A Holistic Approach to the Carbon, Water, Nutrient Cycle and Energy Fluxes

Jan Pokorný et al.

ENKI, o.p.s. research organisation

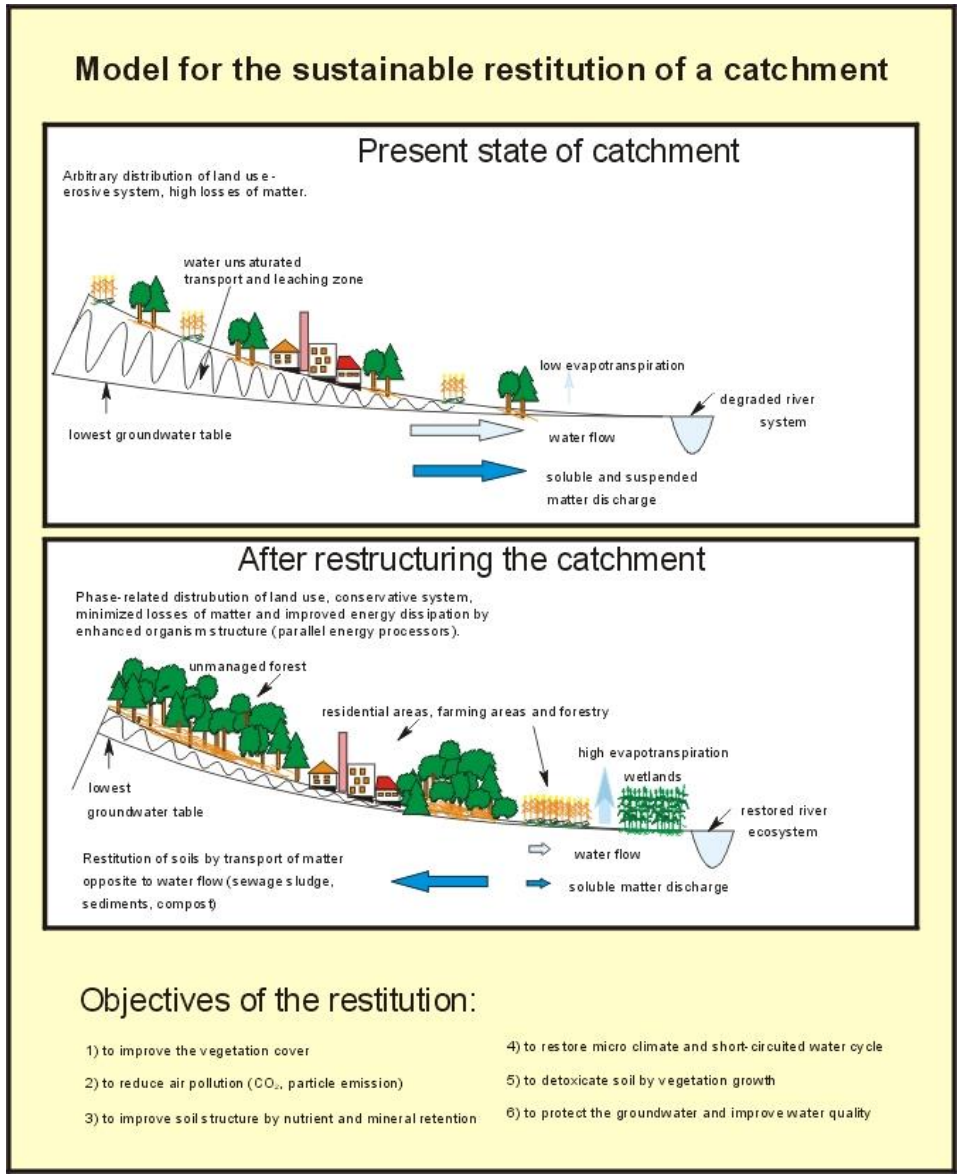
Třeboň, Czech Republic

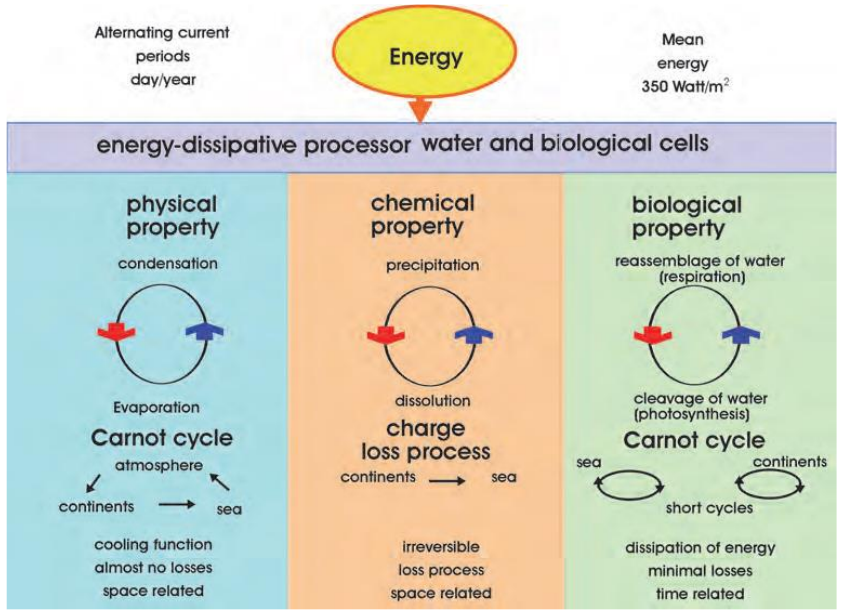
pokorny@enki.cz

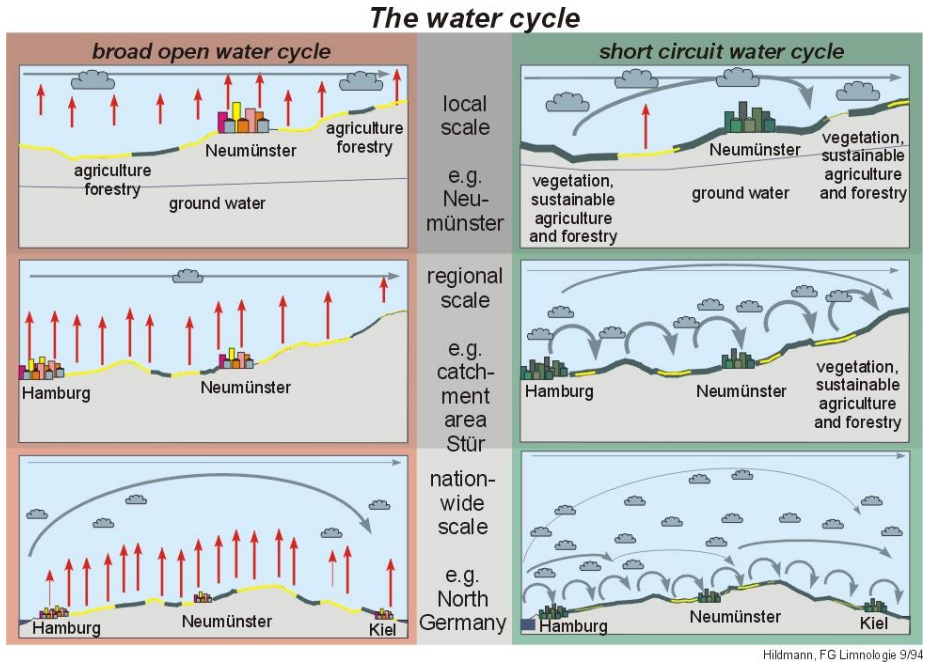
PARTNERING FOR THE FUTURE: BIOEAST AND BEYOND CONFERENCE BUDAPEST, HUNGARY

4-6 DECEMBER, 2024

Water cycle is linked with primary production, nutrient retention, solar energy distribution





