

IMPACT OF CLIMATE CHANGE ON PRODUCTIVITY OF ECOSYSTEMS OF THE POLISSYA ZONE OF THE UKRAINE

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Abstract:

Results of the analysis proved that the net primary productivity has a strong connection with the solar insolation. The length of daylight and the level of solar radiation are the driving forces behind changes in growth of primary products, as floral forms are among the first indicators of changes in ecosystems due to global warming. The group of climatic components that have a moderate connection with the bioproductivity of ecosystems of the Polissya are derivatives of bioclimatic indicators related to air temperature, including annual temperature, seasonality, minimum temperature of the coldest month, and the average temperature of the coldest quarter. Seasonality and the annual variation of temperature affect bioproductive processes inversely: the productivity decreases with the increased temperature range between the warmest and the coldest periods of the year and in the middle of quarters.

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Key words: climate change, productivity of ecosystems, Polissya.

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INTRODUCTION

The present climate change have reached such an extent that it is followed by a significant transformation of ecosystems, manifested in their degradation, imbalance and hydrological regime, loss of natural features and reduced biodiversity. The intensification of these problems calls for restriction of negative effects on natural ecosystems due to appropriate research and well-timed forecasting of the state of biodiversity at all levels of existence of living things, vectors of its development. This primarily applies to meadow ecosystems, which are characterized by high biodiversity, the presence of unique rare habitats that preserve natural features.

In the Ukraine, according to the Ministry of Environmental Protection and Natural Resources of the Ukraine, the average annual temperature has increased by more than 2°C since the beginning of the 20th century (1.2°C for the last 30 years), and the frequency of days with maximum summer temperatures above 35 and 40°C has doubled, which refers to extreme weather events. There is a tendency to increase droughts and the number and duration of hot periods (Ivanyuta *et al.*, 2020). Under the influence of climate change, the productivity of natural and artificial phytocenoses changes, so when substantiating the schemes of optimal nature management, it is important to assess the

change in primary productivity depending on the main and derived climatic factors.

The aim of the study is to assess the degree of influence of climatic parameters on bioproductive processes of ecosystems of the Polissya zone of the Ukraine and to analyze their adaptive capabilities in the context of climate change. For a long time (during the 60–70 years of the 20th century), the International Biological Program (IBP) as a research program of biological productivity across the globe, revealed the basic patterns of distribution and reproduction of the primary productivity of ecosystems. The dynamics of bioproductivity of different ecosystems and the assessment of plant phytomass components were used by P.I. Lakida (Lakida, 1996), D.B. Botkin, L.G. Simpson (Botkin and Simpson, 1990), H.A.I. Madgwick (Madgwick, 1970) and other scientists in their studies.

PROBLEM STATUS

The Ukrainian Polissya is an ecologically specific region, as relatively unsuitable for agriculture soils have allowed to preserve the lower transformation of ecosystems compared to the forest-steppe and steppe, and the main features of Polissya landscapes: coarse topography, significant distribution of sand deposits and high level of bogginess.

The current state of vegetation is characterized by the preservation of ecosystems of deciduous forests and wetlands. The leading biomorphs of flora are annuals, rhizomatous and taproot grasses. In general, the species composition of natural flora retains the ability to self-recovery, but the number of border area species is at a critical level and floristic zones show dependence of the floristic composition of the territory on edaphoclimatic conditions and the degree of anthropogenic impact (Lukash, 2009).

An issue of the influence of climatic conditions on productivity in some areas has been studied on a piecemeal basis and it requires a deeper scientific analysis. For the Polissya zone, there is a risk of desertification and depletion of ecosystems due to drought, which will stimulate a spread of drought-resistant species. The drought will increase the number and frequency of fires and the emergence of unproductive groups formed by invasive species. In Polissya, scenarios for drying up of swamps, reduction of lakes and changing water chemistry are possible. Therefore, all of these symptoms will lead to changes in biotic components of ecosystems and the xerotification of areas can be expected (Ivanyuta *et al.*, 2020).

MATERIALS AND METHODS

For the correlation analysis, GIS layers for the Polissya zone were used. They contain geospatial information on climatic-soil indicators and production processes in ecosystems. (Running *et al.*, 1999). Geospatial data allowed us to estimate the total annual net primary productiv-

ity. For further work in QGIS 3.4.15, these images were converted from HDR format to GeoTIFF format. For the Polissya zone of the Ukraine, a GIS layer was calculated with the values of the average net primary productivity for the period 2008–2018. Correlation analysis was applied using QGIS software and GRASS module *r.regression.line* (QGIS). Bioclimatic variables were taken from the free access database BIOCLIM. Information on soil types was taken from the database of the public cadastral map of the Ukraine (Public cadastral map of the Ukraine).

