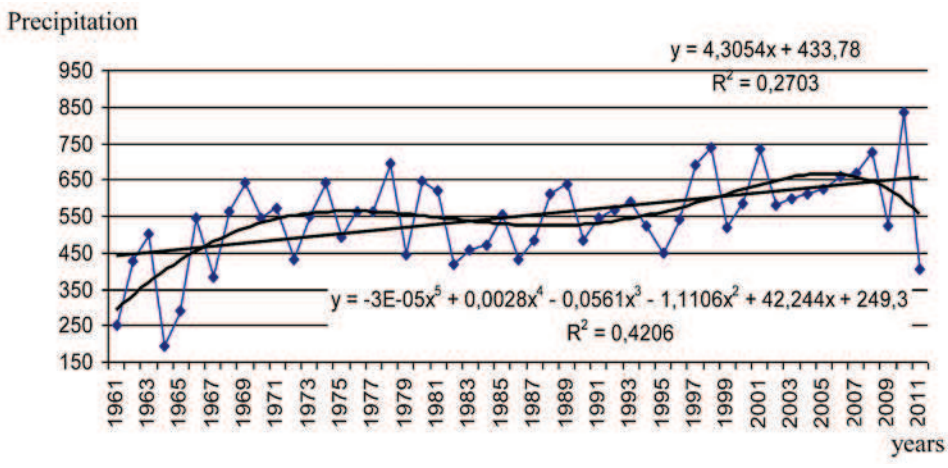

Fig. 3. The dynamic of precipitation quantity change in Rivne: 1 – actual data; 2 – trend line (polynomial); 3 – trend line (straight line)

Rys. 3. Dynamika zmian ilości opadów w Rivne: 1 – faktyczne dane, 2 – linia trendu (wielomian), 3 – linia trendu (linia prosta) in 2-3 times. Therefore, in areas with high average annual temperature geochemical processes occur much faster than in latitudes with cold climate. It defines annual rate of weathering and, as a result, diverse chemical composition of soil. In addition, the degree of dissociation of chemical compounds in aqueous solutions depends on the temperature. When the temperature rises from 0 to 50^0 the dissociation increases in 8 times.

It's worth noting that during the period of observation the average soil temperature at the depth of 20 cm has a growing trend as well. Thus, the increase in soil temperature is strongly observed within the period of July-September but during spring months it is not so noticeable (Figure 4).

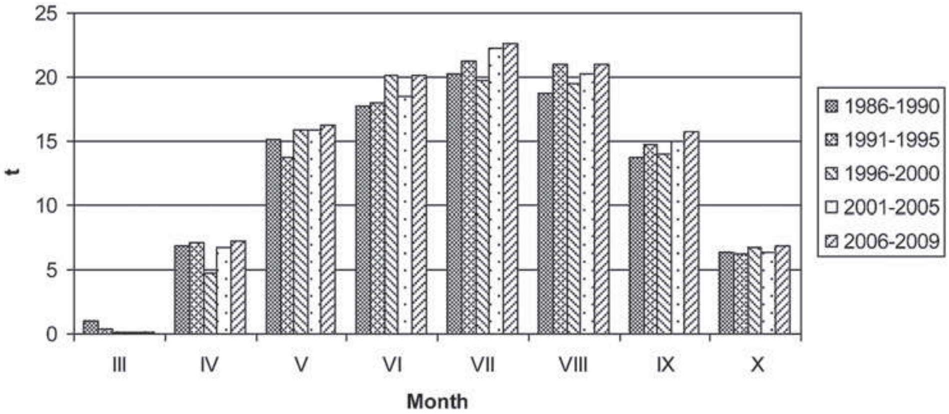

Fig. 4. Soil temperature at a depth of 20 cm, °C (According to the Rivne's meteorological station)
Rys. 4. Temperatura gleby na głębokości 20 cm, °C (Według stacji meteorologicznej w Rivne)

It might be due to the fact that sharp increase in rainfall during this period leads to increasing specific heat capacity of soil and prevents it from heating. At the same time the rising of soil temperature during the period of completion of major crops vegetation is likely to reduce the period of their active growth and accelerate the crop ripening.

The long period of research shows that the vegetation stops in the first-second decade of November. Soil freezing begins in December and lasts till March. Maximum freezing of turphy-podzolic soils is observed in the first and second decades of March. The depth of freezing ranges from 40 to 100 cm [Клименко Н.А. 1990].

