century observed the trend to strong increasing the intensity of wet period in mountain station Yasinya and smaller trend west along the Carpathian ridge.

Studies of statistical relationship between the SPEI at different time scales and minimum runoff rivers of Carpathian region showed that degree of significance interrelation depends on the time intervals of the SPEI and months for which they are calculated. Therefore for the winter time the largest value of the correlation coefficients (R) were obtained for March and April (R = 0.4–0.5) and SPEI – 6 and 12 months. For a low flow in summer time the best results were obtained for August, September and October (R = 0.5–0.7) and SPEI – 12 and 18 months.

**Conclusions.** The review of our investigations shown, that in Ukraine under current climate conditions prevail the spring-summer droughts at all physiographic zones. In summer the drought frequency increasing in Steppe and decreasing in other regions. Autumn period characterized by decreasing of drought intensity everywhere. Severe and extreme droughts occurred mostly in Steppe. In the Forest-and-Steppe area and Poles'e observed only weak and moderate seasonal droughts.

The presence of a significant correlation between the indices of drought and runoff in different periods (floods and low water) shows the possibility of using them for modeling and forecasting the various phases of the water regime of the rivers of Ukraine.

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# The influence of the afforestation and swampiness on the design characteristics of the spring flood peak flow in the river Pripyat basin


**Abstract:** On the basis of the geometric model hydrograph slopeflow and streamflow we offered more sophisticated design scheme, which allows separate categories for factors of floods and freshets. It relies on materials of observations of maximum flood runoff in the basin of Pripyat river.



**Keywords:** maximum runoff, spring freshet, the layer flow, duration of the slope inflow, design characteristics, afforestation, swampiness.


**Introduction**

In most cases in the calculation formulas of maximum flow, the adjustments for the afforestation and swampiness are related integraly to the final results. This methodical approach can not account for the degree of influence of these factors inclined flow into separate components. This notice applies to the principal circumstances, as the direction and level of influence of afforestation and swampiness to certain processes of runoff formation can be different and in different modeling combinations can even compensate each other.

**Accounting for the effects of afforestation and swampiness in the calculation formulas of maximum flow of spring freshet of the rivers**

According to [1], the formulas of maximum flow (of both, floods and freshets) are divided into 2 groups. The first group includes the structures, based on the geometric model of the hydrographs of the runoff — reductional and volumetric formulas. The second group includes those, which are based on the theory of river beds isochrons.

There are two types of reductional formulas:

a) in the following edition

$$q_m = \frac{q_m'}{(F+1)^{n_1}}\delta\delta_1\delta_2; \quad (1)$$

b) in more expanded format

$$q_m = \frac{k_0 Y_m}{(F+1)^{n_1}}\delta\delta_1\delta_2, \quad (2)$$

where $q_m$ — is the maximal runoff modulus of foods or freshets;

$q_m'$ — the maximum modulus of the slope inflow;

$F$ — the catchment area;

$Y_m$ — the flow layer for freshet;

$k_0$ — the slope coefficient of spring flood transformations under the influence of the afforestation, the swampiness, the watersheds tilled surface, the presence of karst, the characteristics of soils and watersheds altitude position;

$\delta = f(f_{lk})$ — reduction coefficient due to the presence in the catchment lakes, reservoirs and flow type ponds;

$\delta_1$ — factor of influence on the maximum flow of the afforestation of watersheds;

$\delta_2$ — factor of influence on the maximum drain of swampiness of watershed;

$n_1$ — exponent of the reduction in the dependence $q_m = f(F)$ or $\frac{q_m}{Y_m} = f(F)$.

From the comparison of (1) and (2) it is obvious that

$$q_m' = k_0 Y_m. \quad (3)$$

On other hand, according to [1],

$$k_0 = \frac{n+1}{n}\frac{1}{T_0}, \quad (4)$$

where $\frac{n+1}{n}$ — time factor of uneven slope inflow;

$$\frac{n+1}{n} = \frac{Q_m' \cdot T_0}{Y_m \cdot F}; \quad (5)$$

$Q_m'$ — maximum water flow rate of the slope inflow during the periods of the floods (freshets);

$T_0$ — the duration of the slope inflow during the period of floods and freshets.

