The Role of Vegetation in Water Cycling and Energy Dissipation

By

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This paper deals with the distribution of solar energy in the landscape. It focuses on the man's role in steering the solar energy fluxes by managing water and influencing vegetation. The key role of landscape managers in mitigating the local climate extremes and influencing water regime is stressed. The role of water and vegetation in the greenhouse effect and global change is discussed. The omitting of water as a stable part in the global change theory is criticised. The complexity of dynamic processes of energy dissipation in water cycle does not allow us to forget the importance of water in preventing the climatic extremes and the aging of landscape. Methods of measurements and monitoring of energy and water fluxes are shown. The paper has been presented on Natural Sequence Farming (NSF) Conference in Bungendora New South Wales (October 2006) therefore data from the Czech Republic and Australia are presented and compared.

Solar energy flux between Sun and Earth

The Sun provides us with 180 000 TW, with ca. 1.4 kW of solar energy approaching every square meter of the insolated Earth's atmosphere. The humankind uses at the beginning of the third millennium in its economy energy of ca. 14TW. The solar energy runs all the natural processes: warms the Earth of about 290 K to the convenient temperature for life, drives the water cycle, provides the processes of photosynthesis with energy, and enables the evolution of life on Earth.

The Sun as a blackbody with the surface temperature of 5900 K emits maximum of the radiation in the visible range (400-700nm). The surface of the Earth with its temperature ca. 300K emits maximum radiation in the IR art of the spectrum at about 10μm. The wavelength at which the blackbody emits maximum radiation is given by Wien´s law ($\lambda_{max} = b/T$, where b is Wien's displacement constant, b = 2897μmK and T is temperature in K). The spectrum of solar radiation incident on both Earth's atmosphere and surface at the sea level are shown in Fig 1. The atmosphere influences the spectrum of incident light both quantitatively and qualitatively. Absorption of radiation through the main atmospheric gases is indicated.

Fig 1 ***Solar spectrum incident on the atmosphere and on the Earth's surface at the sea level. Radiation of the blackbody of 5900K is also shown.*** **Seven gases in the Earth's atmosphere produce observable absorption features in the 0.4 - 2.5 micron range: water vapor, carbon dioxide, ozone, nitrous oxide, carbon monoxide, methane and oxygen. (http://www.csr.utexas.edu/projects/rs/hrs/process.html**). $1Å= m^{-10}$

The amount of solar radiation coming to the Earth's surface varies in daily and seasonal pulses and is highly dependent on the geographical position. The mean distributions of global insolation for different months are to be found in the pages of

NASA SSE (http://eosweb.larc.nasa.gov/sse). According to the NASA SSE data the maximum annual averaged direct normal radiation incident on the Earth surface is up to 3000 kWh*m^{-2}*year with maximum monthly averaged direct normal radiation 8,5 kWh*m^{-2}*day. This intensity of solar radiation is reached for example along the north-west coast of Australia.

Horizontal surface solar radiation monthly averaged data (kWh/m^2 .day) of the measuring site in Sydney near to Bungendora NSW (New South Wales, Australia) where Conference on NSF (Natural sequence farming – the Science & the Practice 2006) was held, are plotted in the graph (Fig. 2). As a comparison, data from Hradec Kralove in Czech Republic (latitude of 50.25 degrees North, longitude of 15.58 degrees West) from the NASA SSE source and measured data from Třeboň (latitude of 49.00 degrees North, longitude of 14.46 degrees West) (Fig 2). Table 1 shows the annual sums of solar radiation incident on the three chosen measuring sites.

Fig 2 ***Monthly Average Insolation (kWh/m^{-2}day) for the years 1983-1993) for Australia - Sydney and Czech Republic – Třeboň, Hradec Králové. The data source for Sydney and Hradec Králové: C.L. Martin, D.Y. Goswami: Solar energy pocket reference ISES, 2005. The data for Třeboň (1997-1999) are measured in ENKI o.p.s***

Tab.1.

