RETENTION – EVAPOTRANSPIRATION UNIT

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Abstract: The aim of this study is to identify the governing role of natural selection in the development of plant cover in cold climate regions of the Czech mountains and foothills. It was found that the plant growth reaches maximum productivity for the plant temperature optimum value of 25şC. The questions "Why is the optimum temperature equal to 25şC in all experimental plots?" and "What mechanism set up the optimum temperature?" are solved using natural selection hypothesis and simulation of hydrological cycle and phytomass productivity based on the retention-evapotranspiration unit RETU model. The RETU model elucidates the way how plants control the heat and water circulation in cold climate depending on the optimum plant temperature. Natural selection hypothesis says that the plant cover will be prevailing on the site occurring in the long-term stable natural conditions that is able (1) to produce the biggest amount of phytomass, and (2) to live through unfavourable conditions. If this hypothesis will be used for a selection of the most suite optimum plant temperature, it can be stated that it is the temperature 25şC, because the (1) highest production is reached at this temperature in the critically dry vegetation seasons, and (2) no hydrologic extreme threating plant live is met in all vegetation seasons.

Keywords: hydrological cycle; plant transpiration; natural selection hypothesis; cold climate

RETENČNĚ – EVAPOTRANSPIRAČNÍ JEDNOTKA

Souhrn: Příspěvek se zabývá rolí přírodní selekce při vytváření vegetačního krytu v chladném klimatu českých hor a podhůří. Bylo zjištěno, že rostlinná produkce dosahuje maxima při optimální teplotě rostlin 25 ºC. Pomocí hypotézy přírodní selekce a simulace hydrologického cyklu a produkce fytomasy se řeší otázky: "Proč je optimální teplota porostů na všech experimentálních plochách rovna 25 ºC?" a "Jakým mechanismem byla optimální teplota vybrána?". Hydrologický cyklus spolu s produkcí fytomasy je simulován pomocí modelu retenčně-evapotranspirační jednotky RETU. Tento model objasňuje, jak rostliny řídí hydrologický cyklus v závislosti na optimální teplotě. Hypotéza přírodního výběru říká, že v dlouhodobě stabilních přírodních podmínkách převládne ten vegetační porost, který (1) produkuje největší množství fytomasy a (2) je schopen přežít v nepříznivých podmínkách. Užitím této hypotézy lze vyvodit, že porost s optimální teplotou 25 ºC bude vybrán jako nejvhodnější pro studované oblasti, neboť (1) dosahuje největší produkce fytomasy v kriticky suchých sezónách a (2) v žádné sezóně není vystaven podmínkám, které by ho zahubily.

Klíčová slova: hydrologický cyklus, transpirace rostlin, hypotéza přírodního výběru, chladné klima

1. Introduction

Hydrologic cycle is monitored in 20 sites in the four mountain and submontane conditions in the crystallinic massifs of the Czech Republic: (1) Šumava Mts., altitude 700–1100 m a.s.l., (2) Krkonoše Mts., altitude 1000–1400 m a.s.l., (3) Jizerské hory Mts., altitude 800–850 m a.s.l., (4) spring area Senotín in Novobystřická Highlands, altitude 600–700 m a.s.l. These sites lie in the cold climate regions characterized in the vegetation season April–September by the mean air temperature 8–10ºC, mean precipitation total 400–700 mm, mean duration of sunshine 1100–1300 hours (1901–1950, Climatic Atlas, 1958), and mean potential transpiration 200–250 mm (1983–2002).

The soil cover in these areas is shallow and highly heterogeneous. At hillslopes is formed namely by Cambisol, Gleyisol and Histosol (terminology after FAO, 1968 and Němeček et al., 1990). The infiltrated rain-water largely flows downwards through the soil, so that a surface and subsurface runoff are rare phenomena. Highly permeable subsoil forms a shallow drainage layer transporting water from the soil to recipients. This layer is not fully filled with water, so that no significant areas with ground water table are in catchments. Geological bedrock, namely paragneiss or granite, forms an impermeable layer.

