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## Spatio-temporal Changes in the Regime of Rivers in the Pripyat River Catchment and Climate Change

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ABSTRACT

In work features of a hydrological regime of catchments of the river of the Pripyat in climate change are considered. Researches of meteorological characteristics of the given territory show the tendency to growth, both temperatures of air, and precipitation, evaporation from a surface of water and ground also show the tendency to increase. That is not unequivocally reflected in change of a course of hydrological characteristics waters objects of territory. On a part of pools of the rivers the mid-annual runoff of water in the rivers in time tends to growth, and Change of levels of subsoil waters decreases for parts - on a turn - here, as a rule, tends a course in time opposite to a mid-annual runoff of water in the rivers. Change of the maximal temperature of water in the rivers in time repeats the tendency of a course of a runoff of water in them, i.e. at increase in a runoff of water in the rivers - the maximal temperature increases, and at reduction - decreases. The increase in temperature of a superficial component of a runoff of the rivers occurs because of the general increase in temperature of air in considered territory. Silt charge waters in all territory decreases, despite of increase in quantity of atmospheric precipitation and increases or reduction of a runoff of water in the rivers. The relationship between the water runoff layer and precipitation and soil moisture has a certain time delay. The average annual water temperature over time shows a tendency to increase at almost all stations, while the change in the maximum water temperature in rivers over time has a multidirectional tendency and to a greater extent depends on the change in water depth in the river, a decrease in high water maximums and frequent thaws, etc. The studies carried out show that the preservation of moisture in thick layers of soil (0 cm-100 cm) contributes to an increase in water flow in rivers and in the modern conditions of Polesie of Ukraine this will solve a number of problems with the provision of high-quality water resources for various industries and the population.

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## 1. Introduction

The hydrological mode of the rivers is characterized by set of parameters, including a runoff of water, precipitation, a temperature mode, etc. Changes of a climate of last decades are reflected in all components of a hydrological mode that causes in their constant research and forecasting of directions of their possible changes for stable work of branches of a national economy, sewn up from flooding, droughts, etc. <sup>[1,2]</sup>. In work the river basin Pripjat (a wood and forest-steppe natural zone) is investigated located in northwest of Ukraine. Territory of pool of Pripjat also it is constantly investigated for changes of components of a hydrological mode <sup>[3-9]</sup>. On catchments of Pripjat settles down two states, scientific both pay to its research significant attention. So, the analysis of dynamics of a runoff of water of the rivers Belarusskoj of a part of catchments of Pripjat has shown <sup>[3]</sup>, that since the middle of 60th years of the last century, mid-annual, minimal years and winter charges have the steady tendency to increase, during too time, the runoff of a spring high water decreases.

As a result of climatic changes there was a displacement of dates of approach of the maximal charges of water of a spring high water for earlier terms (71.5% of cases peak of high waters fall to the third decade of March) in a direction from a southwest on northeast of Belarus <sup>[4]</sup>. Reduction of the maximal charges of water of a spring high water of the large rivers Belarussii, caused is established by winter thawing weather therefore the part of a spring runoff passes in the minimal winter runoff <sup>[4]</sup>. Also it is revealed, that in connection with non-uniform spatial distribution of trends of precipitation on territory of Belarus and in adjoining regions it is observed different directed change of conditions of formation of a river runoff, especially during the open channel <sup>[5]</sup>.

Owing to prevalence of a flat relief, a high arrangement of subsoil waters and significant marshiness of a reservoir, the mode of the river Pripjat is characterized by smooth change of charges of water in time, more inert fluctuations water content and the stretched high waters. The rivers water content in considered pool in each of phases of a hydrological cycle it is caused water content a previous season. The prolonged influence of meteorological factors on formation of a runoff is marked. Calculations of trends of the monthly sums of precipitation for the period 1948-2018 have shown increase in the monthly sums of precipitations, reduction of duration of loss of precipitations and growth of the maximal sums of precipitations that can testify to increase in duration of the periods without precipitations and more frequent formation of droughty conditions. The increase in precipitations was expressed

in small increase in a share of an aestivo-autumnal runoff and positive trends of the least charges of water of the period of the open channel <sup>[5]</sup>.

Modern warming of a climate has affected not only the maximal charges of a spring high water, but also on a level <sup>[6]</sup>. Practically on all rivers downturn of average values of maximum levels of water of a spring high water for the period c1988 for 2014 in comparison with the period with 1946 for 1987 as a whole is observed, for the period (1946-2014) for the rivers of catchments of Pripjat the tendency to decrease in a water level is observed. Local decrease in water levels during with 80th for 90th years of the last century, caused by meliorative influences, and the period of some growth caused by modern climatic changes, and its stabilization in current century takes place <sup>[7]</sup>.