The results of the regression analysis show the relationship between the studied indicators. The correlation coefficient demonstrates the degree and nature of the relationship. The determination coefficient shows the degree of dependence of the variation of the dependent indicator on the variation of independent variables and confirms the obtained correlation coefficient and the predicted models. The results of the correlation analysis were evaluated on the Chaddock scale: the connection is quite high when the indicator is 0.9–0.99, 0.7–0.9 means a high connection, 0.5–0.7 is a significant connection, 0.3–0.5 is moderate, 0.1–0.3 is weak and <0.1 means no connection.

The following data were used: temperature indicators (minimum, maximum, average), precipitation, soil types, level of solar insolation.

RESULTS

Results of the correlation analysis reflect the generalized climatic characteristics of the area, which can be

Table 1. Results of the regression analysis of the dependence of the primary productivity of ecosystems of the Polissya zone in the Ukraine on bioclimatic parameters.

Bioclimatic parameters	R ₁ , correlation coefficient	R ₂ , determination coefficient	Connection according to the Chaddock scale
Insolation index, kW/m ²	0.51	0.26	considerable
Annual cycle of temperature	0.48	0.23	moderate
Temperature seasonality	-0.45	0.21	moderate
Minimum temperature the coldest month	0.44	0.20	moderate
Average temperature of the coldest quarter, °C	0.43	0.19	moderate
Average annual temperature	0.42	0.18	moderate
Average temperature of the wettest quarter, °C	-0.41	0.17	moderate
Precipitation of the warmest quarter, mm	-0.23	0.05	weak
Precipitation of the wettest quarter, mm	-0.18	0.04	weak
Annual precipitation, mm	-0.14	0.02	weak
Precipitation in the wettest month, mm	-0.12	0.02	weak
Seasonality of precipitation (coefficient of variation), mm	-0.13	0.02	weak
Height, m	-0.22	0.05	weak
Soil types	-0.23	0.05	weak
Average temperature of the warmest quarter, °C	0.18	0.03	weak
Annual average air daily temperature amplitudes, °C	-0.12	0.02	weak
Average temperature of the driest quarter, °C	0.10	0.01	weak
Maximum temperature of the warmest month, °C	-0.0036	0.00001	absent
Precipitation of the driest quarter, mm	-0.05	0.003	absent
Precipitation of the autumn-winter-spring period, mm	-0.06	0.004	absent
Precipitation of the coldest quarter, mm	-0.05	0.002	absent
Precipitation of the driest month, mm	-0.03	0.001	absent

used for ecosystem modeling in forecasting an impact of climate change on the ecosystems of the Polissya zone in the Ukraine.

According to the result of regression analysis, the insolation index has the greatest influence on the formation of the net primary productivity indicator as the correlation coefficient is 0.51 (Table 1). The reduction of the received solar radiation will negatively affect the growth of biomass and species diversity.

Moderate connection is recorded for the following characteristics: the annual cycle of temperature, temperature seasonality, minimum temperature of the coldest month, average temperature of the coldest quarter, average annual temperature and average temperature of the wettest quarter. The minimum temperature of the coldest month of the year, the average temperature of the coldest quarter and the average annual temperature demonstrate direct proportion. Therefore, with an increase in the value and rate of the above-mentioned indicators, the indicator of net primary productivity will increase; with a decrease in the level of these values of temperatures, the decline in NPP growth rate and shift in the growing season will take place. The annual cycle of temperatures, seasonality of temperatures and the average temperature of the wettest quarter show the inverse proportional nature of the impact.

According to the regression analysis, the absence of the influence of climatic factors on the growth of flora biomass was recorded for the amount of precipitation of the driest quarter, the amount of precipitation of the autumn–winter–spring period, the amount of precipitation of the coldest quarter, the amount of precipitation of the driest month and maximum temperature of the warmest month.

DISCUSSION

The result of the correlation analysis can be explained by the dependence that reflects the adaptive capabilities of plants. The level of solar radiation is an important environmental factor, as it affects the course of biochemical processes, growth, photosynthesis, seed germination and more. Plants respond to changes in ultraviolet radiation by varying the height of the stem, changes in flower development, cytoplasmic viscosity, photosynthetic activity and nutrition (Mysiak, 2011). The length of daylight and the amount of solar energy are the driving forces, primarily of photosynthesis and bioproductive processes as shading decreases contents of photosynthetic pigments, which leads to growth inhibition and inactive natural regeneration of plant communities. Lack of light can lead to retardation of plants and its excess to the inhibition of the pulling shoots processes. This explains the obtained result of a directly proportional dependence of the growth of flora biomass on the insolation index.

For agroecosystems, the value of the insolation is important in terms of obtaining a higher yield at the end. Accordingly, the feasibility of the use of certain types of crops depends on the change in solar radiation and a number of sunny days.

At present, the Ukrainian agricultural sector is not extremely vulnerable to climate change. However, changes in weather conditions lead to an increase in a number and intensity of droughts. Together with other negative factors of anthropogenic impact, this may lead to the expansion of the zone of risky agriculture and desertification in the southern regions of the Ukraine (Analytical information, 2020).