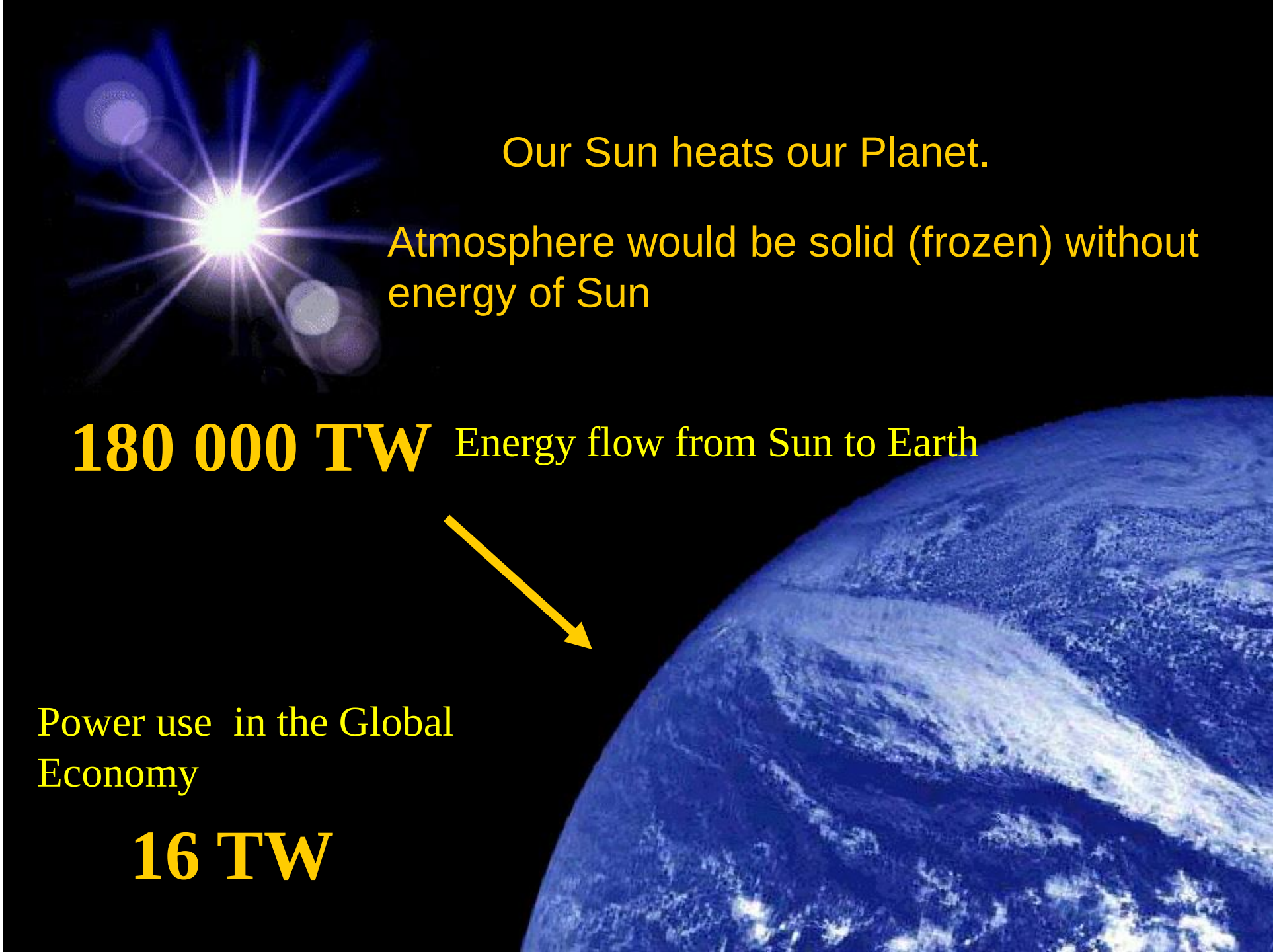


Ripl W. - Water: the bloodstream of the biosphere.2003: Philosophical Transactions of the Royal Society London B 358, pp.1921-1934

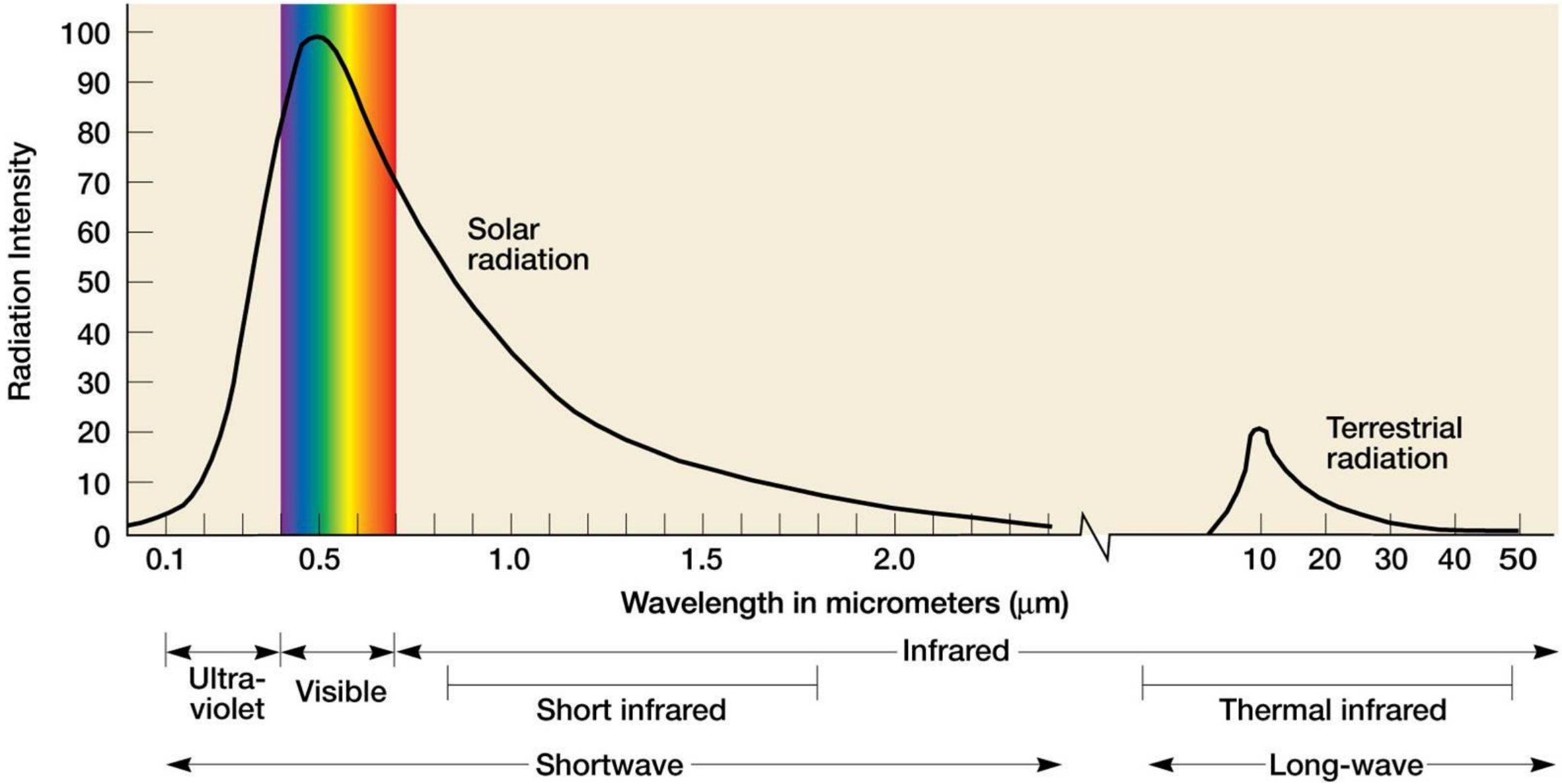
SINE SOLE NIHIL SUM

I am nothing without Sun

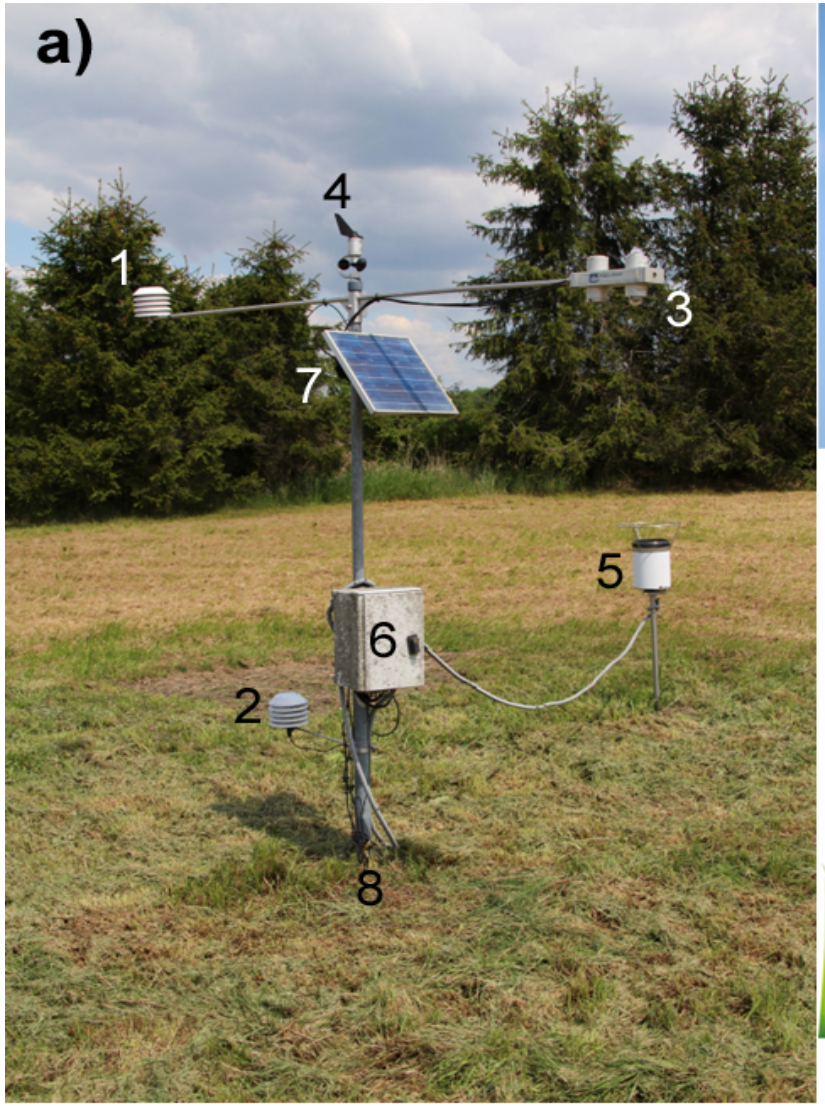
- Sun heats Earth of 290 ^{o}C (*atmosphere would be solid without Sun energy)*
- Do we affect distribution of solar energy by landscape management?
- Yes, markedly and we can measure it
- Landscape drying are more serious than increase of global average temperature shows. Average can not explain climate extremes (torrential rain, tornadoes, morning frosts)
- Wetlands, forests, growing crops cool themselves by water evaporation, increase air humidity = fog, clouds and less incoming solar radiation