The anthropogenic impact on the study area, one way or another, affects the hydrological regime of the rivers. Reclamation work in Polesie could not but affect the water regime of the river. Pripjat and its floodplains <sup>[8,9]</sup>. After the draining of bogs and wetlands on the catchments of rivers, swampy up to 30%, according to studies <sup>[9]</sup>, there is a decrease in spring runoff by 0%-20%, an increase in low-water runoff by 10%-50% and annual runoff by 0%-15%. The decrease in the maximum levels of spring floods cannot be attributed only to the influence of land reclamation, but it has a significant effect <sup>[8]</sup>.

Agriculture also influences the components of the hydrological regime of the rivers in the study area <sup>[12]</sup>, since the plowing of the basins here is 10%-80% (on average 40%-50%).

Based on assessments of possible climate change, it was found that with the most unfavorable development of climate changes, the flow of individual rivers of the Pripjat basin can decrease to 45%, which is equivalent to a change in supply (from 50% to 85%), and the variation coefficient from 0.47 to 0.54. When the anthropogenic component influences the runoff, the decrease in the average annual runoff can reach 50%-70% <sup>[5]</sup>.

## 2. Materials and Methods

To study the features of the hydrological regime of the rivers of the Pripjat River basin on the territory of Ukraine over a long-term period, we used standard observation materials at stationary observation posts of the Hydrometeorological Service of Ukraine for the entire observation period. These are materials of the state water cadastre (basic hydrological characteristics, hydrological yearbooks) and climatic cadastre (climate reference books, meteorological monthly books, etc.).

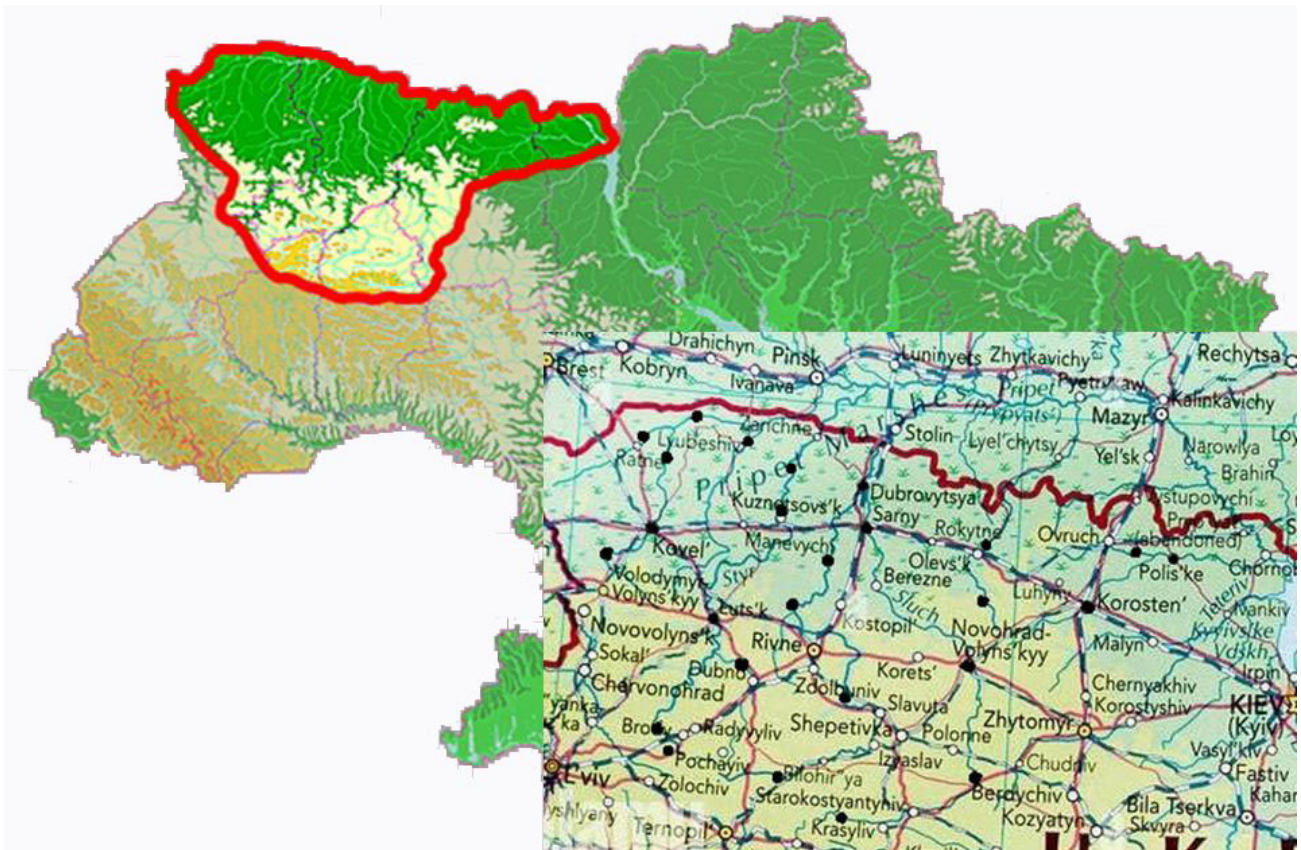
The list of observation points for water runoff, which, in one way or another, were used in the studies is