	Sydney	Hradec Králové	Třeboň
kWh*m^{-2}*year	1679.34	1118.57	1075.03

The amount of incoming energy differs significantly also with the weather conditions Fig.3. The difference between the amounts of incoming radiation on a clear day can be as much as an order of magnitude higher than the amount of incoming radiation on an overcast day (Tab.2).

Tab. 2 ***Daily sums of global irradiation incident on clear (1.3 a) and overcast day measured in Třeboň.***

18.7.2006 clear sky	3.8.2006 cloudy
8.16 kWh/m^2.day	0.78 kWh/ m^2.day

Fig. 3 ***Global irradiation incident on clear July 18th 2006 (3 a) and overcast day August 3rd 2006 (3b). Measured in Třeboň***.

As the energy input from the Sun to the Earth is highly variable, it is very important how flexibly the Earth's surface is capable to balance to such changes without being degraded. This has very much to do with the presence of vegetation and water in the ecosystems.

Distribution of solar energy on land surface

The distribution of solar energy on the land surface is highly dependent on the surface's characteristics (Fig. 4). The incoming solar radiation is partly reflected. The amount of reflected radiation depends on the wavelength of the radiation, on angle of its incidence and on the surface's characteristics. The reflectance (fraction of the incident light shortwave irradiation reflected from the earth's surface) of vegetation is between 5 and 15 % (Arya, 2001, states 10-25%) of incoming radiation whereas the reflectance of dry surfaces is up to 35 %. The average reflectance of dry sandy soil is 0.35 (Nobel, 1991), for dry clay 0.25-0.40 (Arya 2001) and for peat soil 0.10 (Nobel, 1991). For fresh snow however it is 0.45-0.95 (Arya 2001). The radiation which is not reflected is termed net radiation. It is partly dissipated through water vapour, partly converted into sensible heat, partly lead into the soil, partly accumulated in biomass and partly used for photosynthesis processes (Fig 5).

Fig. 4 ***Distribution of solar energy in a drained landscape and landscape sufficiently supplied by water and compactly covered with vegetation. Adapted from Pokorny (2001)***

Fig 5 ***The distribution of solar energy incident on the vegetation. RS - global radiation, Rn - net radiation, a - albedo, H - sensible heat flux, L x E - latent heat x evapotransp., G - ground heat flux, J - accumulation of heat in biomass, P - photosynthesis***

The fate of incoming solar irradiance is significantly dependent on the presence of water in the ecosystem, which highly influences the distribution of energy in two main heat fluxes: latent heat and sensible heat (Fig. 4). In the landscape with sufficient stock of water as much as 80% of the incoming radiation can be dissipated through vapour of water whereas in the dry landscape up to 60% of incoming radiation turns into sensible heat. During vegetation season on sunny days the ground heat flux is commonly 5-10% on dry lands and up to 20% on the wet lands in temperate zone (Přibáň et al 1992). The energy accumulated in biomass is minor, net production of 1kg dry mass per m^2 represents c. 0.45% of annual income of global radiation 1100 kWh.m^2.

The day fluxes of net radiation, ground heat, sensible heat and latent heat measured on an alluvial meadow Mokré Louky (Wet Meadows) near Třeboň on a clear day July 18th 2005 by Eddy covariance method (Kaimal et Finnigan 1994, Lee et al. 2005) are shown in figure 7a. As the water supply was sufficient during the day of measurement, the latent heat flux exceeded, especially in the afternoon when air became warm and dryer and enhanced evapotranspiration. The ground heat flux increases in the afternoon as high amounts of incoming energy warmed the ground.

The daily sums (24 hours) of energy fluxes are shown in figure 7b. The sum of incoming energy was 6.8 kWh*d^{-1} and the net radiation was 4.8 kWh*d^{-1}. High irradiances and temperatures exceeding 30°C in the afternoon lead to great energy fluxes in the ecosystem. The sum of the latent heat flux presented 56.2% of the net radiation, 42.8% of the net radiation energy contributed to the sensible heat. The 24 hours sum of ground heat flux represents the heat stored in the soil as it is the sum of night negative values and day positive values of ground heat flux.

