ARTICLES

Forest hydrological parameters as a function of stand structure meteorological conditions

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Values for evapotranspiration (ET) in drained forests, over growing seasons covering a 27 year period, are calculated by using water balance equations. Over the period, growing stock increased from 100 m^3/ha to 260 m^3/ha, with the ET values varying between 320 and 620 mm. ET values show no correlation with the figures for stock volume ($r= +0.01$), whereas the correlation is fairly close with the amount of precipitation (N) in summer ($r= +0.92$) and potential evaporation ($r= -0.49$).

Developed as mathematical expressions are models for transpiration, evaporation and evapotranspiration in relation to easily inventoried stand parameters: species composition, sum of stem basal areas and average diameter. The validity of models has been analyzed and confirmed. Transpiration in dry summers ($P< 300$ mm) is found to be roughly 3 times less than in rainy summers ($P> 500$ mm); however, it has no effect on stand increment.

Key words: forest ecosystem, stand structure, stock volume, transpiration, evaporation, interception, evapotranspiration.

Introduction

Normally, the amount of water bound by forest ecosystems above ground is below 50 mm. Current stand increment annually consumes no more than 1 to 2 mm of water, although the forest's water balance over the summer frequently exceeds 500 mm. Evapotranspiration (total evaporation) is the most important component that accounts for the drain in water balance.

The estimation of evapotranspiration indices in the forest and the evaluation of data reliability have a number of characteristics:

(i) Evapotranspiration and its constituents, such as transpiration and evaporation from the understory, cannot be measured directly. It is possible to calculate these indices, arising as unknown quantities in water balance, thermal balance and turbulent diffusion equations or in those of complex approach.

(ii) There are no reliable methods for estimating the above indices.

(iii) Repeated measurements in one and the same stand and under the same meteorological conditions are not possible.

(iv) Numerically, the indices for evapotranspiration are affected by a number of factors, varying both in time and over the area.

(v) Collecting data is expensive and difficult and, consequently, is done on a few sites only. Differences between sites and their impact on the evapotranspiration indices are difficult to assess numerically.

(vi) An increased number of sites for collecting data results in a diversification of evapotranspiration data, while the average data precision increases only slightly.

In calculating evapotranspiration, the latter is assumed to be a physical process, and the related numerical values, describing forest evapotranspiration, vary in proportion to energy inflow and soil moisture. However, a similar conclusion contradicts the basic principles of forest ecosystem (a cybernetic system) functioning.

According to the literature, Item (1974), who analyzed diurnal water balance in a deciduous forest, was the first to evaluate evaporation in terms of feedback. Before analyzing the field data, the author assumed the forest would evaporate 90% of the amount of water evaporated by an open water reservoir. The analysis revealed the potential evapotranspiration in forest to be at least twice as high as that from an open water reservoir. Concurrently, the forest starts to curb transpiration as soon as the soil absorbtion power exceeds 5 kPa (0.05 atm), irrespective of the weather staying hot and windy. Transpiration should thus be treated as a physiological process with the amount of water transpired depending on the tree species and its ability to adapt to soil moisture conditions, so as to ensure optimal conditions for survival.

Evapotranspiration (ET) from land ecosystems may be treated as a function of three variables: $ET= f(E_0, W, B)$, where E_0 describes the energy requirements for evaporation, W describes the requirements for soil moisture (i.e., the soil absorbtion power and water inflow to the roots). In all the ecosystems, E_0 is closely related to B, representing the biocenosis (phytocenosis) structure. The energy requirements for evaporation do not show up as a physical quantity alone, since evaporation is highly dependent on the phytocenosis ability to utilize the inflow of energy.

Application of the water balance equation for calculating evapotranspiration is rightly regarded as risky, since it is technically impossible to measure the inflow of precipitation water into deeper soil layers. Quite often the infiltration of water over the season amounts to 500-700 mm (Wechmann, 1963) and these values have erroneously been attributed to evapotranspiration. That is why hydrological observations and water balance estimates in drained forests have a strong advantage, since in waterlogged forests it is the inflow of underground and groundwaters, rather than infiltration, that predominates (Залитис, 1983). The amount of inflowing water may be measured quite easily, and the evapotranspiration in drained forests, when calculated by water balance equation, may be assumed to exclude a gross error, especially with regard to a fairly long period (i.e., the growing season).