presented in the Table 1. In Figure 1 the arrangement of a river basin Pripyat in Ukraine and an arrangement of items of supervision over a runoff of water on it are presented.

Some of the observation points are currently closed, which shortens the observation series and allows the use of this information in the ranges of observation periods as addi-

**Table 1.** Characteristics of observation posts for water flow in the Pripyat river basin

River - observation point for discharge	Distance from the source, km	Catchment area, km <sup>2</sup>	Note
Pripyat - Rechitsa	84	2210	
Pripyat - Lyubyaz	157	6100	
Vyzhevka - Ruda	10	141	
Vyzhevka- Staraya Vyzhevka	44	722	
Tur'ya - Yagodnoye	57	459	
Turya - Kovel	102	1480	
Turya - Buzaki	164	2630	Closed 1988
Stokhod - Malinovka	48	692	
Stokhod - Gulevka	99	1420	Closed 1988
Stokhod - Lyubeshov	173	2970	
Styr - Shchurovtsy	57	2020	
Styr - Lutsk	194	7200	
Styr - Kolki	335	9050	observation point for water level
Styr - Polonnoe	345	10400	Closed 1940
Styr - Mlynok	400	10900	
Radostavka-Troitza	19	316	
Ikva - Velikiye Mlynovtsy	59	632	
Goryn - Yampol	71	1400	
Goryn - Ozhenin	223	5860	
Goryn - Derazhno	379	9160	
Goryn - Stepan	456	10300	
Goryn - Dubrovitsa	488	12000	Closed 1990
Vyrka - Svaryny	21	231	
Sluch - Bolshaya Klitna	30	232	Closed 1983
Sluch -Gromada	139	2480	
Sluch - Novograd-Volynsky	252	7460	Open 1974 r.
Sluch - Sarny	409	13300	
Homora - Poninka	105	1410	Closed 1988
Tnya - Bronniki	68	982	
Smolka - Susly	65	632	
L'va - Osnitsk	24	276	
Ubort' - Rudnya - Ivanovskaya	45	510	
Ubort' - Perga	136	2880	
Uzh - Korosten'	84	1450	
Uzh - Polesskoye	169	5690	Closed 1995
Zherev-Vyazovka	78	1360	Closed 1988
Noreen - Lukishki	40	531	Closed 1943
Noreen - Slavenshina	79	804	
Grezya - Ur.Brod	28	616	Open 1967 - Closed 1982
Ilya - Lubyanka	32	300	Closed 1986



**Figure 1.** Position of a river basin Pripjat and an arrangement of items of supervision over a runoff of water on it.

tional. Among the research methods, the methods of water balance and graphical analysis were mainly used. Sizes of a runoff, precipitations, evaporations were compared, a soil moisture in identical units (in mm), that allows to compare with them among themselves. The graphs of the course of the characteristics of the hydrological regime and the characteristics of the climate in time were plotted for observation posts and stations, and the directions of the trends and the tangents of their inclination angles were revealed. Based on the analysis of the direction and slope of the trend lines, schematic maps of the spatial-temporal direction of changes in the indicators of the hydrological regime of the territory were built.

### 3. Results

The study of changes over time in climate characteristics such as precipitation and temperature showed that they tend to increase in the study area (Figures 2-3). However, over the basin area, this trend is uneven<sup>[11]</sup>. Thus, the maximum increase in atmospheric precipitation falls on the northern part of the study area, and the minimum on the middle course of the Pripjat tributaries. In the southern part of the territory (the headwaters of the Pripjat tributaries, the spurs of the Podolsk Upland), there

is also a small maximum increase in precipitation.