Fig 7 ***Daily course (Fig. 7a) and 24 hours sums (Fig.7b) of main energy fluxes measured by Eddy covariance on Wet Meadows near Třeboň, July 18th 2005.***

Incoming and reflected visible and IR components of net radiation are shown in Fig 7b. Rs↓ incoming visible light, Rs↑ reflected visible light, R_L↓ incoming IR radiation, R_L↑ reflected IR radiation, R_N net radiation, G ground heat flux, H sensible heat, LE latent heat. Temperature and relative humidity daily courses are shown in Fig. 7c

The Earth with its temperature of ca 300K emits in the IR region and thus IR radiation shouldn't be omitted from our energy fluxes considerations. As everything on the Earth emits IR radiation, its measurement is not easy to conduct. Nobel (1991) presents a consideration on the energy fluxes in a leaf and stresses an important role of IR fluxes for its energy balance. In his thought experiment as much as half of the energy input is through the IR radiation and even 70% of all energy input is balanced by the IR radiation.

In our ecosystem experiments we do not follow the fate of IR radiation in detail. However we count with IR in estimating the net radiation, i.e. radiation at disposal of the ecosystem usage. Measuring infrared radiation fluxes is always related to the measuring instrument (net-radiometer). Negative values of both incoming and reflected IR radiation in figure 7b show that the instrument itself was warmer than both the sky and surroundings and the surface of vegetation cover and soil. Thus in both cases the instrument itself is the radiation emitter and the total contribution of IR radiation to the net radiation (R_N) is negative (as the ground surface is warm in this hot summer day, it emits the IR radiation to the sky with its negative temperatures). Although we tend to neglect the contribution of IR to the energy balance of ecosystems, its role is far from negligible. In presented measurement the IR subtracting the net IR radiation component from the net visible radiation lowers the net radiation of 1.3kWh*d-1, which equals 23% of net visible radiation.

Efficiency of fixation of solar radiation in biomass

Only a negligible part of the incoming solar energy is stored in plant biomass via the processes of photosynthesis (1-2%). For the fixation of single carbon saccharide in the photosynthesis processes 8 to 12 photons are needed. The efficiency of usage of the radiation depends on the energy content in photons of different wavelength. It reaches 15-34% in the processes of photosynthesis (electron-transport chain in thylacoid membrane, fixation of CO2 in Calvin cycle), however the efficiency decreases significantly with in-building of carbon into the biomass.

The amount of biomass produced during one year (annual primary production) differs significantly on different places of the Earth according to the incoming radiation, water supply and nutrient availability. In general the higher is the solar radiation the higher the potential for primary production. With increasing solar energy income the water availability becomes the crucial limitation factor. The examples of biomass production in wetland ecosystems and grazing ecosystems in temperate zone and tropics and subtropics are shown in table 3. It is obvious that sufficient water supply is the condition for intensive growth of biomass.

Tab. 3 ***Maximum annual aboveground biomass production (kg*m^{-2}*year) in temperate zone and tropics and subtropics in wetland and grazing ecosystems. Energy stored in biomass (%) is approximated. Mean sums of incident energy in a year of 1100 kWh for temperate zone and 1600 kWh for tropics and subtropics were used for the approximation.***

[1] Westlake et al. (1998)
[2] Cooper (1975)

Importance of the evapotranspiration for the energy balance of the ecosystem

Availability of water determines the sustainability of living systems. The water balance is an indicator of the “landscape’s health”. The essential role of water is its capability of energy dissipation (Ripl, 2003).

Through the active regulation of water and energy fluxes the terrestrial biosphere has an important influence on climate (Hutjes et al., 1998). As shown in fig. 4 the existence of vegetation substantially influences the distribution of the energy into two main currents of net energy income: sensible heat and latent heat.

