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Regularities in the Formation of Groundwater Infiltration Recharge

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Abstract—The effect of meteorological, landscape, geological-pedological, and hydrogeological factors on the formation of total water balance and infiltration recharge of groundwater. The results of analysis of calculated mean annual and within-year values of water balance elements on land surface and in the vadose zone were used to identify some regularities, governing the resulting input of moisture to groundwater table at different depth of its occurrence (infiltration).

Keywords: groundwater infiltration recharge, evapotranspiration, modeling, vadose zone, river runoff, water balance.

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The formation of groundwater infiltration recharge, by which we mean here the natural input of atmospheric moisture on groundwater table (GWT) is a complicated, multifactor, natural process of transformation of atmospheric precipitation. Its studies are directly related to the formation of natural groundwater resources in the zone of active water exchange, for which infiltration recharge is the main factor ensuring its sustainability.

The formation of groundwater infiltration recharge in the context of analysis of moisture transfer processes in unsaturated saturation zone—between land surface and GWT—was considered in studies of S.F. Aver'yanov, L.M. Reks, A.A. Rode, I.S. Pashkovskii, V.M. Shestakov, M. Th. van Genuchten, etc. At the present stage of studies, growing attention is paid to deeper analysis of water balance processes in the single geohydrological cycle [16]—from precipitation event to moisture reaching the soil surface and the formation of water regime of the vadose zone, which have been most thoroughly studied in the works of L.S. Kuchment and A.N. Gelfan [6], I.S. Pashkovskii [8, 15], V.M. Shestakov and S.P. Pozdnyakov [16], and P. Shreder [17]. Such water balance approach to studying groundwater infiltration recharge makes it possible to analyze all natural factors governing its formation and eventually determining the wide variations in recharge values.

In this study, we consider the results of modeling the processes of groundwater infiltration recharge formation, allowing us to identify the regularities in the transformation of atmospheric precipitation under varying meteorological, landscape, geological–pedological, and hydrological–geohydrological conditions on land surface and vadose zone, as is typical of territories with humid climate, using as an example the southwestern part of Moscow Artesian Basin (MAB).

ARRANGEMENT AND METHODS OF STUDIES

The analysis of water balance processes of groundwater infiltration recharge formation was based on their numerical modeling. The general scheme of the calculation models, based on studies [8, 16–18], comprises two blocks, whose content is described in detail in [4].

The first model block simulates the processes of precipitation, the formation and melting of snow cover, precipitation retention by vegetation and evaporation from its surface and from the surface of snow, overland flow formation, moisture imbibitions into soil with allowance made for seasonal soil freezing [4].

The second model block is numerically implemented in the package HYDRUS 1D [18] and implements a model of transient moisture transfer in the vadose zone, taking into account evaporation from soil, moisture absorption by plant roots, and its input to GWT, i.e., infiltration recharge.

The analysis of regularities in the formation of groundwater infiltration recharge was based on modeling various typical conditions on land surface and in the vadose zone, by which we understand some combination of natural factors that jointly control the formation of water balance. The factors that determine the most "contrast" natural conditions of groundwater infiltration recharge include

the meteorological conditions, which determine the total moisture input from the atmosphere and the radiation–heat balance of the surface, as well as their regional variations within the same climate zone;

the landscape conditions, represented at the macrolevel by two major natural types: a closed forest ("forest") and an open, forest-free ("field") types, which determine the character of precipitation trans-

Table 1. Long-term means of total annual precipitation and mean air temperature at weather stations of Kaluga province

Weather station	Precipitation, mm	Air temperature, grad
Maloyaroslavets	662	4.9
Mosal'sk	640	5.0
Spas-Demensk	652	4.6
Zhizdra	609	5.0

formation on the surface through its retention and evaporation, the formation and melting of snow cover, the formation of surface runoff, and the processes of soil moisture withdrawal through transpiration;

soil cover—first, its texture (lithological composition), which affects the processes of moisture imbibitions, evaporation, and surface runoff;

the hydrogeological conditions, among which of greatest importance for infiltration formation are the composition, structure, and properties of the parent rocks of the vadose zone, underlying the soil, and the depth to GWT.

Analysis of a large body of observational data collected at water balance stations and given in [1, 7, 11, 14] shows a distinct effect of micro- and mesoheterogeneity of landscape (the type and age of vegetation, the degree and character of agricultural field development, etc.) on the formation of individual components of water balance. However, it should be emphasized that the major difference between water balance conditions that determines the heterogeneity in the formation of groundwater infiltration recharge manifests itself on the macrolevel. This determines the detail at which the role of individual factors is considered in this study.

Their significance in the processes of water balance formation in general and infiltration recharge in particular is estimated by mean long-term within-year variations in water balance characteristics and their annual sums, obtained by modeling under meteorological conditions slightly varying within a single climatic zone. Model calculations have a daily time step and use the actual long-term series of meteorological characteristics and averaged parameters for typical conditions on the land surface and in the vadose zone, taken from the published data and considered in the description of the models [4].

The calculations used series of daily meteorological characteristics (total precipitation, mean air temperature and solar radiation) over the observation period from 1960 to 2006 at four weather stations in Kaluga province (Table 1). Factor and step-by-step regression analysis of the original data series for different weather stations showed them to have no radical differences—the factor load on the first factor is >0.7 and pair correlation coefficients are 0.73–0.82. This suggests the uniformity of the type of climatic conditions in the territory; however, further analysis revealed some difference in meteorological characteristics. Thus, the characteristics from weather stations at Spas-Demensk and Mosal'sk (central part of the province) are most similar, while the characteristics of Maloyaroslavets and Zhizdra stations (northern and southern parts of the province) have some individual features, reflecting the climatic zonality of the territory.