Experimental sites are located in five small watersheds. They especially differ in the level of the anthropogenic load affecting the vegetation cover. The Liz (Šumava Mts.) catchment represents a relatively healthy productive spruce forest in a clear landscape. The Zábrod locality (Šumava Mts.) is covered by grass. The Uhlířská basin (Jizerské hory Mts.) was in the beginning of the nineties nearly completely deforested. At present, the prevailing part of this catchment is covered with the regenerated forest. The Modrý potok basin (Krkonoše Mts.) represents the original spruce forest in lower part of the basin and the arctic-alpine tundra with dwarf pine stands in the upper part above the timberline. The Senotín basin (Novobystřická Highlands) is covered mainly by grass.

The area of all watersheds is covered by automated monitoring network, supplemented by the additional observation sites for manual data collection. The automated monitoring stations are equipped with sensors for measuring precipitation, air temperature at two levels, soil temperature at five depths, tensiometric pressure at four depths and volumetric soil water content at three depths. Meteorological data are collected by means of fully automated system, which provides gradient observations of water and heat transfer in the surface layer of atmosphere as well as in the soil profile. The discharge in the closing profile is measured in every watershed.

Experimental data in all sites show that in the precipitation – runoff transformation, the soil water content is a crucial factor (Tesař et al., 2001, 2004). Following the soil water content, different mechanisms act in the runoff formation. When the water content is high (percolation phase), water storage recharges in the drainage layer and outflows into the stream in discharge waves immediately reacting to precipitation. When the water content is low (accumulation phase), water slowly outflows from the drainage layer and forms the base flow in a stream. The altering of the accumulation and the percolation phases can be described with the help of these rules: (1) The percolation of soil water to the drainage layer sets in if the threshold value of the soil water content is exceeded. In this situation, the water supplied by rain or snow melting causes a pronounced water outflow and consequently, decrease the soil water content. (2) In a situation where the soil water content is below the threshold value, the percolation is negligible. In consequence of these rules and watersheds' topography, the storm runoff generation is characterized by three effects: (1) The rising hydrograph limb grows very quickly and its duration is short – a few of minutes or hours. (2) The falling hydrograph limb lasts for many days or weeks. (3) The greatest value of the soil water content is reached as a rule before the rain ends.

Experimental data describing the coupling between soil water retention, transpiration, water outflow into the subsoil, and soil and air temperature can be summarized as follows (Tesař et al., 2001): (1) Soil water storage moves between the minimum and maximum value in all the vegetation season. Those values were not changed at individual sites in the course of many growing seasons. The typical soil water retention capacity (i.e. the difference between maximum and minimum storage) is about 60–90 mm. (2) The rain, infiltration of which results in exceeding the maximum soil water storage, is always the cause of water outflow from the soil, regardless of the rain magnitude. (3) The limit value of tensiometric pressure, below which the water uptake for plant transpiration is impossible, was the same in all the vegetation seasons. This limit value is –60 kPa for grass, dwarf pine forest and spruce vegetation. (4) Notwithstanding the incidence of solar radiation on plant cover, plant temperature does not overstep certain maximum temperature (about 25şC) when plants transpirate. In the periods with full transpiration the air temperature does not overstep 25şC. (5) Scarcity of water for plant transpiration is the cause of plant transpiration stop, resulting in an important increase of plant, soil and air temperature. In the periods with insufficient transpiration the plant temperature reaches approximately 35şC, and air temperature approx. 30şC.

In general, hydrologic cycle in all experimental stands exhibits the same pattern independent on vegetation, soil, geological bedrock, exposition and common variations in meteorological conditions. The cause of this phenomenon was investigated in previous stages of this work (Tesař et al., 2001, 2004). It was concluded that biological behaviour of plant cover is the only reason of this uniformity.

The aim of this study is to identify the governing role of natural selection in the development of plant cover in cold climate regions of the Czech mountains and foothills. Crucial questions “Why is the maximum temperature of transpiring plants equal to 25şC in all experimental plots?” and “What mechanism set up this temperature?” are solved using natural selection hypothesis (Eagleson, 1978). Hydrologic cycle and phytomass productivity are modelled by simulation based on the retention-evapotranspiration unit RETU concept (Tesař et al. 2001).

