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Original Research Article

Forest cover and watering of the Pripyat River basin

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ABSTRACT

The paper deals with the issues of the influence of forest cover on the average annual runoff of rivers in the Pripyat River basin. In the study area, under the influence of solar radiation, the temperature of the air and the soil surface increases, evaporation from the water surface also increases, and the moisture content of the upper layers of the soil decreases. In general, with an increase in forest cover, the annual layer of the runoff of the studied rivers increases, as well as with an increase in the amount of precipitation (in contrast to the runoff of short-term floods). However, with a forest cover of more than 20%–30% and a relatively small amount of precipitation, the runoff decreases, which is associated with the retention of part of the precipitation by the forest cover. With a large amount of precipitation and low forest cover, the runoff also decreases, which is probably due to the loss of precipitation water for evaporation, etc. The conducted studies show that, just as the forest affects water resources, the flow of moisture to watersheds also affects the state of forest systems. Moreover, this interaction is expressed by evaporation from forests. Under influence of change of a climate growth of evaporation is observed.

Keywords: Forest; Runoff; Atmospheric Precipitation; Solar Radiation; Changes of A Climate

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1. Introduction

The study of the role of forests on water resources has been repeatedly carried out by scientists from various branches of science (foresters, soil scientists, hydrologists, agrarians, meliorators). This indicates the diverse function of forests and the diverse impact on various aspects of ecosystems. There are various concepts of the role of forests on the watering of territories (withering role, withering-moisturizing, general moisturizing, indefinite role)[1]. Therefore, for example, Voronkov considers it necessary to make a differentiated approach to the assessment of moisture turnover in forests, depending on the climatic conditions of the study area, the humidity of the year and seasons, the composition and properties of soils and soils, the depth of root systems, the species composition of the forest stand, the depth of soil waters, etc.[1].

In connection with climate change, a change in the species composition and distribution limits in the altitudinal zones of vegetation is expected. For the Dniester basin, for example, certain moisture-loving species are expected to disappear in the middle and lower parts of the Dniester[2]. The emergence of new diseases and pests of forests is likely[2]. As part of adaptation to climate change, the protection and restoration of forests is proposed.

In the conservation of water resources, along with forests, a significant role is also assigned to the restoration of wetlands[3]. They act as the main stabilizing element, the ecological framework of the natural environment, minimizing adverse natural processes and phenomena. The anti-flood value of forests is very high under the condition of a normal climatic situation in the region[4–6]. Thus, studies[7] in Transcarpathia, where forest cover varies from 12.5% to 96.1%, showed that the modulus of storm runoff of rivers decreases with an increase in the degree of forest cover. The degree of reduction in storm water runoff can be as high as 50%, which indicates the need to conserve forests in the region to prevent catastrophic floods and soil erosion.

The optimal regulation of flood runoff can be traced in watersheds that have 65%–70% of the forest cover[4].

According to scientific data obtained, the water-regulating capacity of beech forest under favorable hydrological conditions is 100–130 mm, hairpin forest—50–80 mm[4].

After the main cuttings, stabilizing functions are restored in beech forests from 25–30 years of age, in spruce forests from 35–40 years[4].

A lot of research, in this regard, is devoted to small rivers, which react strongly to deforestation and plowing of coastal areas[8]. As a result of deforestation and plowing of coastal areas, there is an activation of landslide and mudflow processes, the development of soil erosion, etc.

The predominance of the positive influence of the forest on the underground runoff has been established[9].

According to calculations for small rivers of Ukrainian Polessya, the optimal forest cover of watersheds is more than 50%, while the total forest cover for the mixed forest zone is up to 40%. The forest cover of Ukrainian Polessya is currently 26.1%. As a result, about 30% of the watersheds of the rivers of this territory have an ecological assessment of their condition as unsatisfactory and below the norm[10].

An analysis of previous studies shows the complexity and diversity of forest influence on water resources and microclimate, especially in the context of global climate change. The task of these studies was to establish the features of changes in climatic characteristics in the study area, which determines the change in the total moisture content of the territory and to trace the effect of the total forest cover of river catchments on their water content.

2. Materials and methods of research

Materials of long-term observations of the annual runoff of rivers in the territory of the Pripyat River basin (Ukrainian part) were taken for the study. 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 climate cadastre (climate reference books, meteorological monthly books, etc.). The list of observation points for water runoff, which were used in one way or another in the studies, is presented in **Table 1**. Some of the observation points are currently closed, which shortens the series of observations and allows using this information in the ranges of observation periods as additional. Among the research methods, water balance methods and graphic-analytical method were mainly used.