In this study, it was assumed that meteorological characteristics used in modeling are identical for the conditions of field and forest landscapes. The observed differences between the annual precipitation sums (e.g., their being 5–7% higher in the forest than in the field [14]) is attributed to the rain gage errors [12, 13], allowing us to consider this sum to be the same for different landscapes [1]. Differences between mean air temperatures in the forest and fields landscapes, especially, during change of seasons, are doubtless [1]. This, no doubt, affects the rates of daily evaporation in summer and, especially, the rate of snow melting in winter and is accounted for in the model by introducing various shadowing factors and degree-day melting factors [4].

The agreement between the results of water balance modeling on land surface and in the vadose zone and the natural regularities was estimated by comparing with field data obtained mostly from materials of observations at water balance stations [1, 7, 11, 14].

ANALYSIS OF MODELING RESULTS

The results of modeling of typical conditions on land surface and in vadose zone reveal characteristic features in the formation of mean annual water balance, which, taken together, determine the groundwater infiltration recharge under different natural conditions.

Evaporation from Land and Vegetation Surface

The main factor that determines variations in evaporation from the surface is landscape conditions, i.e., the character of vegetation and the dynamics of its development within a year, as can be distinctly seen from the analysis of within-year variations in evaporation (Fig. 1). The plots, which generally reflect much larger total evaporation in the forest (due to the retention of precipitation by tree crowns), have to peaks: the main one occurs in the spring–summer period of intense plant vegetation, and the second one appears in the early spring because of evaporation from the snow cover due to spring temperature rise. It is worth mentioning that landscape has only slight effect on spring evaporation (Fig. 1). This is because in the forest, the evaporation from snow in the spring takes place mostly from tree crowns [13, 14].

The estimated share of annual surface evaporation for a forest landscape (Table 2) corresponds to the values typical of deciduous forests with the stand density

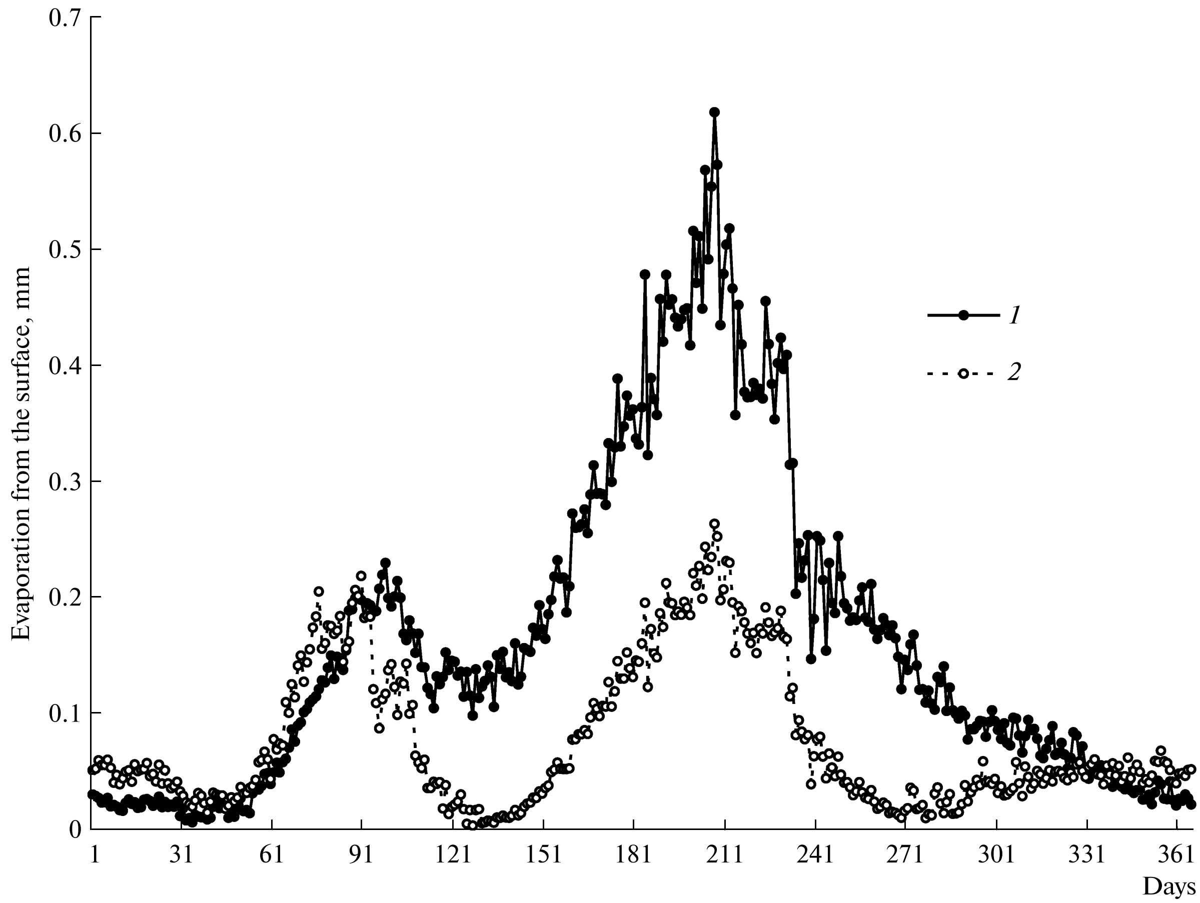

Fig. 1. Within-year variations in total evaporation from the surface for field and forest landscapes. (*1*) Forest, (*2*) field.

of 0.5–0.6 [1, 9]. The major portion of the precipitation retained (~75%) falls in summer months, as can be also seen from actual observations [14]. The total annual evaporation in the field is about half as large as that in the forest.