However, it is possible to build a water balance equation only for fairly large areas, at least several tens of hectares in size. Normally, areas this size comprise diverse-structure stands, thus excluding the application of water balance equations for estimating hydrological parameters for individual stands.

Technically, the problem of forest hydrological parameter dependence on stand structure is difficult to solve. A number of inferences concerning the numerical values of these parameters are still hypothetical. By summing the conclusions made by different authors (Хильми, 1957; Молчанов, 1974; Item, 1974; Андрейчик, 1978) as well as by evaluating in greater detail the site descriptions given, we may formulate some regularities governing the processes in forest hydrology:

1. Similar structure stands are distinguished by a stable relationship, setting in over a comparatively short time (5 to 10 years) between evaporation (evaporation from the understory) and evapotranspiration, as well as between transpiration and evapotranspiration. Short-term differences due to soil moisture fluctuations are levelled out with the time and have no significant effect on the values of this relationship.

2. Provided the soil moisture and energy inflow are equal, the transpiration over the growing season for trees of the same species is directly proportional to the leaf (needle) mass. Under climatic conditions similar to Latvia, 1 kg of pine needles transpires 200 l of water over a growing season. The figures for spruce and birch are 80 l and 400 l, respectively. The said indices should be treated as constants fairly significant for the given tree species, as they illustrate the stand's ability to adapt to the conditions of soil moisture and also modify them in the direction desired.

Following the above regularities, and by using mathematical expressions which relate the leaf (needle) mass to easily inventoried stand parameters, mathematical models are developed for transpiration (T), evaporation (E) and evapotranspiration (ET): T, E, ET = f (S, D, G), where *S* is the share of the given tree species (pine, spruce, birch) in the stand; *D* is mean diameter, cm; and *G* is the stand basal area in m$_2$/ha.

Here are the mathematical expressions for some of the models (Залитис, 1983):

ET = E + T;

In pine stands $ET_P = \frac{300(D+3)}{D}$; $15 < G < 35$; $66 < D < 40$;

In spruce stands $ET_S = \frac{297G(D-3)}{D(G-6)}$; $15 < G < 30$; $4 < D < 30$;

In birch stands $ET_B = \frac{630G(D-5)}{D(G-2)}$; $15 < G < 30$; $8 < D < 28$.

There are two models available for calculating hydrological parameters in drained forests. One is intended for calculating evapotranspiration in terms of the forest's water balance: $ET_{w.b.} = N + P - Q$, where *N* is the precipitation; *P* is the inflow from the adjoining areas and groundwater discharge; *Q* is the runoff through ditches. In the other model, stand parameters are used as independent variables and the expression may be written as: $ET_{struct} = T + E + I$, where *T* is the transpiration; *E* is the evaporation; and *I* is the interception.

The objectives of the study are: (i) to quantitatively evaluate the stand's ability to survive and produce wood over extremely dry as well as extremely wet summers; and (ii) to answer the question: Why does the stand productivity in drained forests exhibit no decline along with ditch deformation and a decrease in runoff?

Materials and methods

The long-term field data taken at the "Vesetnieki" permanent sample site for studies in forest ecology provide for a possibility to calculate, by using water balance equations, annual ET_{wb} values for five runoff basins for the period between 1968 and 1994. These ET values offer an excellent opportunity to check, in terms of stand parameters, the validity of the models developed.

To test the models, the average water balance (ET_{wb}) data over the growing season (May 1 through Oct. 31) and covering the past decade is used. The choice of the period is based on the following prerequisites:

(i) the stand structure is shaped by average soil moisture conditions over a long period of time;

(ii) the stand structure shows no response to the annual weather-dependent variations in soil moisture conditions.

In the summer of 1994, the stand parameters required by T, E, ET models were measured in each basin at randomly chosen points. Depending on the basin area and the restrictions for the model, the number of points varied between 19 and 31. T, E and ET values were calculated for each point, after which the average values for the basin were obtained (Table 1 to Table 3).