Most of the living plants contain a lot of water in their bodies. Fresh growing biomass contains 80-90% of water. Simultaneously both CO_2 is fixed into plant biomass by photosynthesis and water incorporated into the new plant tissues. For a daily growth of 10g of dry biomass per m^2 about 14 g of CO_2 fixed is needed. For 10g of CO_2 being incorporated into the biomass, ca. 1g of other nutrients and 80 -90 g of water is needed for the growth of the cellular structures and plant tissues. A realistic evapotranspiration from $1m^2$ of plant stand is about 3 litres of water a day which represents latent heat 2.1 kWh (7.5 MJ), i.e. in this particular case 3.09kg of water flows through the stand in one day (Fig. 8).

From gasometrical measurements (LICOR 6400) conducted on two hot summer days (July 27th and 28th 2005) with in situ leaves of *Phalaris arundinacea* we estimated that energy consumed for assimilation of CO_2 into first carbon product of photosynthesis was 28.9 (+/- 2.6) and 39.8 (+/- 3.1)% fold lower than energy used for transpiration, respectively (data not shown). 1.6 (+/- 0.4) and 1.8 (+/- 0.3) % of incident PAR (photosynthetic active radiation) was used for CO_2 assimilation. The transpiration coefficient (i.e. number of water molecules transpired per 1 CO_2 assimilated) was 302.0 (+/- 27) and 416.0 (+/-32.7), respectively. Thus as much as 18 – 22 fold more energy was needed for the fixation of one molecule of CO_2 when compared to the energy needed for transpiration of one molecule of H_2O.

Calorific value of 1kg of the biomass is approximately 15 to 20 MJ, or 5 kWh (Květ et Westlake 1998, Larcher 2003). To produce one kilogram of biomass ca. 1.4 kg of CO_2 has to be fixed. The latent heat of water at 20°C is 2.5MJ/l (0.7 kWh/l).

Fig. 8 ***An example of a daily energy balance of CO_2 and H_2O fluxes on $1m^2$ of a plant stand: is following: 10g dry biomass = energy needs of 25kJ (7Wh) for fixing 14g of CO_2 (0.32mol), water needs 80-90g . Evapotranspiration values of 3litres of water = 7.5 MJ (2.1 kWh)***

Potential evapotranspiration and examples of real evapotranspiration rates of some plants and stands

Evapotranspiration is the sum of water evaporated and water transpired through the plants. It is a very dynamic process. It is primarily controlled by energy supply and availability of water. The evapotranspiration rate increases with increasing incoming energy (solar radiation, dry air advection, wind). It is driven by the low water potential of the air. It may range from very low values to maximum which is called potential evapotranpiration. The amount of energy received from the sun accounts for 80 % of the variation in potential evapotranspiration. Wind is the second most important factor influencing potential evapotranspiration. Wind enables water molecules to be removed from the ground surface. The rate of evapotranspiration is associated to the gradient of vapor pressure between the ground surface and the layer of atmosphere receiving the evaporated water (*http://www.physicalgeography.net/fundamentals/8j.html*) The potential evapotranspiration concept was originally defined by Penman (1948) as "the amount of water evaporated and transpired per given time unit by a short green crop, completely shading the ground and never short of water". As the amount of transpired water is species dependent the Penman's determination is questionable, because the short green crop is not specified. Different types of vegetation may have very variable potential evapotranpiration. Gieske (2003) defines the potential evapotranspiration as the maximum possible evapotranspiration according to prevailing atmospheric conditions and vegetative properties with the soil moisture forming no limitation to the stomatal aperture.

Potential evapotranspiration is calculated both on theoretical (Penman, 1948, Montheith, 1975, Doorenboos et Pruitt 1977, Pristley-Taylor 1972) and on empirical (Turc, 1961, Linacre, 1977, Thornthwait, 1948, Ivanov, 1954), Baca, 1970 etc.) basis.