Thus, taking into account (3) and (4) the reductional structures (1) and (2) can be represented in the general form:

$$q_m = \frac{n+1}{n}\frac{1}{T_0}\frac{Y_m}{(F+1)^{n_1}}\delta\delta_1\delta_2. \quad (6)$$

Analysis of the conditions of runoff formation shows that the afforestation and swampiness of watersheds can affect both, the layer flow $Y_m$, and the the duration of the slope inflow $T_0$, i. e.

$$Y_m = f(f_{fr}, f_{sw}) = (Y_m)_{f_{fr}=0; f_{sw}=0} \cdot k_{fr}' k_{sw}', \quad (7)$$

where $(Y_m)_{f_{fr}=0; f_{sw}=0}$ — layer of flow of flood or freshet, reduced to the condition $f_{fr} = 0$ and $f_{sw} = 0$;

$k'_{fr} < 1{,}0$ — the coefficient of the influence of the afforestation of the watersheds on the layer of flood or freshet runoff;

$k'_{sw} \le 1{,}0$ — coefficient of influence of the swampiness of watersheds on the layer of peak flow of flood or freshet.

From the afforestation and swampiness of watersheds also depends the duration of the slope inflow $T_0$, i. e.

$$T_0 = f(f_{fr}, f_{sw}) = (T_0)_{f_{fr}=0; f_{sw}=0} \cdot k_{fr} k_{sw}, \quad (8)$$

where $(T_0)_{f_{fr}=0; f_{sw}=0}$ — the duration of the slope inflow, under conditions $f_{fr} = 0$ and $f_{sw} = 0$;

$k_{fr} < 1{,}0$ — the coefficient of the influence on the duration of the slope inflow of the afforestation of watersheds;

$k_{sw} \le 1{,}0$ — coefficient of influence of the swampiness of watersheds on the duration of the slope inflow.

Taking into account (7) and (8) the formula (6) can be re-written as:

$$q_m = \frac{n+1}{n}\frac{1}{(T_0)_{f=0;f=0}} \cdot (Y_m)_{f=0;f=0} \frac{1}{(F+1)^{n_1}} \frac{k_{fr}' k_{sw}'}{k_{fr} k_{sw}}. \quad (9)$$

Comparing (9) and (6), we conclude that:

$$\delta_1\delta_2 = \frac{k_{fr}' k_{sw}'}{k_{fr} k_{sw}}, \quad (10)$$

where $\delta_1 = \frac{k'_{fr} \le 1{,}0}{k_{fr} \ge 1{,}0} \le 1{,}0$, and $\delta_2 = \frac{k'_{sw} \le 1{,}0}{k_{sw} \ge 1{,}0} \le 1{,}0$ (11)

Taking into account that $\frac{k'_{fr}}{k_{fr}}$, from one hand, and $\frac{k'_{sw}}{k_{sw}}$, from another one, affects $Y_m$ and $T_0$ differently in the numerator and denominator, then to establish the existence of the corrections $\delta_1$ and $\delta_2$ is often impossible, and thus one might get a false idea regarding the impact of afforestation and swampiness on the maximal runoff.

Choose same raw material, so that the catchments were only forested or swamped in real conditions is practically impossible.