Table 1. Statistical data, on a per-basin basis, for transpiration values (mm) depending on stand structure

Statistical data	Basin				
	1	2	3	4	5
Mean arithmetic	189	168	244	210	255
Standard deviation	41	40	61	61	64
Minimal value	114	120	159	112	143
Maximum value	275	299	345	334	367

Table 2. Statistical data, on a per-basin basis, for evaporation values (mm) depending on stand structure

Statistical data	Basin				
	1	2	3	4	5
Mean arithmetic	225	228	148	164	149
Standard deviation	51	48	58	67	68
Minimal value	132	119	53	70	53
Maximum value	292	300	247	354	318

Table 3. Statistical data, on a per-basin basis, for evapotranspiration values (mm) depending on stand structure

Statistical data	Basin				
	1	2	3	4	5
Mean arithmetic	414	396	392	374	404
Standard deviation	59	56	60	43	58
Minimal value	301	321	251	314	291
Maximum value	505	524	496	529	512

The data obtained show considerable variations in each basin. Provided the minimal T values are about 2.5 times less than the maximum ones (variation factor V=25%), then the same index for E values is 3.5 (V=34%). The E values are lowest in fully stocked spruce stands, as well as in those having a dense understory of spruce or vigorous undergrowth. Transpiration and evaporation is the highest in pure stands of birch. The relationship between the minimal and maximum values of ET is below 2 (V=14%).

It should be noted that in these models transpiration (T) is treated as a physiological process, the values of which correspond to the established constants. However, along with transpiration, there is also a physical evaporation of water from the foliage surface during and right after rain. Often the foliage is only partly wet and some part of it still transpires water while the wet part is temporarily excluded from transpiration. For this reason, meeting the condition $ET_{w.b} > ET_{struct.}$ is one of the prerequisites for the validity of the models and the values calculated.

The above condition is confirmed by a comparison between ET values obtained by the water balance equation and those calculated depending on stand structure.

Basin	1	2	3	4	5
$ET_{w.b}$ (mm)	508	481	464	455	476
$ET_{struct.}$ (mm)	414	396	392	374	404

To second the validity of the models, the data for interception (I) must be included. The interception of rainwater retained by the tree crown is fully involved in ET, partly limiting T.

At the "Vesetnieki" permanent sample site over the last decade there have been, during summer, 56 rainy days on average, with the average amount of precipitation 8.5 mm per day. This is roughly 70% of the amount needed to fully wet the foliage and temporarily arrest transpiration (Залитис, 1983).

For this reason, the ET model as dependent upon stand structure, may be written as follows:

$ET_{struct.} = T_1 + T_2 + E + I$,

where T_1 stands for transpiration in rainy days (56 in the given case); and T_2 – transpiration in days with no rain (128 in the given case).

As shown in Table 1, transpiration T, depending upon stand structure and the number of rainy days, is described by the following values (mm).

Basin	1	2	3	4	5
$T_{\text{in single day}}$	1.03	0.91	1.33	1.14	1.39
T_1	18	15	23	19	24
T_2	132	116	170	146	178
$T_{\text{in 184 days}}$	150	131	193	165	202

The values for interception (I) have been obtained by direct measurements and, on a per-basin basis, vary slightly (122 to 132 mm).

Following the values measured and calculated, we may calculate $ET_{struct.}$ and compare it with $ET_{w.b}$

Basin	1	2	3	4	5
T_{184}	150	131	193	165	202
E	225	228	148	164	149
I	125	122	128	124	132
$ET_{struct.}$	500	481	469	453	483
$ET_{w.b}$	508	481	464	455	476

A nearly complete agreement between the total values of evaporation (ET) attests to the validity of the two models. It enables one to calculate the hydrological parameters for individual stands following their current structure and also predict the related variations, in line with the changes in stand structure.

At our disposal the following:

(i) The values of evapotranspiration for five forest tracts over 27 years, calculated by using the water balance equation: $ET_{w.b.} = N + P_p + P_m - Q$, where N stands for precipitation, P_p - groundwater inflow, P_m - water inflow from outside, Q - runoff.