Defreezing of turphy-podzolic soil begins in the middle of March both from below and the top of them and it is under the condition of soil freezing up to 100 cm more than 10 days (Figure 5).

The average depth of dark-grey soil freezing is 40–50 cm and only in years with cold winters it is 80–100 cm. Throughout the whole period of observation there is noticeable trend of decrease in freezing depth. For example, during the period of 1985–1989 maximum depth of freezing was 68,2 cm, the average one – 39 cm, but over the past five years these figures went down to 28,4 and 14 cm respectively (Figure 6).

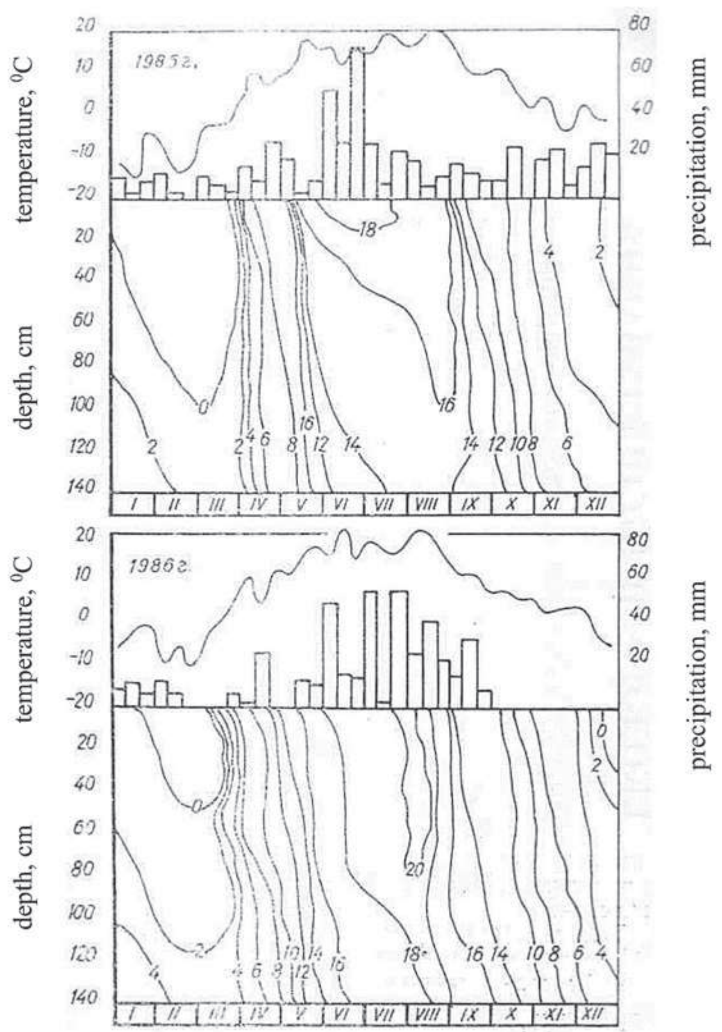

Fig. 5. Thermoisoplates of drained turphy-podzolic soil (1985–1986 years)
Rys. 5. Termoizoplety osuszonej gleby torfo-bielicoziemnej (lata 1985–1986)

Besides, the analysis of weather conditions within the period of 1985–2009 has shown that climate changes greatly influence conditions of moistening in the area of the river Horyn basin, the hydrothermal coefficient, the index of soil heating and the average annual drainage of the river. The relationship between air temperature and evaporation were first noticed and used as a climatic indicators by E. de Martonne, G. Selyaninov.

The analysis of weather conditions during the years of 1985–2009 showed that annual rainfall varied within 446,3 – 775,3 mm, the average value for the last 5 years – 649,6 mm, that greatly exceeds average long-term value – 569 mm.