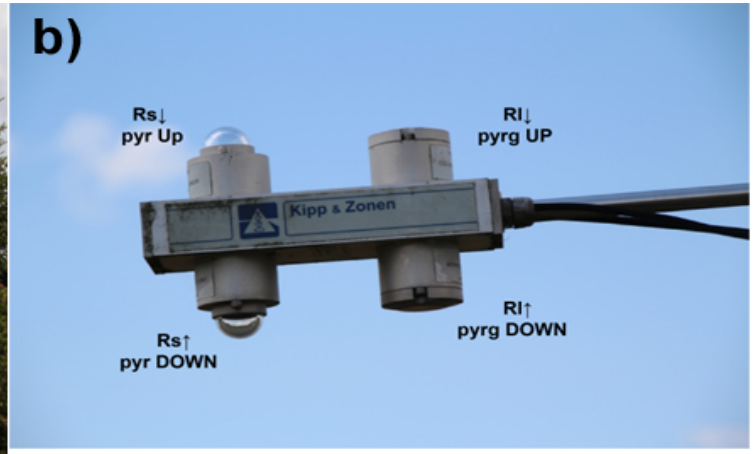

Our Sun heats our Planet.
Atmosphere would be solid (frozen) without energy of Sun
180 000 TW
Energy flow from Sun to Earth
Power use in the Global Economy
16 TW

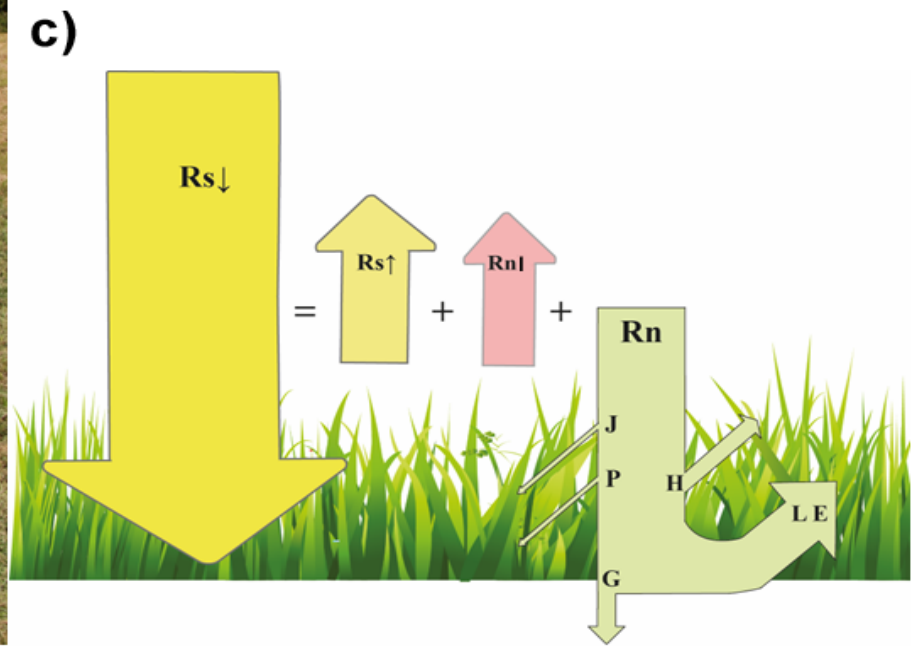
J. Kleczek


Radiation Intensity
100
90
80
70
60
50
40
30
20
10
0
Solar radiation
Terrestrial radiation
0.1
0.5
1.0
1.5
2.0
10
20
30
40
50
Wavelength in micrometers (μm)
Ultra-violet
Visible
Infrared
Short infrared
Thermal infrared
Shortwave
Long-wave

Meteo – station and detail of NET radiometer with the sensors
for measuring shortwave radiation (incident RS↓; reflected Rs↑) and longwave radiation (R1↓; R1↑, Rnl),
Rn = net radiation (H = sensible heat, LE = latent heat of evapotranspiration, G = ground heat flux, P = photosynthesis, J = warming of plant stand))