(ii) In 1994, with regard to the same five tracts, values for evaporation (E), transpiration (T) and evapotranspiration (ETstruct.) were calculated following the stand structure.

(iii) The values of interception (I), as well as the amount of precipitation (Ns) that has reached the soil, have been measured in 10 diverse structure forest stands, as well as on average in each of the five forest tracts, for 27 years.

(iv) Proceeding from the meteorological data, the values of evaporation (E_0) from open water reservoirs have been calculated (Константинов, 1968).

(v) In the forest tracts under analysis, the stand parameters have repeatedly been measured (six times) between 1970 and 1994.

Results

Over the period covered by measurements, the stock volume in the studied stands has increased 2.6 times - from 100 m³/ha to 260 m³/ha. The evapotranspiration was also assumed to increase significantly over that period. To test this assumption, we calculated correlation factors which describe the variations in time (t) of ET and ET/N = m over the growing season (May 1 to Oct.31). The low values for correlation factor, $r_{ET,t} = +0.01$ and $r_{m,t} = -0.14$ at $r_{0.05} = 0.40$ refute the assumption of stock volume dependence on ET.

Over the period of monitoring, the average annual values of ET varied considerably, from 320 mm (1975) to 620 mm (1980), and those of m = ET/N - from 0.81 (1974) to 1.84 (1975) (Fig.1). The differences between the values of m, rather sharp even for two adjacent years, attest to both the stand's ability to accommodate itself to varying meteorological conditions and to evaporate in dry summers considerably more water as compared to the amount of precipitation, whereas in excessively wet summers the stand is incapable of evaporating all the rainfall. The correlation between ET and E_0 values is significantly negative (r = -0.49), since in dry summers, when the potential evaporation E_0 is the highest, the stand reduces its transpiration sharply. On the other hand, a very strong positive correlation is between ET and N (r = +0.91).

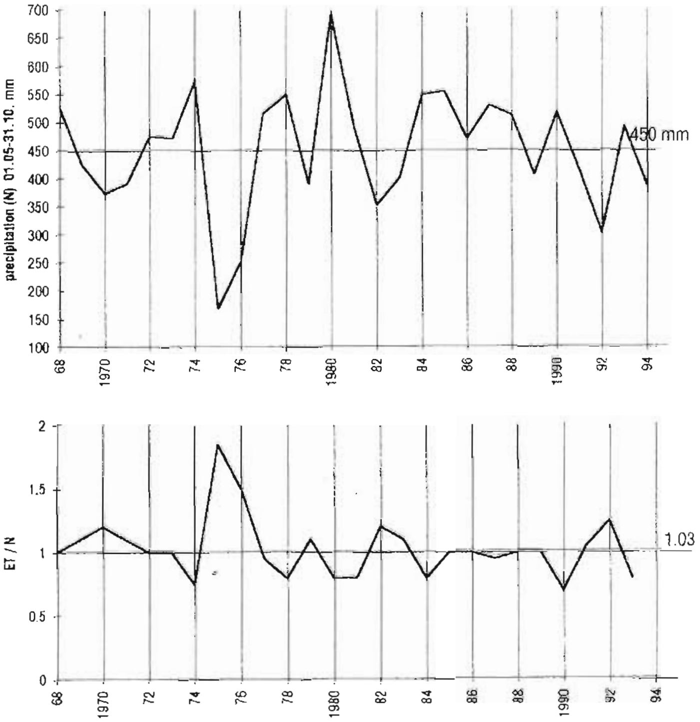

Fig. 1. Evapotranspiration values on a per-year basis as dependent upon the amount of precipitation over the growing season (May 1 through Oct.31).

These dependencies confirm a conclusion that transpiration should be treated as a key constituent of the forest ecosystem self-regulatory mechanism. To investigate in greater detail the regularities that go with evapotranspiration and transpiration, the field data, as well as the values calculated from the meteorological data, were divided into eight groups: Group 1, N<300 mm ('$N_{average}$ = 210 mm); Group 2, N=301 to 350 mm ('N= 328 mm)... (Table 4).