Several methods exist for measuring the evapotranspiration. The direct measurement of the evaporation from either the water or stand surface is done using either pans or lysimeters (see Allen et al. 1991, Nokes 1995, Gieske 2003). The indirect measurement of the evapotranspiration is pursued using micrometeorological methods. The possible ways of use for these methods are described in literature, e.g., Monteith (1975), Monteith & Unsworth (1990), Kaimal & Finnigan (1994), Allen et al. (1998), Arya (2001), Eagleson (2002), Gieske (2003), etc.

Plants differ in their capacity to transpire water. Conifer transpiration rates are generally lower than those of broad-leaved species. The highest conifer transpiration rate observed was around 300 mm for spruce per a season. The highest rates observed were about 500 mm for several hardwoods as oak or ash in floodplain forests on deep alluvial soils (Čermák, 1996). Wetland plants possess highest capacity to transport water through their vascular system and stomata. Common evapotranspiration in temperate zone during a sunny day from natural plant stands supplied with water is several mm (litres from m^2), values above 5mm are considered as high. Some plants are able to transpire even more than 20 litres from m^2 during one day when exposed to sunshine, dry air and well supplied by water. Transpiration rates of several wetland species grown in tanks and exposed to the dry air are presented in table 4 (Kučerová et al., 2001).

In cultural landscape on sunny days evapotranspiration is mostly limited by lack of water. Real evapotranspiration is lower than potential evapotranspiration. Farmers buying water for irrigation of fields in NSW calculate 12mm evapotranspiration a day.

Tab. 4 ***Transpiration rate of six species grown in tanks. (Kučerová et al., 2001).***

The water transpired by plants mustn't be considered as loss as is often the case especially in drainage paradigm of the older hydrological and technological literature. Kramer (1983), Ward, Elliot (1995) even call transpiration an unavoidable evil, in that sense that water is sacrificed for the sake of enabling intake of CO_2 for photosynthesis sakes.

Calder (1990) explains briefly history of controversy on role of the forest in hydrology of catchments. When comparing relatively small catchments, less rainfall is converted to run off from afforested catchments than from meadow (grass covered) catchments or partly drained catchments (Law 1956, 1957). This was later proved many times in studies of hydrology of small catchments. Five year comparative study of small catchments in Šumava mountains showed 40% higher water run off to recipient from drained pasture in comparison to afforested and wetland catchments (Procházka in press). However the runoff was unbalanced and the drained landscape became susceptible to the weather variability. Getting rid of vegetation and draining lead to desertification of the landscape. The transpiring vegetation does not loose the water into the atmosphere, on the contrary, it saves the water in the landscape in a more balanced way and it preserves the landscape against desertification.

Large scale deforestation, drainage and vegetation removal results in change of hydrological cycle on a rather large scale. A decrease of precipitation and/or unbalanced precipitation, i.e. the precipitations are concentrated into short periods of heavy rains followed by long periods of drought, which leads to degradation of vegetation cover, followed by increasing erosion and desertification. Such processes have been in process recently in Australia, where large areas of the landscape are drained and agriculturally overexploited. Well documented examples of such consequences are the increased drought risks in the Mediterranean and in the the Sahel region described by Reale and Dirmeyer, 1998 and Xue and Shukla, 1993, respectively.

The role of water for temperature distribution in the ecosystems

Evaporation and precipitation form a water cycle almost without loss of matter (Ripl, 2003). The water evaporated in the processes of transpiration cools the Earth's surface. Each litre of evaporated water dissipates energy of 0.7kWh. The water evaporated through evapotranspiration condensates later on the cooler places, warming them. Plants and trees are thus perfect air-conditioning system.

The cooling effect of plants through evaporation is shown on Figs 9 and 10. The images in IR spectrum show that the plants are much cooler due to transpiration than the dry soil around them (Fig.9a). In figure 10 warming up of a snipped leaf due to interrupted transpiration is shown. The intact leaf cools itself effectively.