Figure 1 shows the location of the study area on the map of Ukraine. **Figure 1** shows the location of the observation points for water flow according to **Table 1**. According to the physiographic zoning, the Pripyat basin belongs to the Polessye province of mixed forests, except for the upper reaches of the Styr and Goryn rivers, which belong to the area of sufficient moisture in the humid zone of deciduous forests[9]. Materials of supervision over a drain of water on 42 stations (including nowadays closed) and 17 meteorological stations are used (**Table 1**).

We also used the hydrographic characteristics of the studied basins given in the USSR Surface Water Resources and other editions[11,12]. It should be noted that the percentage of forest cover in the study area practically does not change over the years. Since more often there is a change in the nature of forested areas than their percentage in the catchment area, i.e., young forests are being planted on the site of mature forests that have been cut down. Young forests have less protective properties for ecosystems, as already mentioned[4,8]. Their impact on water resources due to the replacement of centuries-old forests by young ones is manifested in a change in total evaporation (it decreases sharply)[13].

Figure 1. The scheme of a location of the study area on the map of Ukraine and location of water runoff observation points in the study area.
—Border of a part of a catchment of the river Pripyat.
●—item of hydrological supervision.

Table 1. Characteristics of observation stations for water flow in the Pripyat River basin.

River—observation point for discharge	Distance from the source, km	Catchment area, km^2	Forest cover, %	Range of changes in the annual runoff layer, mm	Measurement period, years	Meteorological station
Pripyat—Rechitsa	84	2210	17	41–442	1962–2020	Svityaz
Vyzhevka—Ruda	10	141	14	25–372	1946–2020	Kovel
Vyzhevka—Staraya Vyzhevka	44	722	17	31–263	1945–2020	Kovel
Tur'ya—Yagodnoye	57	459	18	26–217	1932–1933, 1940, 1946–2020	Vladimir-Volynsky
Turya—Kovel	102	1480	13	16–236	1923–1933, 1946–2020	Vladimir-Volynsky
Turya—Buzaki	164	2630	17	41–312	1961–1987	Kovel
Stokhod—Malinovka	48	692	4	14–243	1954–2020	Manevichi
Stokhod—Gulevka	99	1420	8	44–296	1959–1987	Manevichi
Stokhod—Lyubeshov	173	2970	20	34–593	1924–1933, 1946–2020	Lyubeshev
Styr—Stanislavchik	37	809	33	71–295	1948–1955	Lutsk
Styr—Shchurovtsy	57	2020	20	67–357	1956–2020	Lutsk
Styr—Lutsk	194	7200	14	70–234	1923–1937, 1939–1940, 1944–2020	Lutsk
Styr—Polonnoe	345	10400	15	81–190	1924–1938	Manevichi
Styr—Mlynok	400	10900	15	61–225	1961–2020	Manevichi
Radostavka—Troitza	19	316	14	61–396	1955–2020	Brody
Ikva—Velikiye Mlynovtsy	59	632	14	79–309	1945–2020	Kremenets

Table 1. (*Continued*).