Surface Runoff

The model results show that the formation of surface (slope) runoff is affected by not only difference in landscape and soil conditions (Table 2), but also variations in meteorological characteristics. In addition to the regular increase in the annual depth of surface runoff, reflecting the increase in the total annual precipitation from the south to the north in the territory, its share in precipitation also increases (from 13 to 16%). Overall, the formation conditions of surface runoff are more favorable on field landscapes with clayey soils, while the minimal values are typical of forests on sandy soils (Table 2). This is due to the active porosity of the upper horizons of podzol soils with different textures, such porosity being much higher in the field than in the forest (in particular, by 3 times in the case of heavy loamy soils) [10]. That is why even on loamy soils, the calculated surface runoff in the forest is almost half as large as in the field.

The main volume of surface runoff forms during spring flood, when the effect of natural landscape and soil factors is especially clear. In the case of an open field landscape, where snow melting is intense, a powerful peak can be seen in runoff plots; this peak is less pronounced in the forest and shifted over time due to later snow melting (Fig. 2a). The model results show that the hampered imbibition of moisture in heavy loamy soils, irrespective of landscape, facilitates the formation of surface runoff all the year round, while the share of spring runoff is about 50%, whereas it reaches 90% on sandy soils. Maximal differences between the calculated runoff in the spring flood as a function of soil cover were recorded on the forest landscape—the spring flood on loamy soils is almost 3 times greater than on sandy soils. This can be seen from comparison of total river runoff on forest watersheds with different soil cover [14].

Overall, the model results show that the annual sum of surface runoff is much less in the forest than in the field (Table 2). This, however, does not mean that forest has a drying effect on territories. Numerous observations show that spring runoff on field water-

Table 2. Mean annual characteristics of water balance on the surface (the top number is the depth, mm; the bottom number is % of precipitation)

Soil type	Evaporation from soil		Surface runoff		Moisture available for imbibitions	
	forest	field	forest	field	forest	field
Sandy	59/9.2	29/4.5	13/2.0	84/13.0	572/88.8	531/82.5
Sandy loam	59/9.2	29/4.5	46/7.1	140/21.8	538/83.7	474/73.7
Loamy	59/9.2	29/4.5	96/14.9	169/26.2	488/75.9	446/69.3

sheds exceeds the corresponding values on forest watersheds by a factor of 2 to 3 and even greater in the forest–steppe and steppe zones [2, 14]. At the same time, the total river runoff from a watershed can either increase or decrease with increasing forest land percentage [5], since the main water-regulating role of the forest consists in runoff redistribution between the subsurface and surface components.

Water Available for Imbibition

The differences in the formation conditions of surface evaporation and runoff result in different moisture volumes available for imbibitions into the soil and the formation of groundwater infiltration recharge; these volumes generally increase with increasing total annual precipitation from the south to the north in both absolute values and as percentage of the total annual precipitation (from 79 to 85%).

The maximal values of moisture available for imbibitions are typical of forest landscape with sandy soils, while the minimal values are recorded in the field and loamy soils (Table 2). As can be seen from plots, the hampered flow of melt water in the forest creates favorable conditions for water imbibition into soil and the formation of infiltration recharge (Fig. 2b). This is confirmed by the observational data collected at the Istrinskaya station [3] and Podmoskovnaya Water Balance Station [11], according to which up to 80% of the total snow storage in the forest and liquid precipitation during flood are retained on the watershed.

Evaporation from Soil

In the case of forest landscape, total annual evaporation from soil under forest canopy is determined mostly by the character of soil cover and almost does not depend on the composition of the underlying rock of the vadose zone (Table 3). Under the conditions of a field landscape, where evaporation from soil is the main component of total evaporation, the picture is somewhat different. The maximal values of annual evaporation are typical of loamy soils where they practically correspond to the potential values and are almost independent of the composition of the underlying parent rocks. In the case of sandy-loam and sandy soils, the evaporation gradually decreases, such that the minimal values are typical of sandy underlying rocks in the vadose zone (Table 3). Such regularity can be attributed to the dry layer that rapidly forms on the surface of sandy soils with low capillary capacity and serves as a mulch layer, reducing evaporation [2].

The annual variations of daily evaporation from soil under different landscape and geological–pedological conditions are shown in Fig. 3a. When air temperature is positive, two peaks can be seen in the annual cycle. The first, spring cycle corresponds to the beginning of an increase in mean daily air temperatures, when transpiration by plants has not reached its full strength. After that peak, an appreciable drop in soil evaporation takes place due to intense development of vegetation cover and an increase in transpiration. The second peak appears in early autumn. In this period, when the mean daily air temperature is still relatively high, the vegetation cover degrades and moisture transpiration almost ceases; at the same time, the soil is well warmed, and evaporation from it increases appreciably. In the moderate zone of Russia, this time corresponds to the onset of "Indian summer" and features high air temperature and fogs in the morning.

Transpiration

Overall, the difference between meteorological conditions cause only a slight increase in transpiration, proportional to the increase in the total annual precipitation. Analysis of calculated mean annual values of transpiration by vegetation as a function of landscape and geological–soil conditions on the surface (Table 3) shows that the total annual transpiration in the forest is much higher than in the field; the maximal difference is recorded on clayey soils, where the root system of field vegetation is least developed. Notwithstanding the higher potential demand for moisture in herbage plants, the values of transpiration is determined mostly by the ability to use its reserves in the soil by the root system [2], which is better developed in woody vegetation. The annual values of transpiration in both field and forest noticeably increase with increasing sand content of the upper part of the section, which is also due to the better development of plant root system in sandy and loamy soils. The worse conditions for transpiration are typical of loamy soils and almost independent of the composition of underlying deposits. In sandy and sandy-loam soils with a well developed plant root system, transpiration somewhat increases, in both the forest and the field, with increasing clay content of the underlying deposits (Table 3). This is because the less permeable deposits under the soil retain moisture in it, thus facilitating its absorption by plant roots.