Fig. 9. ***Sparce rural vegetation on a sunny day in IR (Fig. 9 a) and visible (Fig. 9 b) spectrum. The bare soil is significantly warmer than the leaves, which are cooled by transpiration. Třeboň, 12. 7. 2002, 10:00 a.m.***

Fig. 10. ***Distribution of temperatures in an intact and snipped leaf of Convolvulus arvensis L. in situ on a clear sky afternoon on July 27th 2004, 12:00. The leaf was snipped and left for 24 minutes on the original place in the vegetation. In the graph the course of mean surface temperatures of both intact and snipped leaves are shown. The oscillation of temperature is due to changing cloud cover. The mean temperatures were counted from the surfaces in circles.***

The cooling effect of vegetation is also well documented in figure 11 which is an IR image of the town square of Třeboň with the grown up trees in the background. Roofs and facades of the houses as well as the car in the square are over 30°C, the pavement's temperature is around 25°C while the temperature of the near trees in the park is around 17°C. The vegetation cools itself effectively.

Fig.11. ***Picture of the town square Třeboň and adjoining tree park taken by IR thermal camera shows temperature differences between vegetation, facades of houses and pavement.***

As the vegetation, in particullar the forests, is regularly of a dark colour and its reflectance is lower than that of many other surfaces (clay, sand ets.) the shift in reflectance values can be concerned in terms of possible enhancing warming of the Earth's surface. Figure 11 shows that no matter how big the reflectance of the biomass is, the trees prove high capacity of cooling themeselves due to transpiration. Minor effect of reflectance in comparisson to the latent heat flux can be followed also on an example of energy fluxes in the wetland grassland in fig. 7b.

Satellite pictures show status of vegetation and temperature distribution in landscape

Satellite imaging represents a convenient tool to assess on a large scale the vegetation status, its functioning as well as its structure and development in time. The satellite remote sensing methods give us also the possibility to measure the temperatures distribution of the Earth's surface and its distribution in time and space. Thus remote sensing methods are ideal to follow the dynamics of energy fluxes in the landscape.

Multispectral spaceborne data acquired by Landsat Thematic Mapper and Enhanced Thematic Mapper+ sensors were used to compare two types of cultural landscapes in the Czech Republic (Pokorný and Šíma 2006). Mostecko region is situated in North Bohemia. It has been largely influenced through the open mining of the tertiary lignite. Large areas have been drained and turned either into deep and vast mines or spoil heaps. The Třeboňsko region (Třeboňsko Biosphere Reserve) on the contrary is a landscape in Southern Bohemia which although historically largely influenced by mankind, has maintained high nature qualities. It is a rural landscape characterised by a great appearance of man made lakes (large fish ponds) which have been constructed since 15th century and cover ca. 12% of the total area. Apart from the fish ponds there are also other wetlands in the area such as flood plains and peat bogs. The temperature distribution in these two areas is shown in figure 12 (12a- Mostecko, 12b Třeboňsko). The temperatures are presented in false colour spectrum with the highest temperatures being yellow, orange, red and violet and lowest temperatures being green (see the temperature scale in figure 12). The hottest spots correlated spatially with non-vegetated areas. Large hot spots in figure 12a represent mostly the mines and heaps areas (green and blue colours in the upper half of figure 12a represent the Ore mountains). The temperature variance was much higher in Mostecko region in comparison to the Třeboňsko region. At first sight the shift of colours, i.e. temperatures, into blue and green in the Třeboňsko region is visible. We assume this is due to the higher heterogeneity of the land cover and greater abundance of water in the Třeboňsko region. Histograms of temperature distribution are shown in figure 13.

Fig. 12 ***Comparison of temperature distribution of two differently treated areas of cultural landscape in North (Mostecko) and Southern (Třeboňsko) Bohemia. The impact of vegetation cover densities and water stocks in the landscape is shown. Fig. 12a: Mostecko, coal mining area. Fig. 12b Třeboňsko, man-made landscape with a lot of fish ponds. The more heterogeneous and well water-***

saturated Třeboňsko area shows a substantially lower temperature variance with temperature extremes of Fig 12a completely missing. Landsat TM data (Mostecko: scene 192-025, acquisition dates 1 July 1995; Třeboňsko: scene 191-026, acquisaition date 10.7.1995).