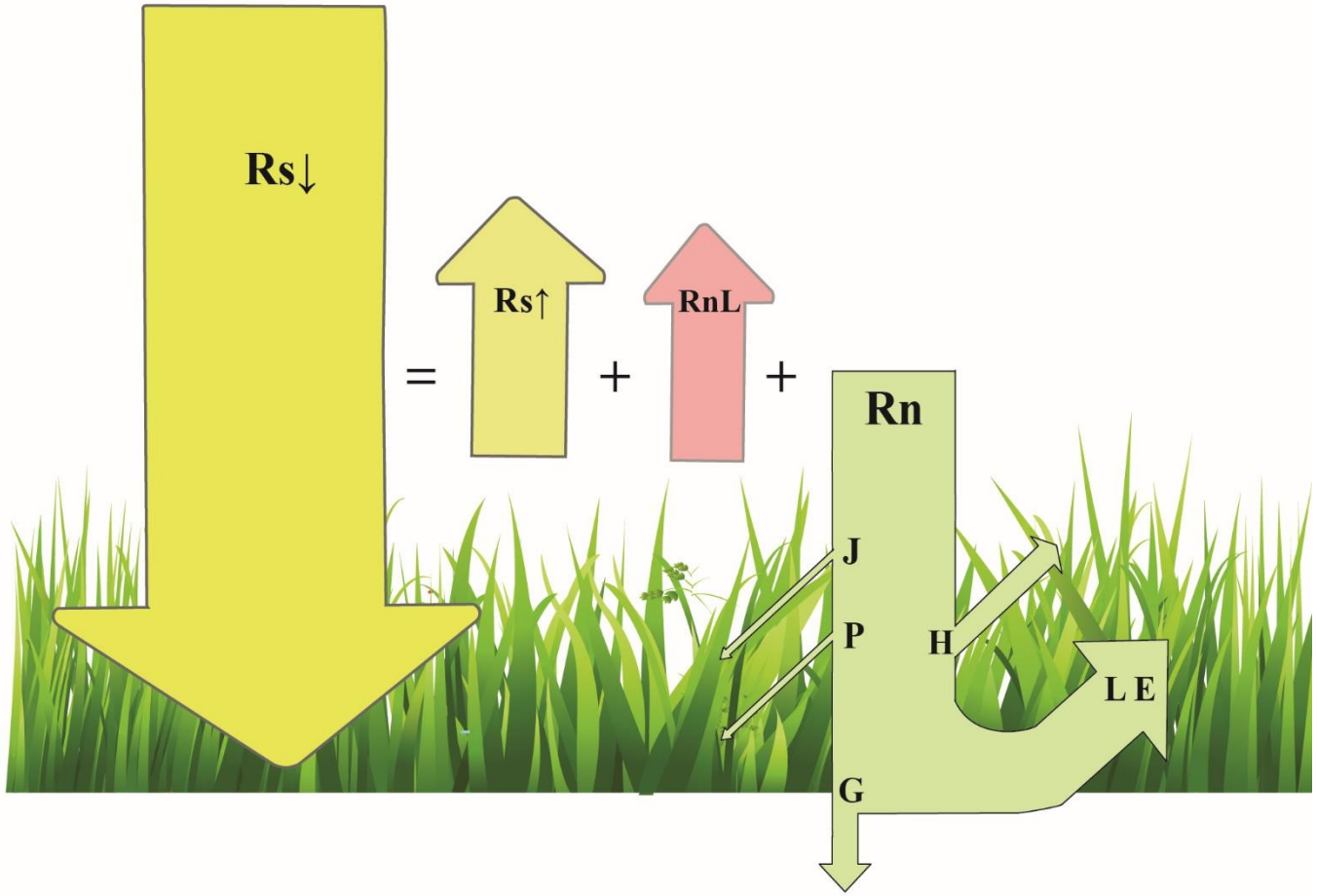




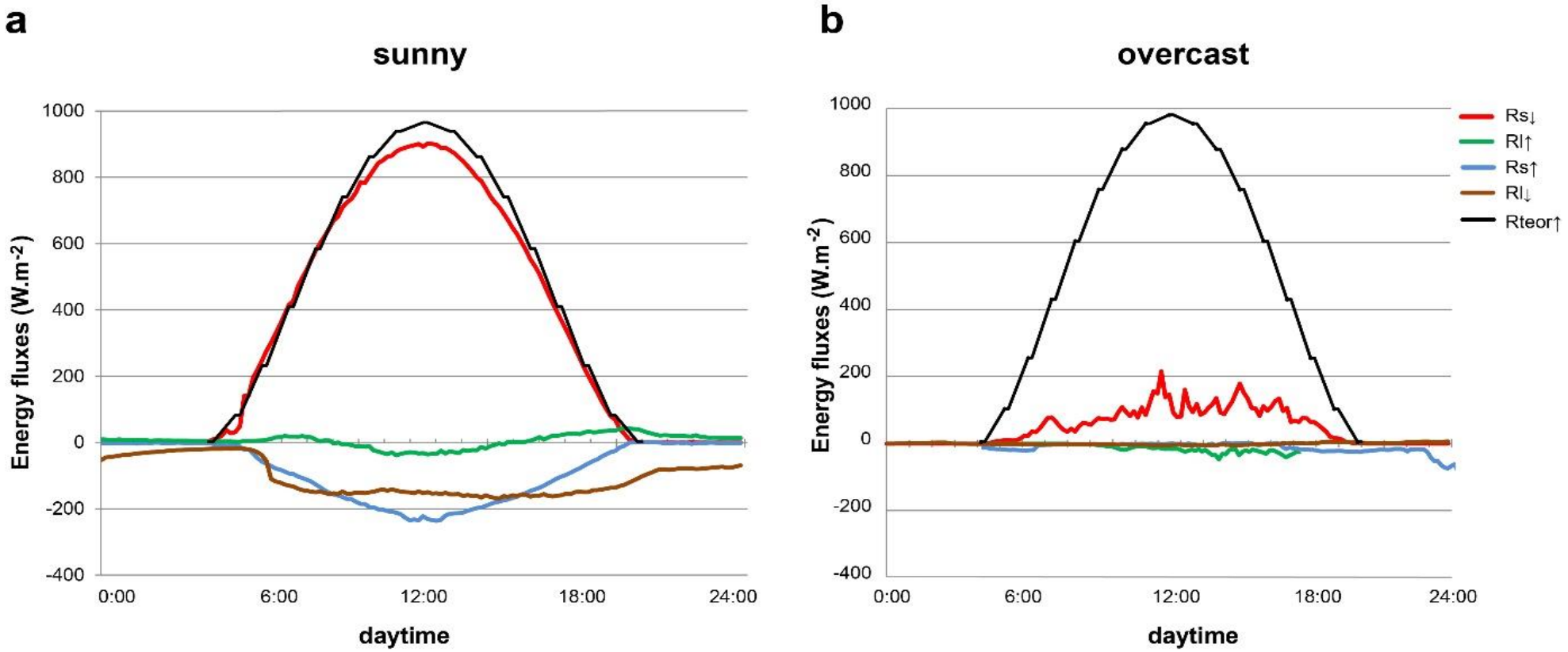


Jirka V., et al., 2021
Energetická výměna mezi zemským povrchem a atmosférou v závislosti na meteorologických podmínkách bez ohledu na obsah CO2.
Vytápění, větrání, instalace.
5/ 2021, str. 234 - 239

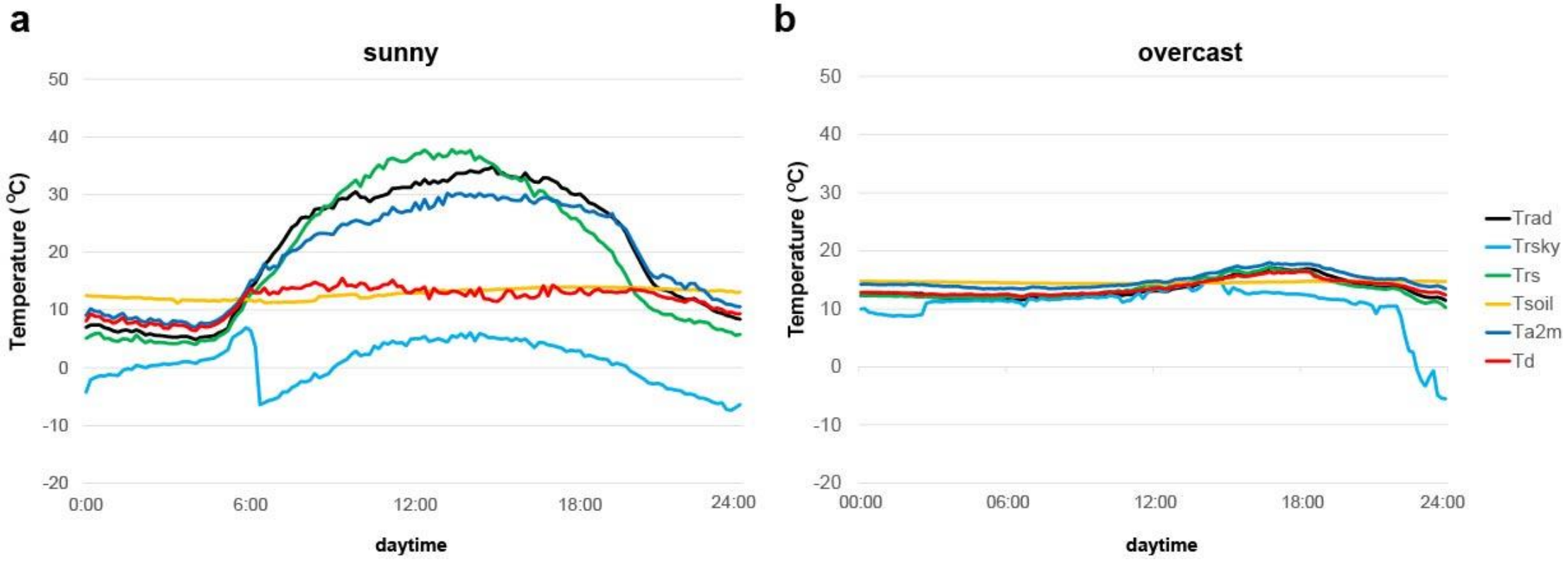
Radiation balance incoming ($R_S\downarrow$), reflected (Rs↑), long wave/heat flux between land and sky (RnL), net radiation (Rn) (H sensible heat, LE latent heat of vaporization, P photosynthesis, G round heat flux, J warming of plant stand/biomass)



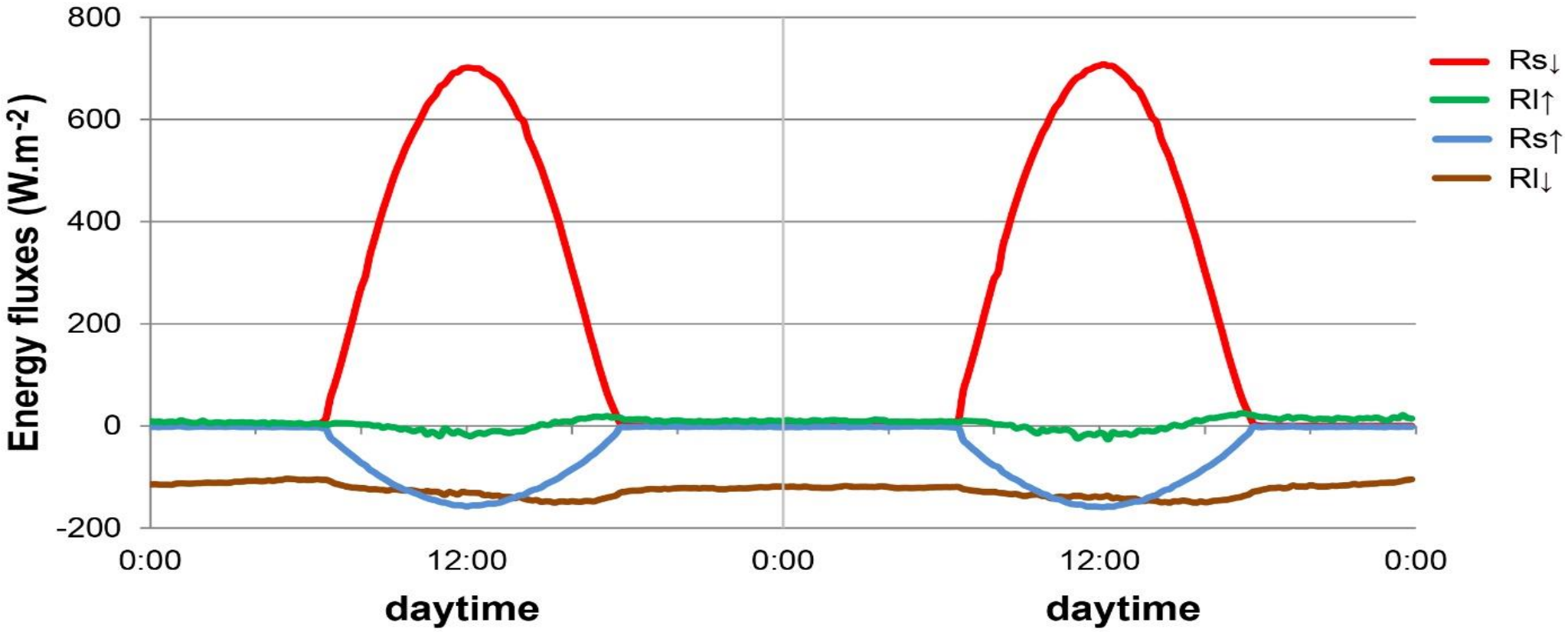
Daily course of incoming ($R_S\downarrow$), and reflected ($Rs\uparrow$), solar radiation ($W.m^{-2}$) and long wave/heat radiation between the sensor and sky ($Rl\downarrow$), and between the sensor and grass ($Rl\uparrow$), on the summer solstice 19. 6. 2017 with a clear sky (a) and 21. 6. 2020 with an overcast sky (b). RsTeor↓ shows the theoretical daily course of incoming solar radiation from a clear sky. (Jirka et al. 2021)