Table 4. Hydrological parameters depending upon the amount of precipitation over the growing season

No	Precipitation in summer (N), mm	Years	Actual precipitation (averaged 'N), mm	Interception I, mm	Precipitation that has reached soil, Na, mm	Number of rainy days (RD)	Amount of precipitation per rainy day, NRD, mm	Evaporation (E_0) from open water, mm		Evapotranspiration ET, mm (from water balance)	ET-E_0, mm
								actual	relative		
1.	200-300	1975, 1976	210	73	137	35	6.0	464	1.11	350	-114
2.	301-350	1982, 1992	328	101	227	44	7.4	415	0.99	393	-22
3.	351-400	1970, 1971, 1979, 1983, 1994	390	118	272	51	7.6	452	1.08	430	-22
4.	401-450	1969, 1989, 1991	416	115	301	53	7.8	433	1.03	446	-13
5.	451-500	1972, 1973, 1981, 1986, 1993	481	124	357	58	8.3	418	1.00	470	+52
6.	501-550	1968, 1977, 1978, 1987, 1988, 1990	526	135	391	60	9.1	382	0.91	537	+155
7.	551-600	1984, 1985	552	187	365	75	7.4	397	0.95	534	+137
8.	600 +	1974, 1980	633	183	450	71	8.9	394	0.94	541	+147

Table 4, continued

No	Precipitation in summer (N), mm	Evaporation E_{str} in forest (183 mm) adjusted for y, mm	Transpiration T_{str} (213 mm, adjusted for RD), mm	$T_{actual}=ET_{w.b.}+E_{str}$, mm	$T_{actual}/T_{str}=x$	$T_{act}-T_{str}$, mm	T_{act}/N_a
1.	200-300	203	185	74	0.4	-111	0 54
2.	301-350	181	177	111	0.63	-66	0.49
3.	351-400	198	172	114	0.66	-58	0.42
4.	401-450	188	171	143	0.84	-28	0.48
5.	451-500	183	166	163	0.98	-3	0.46
6.	501-550	166	165	236	1.43	+71	0.61
7.	551-600	174	152	173	1.14	+21	0.47
8.	600 +	172	156	186	1.19	+30	0.41

Each group comprises data for a number of years, occasionally with an interval of 20 years, thus greatly reducing the impact of stand structure on hydrological parameters and enabling a relatively "sterile" evaluation of forest hydrological parameter dependence upon the amount of atmospheric precipitation or its share that has reached forest soils.

In the last three gradation classes (during wet summers) the precipitation ('N) varies between 526 mm to 633 mm, while the values of ET and E_0 remain virtually the same: $534<ET<541$ (mm); $382<E_0<397$ (mm). At this level of moisture, the ET in forest considerably exceeds (137 to 155 mm) that from an open water reservoir (E_0), believed to be due to an enhanced transpiration in wet summers.

The analysis is based on the evapotranspiration equation:

$$ET_{w.b.} = I + xT_{struct.} + yE_{struct.},$$

where $ET_{w.b.}$ represents evapotranspiration values derived from the water balance equation; I - interception; $xT_{struct.}$ - transpiration; yE_{struct} - evaporation. xT_{struct} is derived from the equations where stand inventory elements are used as arguments. The values of $xT_{struct.}$ obtained were, within each of the eight groups, adjusted to the number of rainy days in the growing season: $xT_{struct.} = T_1 + T_2$, where T_1- transpiration in days with no rain, T_2 - transpiration in rainy days: $T_2 = 0.3\ T_1\ n$, where n denotes the number of rainy days. In the given case, $35 \leq n \leq 75$ and $152 \leq xT_{str} \leq 185$ (mm). As it follows, the transpiration values, calculated proceeding from stand structure and adjusted to the number of rainy days, vary over a relatively narrow range, irrespective of the amount of precipitation varying over a fairly large range: $210 < N < 633$ mm. As already stated in prerequisites, the stand structure corresponds to the most common moisture conditions encountered, and remains the same even in case the difference between precipitation levels in two consecutive summers exceeds 400 mm: 574 mm in 1974; 169 mm in 1975; 692 mm in 1980. Decisive is the role of the hypothetical factor x, which describes the relationship x= Tactual :Tstr. and illustrates the self-regulatory ability of the forest stand.