Fig. 13 ***Histograms of temperature distribution in figure 12a and 12b. Fig. 13a: histogram of temperature distribution in Mostecko area, Fig. 13b: histogram of temperature distribution in Třeboňsko area.***

In figure 14 correlation between the densities of the vegetation cover and surface temperatures of a spoil heap under man-made and spontaneous reclamations. Figure 14a shows the vegetation density and figure 14b shows the temperature distribution in the same area. If we compare the pictures with respect to the colour scale (NDVI – normalized difference vegetation index versus temperature) we can see that the temperature negatively correlates with the density of vegetation. The positive cooling effect of vegetation due to he transpiration processes is shown. Redevelopment of new vegetation and restoration of its ecological functions on the no more used heaps leads to the moderating of temperature extremes.

Fig. 14 ***Correlation between the density of vegetation cover (NDVI) and surface temperature on a 'Velká podkrušnohorská' spoil heap (The Sokolovo Lignite Basin, NW Bohemia), area of 22.25 km^2, date of imaging: July 1st 1995. Fig. 14a the vegetation density, fig. 14b temperature distributions shown separately***

Drainage and vegetation removal results in an uneven release of heat

Drainage and suppression of vegetation on large areas are associated with release of huge amount of heat and formation of heat potentials (Fig. 13). Changes in solar energy fluxes in the landscape by due to its drainage cause on a sunny day a release of several hundreds watts of sensible heat per square meter.

A decrease of evapotranspiration from 1m^2 of 3 litres per day results in an increase of sensible heat of 2.1 kWh (7.5MJ). Drainage of 1000ha (10km^2) accompanied with decrease of evapotranspiration by 3mm (3litres/m^2.day) results in a daily release of sensible heat of 2.1kWh.10^7 (2.1MWh.10^4, 21GWh). Decrease of evapotranspiration of 1 mm a day on total area of the Czech Republic (79 000 km^2) results in sensible heat release of cca 56 000 GWh per a sunny day (total annual production of electricity in the Czech Republic is 65000 GWh). Sensible heat flux from only 25 km^2 of drained land on a sunny day is equal to installed energy production of all power plants in the Czech Republic (15 000 MW).

Growth of vegetation is associated with fixation of carbon dioxide whereas vegetation decline and decomposition of biomass are associated with release of carbon dioxide. The average annual production of dry biomass is 0.5kg/m^2. On an area of 100 000 km^2 50 x 10^6 metric tons of biomass is produced and thus 70 x 10^6 metric tons of carbon dioxide fixed. Paralelly, if present, ca. 50 x 10^8 metric tons of water are evaporated via evapotranspiration which represents air-conditioning effect of 35 x 10^8 MWh. The drained landscape does not posses sufficient supply of water and the incoming energy contributes mostly to the sensible heat fluxes.

Does greenhouse effect theory reflect role of water and plants?

Recently the threat of global warming has become a great topic. The human's production of greenhouse gases (CO_2, CH_4, N_2O, hydrofluorocarbons et.) is nowadays accepted as a direct cause of recent weather irregularities. More and more sophisticated models of the impact of increasing concentrations of greenhouse gases are constructed. As the circulation of water is very dynamic and complex, the water, although an important greenhouse gas, is in the models more or less omitted. Water is seen as a stable component of the atmospheric system.

The water vapour is an order of magnitude more ample in the lowest layers of atmosphere than other greenhouse gases. It influences the climate substantially. Short cycling of water is disturbed and thus the incoming solar energy is turned mostly into sensible heat. As water condensates preferentially on cooler places and the vast drained areas are hot the precipitation is lowered. In particular the small precipitation (i.e. dew, hoar-frost etc.) which is very important to vegetation is influenced. The precipitation falls then usually in great amounts, causing floods and erosion. Precipitation falling down on a drained landscape flows straight away. We are loosing water from the land sending it as quickly as possible to the sea parallely being scared of rising sea level.