Analysis of the course of water runoff over time for most rivers in the Pripjat River basin shows that surface runoff tends to increase (Figures 4a, 5b). However, in part of the catchments of the study area, the opposite tendency is observed: the surface runoff decreases (Figures 4b, 5a), while the groundwater runoff increases. Some researchers also argue that an increase in the water content of rivers is observed in the upper reaches of the Dnieper<sup>[11,12]</sup>, while others<sup>[13]</sup> argue that the water content decreases in the middle and lower reaches of the Dnieper.

It is important that if we consider the observation series for the Tur'ya River not for the entire observation period, but in the range of 1962 -2018, then the direction of the trend changes, at the Tur'ya-Yagodnoye post the runoff decreases, and at the Tur'ya-Kovel it increases.

This is shown by the manifestation of the cyclicity of hydrological processes in the directions of trends with longer observation periods. The longer the observation series, the more information about the cyclicity of hydrological processes they carry and the more important the information at these posts. I would like to emphasize that the more observation posts cover secular observation periods, the more informative the observation materials



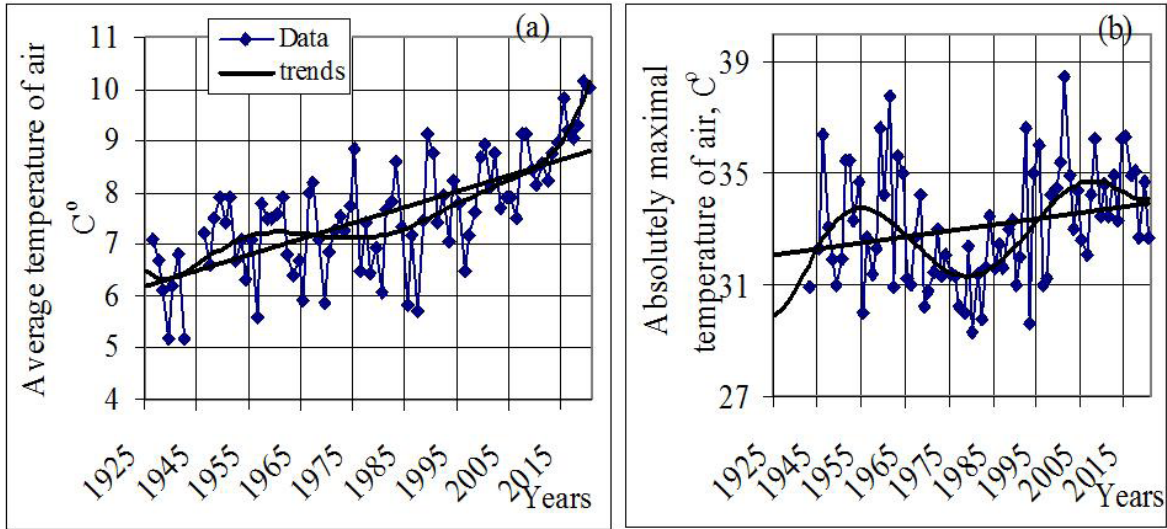


Figure 2. Change in time of Average (a) and maximal (absolutely) (b) temperature of a on meteorological station Sarny

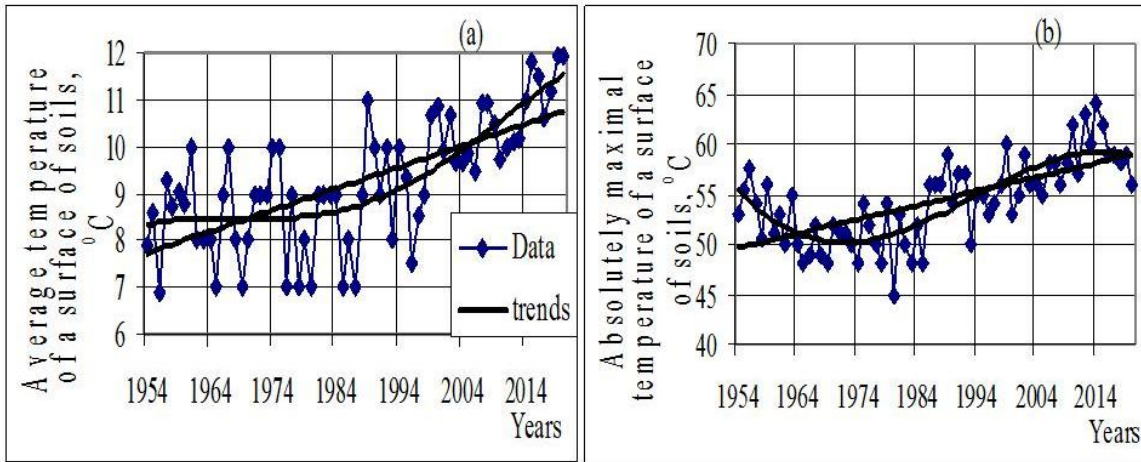


Figure 3. Change in time of average (a) and maximal (absolutely) (b) temperature of a surface of soils on meteorological station Sarny