The foregoing leads to the conclusion about the lack of a theoretical framework that underlies reducing-types formulas such as (1) and (2). More acceptable is the structure (9), but it is inconvenient because of its bulkiness. A simplified version may be represented by the expression:

$$q_m = q_m' \cdot k_F \cdot \delta, \quad (12)$$

where $q_m'$ — is the maximal modulus of the slope inflow:

$$q_m' = \frac{n+1}{n}\frac{1}{T_0} Y_m, \quad (13)$$

$T_0$ — is the duration of the slope inflow:

$$T_0 = f(f_{fr}, f_{sw}) = (T_0)_{f_{fr}=0; f_{sw}=0} \cdot k_{fr} k_{sw}, \quad (14)$$

$Y_m$ — layer of slope inflow for the flood or freshet:

$$Y_m = f(f_{fr}, f_{sw}) = (Y_m)_{f_{fr}=0; f_{sw}=0} \cdot k_{fr}' k_{sw}', \quad (15)$$

$k_F$ — is the generalized coefficient of channel-floodplain regulation of floods and freshets:

$$k_F = \frac{1}{(F+1)^{n_1}}, \tag{16}$$

$\delta$ — rate regulation coefficient of floods and freshets by drainage lakes, reservoirs and ponds.

For the calculus the parameter $k_F$ is reasonable present as:

$$k_F = k_m \cdot k_n = e^{-(a+b)\cdot \lg(F+1)}. \tag{17}$$

**Establishment of design parameters for maximum flow of the spring flood considering afforestation and swampiness of watersheds (based on Pripyat river example)**

Pripyat river is one of the largest (right bank) tributaries of the Dnepr river. Geographically located within the Steppe and Forest-steppe zones. The catchment area — 68300 km$^2$. Time series of the observation during more than 15 years (to 2010), there are available for 43 watersheds with an area from 141 km$^2$ (riv. Vizhevka – vill. Ruda) to 13,300 km$^2$ (riv. Sluch – city Sarny).

Statistical processing of time series of maximum rows and layers of spring flood runoff was performed using the method of maximum likelihood, and the calculated values $Q_m$ and $Y_m$ for reference provision of $P = 1\%$ were established using the of three-parameter curve of gamma distribution of S. N. Kritskyi and M. F. Menkel [2].

Getting to the spatial generalization of runoff layers $Y_{1\%}$, first of all we build the dependance $\mathrm{Y}_{1\%} = f\left(\varphi^{\circ}_{n.l.}\right)$, where $\varphi^{\circ}_{n.l.}$ — geometric latitude of watersheds centers. In general

$$Y_{1\%} = \left(Y_{1\%}\right)_{\varphi=51} + 19{,}9(\varphi - 51), \tag{18}$$

where $\left(Y_{1\%}\right)_{\varphi=51}$ — layer of spring flood runoff, reduced to conditional latitude $\varphi = 51^{\circ}\, n.l.$

$$\left(Y_{1\%}\right)_{\varphi=51} = \mathrm{Y}_{1\%} - 19{,}9(\varphi - 51). \tag{19}$$

Now it is possible to investigate the effect on the runoff layers $\left(Y_{1\%}\right)_{\varphi=51}$ of the afforestation $(f_{fr})$ and swampiness $(f_{sw})$ of watersheds.

In relation to the right bank pool of the Pripyat river, we found that the correlation coefficients of dependencies $\left(Y_{1\%}\right)_{\varphi=51} = f(f_{fr})$ and $\left(Y_{1\%}\right)_{\varphi=51} = f(f_{sw})$ — are insiginificant. From this follows that $Y_{1\%}$, caused by the latitudinal position of watersheds are subjects to direct spatial generalization. The $Y_{1\%}$ are changed from 200 to 100 mm. in the basin of Pripyat river.

The duration of the slope inflow $T_0$ is also the subject to the spatial generalization. The dependance $T_0$ on the geometrical latitude of the centers of river watersheds $\varphi_{n.l.}$ is given by the equation:

$$T_0 = \left(T_0\right)_{\varphi=51} + 89(\varphi - 51), \tag{20}$$

where $\left(T_0\right)_{\varphi=51}$ — the duration of the slope inflow, reduced to conditional latitude $\varphi = 51 n.l.$

$$\left(T_0\right)_{\varphi=51} = T_0 - 89(\varphi - 51). \tag{21}$$

The dependance $\left(T_0\right)_{\varphi=51}$ on the degree of swampiness of watersheds is as follows:

$$\left(T_0\right)_{\varphi=51} = 236[1 + 0{,}27\lg\left(f_{sw} + 1\right)]. \tag{22}$$

As for the afforestation, it has no significant effect on the duration of the slope inflow.