As draining of the landscape may change the energy fluxes in hundreds of Watts/m^{-2}, we suggest that the role of landscape management play a very important role which is constantly underrated. Furthermore drainage of landscape results in heterogenic distribution of heat and creation of heat potentials which drive movement of air and water vapour and affect weather and climate.

The effect of greenhouse gases on the climatic change is quantified by two values: radiative forcing and global warming potential. The radiative forcing of the surface-troposphere system (due to a change, for example, in greenhouse gas concentration) is the change in net irradiance (in W.m-2) at the tropopause after allowing stratospheric temperatures to readjust to radiative equilibrium, but with surface and tropospheric temperatures held fixed (IPCC, 1995). It is assumed that the probable increase of greenhouse gases in the near future will enhance the radiative forcing by units of Watts/m^{-2}, i.e. the incident radiation will be on average of units of Watts higher on every square meter.

Restoration of water cycle

Bringing back water and vegetation into the landscape would result in recovering of basic ecological functions of the landscape – soft dissipation of solar energy via water cycle, sequestration of carbon dioxide into biomass as well as retention and recycling of nutrients. Recovering the ecological functions is the prerequisite for mitigating the climate extremes.

Long term monitoring of energy dissipation in landscape and water discharge as well as matter losses are demonstrated in some case studies. In three small subcatchments (drained, forested and wetland, each c. 200ha) in the Šumava mountains (Czech Republic) solar energy dissipation and water and matter outflow have been monitored since 1990s (Procházka in press, Procházka et al. 2001). Solar energy in the drained catchment was converted mostly into sensible heat which enhanced the temperature amplitudes if compared with the other catchments studied (Procházka et al. 2001). The efficiency of closed water, energy and matter cycles in a virgin forest in the austrian Alps was shown in a study of Ripl (2004). These results show clearly the important role of vegetation for the landscape. The effects of restoration of water cycle is demonstrated in several years and they can be monitored on scientific bases. As vegetation and water abundance possitively influences the climate we suppose that nowadays, in time of a great discussion about the causes of global change, much more attention should be paid to it. Managing of the landscape has vast impact on our local climate.

Conclusion

Drainage of the cultural landscape has lead to the loss of functional vegetation. We have become victims of desertification of vast areas of once productive landscapes such as in Australia and in other subtropical and tropical areas. We have experienced degradation of soils due to unbalanced water cycle all around the rural world.

Water cycle is a very complex system, which can be, because of its complexity, only a little incorporated into the models of climate change. However, the regional climate can be substantially influenced and deteriorated as a consequence of the landscape management (Hutjes et al., 1998). The degradation of vegetation and interfering of water cycle due to drainage can lead to long termed decrease of precipitation, thus changing substantially the local conditions (Reale and Dirmeyer, 1998 and Xue and Shukla, 1993).

It is always difficult to show the effects of changes of the landscape, because it is a complex system influenced by innumerable factors. However, the negative effect of loosing water and vegetation from the landscape on the precipitation and temperature balance was shown for example in the articles written by Ripl (1995, 2003). We can hardly presume the evolution of our climate and the scientists argue much about the Earth's weather future. Recently the weather has been more unpredictable and with lots of extreme values of temperature and precipitation variations. We suggest that reintroducing of vegetation and water into the landscape can have only positive effects. The landscape with sufficient supply of water is less sensitive to the extreme weather as the temperature potentials are moderated by energy dissipation in transpiration and condensation processes. Thus we not only defend our landscape against weather extremes, by supporting vegetation and water in the landscape we positively influence the climate. Vegetation also retains water in the rhizosphere and prevents excess outflow of nutrients. By wise management of the landscape we moderate the negative aspects of climate. We very much appreciate the methods of Natural sequence farming. And as we show, we can not only do something with our weather, we can also measure it.

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