2. Retention - evapotranspiration unit RETU

Water exchange between the soil and plants is driven by heat from solar radiation that, in combination with the air temperature, is the cause of plant heating. The plants protect themselves by transpiration against heating up over the certain temperature. In this way, heat input is divided into two parts – latent heat (used for water vaporization) and sensible heat. Sensible heat irradiated from plant cover is the dominant cause of heating of the low atmosphere layer. Water for transpiration is imbibed from the root zone of soil. In case of water scarcity, transpiration ceases, the plants do not cool (latent heat is equal to zero), and therefore, the plant cover and atmosphere are overheated by incident solar radiation.

Soil is filled by infiltrating rain water. If the soil water storage oversteps the maximum retention capacity of soil, excessive water flows from the soil into the bedrock. In this way, the rain income is divided into two parts – water that is stored in the soil and subsequently returned to the atmosphere and water that flows from soil in recipients. These mutually linked transport processes, named Retention-Evapotranspiration Unit RETU, are subjects of simulation modelling. RETU is described by transport and mass and energy conservation equations and realized as the program simulating water and heat circulation (Tesař et al., 2001). The RETU model consists of two submodels: the submodel of soil water retention and flow, and the submodel of potential transpiration.

The soil water flow is described by the Richards’ equation. Appropriate model (Vogel et al., 1996) is considered to be a standard tool for simulation because its numerical accuracy and computational efficiency. This model is parameterised using hydrophysical characteristics of the soil profile (retention curve, saturated and unsaturated hydraulic conductivity for each genetic soil horizon) and by the limit value of suction pressure that makes the water uptake for transpiration (calculated by model of potential transpiration) impossible. Water uptake by plant roots is modelled with the help of extraction (sink) term in the Richards’ equation. Primary output of this model is a time course of the suction pressure of the soil moisture (Kutílek, Nielsen, 1994) in the soil profile.

Plant transpiration is described by the model of potential transpiration (Pražák et al., 1994, 1996; Dekker et al., 2000). This model is parameterised with the help of optimum temperature that is a characteristics of the vegetation cover. Primary output of this model is a time course of potential transpiration and corresponding plant temperature. Reduction of the potential transpiration to the actual transpiration is calculated in that way that the actual transpiration is equal to the potential one in the case, when the suction pressure in the root horizon (calculated by Richards’ equation) is higher than certain limit value (about –60 kPa). If the suction pressure in the root horizon falls below the limit value, the actual transpiration is equal to zero. The potential production time is defined as a sum of time intervals in which the vegetation temperature is equal to the optimum value, supposing that the actual transpiration is equal to the potential one. In this way, the time intervals when the plant is undercooled are deleted. If the actual transpiration is less then the potential one, the actual production time is less than the potential one. The reduction of the potential to the actual production time is calculated by multiplication of ratio of actual and potential transpiration. In this way, the time intervals when the plant is overheated are deleted.

Meteorological data serving as an input of the RETU model are as follows: the time course of precipitation, air temperature and global radiation (for calculation of potential transpiration). Secondary outputs of the RETU model are as follows: the time course of water infiltrated in the soil, water stagnant on the soil surface, water in surface runoff, water extracted from the soil for actual transpiration, water drained from the soil into subsoil horizons, suction pressure and soil moisture in individual soil horizons, vegetation temperature, latent heat used for transpiration, and sensible heat emitted from the plant cover into the atmosphere. These values are derived from primary outputs by course of common procedures (e.g. Belmans, 1983).

Input data are routine measured in meteorological stations. The RETU parameters have a clear physical meaning and can be experimentally evaluated (Šír et al., 1988, Pražák et al., 1996). Output data can be directly compared to measured data in experimental catchments (e.g. Tesař, Šír, 1998; Tesař et al., 2001). Because of the RETU model parameters, inputs and outputs can be measured the model can be validated in every natural conditions comparing measured and simulated data. This validation has been done for all experimental plots mentioned in this article (Bayer at al., 2000; Tesař et al., 2001, 2004).