E represents evaporation from understory, calculated from equations where stand inventory elements are used as arguments. The data obtained are adjusted to the rated E_0 value, y, (evaporation from an open water reservoir). We assumed E_{str} within the eight groups to vary in proportion to the variations in E_0: $E_{str} = Ey$, providing $0.91 \leq y \leq 2.11$; $y=1.0$ at $E_0= 418$ mm.

A significant correlation between E_0 and LD (number of rainy days) testifies in favour of this assumption: r = - 0.87, i.e. we assume that in wet summers, when evaporation from open water reservoirs is less, the same holds for undercanopy space, too. $T_{actual} = ET_{w.b.} - I - E_{str}$ has been calculated in each of the eight groups, and over 27 years $74 \leq T_{actual} \leq 236$ (mm); the factors for transpiration self-regulation, $x = T_{actual} : T_{str}$, varies over a wide range, from 0.40 to 1.43.

The value of coefficient x describes how many times in each of the eight groups of soil moisture conditions the actual transpiration deviates from that calculated following the stand structure (Fig. 2). In extremely dry summers (1975, 1976) the transpiration from tree stands is roughly half as much as in

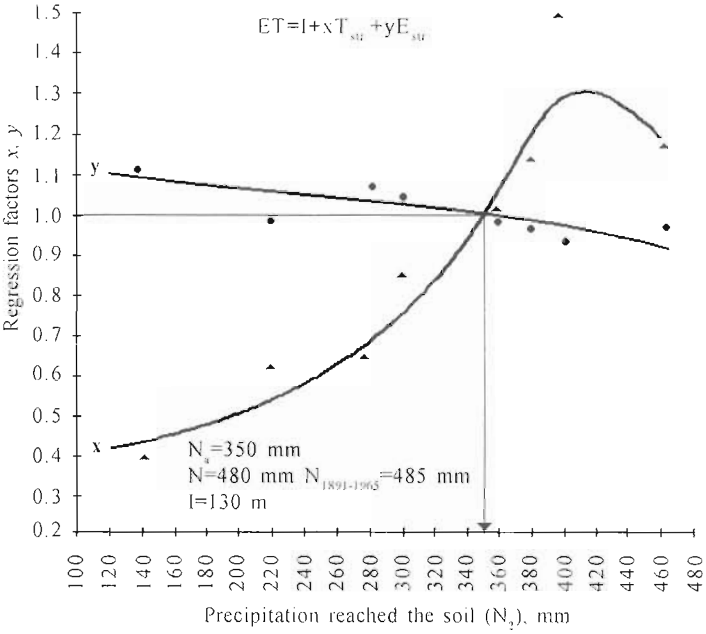

Fig. 2. Transpiration and evaporation regression factors (x, y) in water balance equation as a function of precipitation that has reached the soil over the growing season.

normally wet summers with the precipitation of 480 mm, where 350 mm reach the soil and x ≈ 1.0. The fact that x=1.0 just at N=480 mm, which is in agreement with the average long-term precipitation level at the "Vesetnieki" permanent sample site ($N_{1891-1965}$ = 485 mm) as well as with the average precipitation level over the past decade ($N_{1984-1993}$) = 476 mm), is yet another proof to the validity of given models and rightness of the above conclusions. The amount of precipitation increasing, transpiration increases sharply and attains its maximum value (x ≈ 1.3) at N= 530 mm, where the amount of precipitation that reaches soil is 400 mm. At higher levels of soil moistening, the transpiration intensity starts to decrease; however, under the local conditions this factor remains x > 1.0 also in extremely wet summers.

A conclusion on a relative decrease in transpiration under conditions of extreme wetness is well in line with the research data on diurnal variations of ET as a function of the rate of groundwater table decrease over periods with no rain (Zālītis, 1994). With the groundwater table no deeper than 40 cm from the soil surface, a part of the root systems get submerged and the value of ET decreases. Evapotranspiration is the most intensive at the depth of groundwater table ≈ 60 cm.