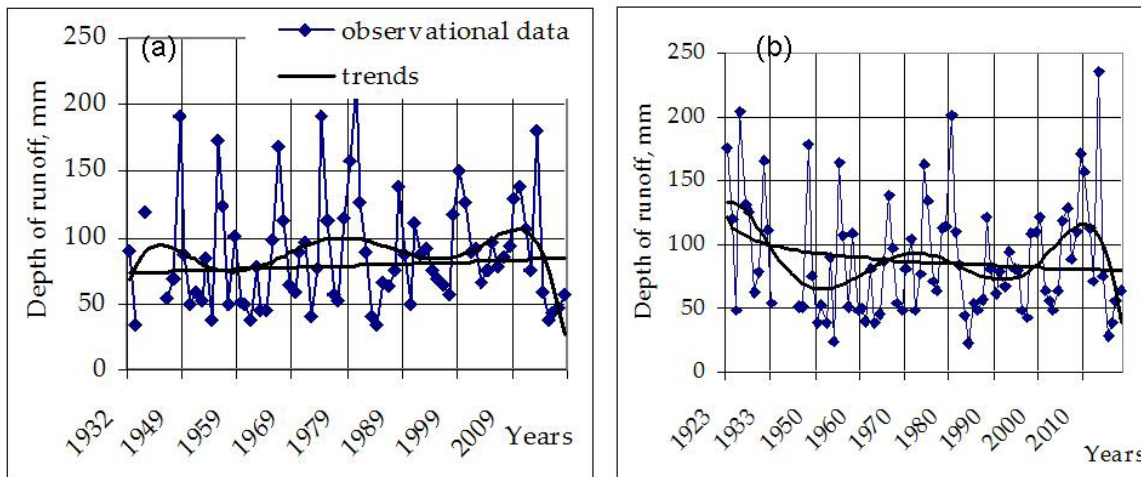


Figure 4. Changes in the depth of runoff in the time of the Tur'ya river observation point (a) - post Yagodnoe, (b) -post Kovel

and, accordingly, the conclusions about the hydrological regime of the territory, the more substantiated the conclusions.

The study of the relationship between the direction of the trend in the course of water runoff in time with the hydrographic characteristics of the catchments showed that the trend of a decrease in runoff is traced in the entire range of changes in the areas and heights of catchments, their plowing, forest cover, swampiness, etc. no quantitative regularity was found (the territory is flat and swampy in places). A change in water content and air temperature also affects a change in the temperature regime of rivers (Figures 6-8), Namely, a change in water depth and ratios in the components of river feeding (an increase or decrease in the ground component of river

feeding) is reflected in a change in water temperature along the length of the river. Thus, in the upper reaches of the Pripyat at the Pripyat-Rechitsa post, an increase in the average and maximum water temperature is observed, and 73 km lower at the Pripyat-Lyubyaz post, the maximum water temperature in the river shows a tendency to decrease (Figures 6-8).

The analysis of observational materials showed that the average water temperature for the year in the river changes to a greater extent with time than along the length of the river. Moreover, over time, it mainly increases. The lowest temperature is observed closer to the source of the river and to its mouth. The temperature of the sources is influenced by the outflow of groundwater (from which, in fact, the rivers originate), and the lower temperature of