3. Experimental area

The long-lasting monitoring of hydrological cycle (since 1983) has been done at the Liz catchment and at the near experimental areas Zábrod – field and Zábrod – meadow. These localities represent the typical hydrological conditions in submountain headwater regions in the Šumava Mts. (altitude 700–1100 m a.s.l., annual air temperature 6.3şC, annual precipitation sum 851 mm/year, runoff coefficient 0.38, average air temperature from 5 to 20 hours in the vegetation season 12.6şC, sum of global radiation in the vegetation season 500 kWh/m^2). Dry years, when insufficient precipitation (230–370) mm did not cover the need of water for transpiration (330–360 mm) were: 1983, 1992, 2000 (1983–2002). In these dry seasons were mean air temperature between 5 and 20 hours 13.5–14.5şC while in wet seasons only 11–13 ºC. In the long-term period is dry one year in seven years. Characteristics of both the catchment and experimental areas are described in (Pražák et al., 1994; Tesař, Šír, 1998). Their soil cover is an acid brown soil. The Liz catchment is covered by mature spruce forest, Zábrod – field and Zábrod – meadow localities are covered by permanent grass.

Table 1. Climatic characteristics of growing seasons

Season	1987	1992	1995
Duration	15.5.–30.9.	27.5.–30.9.	27.5.–30.9.
Number of days	139	127	127
Precipitation sum (mm)	372	204	544
Potential transpiration sum (mm)	178	360	222
Mean deaily potential transpiration (mm/day)	1.28	2.83	1.75
Mean air temperature (şC) from 5 a.m. till 8 p.m.	11.7	14.3	12.1
Global radiation sum (kWh m^{-2})	600	764	643

Hydrological cycle is simulated at the site Zábrod – field in the growing seasons 1987, 1992, 1995 (Table 1). Natural conditions of the site are reflected as follows: (1) Soil profile composition and hydrophysical characteristics: The soil profile is schematized into three soil horizons: 0–17 cm, 17–60 cm and 60–100 cm. The retention curves were obtained from data measured in the overpressure apparatus. Saturated hydraulic conductivity of the soil horizons (2x10^{-5}, 1.5x10^{-5}, and 6.5x10^{-5} m.s^{-1}) was obtained from field infiltration tests. (2) Water flow in the soil: The flow is described by the one-dimensional Richards equation. Water moves vertically from the soil surface up to the depth of 100 cm, where is a highly permeable layer. Water exchange is described by the boundary conditions and the sink term in the root zone of soil. (2a) Infiltration of a rain into the soil: At the top of the soil profile, the boundary condition variable in time is equal to the average daily rainfall intensity. (2b) Outflow from the soil into the subsoil: At the bottom of the soil profile, the free drainage boundary condition is set, that means the outflow into a very permeable subsoil not saturated with water. (2c) The withdrawal of water for transpiration is modelled as the sink term located at the depth of 0 – 40 cm, the intensity of water withdrawal is equal to the average daily potential transpiration intensity. The limit value of suction pressure inhibiting water withdrawal is –60 kPa. (3) Precipitation and potential transpiration: The mean daily rain intensity is calculated from the daily rain totals measured in the experimental site. The mean daily intensity of potential transpiration is calculated from daily totals of potential transpiration. Hourly-measured air temperature in the height of 2 m over the soil surface and hourly totals of global radiation are measured in the near meteorological station Churáňov.

4. Simulation of hydrologic cycle and phytomass productivity

The RETU model allows to examine hydrologic cycle in conditions that are not usually met in nature. Two ways can be chosen: (1) The simulation using model parameters values differing from that observed in the reality. (2) The simulation using synthetic meteorological data.

In the case of investigation the response of hydrologic cycle on variations of optimum temperature, the first way is followed. The optimum temperature is varied in the range from 22 to 28şC and the hydrologic cycle is simulated for each value using unchanged meteorological data as were observed in corresponding natural conditions. As a result, the sensitivity analysis of hydrologic cycle is done on the optimum temperature. This is the only way to discover the governing role of plant transpiration in hydrologic cycle because no experimental catchment is available which is covered by vegetation with optimum temperature different from 25şC.

This procedure is loaded by a small inconsistency of meteorological data. These data were measured in a catchment covered by vegetation with the optimum temperature 25 şC but they are subsequently used in an unchanged form for simulation of hydrologic cycle in conditions with other optimum temperature. While it is evident that at least the air temperature depends on the optimum plant temperature. This link is omitted in this stage of work because no appropriate data or theory are available.