When testing the transpiration relationship by using the current increment of wood, we analyzed the impact of two consecutive extremely dry summers (1975, 1976) on the increment for pine, spruce and birch against the background of diverse growing conditions (Zālītis, Šitca, 1986.) It is to be noted that none of the above tree species showed a decrease in increment, either in the extremely dry years or the two years after the drought.

Discussion

The calculations within the frame of the given study once again attest to the excellent ability of forest to adapt itself to highly varying soil moisture conditions that differ from year to year or within a single growing season. The precipitation-induced excessive soil moisture is, via higher transpiration, reduced by the stand to a level acceptable for it. With the stand structure roughly equal, the transpiration in rainy summers is three times higher than in dry summers.

The typological division of forests into essentially dry and waterlogged ones, with all the modifications for the latter involved (wet mineral soils, marshlands, drained peatlands), and precisely the soil moisture taken here as the dominant factor, may be treated as arbitrary. Moreover, the excessive soil moisture is only an indicator traditionally used to describe poor soil aeration. It is just the soil aeration that the stand productivity depends on, at otherwise equal nutrient availability.

That is why discussions on the adverse impact of hydrotechnical amelioration on the productivity of dry site-type forests contiguous to the area drained are not valid; the productivity of the dry-site forest will either increase or remain unchanged. Similarly, no higher stand productivity can be expected on the brookside after the beaver has dammed the stream, inundating the floodplain.

If the soil aeration is maintained, stands with a relatively low stock volume may provide favourable conditions for survival even in extremely wet summers at high groundwater tables. It is neither the high groundwater table that is the prime cause for low stand productivity, nor its lowering that markedly increases the productivity after hydrotechnical amelioration. The very essence of hydrotechnical amelioration is to provide for better soil aeration resulting in an increased activity of soil as a forest ecosystem component. This process is initiated simultaneously with ditching over the forest tract.

During a number of decades following the drainage, while a groundwater flow is still maintained in the forest, another, well-aerated soil surface layer takes shape. Research in soil aeration and comparative evaluation of soil agrochemical properties in drained and undrained forests should be ranked among the most essential research problems, the solution of which will be a significant contribution to our understanding of the ecological role of forest hydrotechnical amelioration and soil drainage as among deciding prerequisites for shaping and maintaining high-yield forest stands in both originally wet and dry site type forests.

Conclussions

1. Long-term field data on processes in forest hydrology, obtained on permanent sample sites, provide a unique opportunity for analyzing and modelling these processes, both in terms of stand structure and meteorological conditions.
2. The validity of two models suggested, i.e. those of water balance and stand structure including the restrictions for their application, has been established by comparing evapotranspiration values derived following the said models. It enables one to use stand structure models for evaluating water regulatory properties of the forest both in continuous tracts and individual stands.
3. Stand structure based models describe transpiration as a physiological process. That is why the values of interception (amount of water retained by the tree crown) should be added to the transpiration values calculated. On rainy days, transpiration is at the same time partly restricted: when compared on a per-day basis, transpiration over a rainy day is only 30% of that during a day with no rain.
4. Transpiration is quite sensitive to soil moistening: transpiration in extremely dry summers is only 40% of that in normally wet (on average) summers. On the other hand, in rainy summers transpiration is 1.3 times higher than in normal

summers. The transpiration is the highest in summers with the level of precipitation 500 to 550 mm. The amount of water transpired has no impact on stand productivity.

References

Item H. 1974. Ein Modell fur den Wasserhaushalt eines Laubwaldes (A Model for the Water Regime of a Deciduous Forest). Mitt. Eidgenoss. Anstalt f. fortliches Versuchswesen. Bd 50, H.3, 127-331.

Wechmann A. 1963. Hydrologie. Berlin, 535 S.

Zālītis P., Šitca D. Kokaudžu ražība ekstrēmi sausās vasarās (Forest Stand Productivity in Extremely Dry Summers). Jaunākais mežsaimniecībā, 28., 1986., p. 24.-29.