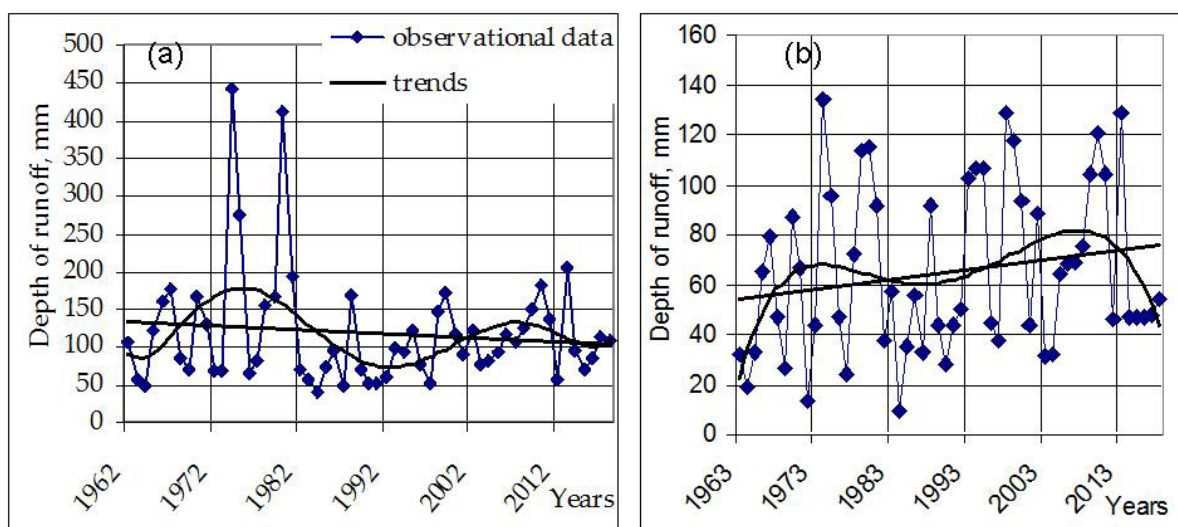


Figure 5. Changes in the depth of runoff in the time of the Pripyat river observation point (a) - post Rechitsa, (b) - post Lyubyaz

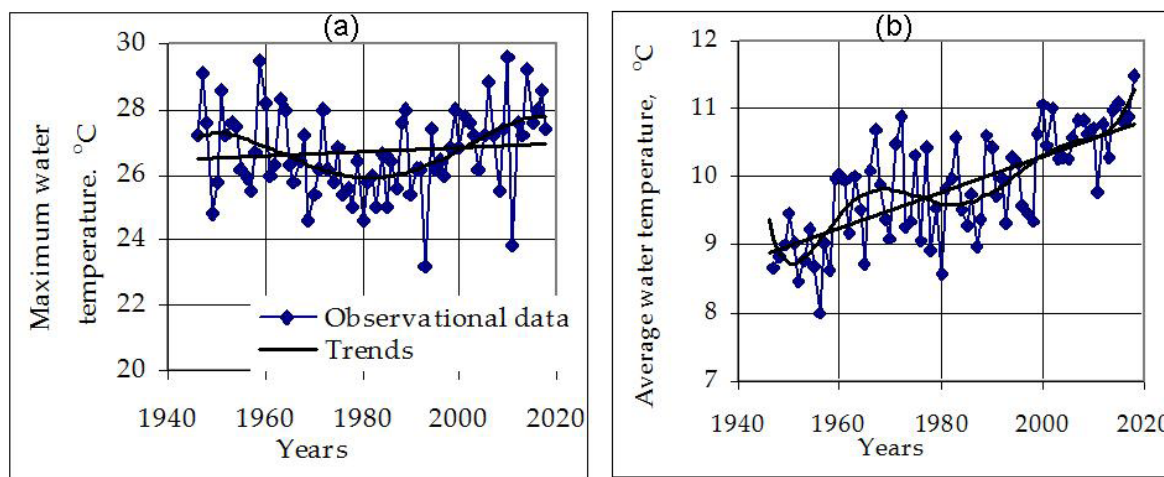


Figure 6. Change in time of the maximum (a) and average (b) water temperatures in the river Pripyat - post Rechitsa

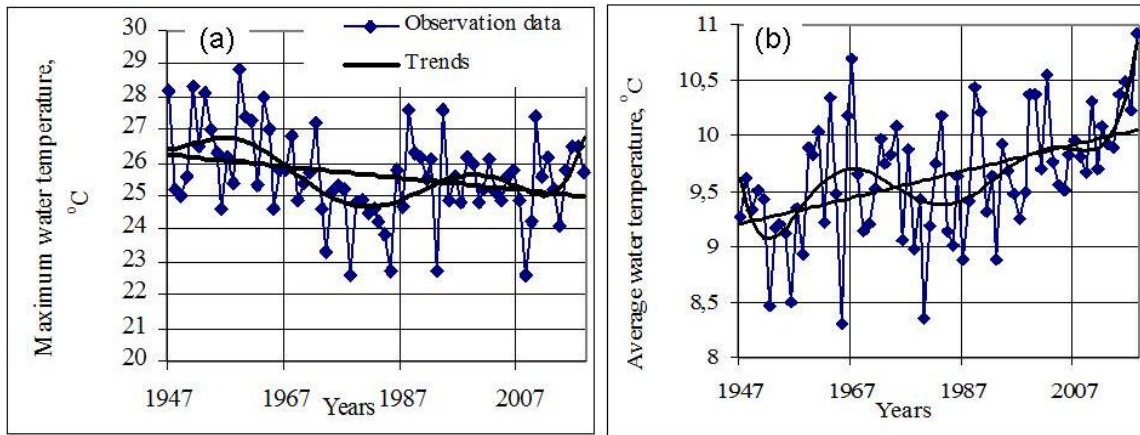


Figure 7. Change in time of the maximum (a) and average (b) water temperatures in the river Pripyat - post Lyubyz

the estuaries is most likely explained by an increase in the water depth in the river and, accordingly, a decrease in the heating of the water column.