Analysis of the annual distribution of daily transpiration values (Fig. 3b) shows them to be close to zero in cold seasons. This is typical of the field landscape where almost all vegetation degrades in winter. The actual transpiration in the forest in this period is ~5% of the total winter evaporation [14] and also insignificant. In the middle of the vegetation period, in the field landscape, the transpiration peak shifts by about a month. This is due to the more intense evaporation from soil in open areas in the early summer (Fig. 3a).

Infiltration Recharge

The result of modeling is an estimate of mean annual values of groundwater infiltration recharge. Under the assumed meteoclimatic conditions in the territory of the southwestern part of MAB, the annual depth of infiltration recharge, the conditions on the surface remaining the same, increases with increasing precipitation, on the average, by 11 to 15% of average total precipitation.

The results of modeling made it possible to quantitatively evaluate the effect of landscape conditions on the formation of infiltration (Table 3). The minimal values of infiltration are typical of field landscapes with clayey soil and underlying rocks of the vadose zone. The mean annual infiltration recharge steadily increases with increasing sand content in the section. The most favorable conditions for the formation of groundwater infiltration are typical of forest landscapes with sandy section of soil and aeration rock, determining the increase in the observed dry-season runoff with increasing forest-land percentage, mentioned by many authors [14]. It should be mentioned that the composition of the rocks of the vadose zone, underlying the soil, has much lesser effect on the infiltration than the soil (Table 3), as was also mentioned before [8].

An increase in the clay content of soil and the zone of aeration causes an appreciable drop in the within-year variations in infiltration (Fig. 4). While in the case of sand section in the forest, the recharge forms in a pulse regime—mostly during the spring and summer, it is more uniformly distributed under field conditions, and in the case of clay deposits, it is practically constant throughout the year (Fig. 4).

The estimation of the role of depth to GWT in the formation of infiltration was based on modeling variants of typical natural conditions at different specified

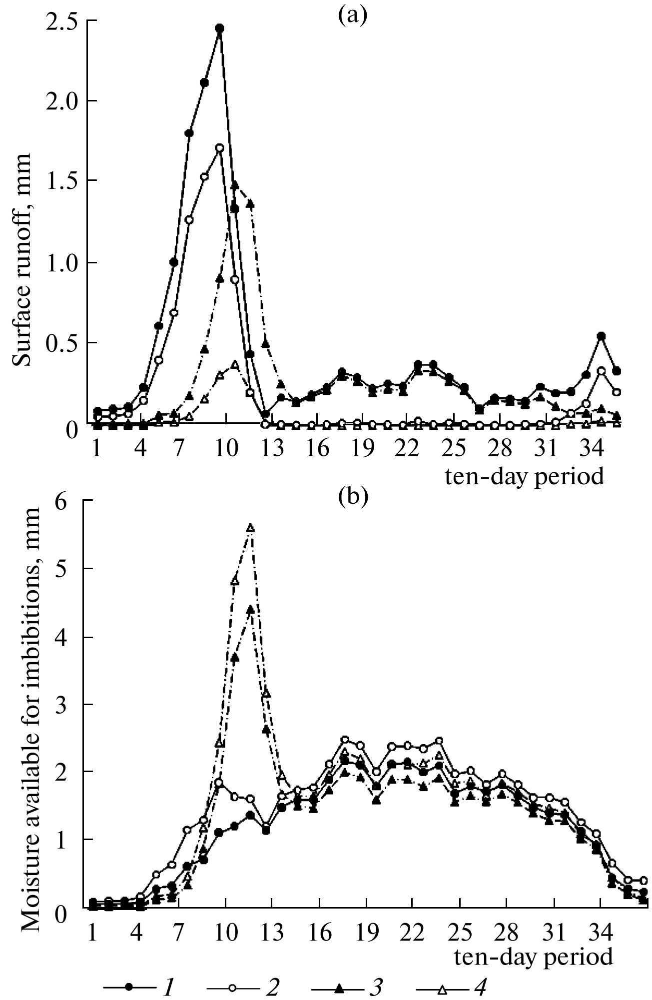

Fig. 2. Within-year variations in ten-day-averaged depths of (a) surface runoff and (b) moisture available for imbibitions under different landscape and soil conditions. Field: (*1*) loam; (*2*) sand; forest: (*3*) loamy sand; (*4*) sand.

values of head at the lower boundary of the model, reflecting the different mean annual depth to GWT. The characteristic type of the model curves of the dependence of infiltration recharge W on the depth to GWT Z_{GWT}(Fig. 5) corresponds to the known characteristic relationships of the following form [15]:

$$W = W_p - (W_p - W_0)e^{-z_{\mathrm{GWT}}/z_0}, \quad (1)$$

where W_p is the constant value of recharge at deep occurrence of GWT; Z_0 and W_0 are constants, and the value of W_0 is the recharge value at $Z_{\mathrm{GWT}} = 0$.

Analysis of model results shows that the physical cause of such nonlinear dependence is the restructuring of water balance in the zone of incomplete saturation as a function of the depth to GWT. With a decrease in the thickness and storage capacity of the vadose zone, resulting in its more intense wettening, the moisture flow faster reaches the GWT and the

Table 3. Calculated characteristics of long-term mean annual water balance of the vadose zone at deep groundwater table (> 5 m)