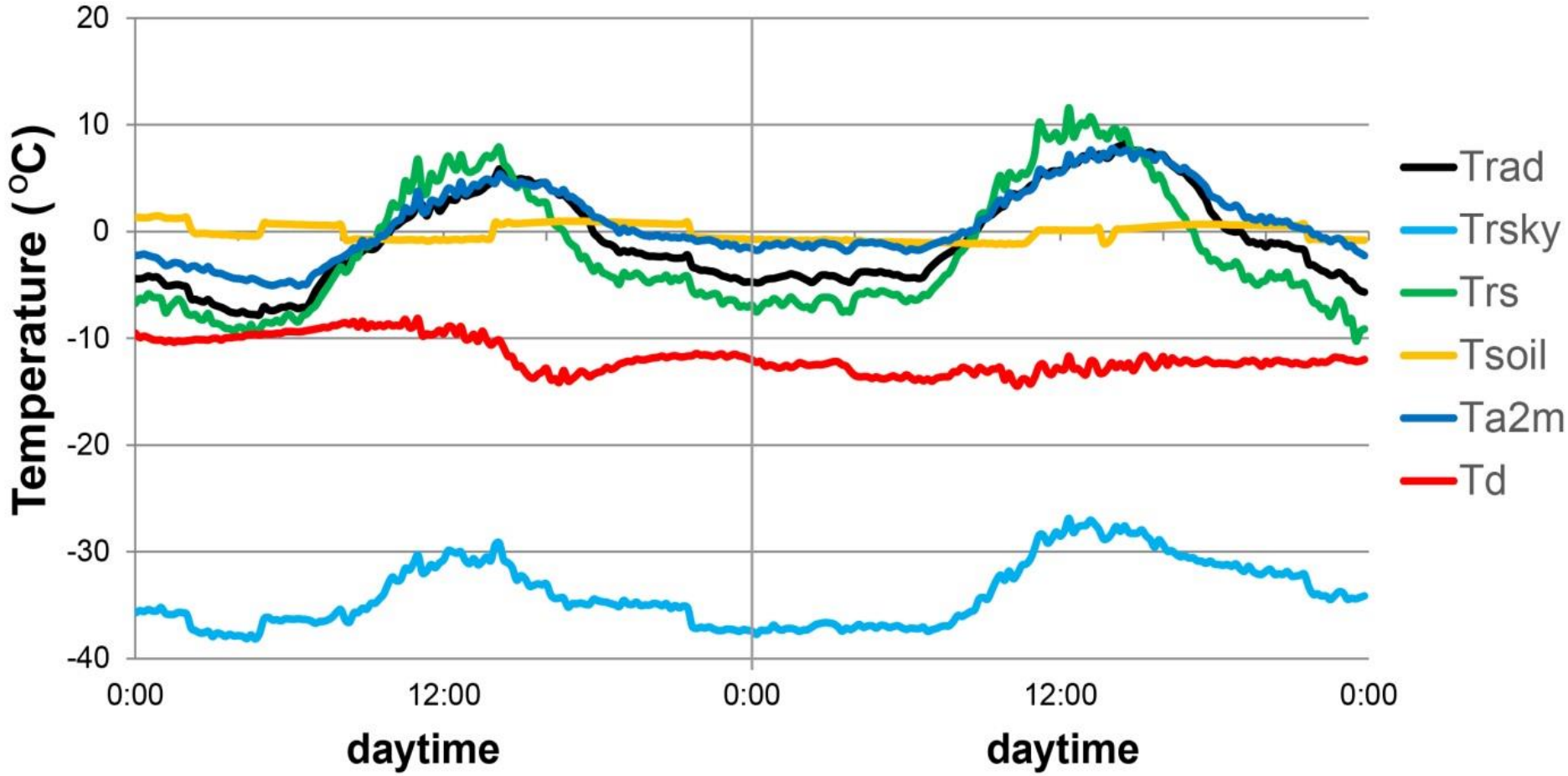
Daily course of surface temperature of grass (Trs), air temperature at 2m (Ta2m), temperature of radiometer (Trad), effective temperature of sky (Trsky), temperature of soil at 5cm depth and temperature of dew point (Td) on the summer solstice 19. 6. 2017 with a clear sky (a) and 21. 6. 2020 with an overcast sky (b)



Daily course of incoming ($R_S\downarrow$) and reflected ($Rs\uparrow$) solar radiation ($W.m^{-2}$) and long wave/heat radiation between the sensor and sky ($Rl\downarrow$) and between the sensor and grass ($Rl\uparrow$) on 11- 12 March 2022 (clear sky, low air humidity)



Daily course of surface temperature of grass (Trs), air temperature at 2m (Ta2m), temperature of radiometer (Trad), effective temperature of sky (Trsky), temperature of soil at 5cm depth and temperature of dew point (Td) on 11 – 12 March 2022



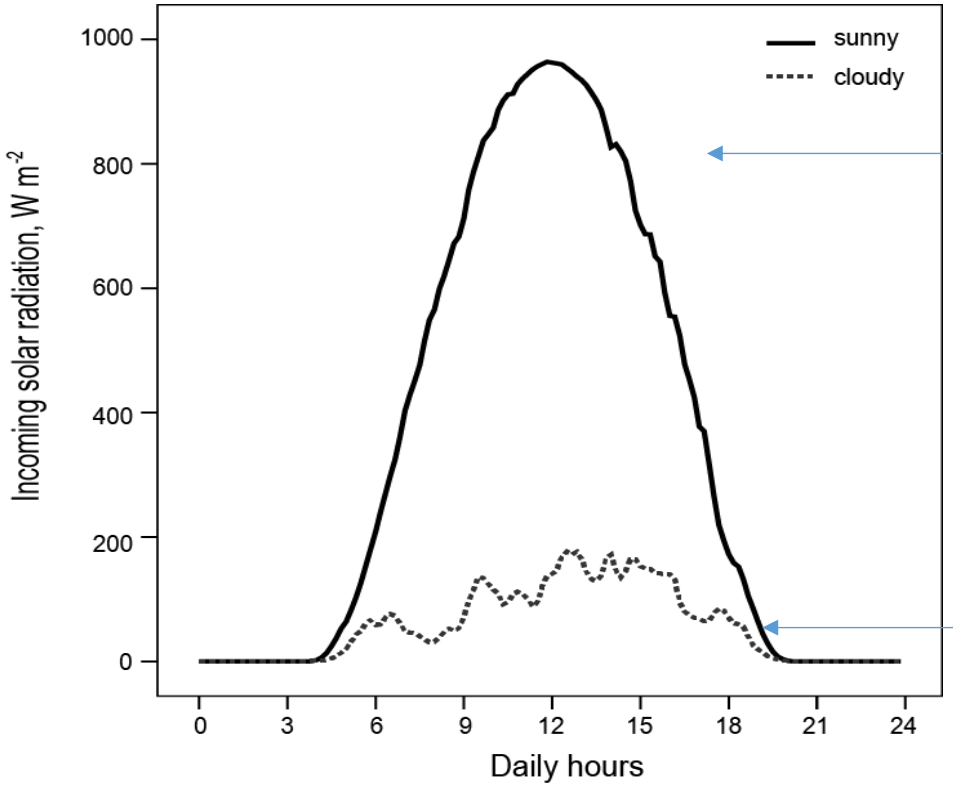
Daily sum of incoming solar radiation $\sum R_S\downarrow$ (kWh.day^{-1}.m^{-2})

Daily sum of flow of heat to atmosphere $\sum(Rl\downarrow - Rl\uparrow)$ (kWh.day^{-1}.m^{-2})

air humidity and clouds control both incoming solar radiation and flux of heat to sky

19.06.2017		21.06.2020		11.03.2022		12.03.2022	
$\sum R_S\downarrow$ **kWh**.day^{-1}.m^{-2}	$\sum(Rl\downarrow - Rl\uparrow)$ **kWh**.day^{-1}.m^{-2}	$\sum R_S\downarrow$ kWh.day^{-1}.m^{-2}	$\sum(Rl\downarrow - Rl\uparrow)$ kWh.day^{-1}.m^{-2}	$\sum R_S\downarrow$ kWh.day^{-1}.m^{-2}	$\sum(Rl\downarrow - Rl\uparrow)$ kWh.day^{-1}.m^{-2}	$\sum R_S\downarrow$ kWh.day^{-1}.m^{-2}	$\sum(Rl\downarrow - Rl\uparrow)$ kWh.day^{-1}.m^{-2}
8.22	-2.43	**1.19**	-3.42	**4.93**	-2.92	**5.0**	-2.94
100 %	30%	100 %	29 %	100 %	59 %	100 %	59 %

Clouds regulate the amount of incoming solar energy



On a sunny day:
Solar energy reaching the land surface

up to 1,000 Watts/m^2

Overcast day:
Clouds disperse solar energy.

Plants regulate clouds.

Humans control plants.

Humans control heat.