The amount of water available for plant transpiration (mainly in the soil) and input of solar heat creates two markedly different combinations: (1) the water source for plant cooling by transpiration is sufficient – plant transpiration is fully controlled by heat input in the hydrologic cycle (i.e. heat-controlled hydrologic cycle), (2) the water source is insufficient – plant transpiration is limited by water scarcity in the hydrologic cycle (i.e. water-controlled hydrologic cycle).

Table 2. Potential transpiration as a function of the optimum temperature

1.5.–30.9.	Potential transpiration (mm) at optimum temperature (şC)						
Year	22	23	24	**25**	26	27	28
1987	261	233	204	**178**	154	132	112
1992	508	456	406	**360**	317	278	241
1995	336	298	264	**232**	203	177	153

Simulations of hydrologic cycle were worked out for three growing seasons at the site Zábrod – field (Table 1) with the same duration from May 1 till September 30. The 1987 season is the long-term mean one. The 1992 season has been the driest and warmest season since 1983. The 1995 season was uncommonly rich in precipitation. At the end of this season, the soil water content was in about 50 mm higher than at its beginning. The seasons 1987 and 1995 represent two typical variants of a heat-controlled hydrologic cycle while the season 1992 represents an extreme variant of mainly water-controlled hydrologic cycle.

Results of simulation of hydrologic cycle in all three seasons (Table 2) reveal strong dependence of the potential transpiration PET (mm/growing season) on the optimum temperature of vegetation. This dependence, expressed as a ratio (%) of PET at the optimum temperature from 22 to 28şC and PET at the optimum temperature of 25şC, is shown in

Table 3. It can be stated from Tables 2 and 3 that optimum temperature increase in 1şC results in the PET increase in about 15%. This means that all the hydrologic cycle is very sensitive to the optimum temperature of plants.

Table 3. Ratio (%) of potential transpiration (PET) at the optimum temperature from 22 to 28°C and PET at the optimum temperature of 25°C

1.5.–30.9.	Ratio of PETs (%)						
Year	22	23	24	**25**	26	27	28
1987	147	131	115	**100**	87	74	63
1992	141	127	113	**100**	88	77	67
1995	145	128	114	**100**	88	76	66

Phytomass productivity is supposed to be proportional to the productivity time defined as a sum of time intervals in which the vegetation temperature is equal to the optimum value. The relation between the temperature of plant organs and phytomass (or primary) productivity is rather complicated. The cell division and extension are generally more sensitive to temperature then is the rate of photosynthesis, and the growth is less dependent on photosynthesis (Grace, 1988). It means that the concept of optimum temperature can be related rather to the plant growth than to the photosynthesis itself.

4.1 Heat-controlled hydrologic cycle and potential production time

Let us analyse the sensitivity of potential production time on optimum temperature providing that the water is not a factor limiting plant transpiration (i.e. heat-controlled hydrologic cycle). The results of the RETU simulation are presented in Tables 4 and 5. Potential production time PPT for all the three seasons and the optimum temperatures from 22 to 28 şC is shown in Table 4 in hours per season. A ratio (%) of the PPT for the optimum temperatures from 22 to 28şC and PPT for the optimum temperature of 25şC is shown in Table 5. It can be stated from Table 4 that the mean PPT is of about 3–7 hours daily. Vegetation is undercooled during remaining time. The heat input from the solar radiation is an important factor of plant growth, and is demonstrated by the mean air temperatures between 5 a.m. and 8 p.m. presented in Table 1. The temperature reaches from 11.7şC in 1987 to 14.3şC in 1992. Taking into account the optimum temperature of 25şC it means that the solar radiation permits the vegetation heating of about 13–15şC over the air temperature in the production time.