According to the preferential correlation coefficient $(r = 0{,}28)$, which is significant, from (22) one can get the expression for the swampiness coefficient $k_{sw}$:

$$k_{sw} = 1 + 0{,}27\lg\left(f_{sw} + 1\right). \tag{23}$$

The next step is to bring all values $\left(T_0\right)_{\varphi=51}$ to the condition $f_{sw} = 0$, i. e. to $\left(T_0\right)_{\varphi=51; f_{sw}=0}$. Plotting the dependance $(T_0)_{\varphi=51; f_{sw}=0}$ on the afforestation of the watersheds shown that it is insignificant. Thus, in the river Pripyat basin the duration of flow of water from the slopes in the fluvial network is affected only by swampiness of the watersheds, which is a factor in the natural freshet-regulation.

Coming to the spatial generalization of $T_0$, one should bring first all original values $T_0$ to the condition $f_{sw} = 0$, i. e.

$$\left(T_0\right)_{f_{sw}=0} = \frac{T_0}{k_{sw}}, \tag{24}$$

where $k_{sw}$ — coefficient of influence on the duration of the slope inflow of spring freshet in the river Pripyat basin of the swampiness, which is calculated accoriding to (23).

On the territory $\left(T_0\right)_{f_{sw}=0}$ varies from 350 to 125–150 hours.

Test calculations performed within the proposed structure (15), lead to the conclusion of satisfactory convergence of the results with the original data. The average deviation of ± 16,5 % taking into account the accuracy of the initial information on the maximum spring flood runoff in the Pripyat basin, is within standard mean-square uncertainty $\sigma_{\mathrm{Q}_{1\%}} = 16{,}7\%$.

When using the formula (12) the layer of runoff $Y_{1\%}$ is taken directly from the map (at the geometrical centers of watersheds); the time factor coefficient of uneven slope inflow $\frac{n+1}{n}$ for all watershed is taken to be 6,25; the reductional coefficient $k_F$ is calculated according to equation (17); the duration of the slope inflow $T_0$, which, as well as $\frac{n+1}{n}$, is included to the parameter $k_0$ is determined basing on a map $\left(T_0\right)_{f_{sw}=0}$, and:

$$T_0 = \left(T_0\right)_{f_{sw}=0} \cdot k_{sw}, \tag{25}$$

where $k_{sw}$ is determined by the swampiness of the largest watersheds $f_{sw}$ (in per-cent), according to (23).

**Conclusions:**

1. The author substantiates the version of design scheme that provides in a parametric form the allocation into separate categories the impact of the afforestation and swampiness on maximal runoff of floods and freshets.

2. The implementation of the proposed calculation formula of maximum flow of the spring flood was carried out basing on the materials of observations in the river Pripyat basin.

2.1 The study of the impact on the layers of the runoff $Y_{1\%}$ and the duration of the slope inflow $T_0$ does not found their significant dependencies from the afforestation of the watersheds.

2.2 From other hand we determine the dependence of the duration of the slope inflow $T_0$ on swampiness $f_{sw}$, wherein swampiness is a controlling factor of spring flood runoff on the slopes, and the coefficient of influence $k_{sw} \geq 1{,}0$. On layer of the runoff $Y_{1\%}$ the effect of swampiness is not revealed. From this it follows that the normative parameter $\delta_2$ by its nature in the river Pripyat basin relates only to the duration of the inflow $T_0$.

3. With respect to the river Pripyat basin, the proposed design scheme is recommended for practical application in the whole range of watershed areas.

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