Fluxes of energy in ecosystems

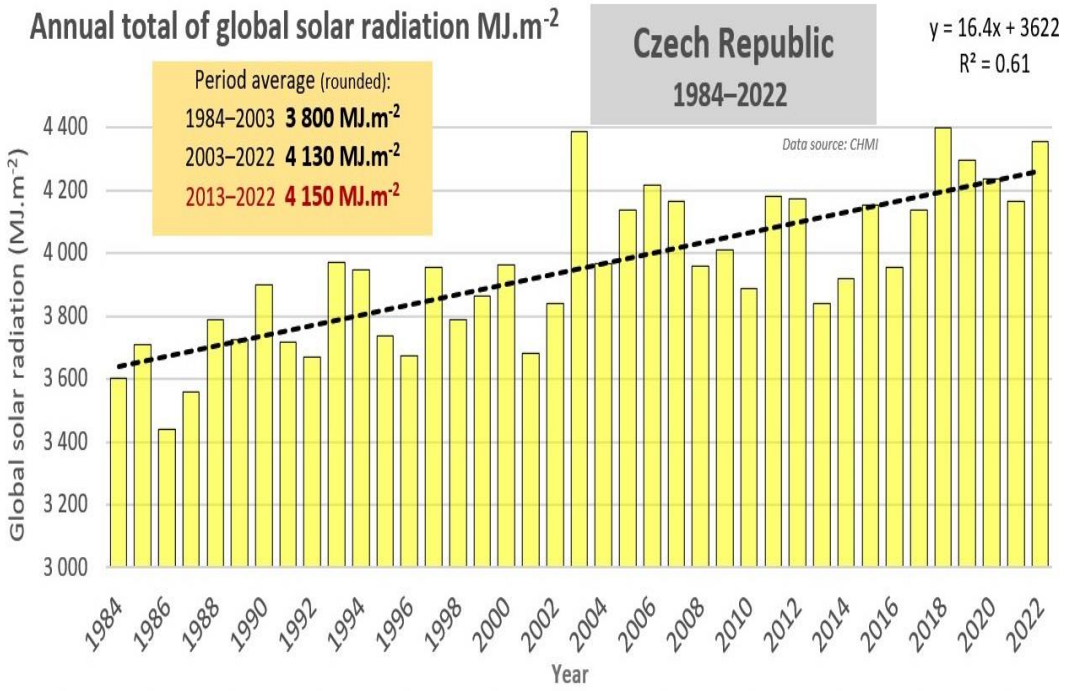
- Primary production (photosynthesis): **several Wm^{-2}**
- **Evapotranspiration**: **hunderds Wm^{-2}**
- Decomposition of organic matter in soil: **tens Wm^{-2}**
- Heating of plant stands: **several to tens** Wm^{-2}
- Solar radiation on atmosphere during one year: **1321 Wm^{-2} - 1412 Wm^{-2}**
- Radiative forcing: **0.2 W.** m^{-2} for 10 years
- **Life processes use (dissipate) solar energy and affect clouds formation**

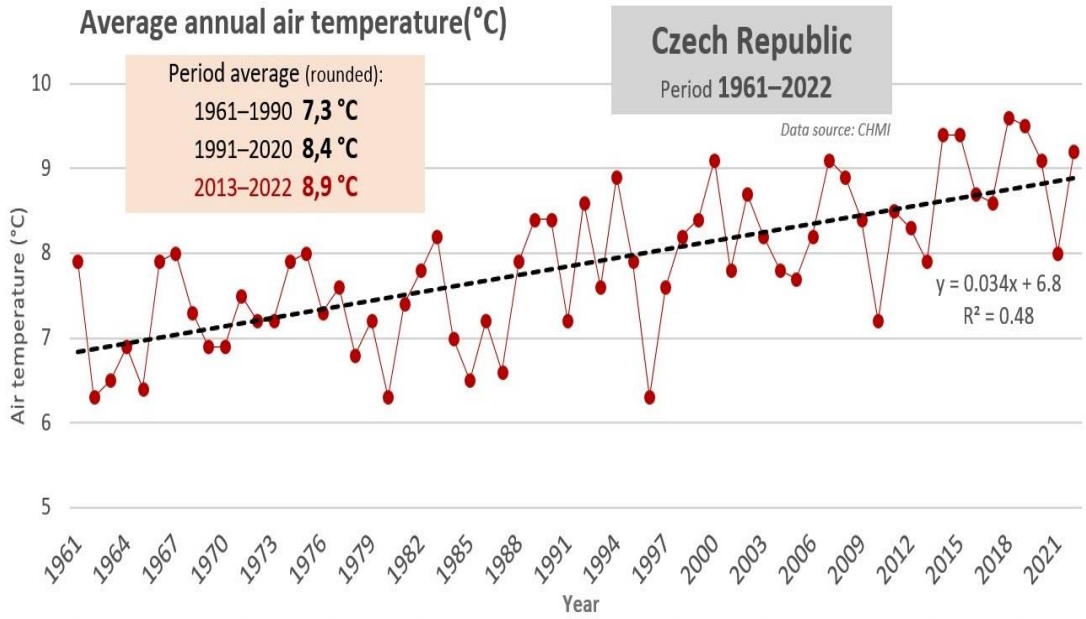
Increase of incoming solar radiation and air temperature in Czech Republic

1984 - 2003: 1055 kWh.m^{-2} 2003 - 2022:1147 kWh.m^{-2}
2013 -2022: 1153 kWh.m^{-2}

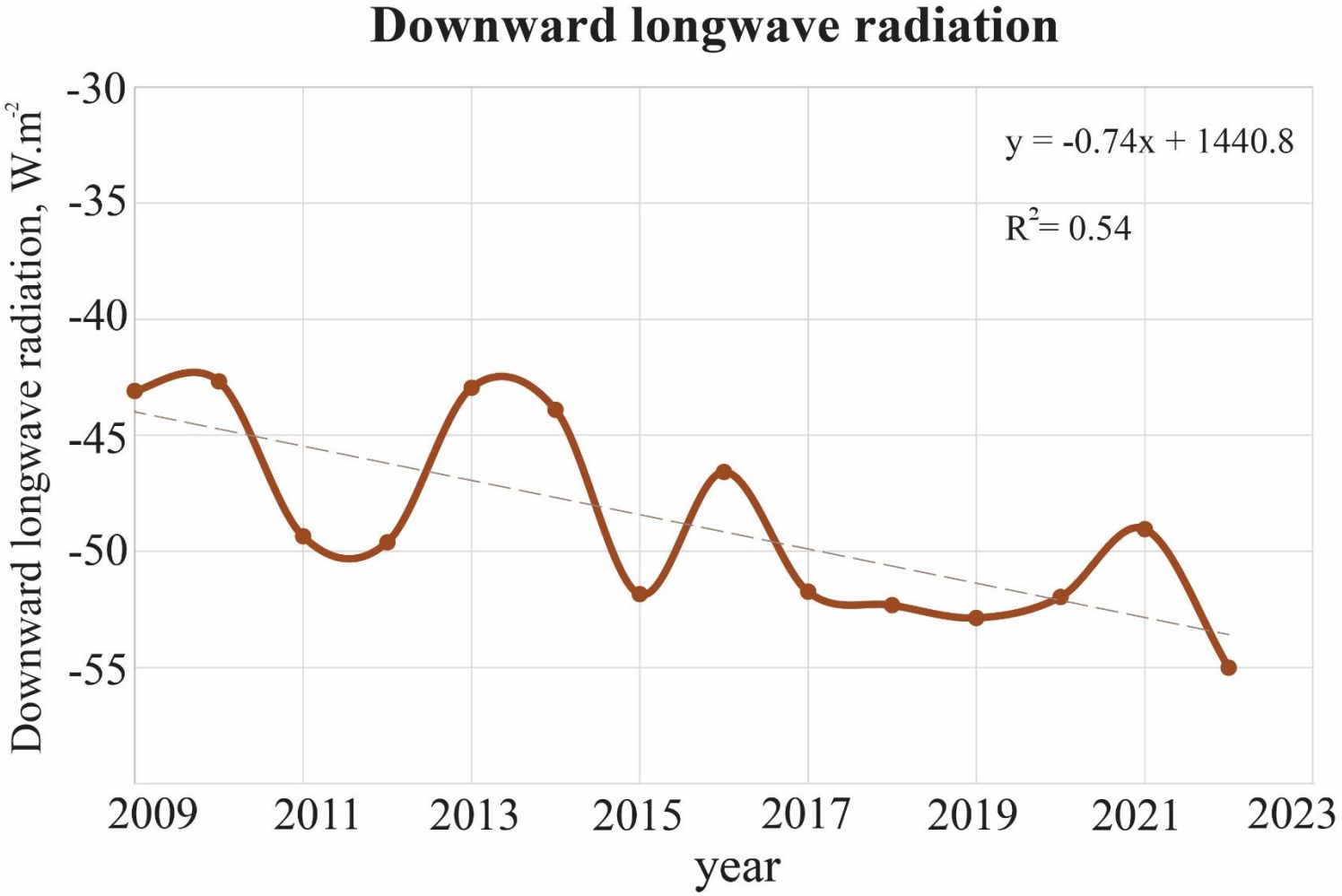
Wild, M. (2009). Global dimming and brightening: a review. Journal of geophysical research, 114, D00D16, doi:10.1029/2008JD011470, 2009

NASA CERES, Dübal a Vahrenholt (2021): **Radiative Energy Flux Variation from 2001–2020 – less clouds**





Annual average long wave (heat) flux from land surface to atmosphere from 2009 to 2022