Table 4. Potential production time as a function of the optimum temperature

1.5.–30.9.	Potential production time (hours) at the optimum temperature (şC)						
Year	22	23	24	**25**	26	27	28
1987	738	680	625	**570**	517	465	418
1992	1134	1061	989	**923**	860	794	726
1995	809	743	683	**626**	573	523	468

Table 5. Ratio (%) of potential production time at the optimum temperature from 22 to 28şC and potential production time at the optimum temperature of 25şC

1.5.–30.9.	Ratio (%) of production times						
Year	22	23	24	**25**	26	27	28
1987	130	120	110	**100**	91	82	73
1992	123	115	107	**100**	93	86	79
1995	129	119	109	**100**	92	84	75

Heat scarcity is the growth limiting factor in cold climate as it can be seen in Table 5 where the optimum temperature increase in 1şC results in a drop of the PPT in about 10 % in 1987, 7 % in 1992, and 9 % in 1995. PPT is 162 % in 1992, and 110 % in 1995, compared with the production time in 1987 for all the values of optimum temperature, as it can be seen in Tables 4 and 5. These findings confirm the well-known fact that the phytomass production increases with increasing air temperature, providing that available water is in the soil, and therefore, plants can cool.

4.2 Water-controlled hydrologic cycle and actual production time

Let us extend the above-mentioned analysis of the production time sensitivity on optimum temperature providing that the water can be a factor limiting plant transpiration (i.e. heat-control of hydrologic cycle can be replaced by water-control). The results of the RETU simulation in such complex conditions are presented in Tables 6, 7, and 8, where PET is potential transpiration, ET actual transpiration, and O outflow from the soil into bedrock in seasonal sums. The ratio ET/PET shows the degree in which water demands of the vegetation cover were supported in the seasonal scale. The ratio O/P determines the outflow from soil as a part of seasonal precipitation total.

Table 6. Soil water balance in the growing season 1987 as a function of the optimum temperature

Year 1987 15.5.–30.9.	Optimum temperature (şC)						
	22	23	24	**25**	26	27	28
PET (mm)	255	234	205	**178**	154	132	112
ET (mm)	255	233	204	**178**	154	132	112
O (mm)	174	193	213	**234**	254	273	291
ET/PET (%)	100	100	100	**100**	100	100	100
O/P (%)	55	58	63	**67**	72	77	81

Table 7. Soil water balance in the growing season 1992 as a function of the optimum temperature

Year 1992 27.5.–30.9.	Optimum temperature (şC)						
	22	23	24	**25**	26	27	28
PET (mm)	433	389	348	**309**	274	240	209
ET (mm)	197	193	188	**181**	172	160	150
O (mm)	19	20	22	**24**	27	32	37
ET/PET (%)	45	50	54	**59**	63	67	72
O/P (%)	9	10	11	**12**	13	16	18

Table 8. Soil water balance in the growing season 1995 as a function of the optimum temperature

Year 1995 27.5.–30.9.	Optimum temperature (şC)						
	22	23	24	25	26	27	28
PET (mm)	317	282	250	**221**	194	169	147
ET (mm)	267	246	226	**205**	182	160	140
O (mm)	242	257	275	**296**	318	339	359
ET/PET (%)	84	87	90	**93**	94	95	95
O/P (%)	44	47	51	**54**	58	62	66

The ratio ET/PET in the mean season 1987 (Table 6 and 9) shows that actual production time is not reduced in comparison with the potential one (Table 4). It means that the plants are not heated over the optimum temperature as the results of cooling fall-out resulted from a scarcity of soil water. It also means that the hydrologic cycle is heat-controlled during the whole vegetation season for each value of optimum temperature between 22 and 28şC.

In the 1995 season that was medium in temperature and rich in precipitation (Table 8), a decrease in the production time due to water scarcity is less important (Table 4 and 9). It means that in the growing season medium in temperature and sufficient in precipitation, the limiting factor in plant growth is mainly heat scarcity. But the importance of water-control increases with the optimum temperature falling below 25şC.

In the warm growing season 1992 that was poor in precipitation (Table 7), the actual production time was reduced considerably due to water scarcity. Due to overheating, 28–

55% of potential production time is lost. It means that water scarcity is the limiting factor of plant growth in a dry season.

Actual production time (Table 9) was calculated with the help of ratios ET/PET (Tables 6, 7, and 8) and potential production time (Table 4). Actual production time means actual duration of the optimum plant temperature, because the ET/PET reduction eliminates the periods, in which plants are heated over the optimum temperature due to transpiration cooling fall-out, resulting from the available soil-water scarcity.