Type of soil or vadose zone rock	Components of annual water balance of vadose zone, mm			
	imbibitions, v	evaporation from soil, E_p	transpiration, TR_p	infiltration, W
Forest				
Loamy	488			
clay		102	307	78
loam		101	299	88
sandy loam		101	299	88
sand		101	297	89
Sandy loam	538			
clay		91	364	83
loam		88	345	105
sandy loam		88	327	123
sand		88	329	120
Sand	572			
clay		77	385	109
loam		77	376	119
sandy loam		77	354	141
sand		77	357	138
Field				
Loamy	446			
clay		357	67	21
loam		359	64	23
sandy loam		358	59	30
sand		357	59	30
Sandy loam	474			
clay		343	96	36
loam		340	92	42
sandy loam		331	82	61
sand		337	79	58
Sand	531			
clay		320	150	60
loam		315	144	72
sandy loam		293	130	108
sand		298	133	100

infiltration recharge acquires more and more pulse character (Fig. 6a). At the same time, as the moisture content of the vadose zone increases, the transpiration (Fig. 6b) and evaporation from soil also increases (to a certain limit, corresponding to potential evapotranspiration). This leads to the formation of an ascending moisture flux from GWT in summer, making the infiltration negative. However, in the annual balance as a whole, the descending flux is greater; therefore, the mean annual groundwater recharge is positive. The further decrease in infiltration in the case of even smaller depth to GWT is due to the lesser free absorbing capacity of the vadose zone and its "imbibing" ability; the excessive moisture on the surface forms additional (to that calculated at the first stage of modeling) surface runoff (Fig. 6c). This results in that water withdrawal through evapotranspiration exceeds its input in the annual balance and the annual sum of

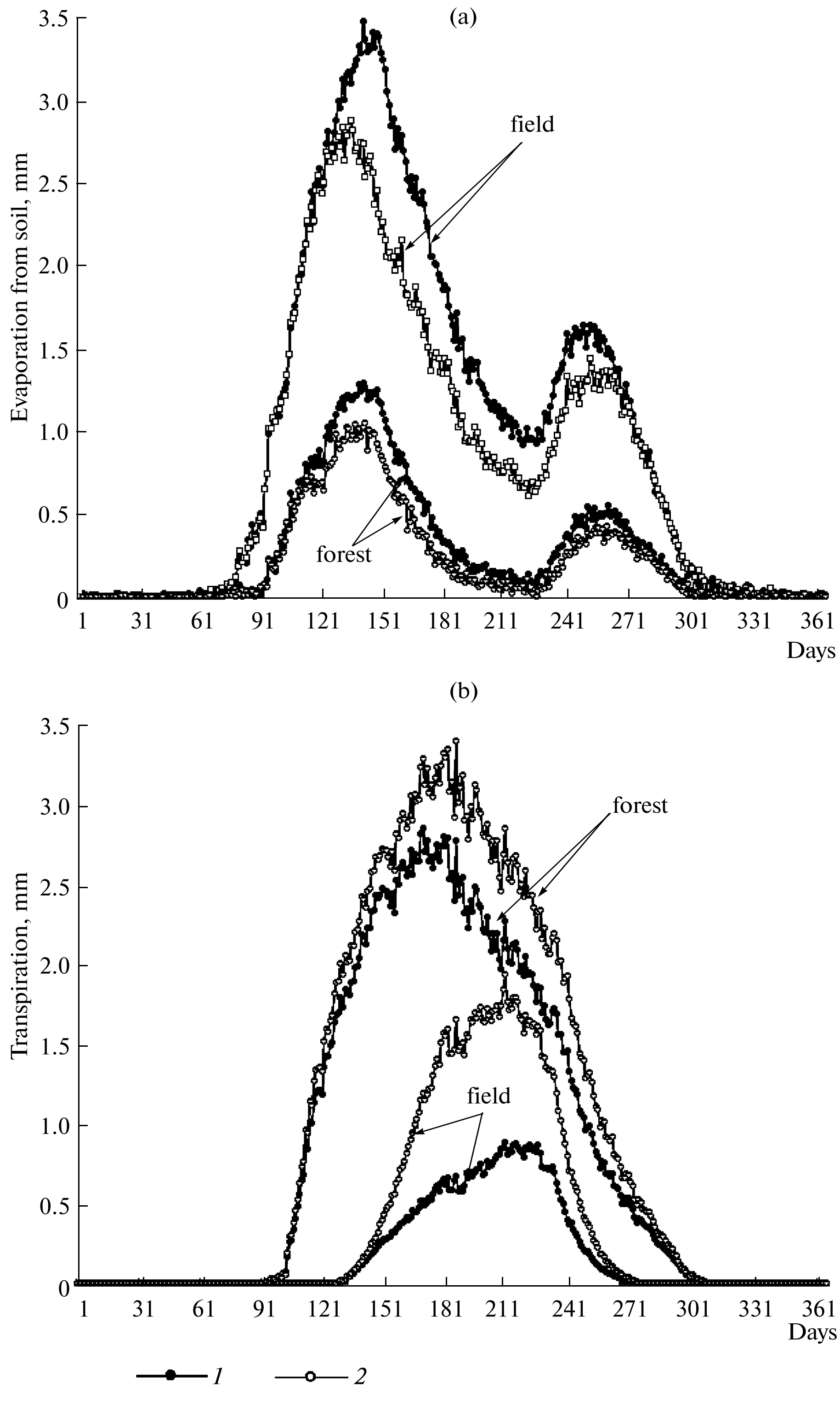

Fig. 3. Annual dynamics of daily (a) evaporation from soil and (b) transpiration for different landscape and geological-pedological conditions at deep GWT (here and in Fig. 4, (*1*) loams, (*2*) sands).