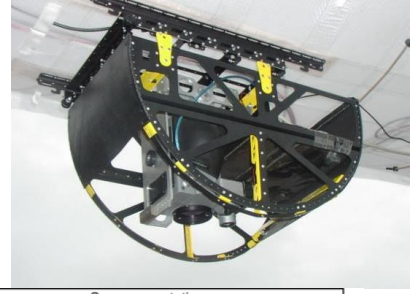


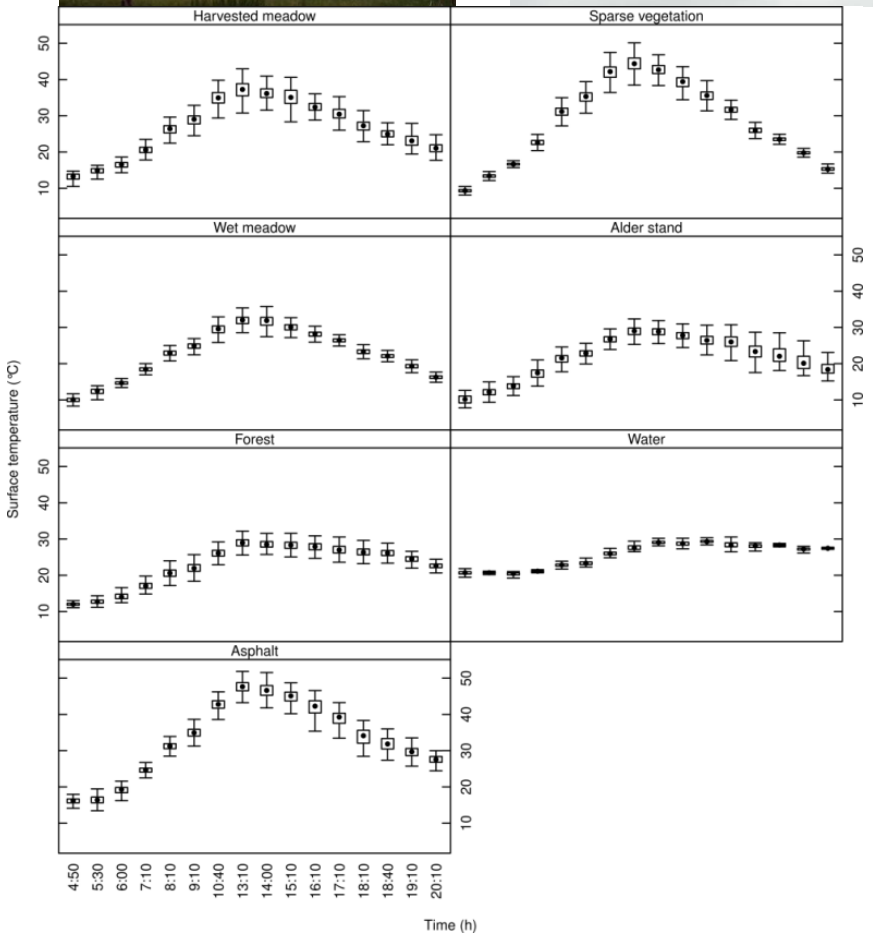
Due to negative values decreasing trend means increasing long wave radiation (heat) from land to the atmosphere.

Declining trends of green house effect.

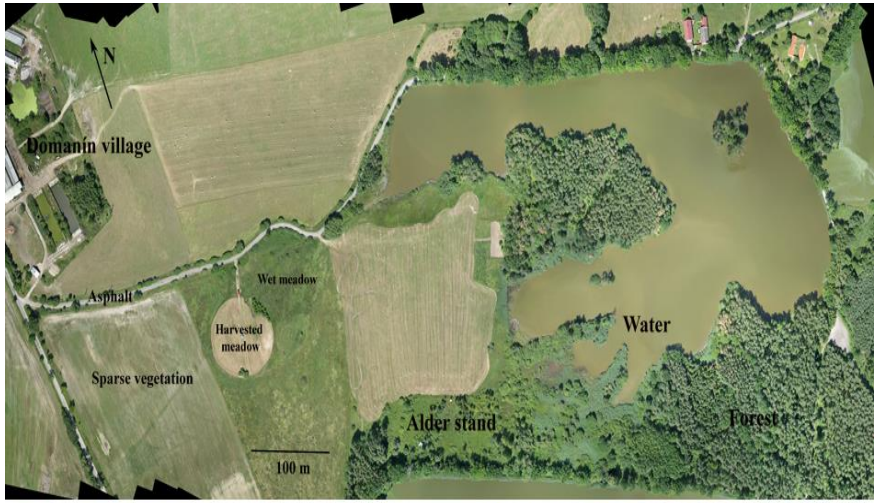
Why?
Explanation: less clouds, less fog, lower air humidity
Consequence of drainage, deforestation, urbaniasation

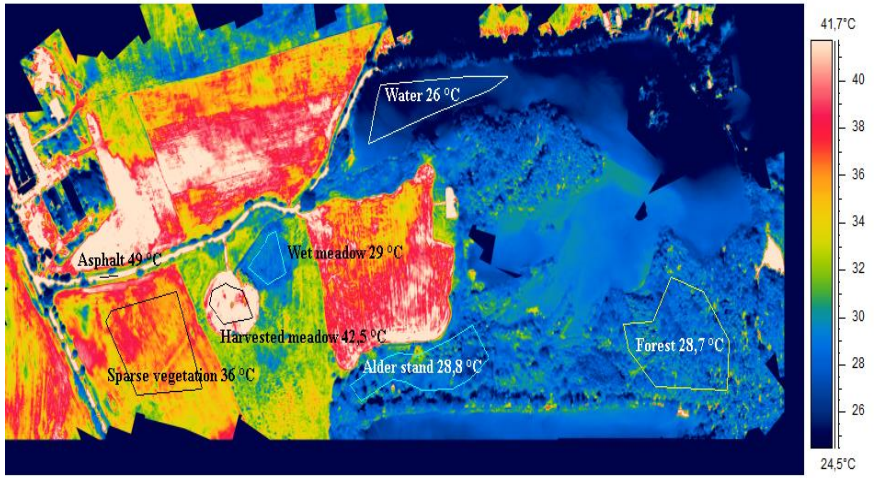
Evapotranspiration controls surface temperature





asphalt, bare grounds much more hotter than forest,meadows, and growing crops





Ellison, D., et al. 2017, **Trees, forests and water: cool insights for a hot world, Global Environmental Change 43, 51–61**

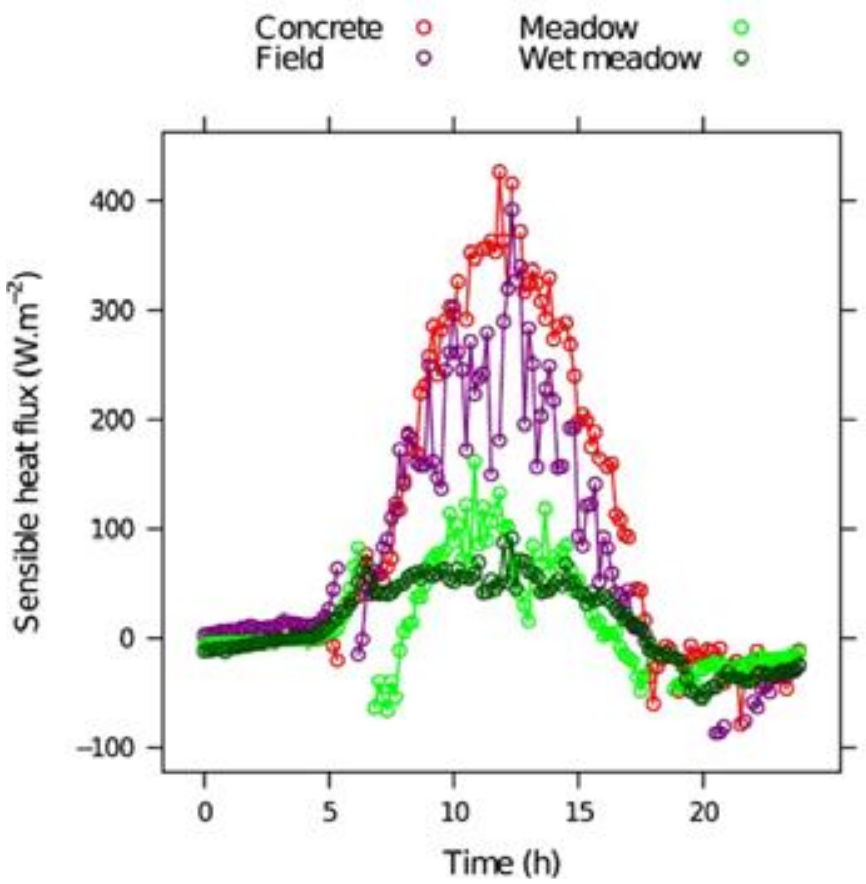
Hesslerová, P. et al. 2013, Daily dynamics of radiation surface temperature of different land cover types in a temperate cultural Landscape: consequences for the local climate.Ecological Engineering 54, 145 – 154

Ellison, D., Pokorný, J., Wild, M. 2024, Even cooler insights: On the power of forests to (water the Earth and) cool the planet Glob Change Biol