Over the periods from January to March and from October to November, there is a moderate directly proportional dependence of the biomass growth rate on the maximum temperature. Because during these periods the plants are at rest, first physiological and then forced, an increase in maximum temperature during these periods leads to a shift in the completion or beginning of the growing season and this affects a growth of biomass (Table 2). There is no connection at the maximum temperature in July and August as the plant species are adapted to the temperatures of the temperate continental climate, including the maximum values. All indicators, except for the maximum temperature in the period from May to June inclusive, are directly proportional. For the maximum temperature values for May and June, the directly inverted result is typical.

Compared to the results of the temperature maximum, the increase in biomass for the Polissya zone depends more on the minimum temperature as the critical minimum temperature values can negatively affect the physiological characteristics of plants. With an increase in amplitude between the minimum and average temperatures, the plants are in a state of suppression, and therefore, the biomass growth is minimal.

It is practically confirmed that the value of the minimum temperature has mostly a moderate effect on the growth of net primary products. The obtained data of the correlation coefficient for the minimum temperature indicator are directly proportional: the more the minimum temperature indicator decreases, the lower the value of biomass growth is (Table 2).

A weak connection was recorded at minimum temperatures in the period from May to July inclusive that makes sense given that in the above-mentioned months, the minimum air temperature is higher than in other seasonal periods, and therefore it is suitable to perform and maintain vital functions, including for the photosynthetic activity.

The correlation coefficient for the average temperature is recorded to have a moderate effect on the growth of net primary production in the period from September to April inclusive. However, in contrast to the values of the correlation coefficient of the maximum temperature, there is no connection in the period from May to June inclusive (Table 3).

The result of the correlation analysis of the influence of precipitation on the indicator of net primary production showed that there is no connection. Because most species of the Polissya zone belong to the mesophytes and the climate is temperate-continental, mild, fairly wet, with relative humidity in the warm season (April–October) from 60% in spring to 80% in autumn, the average annual precipitation of 500–600 mm, humidity factor in the range of 1.9–2.8 it has no significant impact on biomass growth. In

Table 2. Results of the regression analysis of the influence of maximum and minimum temperature on the indicator of net primary production.

Months	R ₁ , correlation coefficient <i>T_{max}/T_{min}</i>	R ₂ , determination coefficient <i>T_{max}/T_{min}</i>	Connection according to the Chaddock scale <i>T_{max}/T_{min}</i>
January	0.45	0.2	moderate
	0.43	0.19	moderate
February	0.43	0.19	moderate
	0.41	0.17	moderate
March	0.42	0.18	moderate
	0.43	0.19	moderate
April	0.28	0.08	weak
	0.43	0.19	moderate
May	-0.16	0.03	weak
	0.23	0.05	weak
June	-0.14	0.02	weak
	0.23	0.05	weak
July	-0.006	0.00004	absent
	0.27	0.07	weak
August	0.08	0.006	absent
	0.33	0.11	moderate
September	0.27	0.07	weak
	0.42	0.18	moderate
October	0.36	0.12	moderate
	0.45	0.2	moderate
November	0.43	0.19	moderate
	0.44	0.2	moderate
December	0.14	0.019	weak
	0.41	0.17	moderate

Table 3. A result of the correlation analysis of the monthly influence of the average temperature on the indicator of net primary production.

Months	R ₁ , correlation coefficient	R ₂ , determination coefficient	Connection according to the Chaddock scale
January	0.441	0.193	moderate
February	0.421	0.176	moderate
March	0.433	0.187	moderate
April	0.440	0.193	moderate
May	0.040	0.002	absent
June	0.063	0.004	absent
July	0.148	0.022	weak
August	0.251	0.062	weak
September	0.386	0.149	moderate
October	0.416	0.176	moderate
November	0.435	0.190	moderate
December	0.434	0.189	moderate

abnormally dry years, years with weakened cyclones in the Left Bank Polissya, droughts and dry winds may appear, but due to the formation of meadow, swamp and forest vegetation on mostly sod-podzolic and swamp soils and high groundwater levels, these effects are not critical and do not cause significant deviations in the formation of primary products.

CONCLUSIONS

As a result of the regression analysis, a strong influence of insolation on the growth rate of net primary productivity in the Polissya zone of the Ukraine was revealed. The main and derivative temperature factors had a moderate influence on the growth of biomass of plant groups. They are the annual cycle of temperatures, temperature seasonality, minimum temperature of the coldest month of the year, average temperature of the coldest quarter, average annual temperature, average temperature of the wettest quarter. The main and derivative indicators of the precipitation level and the maximum temperature of the warmest month of the year (July) have no effect on the biomass growth. The insignificant influence of precipitation is explained by the sufficient wetness of the region, the developed river network and the predominance of floodplains of land. Correlation analysis revealed that the nature of the relationship between indicators is directly and inversely proportional. Accordingly, the productivity of Polissya ecosystems will depend on the particular influence of climatic factors. Since the biomass growth rate is sensitive to climate impacts, the projected climate change scenarios will primarily affect the primary productivity of ecosystems, which in turn may shift the habitats of plant and animal communities and threaten the loss of unique biodiversity of the Polissya zone.

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