5. Natural selection of optimum temperature

From the point of view of plant ecology, if the water-controlled hydrologic cycle occurs in a multiyear series the water-controlled ecosystem is developed in a landscape scale (Rodriguez-Iturbe et al., 2001). Analogically, a multiyear series of heat-controlled hydrologic cycles is the reason for development of the heat-controlled ecosystem. In the cold climatic conditions of Czech mountains the heat-controlled ecosystem comprehensive climax vegetation was developed during 6000 years after the end of next glacial period. Than persisted unchanged for 8000 years. In last 4000 years in consequence of forestry and agriculture gradually changes of plant composition has been arisen. So that former climax vegetation has been changed by present non-natural vegetation.

On the basis of past climate re-constructions, it can be supposed that the heat-controlled hydrologic cycle lasted for the whole period after next glaciation in spite of vegetation changes (Bodri, Čermák, 1997). It can be supposed too that the non-natural vegetation has the same optimum temperature as the original climax vegetation. The species composition of climax vegetation is known (e.g. Neuhäuslová, 2001). The species composition of present non-natural vegetation cover has been constituted in the 19-th century before the beginning of current climate warming. It means that the vegetative cover has been developed in the long-term stable meteorological conditions under the incidence of natural and partly human selection.

Human selection of the species mix of vegetation had the same strategy as natural selection – to maximize the phytomass production in the long-term scale. Therefore the natural selection hypothesis can be used in order to solve the questions "What mechanism set up the optimum temperature of climax (and present non-natural) plant cover?" and "Why is the optimum temperature equal to 25şC?"

Table 9. Actual production time as a function of the optimum temperature

1.5.–30.9.	Actual production time (hours) at the optimum temperature (°C)						
Year	22	23	24	**25**	26	27	28
1987	738	680	625	570	517	465	418
1992	510	531	534	**545**	542	532	523
1995	680	646	615	582	538	497	445

Natural selection hypothesis (Eagleson, 1978) says that the plant cover will be prevailing on the site occurring in the long-term stable natural conditions that is able (1) to produce the biggest amount of phytomass, and (2) to live through unfavourable conditions. If this hypothesis will be used for a selection of the most suite optimum plant temperature, it can be stated that it is the temperature 25şC, because the (1) highest production was reached at this temperature in the critically dry season 1992 (Table 9), and (2) no hydrologic extreme threated plant live was met in all vegetation seasons. It must be stated that a lot of plant species exists differing in the optimum temperature for growth. So that the supposed selection can be realized in the nature.

6. Discussion and conclusions

The value 25şC of optimum temperature, obtained using natural selection hypothesis, reaches a good agreement with the value, obtained from the direct measurement of optimum temperature 23–24şC for plant growth in cold climate (Körner, Larcher, 1988). Therefore it is probable that supposed natural selection is the true mechanism inductive of plant cover development.

The sensitivity analysis of hydrologic cycle on optimum temperature of plant cover shows that the plant transpiration plays a governing role in all the hydrologic cycle. Many authors pay attention to this fact (Eagleson, 1978; Ripl, 1995; Pokorný, 2001; Farmer et al., 2003; Wood, 2003).

It can be supposed that the main role of natural selection in the development of plant cover is the selection of species composition with suitable optimum temperature. This optimum temperature strongly affects plant transpiration and therefore constitutes the pattern of the whole hydrologic cycle.

The concept of retention – evapotranspiration unit, used in this article, seems to be a promising tool for investigation of mutual links between purely physical governed (soil water retention and flow) and biological governed (plant transpiration) processes constituting the hydrologic cycle.

Conclusions were obtained by an interpretation of monitoring and simulation of hydrological cycle in mountain and submontane localities in the Czech Republic at altitude 600–1400 m a.s.l. covered with grass, dwarf pine forest and spruce vegetation: (1) Vegetation with optimum temperature of 25şC is most able to live in those conditions. (2) In the seasons poor in precipitation, only a small phytomass production decrease can be expected in comparison with the wet seasons.

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8. References

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