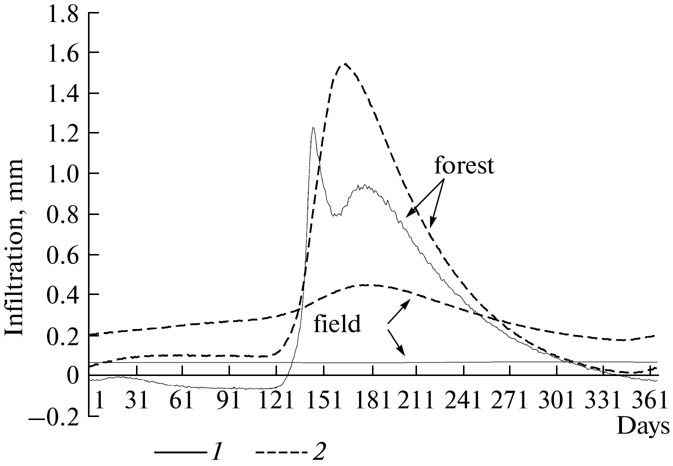

Fig. 4. Within-year dynamics of daily infiltration rates for different landscape and geological-pedological conditions at deep GWT.

infiltration recharge becomes negative, i.e., groundwater discharge takes place (Fig. 5a).

Noteworthy, the picture is somewhat different in sandy beds with high absorbing capacity of the soil and the vadose zone. In the cases where the depth to GWT is small and soil moisture content is high, when the total evapotranspiration has reached its maximal values and remains constant (Fig. 6b), the absorbing capacity of soil still does not correspond to its limiting values. Here, the entire moisture that has entered soil surface, less the potential evapotranspiration, will contribute to the formation of the ascending flux. The result is that, in a certain interval of small depths to GWT, while the absorbing capacity of the sand bed has not reached its limiting values, the total annual recharge will remain constant (Fig. 5b). Such conditions, especially in the most high-permeability sand beds in forest landscape, cause the prevalence of the ascending moisture flux and the preservation of a practically constant total annual infiltration recharge even at small depth to GWT. In such cases, the approximation of the function $W(Z_{GWT})$ by equation (1) at small depth to GWT would result in considerable errors (Fig. 5b).

Analysis of the obtained curves $W(Z_{GWT})$ for different landscape and geological–pedological conditions shows that their form only slightly changes depending on the composition of the parent rocks in the vadose zone (Fig. 5). The difference manifests itself only in the case of a contrast change of deposits underlying the soil. The same regularity can be seen in the analysis of the limiting recharge values W_p at large depth to GWT (Table 4). Thus, the results of modeling confirm the governing role of the top soil layer of the vadose zone in the formation of infiltration recharge [8].

The obtained calculation parameters of relationship (1) show that as the sand content of the soil and

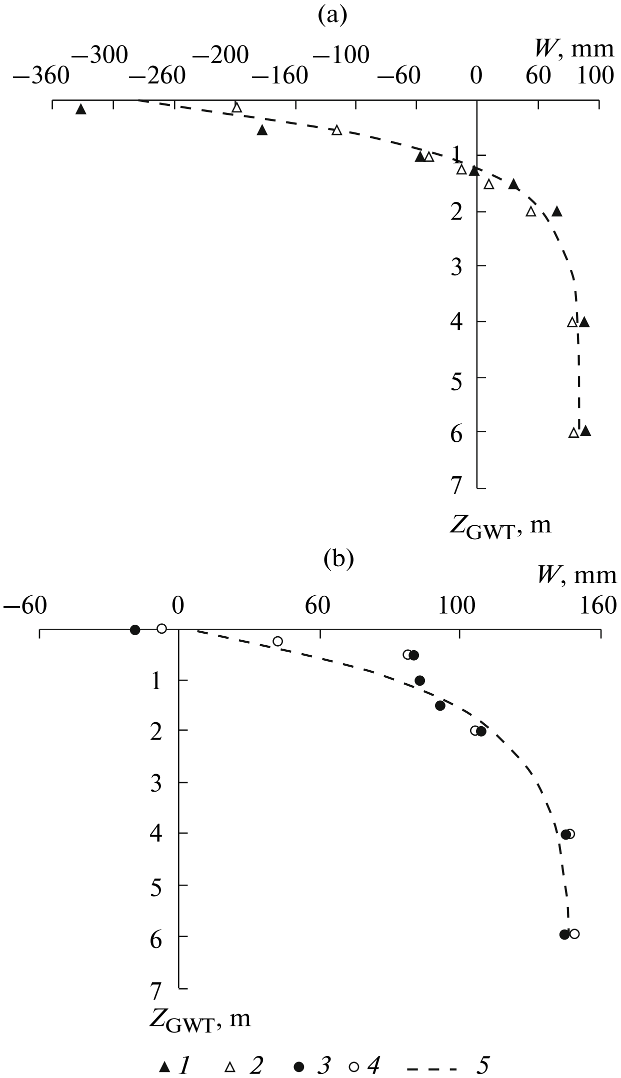

Fig. 5. Typical calculated dependence of infiltration W on the depth to GWT Z_{GWT} for (a) loam sand and (b) sand bed for the case of a forest landscape. (*1*) Loamy sand, (*2*) loamy sand overlying clay, (*3*) sand, (*4*) sand on sandy loams, (*5*) approximating curve.

the vadose zone increases, the values of parameters W_0 and Z_0 also increase and the critical depth to GWT, at which groundwater recharge changes into discharge, decreases (Table 4). The values of W_0 and Z_0 for the conditions of field relative to forest landscapes are somewhat less (on the average), while the critical depth to GWT features an inverse relationship. This means that the loamy composition of the soil and vadose zone causes a closer dependence of mean annual infiltration recharge on the depth to GWT. The most favorable conditions for groundwater discharge through evapotranspiration at shallow occurrence of its table are typical of open field landscapes with loamy section of soil and vadose zone. Here, groundwater