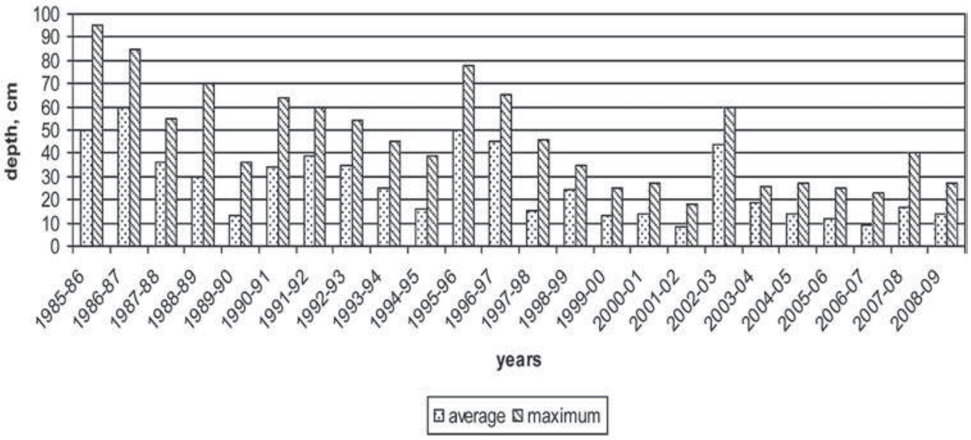

Fig. 6. The depth of freezing (dark gray soil), cm (according to the Rivne's meteorological station)
Rys. 6. Głębokość zamarzania (gleba ciemnoszara), cm (według stacji meteorologicznej w Rivne)

For all this, 60–65 per cent of precipitation falls during the period of active temperatures and the most supplied with precipitation months are May – July. At the same time evaporation rates calculated by the amount of active temperatures showed that the total ratio of precipitation and evaporation is less than a unit and varies from 0,80 to 0,96 [Димо В.Н. 1972].

Simultaneously, there is a clear tendency to increase this ratio (and hence to increase the humidity of the area) in recent years due to a significant increase of rainfalls (Table 4).

Table 4. Moisture conditions (over the period of 1985–2009)
Tabela 4. Warunki wilgotności (w okresie 1985–2009)

Year Rok	**Precipitation** Opady	**Evaporation** Parowanie	**Evaporation/Precipitation** Parowanie/Opady
1985-1989	555	665	0,83
1990-1994	541	674	0,80
1995-1999	603	688	0,87
2000-2004	610	715	0,85
2005-2009	670	697	0,96

At the same time, the calculated Hydrothermal Coefficient over the years 1985–2009 varied within the range of 1,40 – 1,65 with maximum values in recent years. At the same time there was a significant increase not only of rainfall amount that fell during the period of active temperatures, but of amounts of active air temperatures > 10 ^{0}C (Table 5) [Веремеєнко С.И., Фурманец О.А. 2011].

The criterion for evaluating sufficiency of moisture for the plants should be not only moisture content, but also the value of soil heating, because soil heating changes the conditions of evaporation. This ratio is important for plant growth and development.

Table 5. Calculation of Hydrothermal Coefficient (HTC)
Tabela 5. Obliczenie współczynnika hydrotermalnego (HTC)

Year Rok	**Sums of effective air temperatures > 10 ^{0}C** Sumy efektywnych temperatur powietrza > 10 ^{0}C	**Precipitation over the period of air temperature > 10 ^{0}C** Opady w okresie temperatury powietrza > 10 ^{0}C	**HTC** współczynnik hydrotermalny
1985-1989	2583	389	1,5
1990-1994	2620	368	1,4
1995-1999	2678	411	1,53
2000-2004	2797	399	1,43
2005-2009	2718	450	1,65

According to S. Radchenko (1966), it defines patterns of vegetation distribution on the Earth. The soil heating index also determinates the main direction of heat exchange in the system: soil – soil – level air layer in the period of active temperatures.

The calculated soil heating index has a clear upward trend throughout the observation period, a slight decrease in this index over the past five years, is probably due to the sharp increase of rainfall in this period, which significantly affects the heat capacity of soils (Table 6).

Table 6. Calculation of Soil Heating Index (by V. Dimo)
Tabela 6. Obliczenie Wskaźnika Nagrzewania się Gleby (przez V.Dimo)

Year Rok	**Sums of effective air temperatures > 10 ^{0}C** Sumy efektywnych temperatur powietrza > 10 ^{0}C	**Precipitation over the period of air temperature > 10 ^{0}C** Opady w okresie temperatury powietrza >10 ^{0}C	**SHI** Wskaźnik nagrzewania się gleby
1985-1989	2583	389	1,054
1990-1994	2620	368	1,062
1995-1999	2678	411	1,073
2000-2004	2797	399	1,091
2005-2009	2718	450	1,086

CONCLUSIONS

1. The results of statistical processing of long-term observation of key climate-indices indicate that in the region there are really distinct climate changes.
2. Average air temperature during the years of 1961-2009 has increased by 1,5 ^{0}C, that is significantly above the average rate of global warming on the planet.
3. Over the past 50 year the amount of effective air temperatures over 5 ^{0}C has increased by 10 per cent (from 1843 to 1093 ^{0}C) and the amount of effective temperatures over 10 ^{0}C has increased for the same period by almost 22 per cent (from 916 to 1108 ^{0}C).