The temperature of groundwater water, which can be taken as average with a minimum runoff and a predominance of groundwater supply, within Pripyat is 8 °C-9 °C [16-18]. The change in the maximum water temperature in the Goryn River in time and along the length of the river has minima almost along the entire length of the river in the 70s-80s of the last century, it seems, this is due to the presence of some long-term cycles (Figure 8). However, in recent years it has also shown an upward trend over time. The change in the overgrowth of the river channel [19] is also consistent with the change in water temperature and the change in the water depth in the river.

While the surface runoff in the study area has different directions of its course in time, the course of water silt charge in time along all the rivers of the region shows a tendency to decrease, starting from the 60s-70s of the XX century (Figure 9). The reasons for the decrease in silt charge are high regulation of the flow of water bodies, agroforestry in the catchments area, and a decrease in high water maximums [10]. A good dependence of the maximum silt charge of water on the reserves of productive moisture in the soil was revealed. With an increase in soil moisture, the maximum silt charge increases, since the total moisture supply to the catchments increases.

The study of the relationship between the annual layer of river runoff with the annual precipitation and the average annual air temperature showed a weak dependence, probably due to the presence of a shift in the

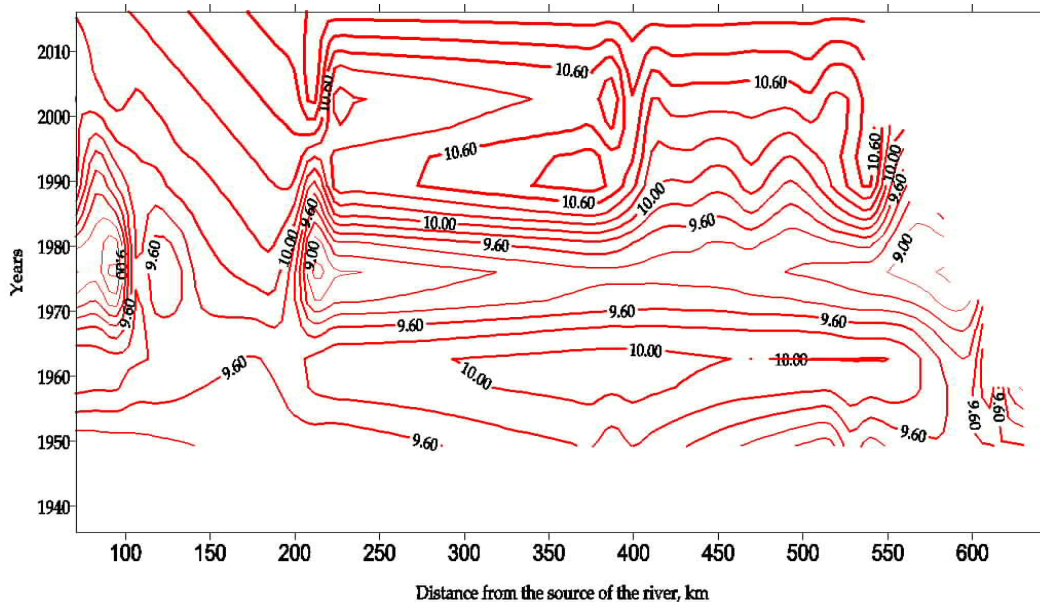
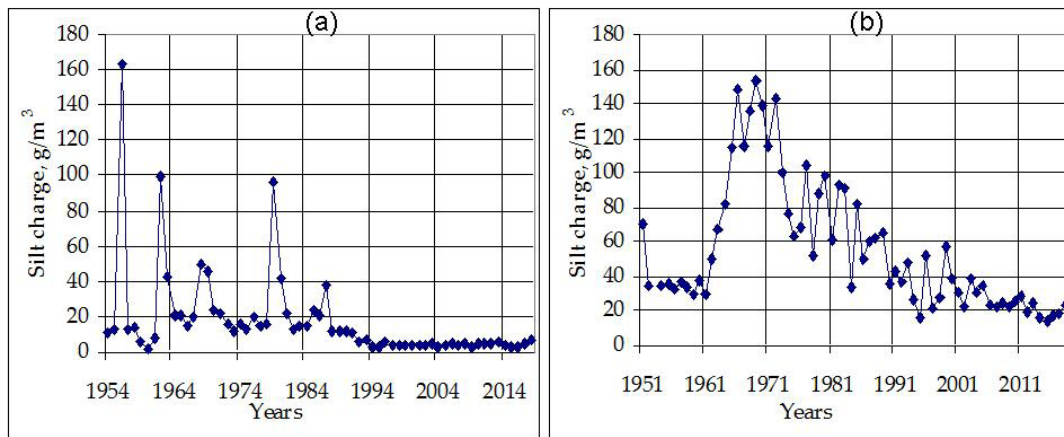