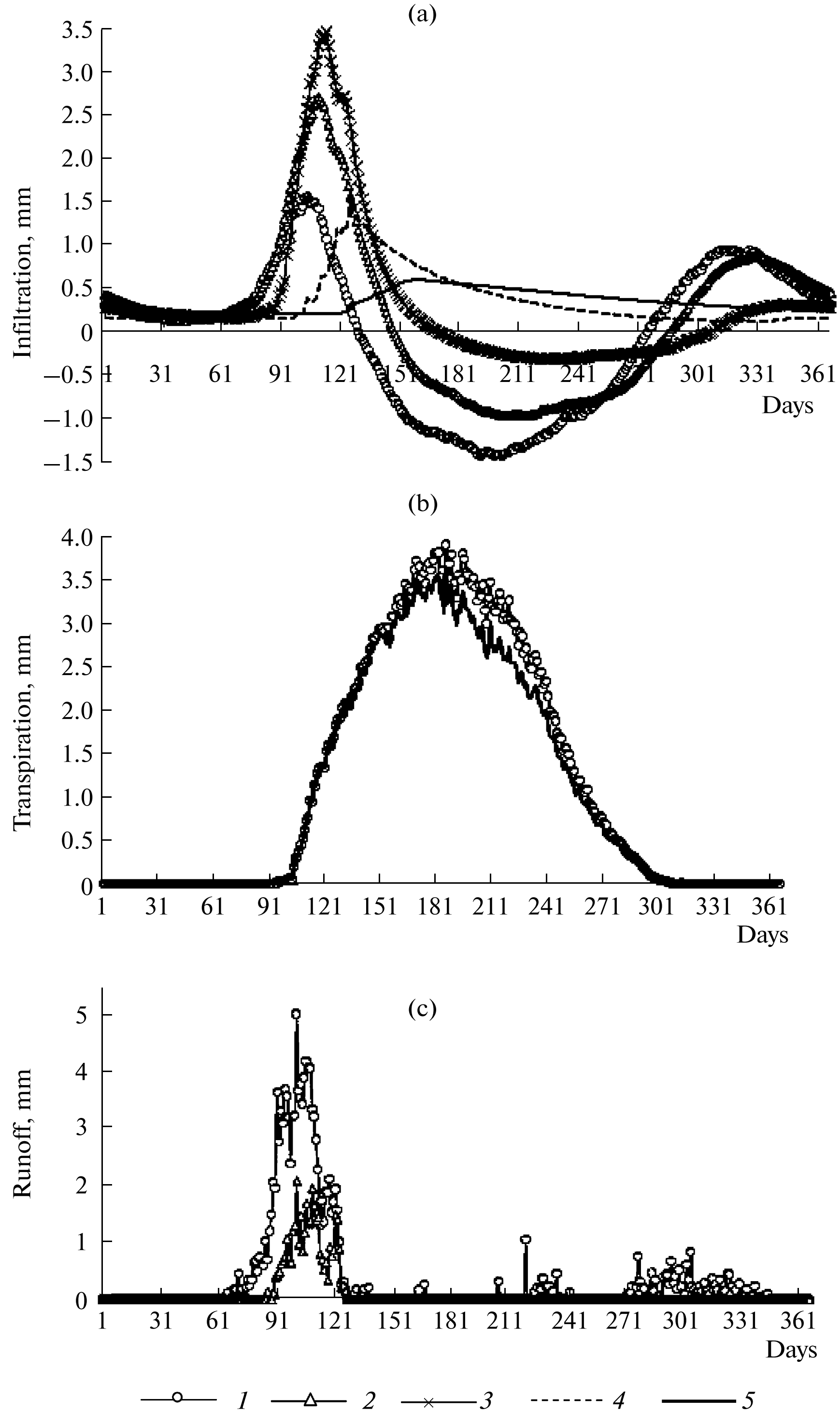

Fig. 6. Annual dynamics of water balance components for vadose zone: (a) infiltration, (b) transpiration, (c) surface runoff at different depth to GWT for forest sandy loam-loamy soil. Depth to GWT: (*1*) 0.5 m, (*2*) 1, (*3*) 2, (*4*) 4, (*5*) 6 m.

discharge takes place even at the depth to GWT of 2.0–2.5 m (Table 4). At the same time, in closed forest landscapes, groundwater discharge through evaporation is possible only in the case of loamy section and shallow (on the average up to 1 m) depth to GWT. When the composition of soil and vadose zone is sandy, groundwater infiltration recharge will take place irrespective of the depth to GWT.

Table 4. Parameters of dependence of long-term mean annual recharge W on the depth to GWT Z_{GWT} for different conditions in the territory of Kaluga province

Soil	Vadoze zone material	Parameters of dependence $W(Z_{GWT})$			Z_{GWT}, m, at $W = 0$
		W_p, mm	W_0, mm	Z_0, m	
Forest					
Loamy	Clay, loam	83	–300	0.80	1.22
	Sandy loam, sand	89	–150	1.00	0.99
Sandy loam	Clay, loam	95	–250	0.80	1.03
	Sandy loam, sand	123	10	1.40	<0
Sand	Clay, loam	114	–220	0.60	0.64
	Sandy loam, sand	140	0	1.25	0.00
Field					
Loamy	Clay, loam	22	–350	0.60	1.70
	Sandy loam, sand	30	–250	1.20	2.68
Sandy loam	Clay, loam	39	–320	0.55	1.22
	Sandy loam, sand	60	–170	1.35	1.81
Sand	Clay, loam	66	–280	0.63	1.04
	Sandy loam, sand	104	–100	1.10	0.74

CONCLUSIONS

The quantitative characteristics of mean long-term annual water balance as a whole and groundwater infiltration recharge, in particular, are radically different, depending on the individual natural conditions in the territory. These variations are largely determined by the landscape and geological–pedological characteristics and, to a lesser extent, by meteoclimatic properties. On the average, the difference in meteorological conditions in the examined territory for the southwestern MAB cause variations in the infiltration recharge from 60 to 100 mm/year. At the same time, because of the heterogeneity of landscape, soil, and hydrogeological conditions, the recharge rates can vary from 0 to 160 mm/year. Moreover, areas with near-surface GWT feature negative annual recharge rates, corresponding to groundwater discharge. The mean values of total annual groundwater infiltration recharge clearly tend to increase with increasing precipitation and decreasing mean annual temperatures in both absolute values and relative characteristics—in percentage of precipitation (from 11 to 15%) and total runoff (from 45 to 50%).