4. Average annual precipitation over the same period has increased from 429 to 717 mm.
5. Soil temperature at the depth of arable horizon (20 cm) for the period 1986–2009 has increased by an average 7 per cent.
6. Depth of soil freezing in winter for the same period has fallen more than twice.
7. Over the period of observation the ratio of total precipitation and evaporation has increased by 16 per cent and the value of HTC has also increased by 10 per cent indicating the increase of humidity of the area.
8. Soil Heating Index also has gone up by 3 per cent for the period 1986–2009.
9. The increase of total annual precipitation up to 100–150 mm in the area of the river Horyn basin is accompanied by the increase of the value of average river drainage by 18–22 m^3/c.
10. Dynamics of climate changes in the area under investigation pass ahead the rate of global climate changes, determined by the leading scientists of the world.
11. Such change of climatic indices of the region is likely related to changes in atmospheric composition, particularly to increasing content of greenhouse gases. At the same time the rising of average air temperature, and the increase of heating and moistening of the areas will further increase volatility of water vapor and carbon dioxide emissions, which are the main components of the greenhouse effect on the Earth.

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WPŁYW WSKAŹNIKÓW METEOROLOGICZNYCH NA GÓRSKIE I WODNE ŚRODOWISKO ŻYCIA W DORZECZU RZEKI HORYN (UKRAINA)

Streszczenie

Niniejsza praca poświęcona jest badaniu szczególnych cech wskaźników meteorologicznych w dorzeczu rzeki Horyn. W pracy podane są wyniki długofalowej obserwacji głównych wskaźników meteorologicznych ze stacji meteorologicznej Rivne. Odkryto przyczyny i prawdopodobne konsekwencje zmiany klimatu. Wzięto pod uwagę wpływ globalnego ocieplenia na lądowe i wodne środowisko życia. Potwierdzono dostępność zmian głównych elementów warunków meteorologicznych na terenie dorzecza (opad atmosferyczny, temperatura powietrza, wartość temperatury aktywnej i efektywnej) oraz ich wpływ na temperaturę gleby, zamarzanie gleby, warunki wilgotności, współczynnik hydrotermiczny, nagrzewanie się gleby i wysychanie rzeki.

Słowa kluczowe : temperatura gleby i powietrza, opad atmosferyczny, temperatura aktywna i efektywna, zamarzanie, wilgotność, nagrzewanie, wysychanie rzeki, gazy cieplarniane.

DER EINFLUSS DER METEOROLOGISCHEN IDIKATOREN AUF DAS LEBEN IM GEBIBRGE UND IN AQUATISCHER UMWELT DES ZUFLUSSGEBIETS VOM FLUSS HORYN (UKRAINE)

Zusammenfassung

In dieser Bearbeitung wurden die besonderen Merkmale der meteorologischen Indikatoren des Zuflussgebiets des Flusses Horyn erforscht. Es wurden hier die Ergebnisse einer langzeitigen Beobachtung der meteorologischen Indikatoren aus der Wetterstation Rivne vorgestellt. Man entdeckte die Ursachen für wahrscheinliche Konsequenzen des Klimawandels unter Berücksichtigung der globalen Erwärmung auf die terrestrische und aquatische Umwelt. Man bestätigte auch Zugänglichkeit der Hauptelementveränderung an meteorologischen Bedingungen des Zuflussgebietes (Regenfälle, Lufttemperatur, aktive und effektive Temperaturwerte) und ihr Einfluss auf Bodentemperatur, Bodenerfrierung, Feuchtigkeitsbedingungen, hydrothermische Indikatoren, Bodenerwärmung und Flussaustrocknung.

Schlüsselworte: Boden- und Lufttemperatur, Regenfall, aktive und effektive Temperatur, Erfrierung, Feuchtigkeit, Erwärmung, Flussaustrocknung, Treibgase