Zālītis P. 1994a. Productivity of Pine on Drained Sites and the Effect of Ditch Deformation - Proc. of Latvian Acad.Scien. 7./ 8., p. 128-131.

Zālītis P. 1994b. Evapotranspirācija nosusinātā mežā un izcirtumā (Evapotranspiration in Drained Forest and in Narrow Cutover). Mežzinātne, Y(37), p. 3-10.

Андрейчик М. 1978. Тепловой режим и непродуктивное испарение влаги в основных типах леса Белорусского Полесья. (Andreychyck M., 1978. Heat Regime and Non Productive Evaporation of Moisture in Site Types under Pine in the Forests of Belarus Polesye). Thesis f. obtaining the degree cand.scien., Tartu, 19 p.

Залитис П. 1983. Основы рационального лесосушения в Латвийской ССР. Zālītis P., 1983. Basics of Rational Forest Drainage in Latvian SSR). Rīga, 232 p.

Молчанов А. 1963. Суммарное испарение и трансапирация в лесу и на безлесных площадях. (Molchanov A. Total Evaporation and Transpiration in the Forest and Non-Stocked Areas). In: Лес и воды, Moscow, p. 55-76.

Федоров С. 1977. Исследования лементов водного баланса в лесной зоне европейской территории СССР. (Fedorov S., 1977. Research on the constituents of Water Balance in the Forest Zone of the European Part of the USSR). Leningrad, 264 p.

Хильми Г. 1957. Задержание лесом дождевых осадков. (Khilmi G. Rainwater Retention by Forest) in Теоретическая биофизика леса. Moscow, p. 60-78.

ГИДРОЛОГИЧЕСКИЕ ПАРАМЕТРЫ ЛЕСА КАК ФУНКЦИИ СТРУКТУРЫ ДРЕВОСТОЯ И МЕТЕОРОЛОГИЧЕСКИХ ХАРАКТЕРИСТИК

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Резюме

Результаты продолжительных стационарных наблюдений за гидрологическими процессами в осушенных лесах служат надежной опорой для моделирования их процессов в зависимости как от структуры древостоев, так и метеорологических условий. По уравнению водного баланса нами вычислены величины вапотранспирации ЭТ (суммарного испарения) для каждого вегетационного периода в течение 27 лет (1968-1994 г.г.). За то время средний запас древостоев увеличился от 100 м^3/га на 260 м^3/га и величины ЭТ колебались в пределах 320-620 мм. Величины ЭТ не коррелируют с показателями запаса древесины (r= +0.01), но тесно коррелируют с количеством выпавших осадков (r= +0.92) и показателями потенциальной испаряемости (r= -0.49).

Нами разработаны модели транспирации, вапорации с подпологового пространства и вапотранспирации за вегетационный период в виде математических уравнений с легко измеряемыми параметрами древостоя в качестве независимых переменных. Проверялась и подтвердилась достоверность разработанных моделей. В результате того открывалась возможность использования моделей для выявления водорегулирующих характеристик как отдельных насаждений так и лесных совокупностей в целом.

Модели транспирации как функции структуры древостоя описывают транспирацию в виде физиологического процесса. Потому вычисленных показателей транспирации следует увеличить на величины механического задержания атмосферных осадков в кроновом пологе древостоя (интерцепции), испарение которых ограничивает интенсивности транспирации; за один дождевой день транспирация в среднем составляет всего 30% транспирации за бездождный день.

Интенсивность транспирации очень чувствительно реагирует на изменения влагосодержания в почве: засушливым летом (осадков менее 300 мм) транспирация составляет 40% от транспирации в нормальных годах со средним количеством осадков 480 мм за вегетационный период. За дождливые периоды вегетации (осадков больше 500 мм) показатели транспирации в 1.3 раза превышают показателей ее за нормальные годы. Показатели транспирации не коррелируют (r= +0.08) с показателями текущего прироста древесины.

Ключевые слова: испаряемость, структуры древостоя, вапорация, вапотранспирация, транспирация, гидрологические параметры.