River—observation point for discharge	Distance from the source, km	Catchment area, km^2	Forest cover, %	Range of changes in the annual runoff layer, mm	Measurement period, years	Meteorological station
Ikva—Mlynovskaya HPP (Mlynov)	131	1960	20	84–278	1953–1954, 1962–1990	Kremenets
Goryn—Yampol	71	1400	4	74–215	1936–1940, 1945–2020	Kremenets
Goryn—Ozhenin	223	5860	13	57–222	1946–2020	Kremenets
Goryn—Voloshki	330	6860	11	73–178	1924–1933	Rivne
Goryn—Derazhno	379	9160	12	61–235	1958–2020	Rivne
Horyn—Antonovka	488	11400	17	85–173	1924–1933	Rivne
Viliya—Kunev	56	969	1	79–176	1956–1963	Kremenets
Ustie—Rivne	43	558	5	91–168	1927–1933, 1943	Rivne
Vyrka—Svaryny	21	231	42	41–264	1947–2020	Rivne
Berezhanka—Podlesnoye (Rudnya)	25	187	18	64–300	1948–1974	Rivne
Sluch—Bolshaya Klitna	30	232	3	46–259	1954–1982	Yampol
Sluch—Gromada	139	2480	4	20–216	1926–1940, 1945–2020	Yampol
Sluch—Sarny	409	13300	17	27–280	1924–1933, 1946–2020	Novograd-Volynsky
Homora—Poninka	105	1410	11	44–233	1936–1940, 1955–1987	Yampol
Tnya—Bronniki	68	982	16	10–294	1936–1938, 1940, 1946–2020	Zhitomir
Smolka—Susly	65	632	18	5–258	1945–2020	Shepetovka
L’va—Osnitsk	24	276	47	54–361	1958–2020	Sarny
Ubort’ Rudnya—Ivanovskaya	45	510	38	13–356	1928–1940, 1959–2020	Novograd-Volynsky
Ubort'—Perga	136	2880	44	23–288	1954–2020	Olevsk
Uzh—Polesskoye	169	5690	14	17–295	1916–1940, 1942, 1946–1995	Novograd-Volynsky
Uzh—Bolshoy Cherevach	240	7980	19	28–201	1917–1918, 1926–1940	Korosten
Zherev—Vyazovka	78	1360	25	64–313	1970–1987	Korosten
Zherev—Babinichi	88	1440	26	40–223	1945–1968	Korosten
Noreen—Slavenshina	79	804	13	53–550	1964–2020	Ovruch
Ilya—Lubyanka	32	300	52	38–306	1960–1985	Ovruch

3. Results

Climate change is manifested not only in changes in air temperature (**Figure 2**) and precipitation[14], but also in the warming of the soil surface, changes in soil moisture, evaporation from the water surface and river runoff[14]. Thus, there is a trend towards an increase in the absolute maximum temperature of the soil surface under the influence of solar radiation (**Figures 3** and **4**). The influence of solar radiation on water resources is directly manifested in the change in evaporation in the water balance of the territories. Evaporation from the water surface also increases under the influence of solar radiation (**Figure 5**). Observations of solar radiation are not carried out at all meteorological stations of the territory under consideration. Moisture reserves in different soil layers over a long period show dependence on solar radiation; with an increase in total solar radiation, there is a tendency to decrease soil moisture and vice versa (**Figures 6** and **7**).

Figure 2. Change in the absolute maximum air temperature for the year in time and total solar radiation at the Kovel meteorological station.

Figure 3. Changes in the absolute maximum temperature of the soil surface (Kovel and Sarny meteorological station) and total solar radiation (Kovel meteorological station) over time.

Figure 4. Dependence of the absolute maximum temperature of the soil surface for the year on the total solar radiation at the Kovel meteorological station.

Figure 5. Dependence of aging from the water surface along the Sarny meteorological station from the total solar radiation along the Kovel meteorological station.

Figure 6. Change in time of water reserves in the soil in layers 0–10 cm, 0–20 cm, 0–50 cm, 0–100 cm according to Sarny meteorological station and total solar radiation for the year according to the Kovel meteorological station.

The graphs (**Figures 4, 5,** and **7**) consider average annual or total indicators for the year, which increases the scatter of points. However, the communication trend is clearly visible. With a decrease in the averaging or summation period (season, month), the tightness of the connection is higher. These graphs emphasize the existence of a general trend in the change in the studied climate characteristics. *P*-value for the graph (**Figure 4**) is 4.50×10^{-8}, for the graph (**Figure 5**) is 3.10×10^{-5}, and for the graph (**Figure 7**) is 5.37×10^{-6}.

The presented changes in the course of meteorological elements (soil surface temperature, total solar radiation, evaporation, soil moisture), etc. directly or indirectly characterize climate change in the study area.

Figure 8 shows that, in general, with an increase in forest cover, the annual layer of the runoff of the studied rivers increases, as well as with an increase in the amount of precipitation (in contrast to the runoff of short-term floods). However, with a forest cover of more than 20%–30% and a relatively small amount of precipitation, the runoff decreases, which is associated with the retention of part of the precipitation by the forest cover. With a large amount of precipitation and low forest cover, the runoff also decreases, which is probably due to the loss of precipitation water for evaporation, etc.

Despite the growth of factors drying up the surface of the Pripyat watershed (**Figures 2–7**), forested watersheds still retain the ability to maintain river watering (**Figure 8**)[14].

Figure 7. Dependence of moisture reserves in the soil in the 0–20 cm layer on the total solar radiation.