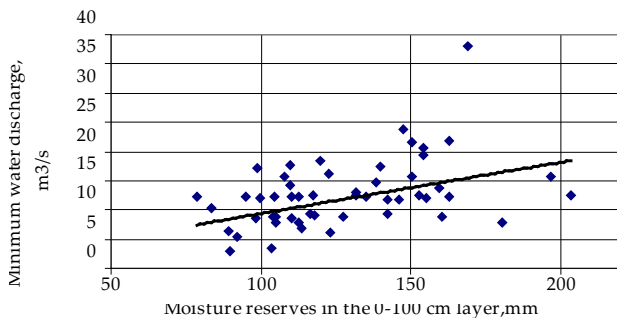
Figure 8. Change in the average water temperature in the Goryn River along the length of the river and in time





**Figure 9.** Change silt charge waters in time in the river Sluch posts the Gromada (a) and Sarny (b)

response time of the basin to precipitation (flat, in places swampy territory). Moistening of the catchments surface has a more significant effect on the course of the average annual water runoff layer, which is determined by the presence of a significant amount of wetlands and marshes. With an increase in moisture reserves in the soil, the minimum water runoff per year increases (Figure 10).



**Figure 10.** Dependence of the minimal discharges of water for a year in river Sluch - post Sarny from stocks of a moisture in 0-100 sm a layer of soils.

#### 4. Conclusions

It has been established that the surface runoff of the rivers in the humid zone tends to increase predominantly, while the groundwater runoff tends to decrease. However, in part of the catchments of the study area, the opposite tendency is observed that the surface runoff decreases, while the groundwater runoff increases. The directions of the trend of the course of water runoff in time are not consistent with the hydrographic characteristics and the geological and geomorphological structure of the territory. The main climatic indicators (precipitation and air temperature) under conditions of the humid zone do not have a direct effect on the course of the average annual water flow layer; flow rationing for these indicators

practically does not change the flow trend. Among the components of the water balance, humidification of the catchments surface plays a significant role in the flow of water in the rivers of the humid zone. The relationship between the water runoff layer and precipitation and soil moisture has a certain time delay. The average annual water temperature over time shows a tendency to increase at almost all stations, while the change in the maximum water temperature in rivers over time has a multidirectional tendency and to a greater extent depends on the change in water depth in the river, a decrease in high water maximums and frequent thaws, etc. The silt charge of water in all rivers of the study area decreases with time.

The studies carried out show that the preservation of moisture in thick layers of soil (0-100 cm) contributes to an increase in water flow in rivers and in the modern conditions of Polesie of Ukraine this will solve a number of problems with the provision of high-quality water resources for various industries and the population.

Preservation of moisture in thick layers of soil and soil can be achieved 1) restoration of bog massifs, 2) construction of small dams in the upper reaches of gullies and hollows with a seasonal delay in the runoff of rain and melt water (for example, the Unitsky reserve - the experiments of V. Dokuchaev) with 3) mandatory forest reclamation work to create a favorable microclimate (reduce wind speed, temperature, evaporation, etc.). It should also be borne in mind that an increase in evaporation ultimately contributes to an increase in air humidity, cloudiness and precipitation.

A decrease in the surface component of the river runoff of small rivers due to dams should not ultimately negatively affect the runoff of larger rivers. Part of the runoff will go into subsurface and groundwater, which will reduce the water temperature in the rivers and thus remove a number of environmental problems caused by



the rise in water temperature in them. The use of fully anti-erosion methods for protecting the territory of river catchments (hydrotechnical, agro and forest reclamation) will reduce the negative manifestations of climate change, including reducing the dehydration of the territory, overheating of the earth's surface.

### Declaration of Conflict of Interest

The author declares that they have no individual relationships that could have performed to affected the work reported in this study and have no known conflict of financial interests.

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