Noteworthy, the mean annual characteristics of total evapotranspiration and total runoff (the sum of infiltration and surface runoff) are weakly dependent on landscape and geological–pedological conditions. Depending on a combination of landscape and geological–pedological conditions within the examined climatic zone, the total runoff accounts for 23–30% of precipitation, while the total evaportranspiration accounts for 70–77% (Fig. 7). About the same range of their variations is due to meteorological factors. The landscape and geological–pedological conditions have a considerable effect only on the relationships between the surface and subsurface runoff (infiltration) and between different components of total

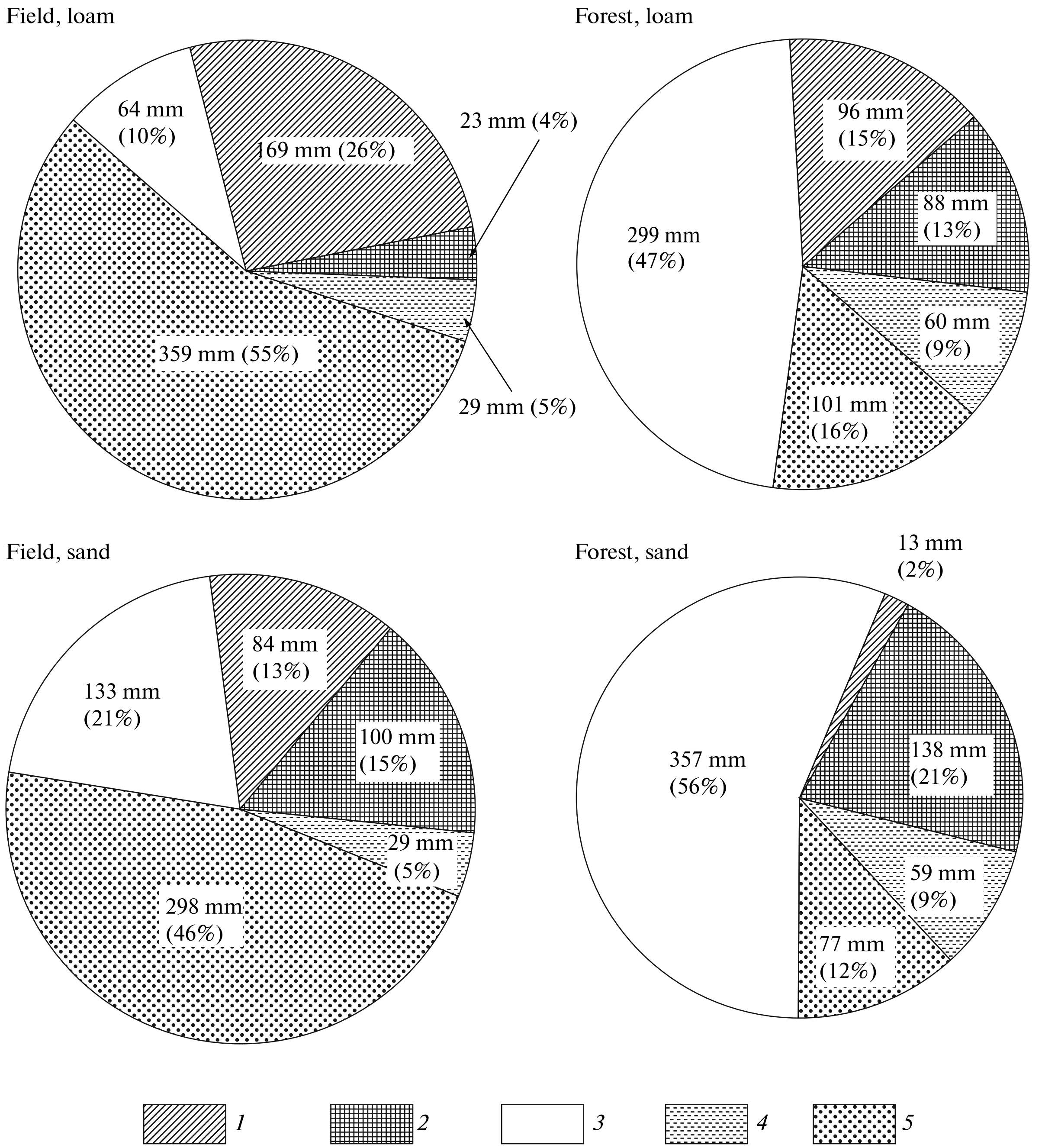

Fig. 7. Comparison of calculated characteristics of annual water balance, mm of depth and % of precipitation, for different landscape and geological-pedological conditions at deep GWT. (*1*) surface runoff, (*2*) infiltration, (*3*) transpiration, (*4*) surface evaporatioin, (*5*) evaporation from soil.

evapotranspiration (surface and soil evaporation and transpiration).

The above conclusions refer mostly to the most widespread territories with a considerable (>3 m) depth to GWT. When this depth is small, as is mostly typical of river valleys, the relationships between individual components of water balance are somewhat different—the infiltration recharge of groundwater decreases (down to 0), while the total evapotranspiration and surface runoff increases.

The comparison of obtained estimates of individual components of mean annual water balance with the published observational data at the level of both annual characteristics and within-year dynamics shows that the model adequately reflects the natural formation processes of groundwater infiltration recharge. Thus, the model-oriented approach is promising for the assessment of mean annual rates of infiltration and their area heterogeneity, caused by the difference in landscape, soil, and geohydrological conditions of the territory.

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