Figure 8. Influence on the flow of rivers by the amount of precipitation per year and the forest cover of the catchment areas of the rivers.

Studies show that one should distinguish between optimal forest cover and possible forest cover under given physical-geographical and anthropogenic conditions. So, in the absence of natural or artificially created conditions of sufficient moisture for forest growth, its plantings will be short-lived and not able to fully play a stabilizing role in the ecosystem. To ensure the sustainability of forest ecosystems, it is advisable to carry out hydro-reclamation work to retain surface runoff in the upper links of the hydrographic network, similar to the experiments of V. Dokuchaev in the Buryannaya stepped on the catchment area of the Derkul River (now the Yunitsky reserve).

4. Conclusions

In the study area, under the influence of solar radiation, the air and soil surface temperatures increase, evaporation from the water surface also increases, and the moisture content of the upper soil layers decreases. In general, with an increase in forest cover, the annual layer of the runoff of the studied rivers increases, as well as with an increase in the amount of precipitation (in contrast to the runoff of short-term floods). However, with a forest cover of more than 20%–30% and a relatively small amount of precipitation, the runoff decreases, which is associated with the retention of part of the precipitation by the forest cover. With a large amount of precipitation and low forest cover, the runoff also decreases, which is probably due to the loss of precipitation water for evaporation, etc. The conducted studies show that, just as the forest affects water resources, the flow of moisture to watersheds also affects the state of forest systems. Moreover, this interaction is expressed by evaporation from forests. Under the influence of climate change components, an increase in evaporation is observed.

Conflict of interest

The author declares no conflict of interest.

References

1. Voronkov NA. The role of forests in water protection (Russian). Leningrad: Gidrometizdat; 1988.
2. Denysov M, Andryeyev O, Babych M, Baylshtayn M. Strategic directions for adaptation to climate change in the Dniester Basin (Ukrainian). Envsec Yeek Oon Obsye; 2015.
3. Snizhko S, Shevchenko O, Didovets' YU. Analysis of the impact of climate change on water resources of Ukraine (Ukrainian). Kyiv; 2021. p. 68.
4. Parpan VI. Analytical report on the main causes of floods in the Carpathian Region and Ivano-Frankivsk Region. Ivano-Frankivsk; 2008. p. 5.
5. Sidău MR, Horváth C, Cheveresan M, *et al*. Assessing hydrological impact of forested area change: A remote sensing case study. Atmosphere 2021; 12(7): 817. doi: 10.3390/atmos12070817.
6. Bonnesoeur V, Locatelli B, Guariguata MR, *et al*. Impacts of forests and forestation on hydrological services in the Andes: A systematic review. Forest Ecology and Management 2019; 433: 569–584. doi: 10.1016/j.foreco.2018.11.033.
7. Kindyuk BV. Hydrographic network and storm runoff of the rivers of the Ukrainian Carpathians (Russian). Odessa: TES; 2003.

8. Snityns'kyy VV, Khirivs'kyy PR, Hnativ IR. Peculiarities of formation of surface flow of mountain rivers due to deforestation and plowing of power territories (Ukrainian). Ekolohichni Nauky 2020; 3(30): 73–77. doi: 10.32846/2306-9716/2020.eco.3-30.12.
9. Pimenova GS. Runoff factors in the southern part of the ETS and the effect of forest cover on effective infiltration (Russian). In: The impact of forests on water resources. Moscow: Science; 1986.
10. Hopchak IV. Assessment of the anthropogenic load on the basins of small rivers of the Rivne Region (Ukrainian). Melioratsiya i vodne hospodarstvo 2017; 106: 49–52.
11. Mikhailova KL. Surface water resources of the USSR. Basic hydrographic characteristics. T.6. Ukraine and Moldova. V. 2. middle and lower Dnieper (Russian). Leningrad: Gidrometizdat; 1967. p. 491.
12. Kupriyanova VV. Hydrographic characteristics of the river basins of the European territory of the USSR (Russian). Leningrad: Gidrometizdat; 1971. p. 100.
13. Krestovskiy OI. Influence of deforestation and reforestation on the water content of rivers (Russian). Leningrad: Gidrometizdat; 1987.
14. Budnik SV. Spatio-temporal changes in the regime of rivers in the Pripyat River catchment and climate change. Journal of Atmospheric Science Research 2022; 5(2): 1–9. doi: 10.30564/jasr.v5i2.4396.