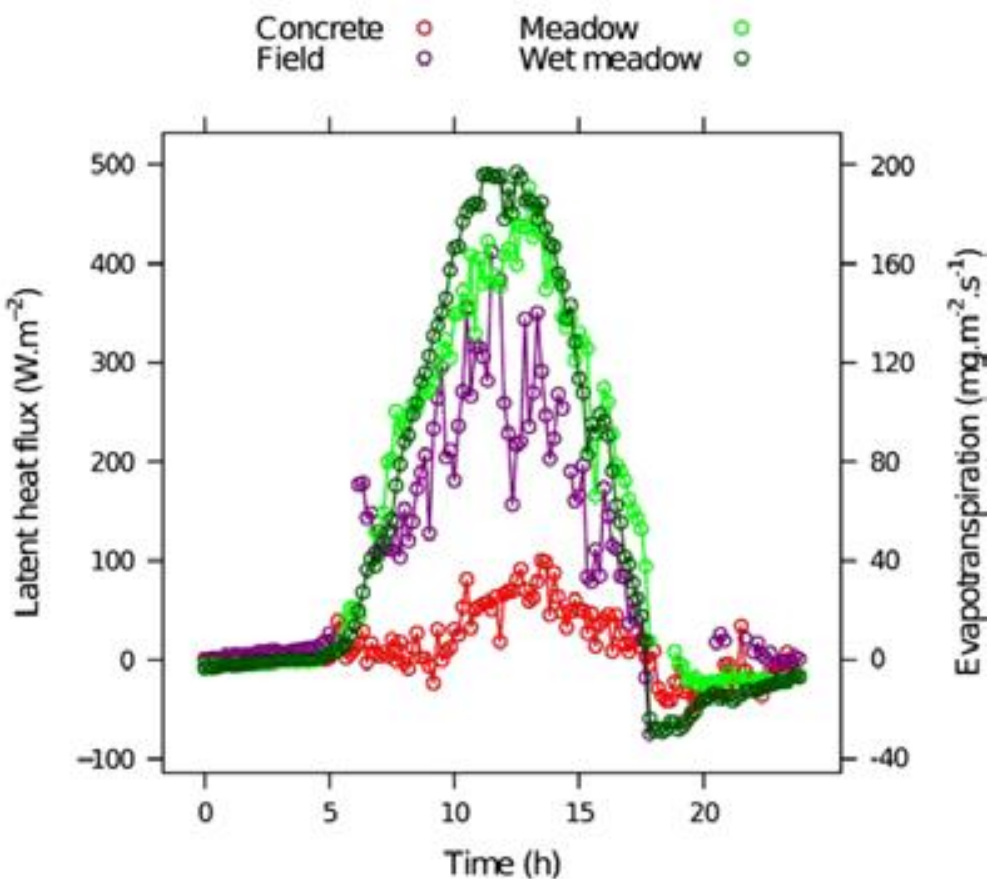
Sensible and latent heat fluxes

Wet meadow, growing crop evaporate up to 500 $W.m^{-2}$ (cooling)concrete release solar energy as sensible heat. **Average value of evaporation 240 $W.m^{-2}$ = 100$mg.m^{-2}.s^{-1}$**

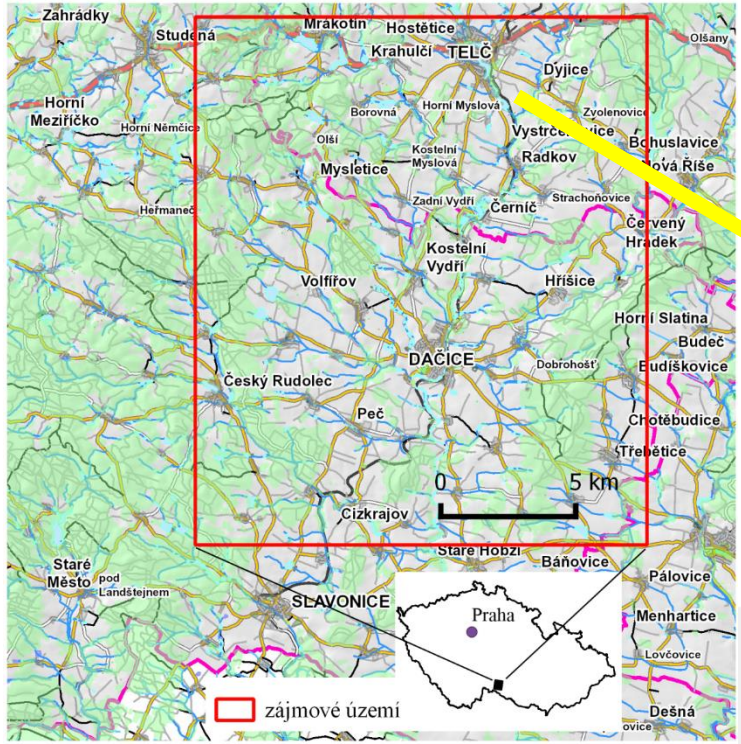
Pokorný, J., Brom, J., Čermák, Hesslerová, P., J., Huryna, H., Nadezhdina, N., Rejšková, A. 2010 Solar energy dissipation and temperature controlby water and plants, Int. J. Water, Vol 5, No 4, 311 - 336



Release of heat

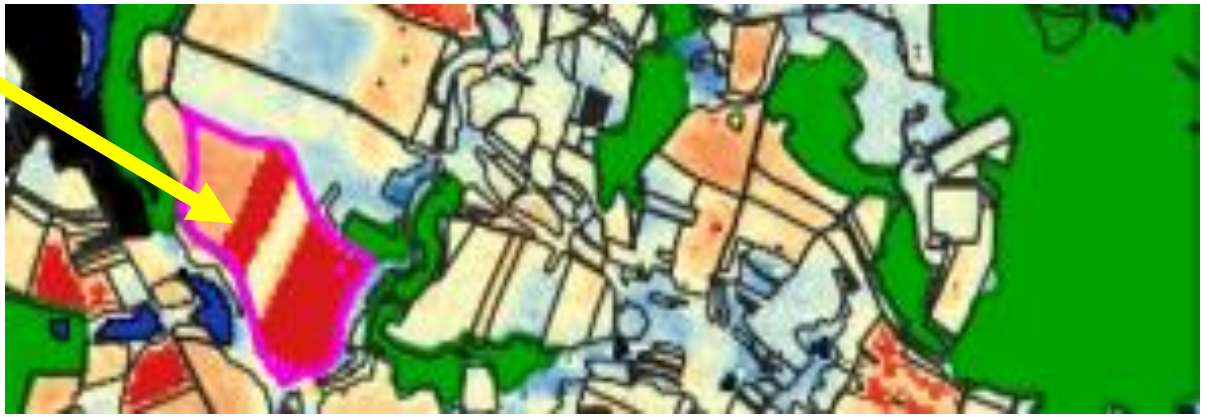


airconditioning



Landsat satellite data + meteorological data enable calculation of latent heat, sensible heat, ground heat flux

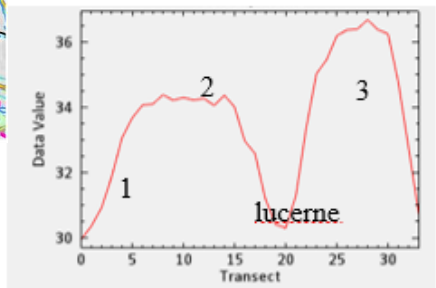
The assessment of field blocks (more than 50 ha) after their division by multiple crop species and application of intercrops



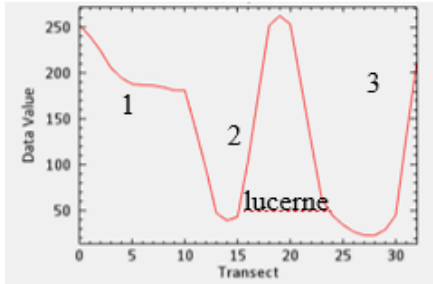
latent heat flux W.m-2

- do 90
- 90 - 150
- 150 - 210
- 210 - 270
- 270 - 330
- 330 - 395
- 398 - 460

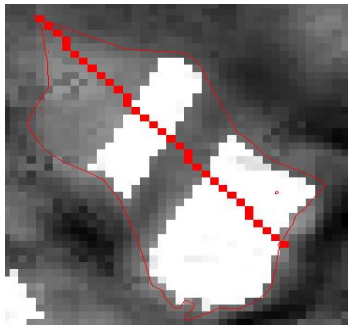
16. 9. 2020



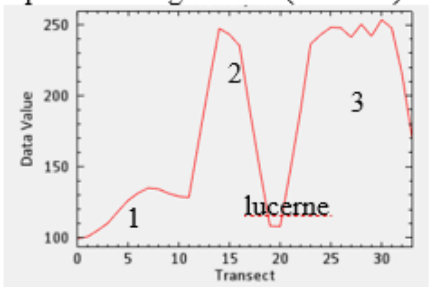
Surface temperature (°C)



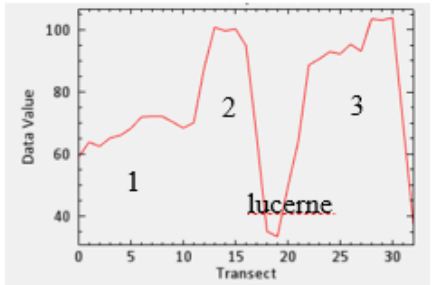
Latent heat flux (W.m^{-2})



1 – intercrop, post-harvest residues - unverified information
2- preparation for sowing winter barley (bare soil) - unverified information
3- preparation for grassland (bare soil) - unverified information



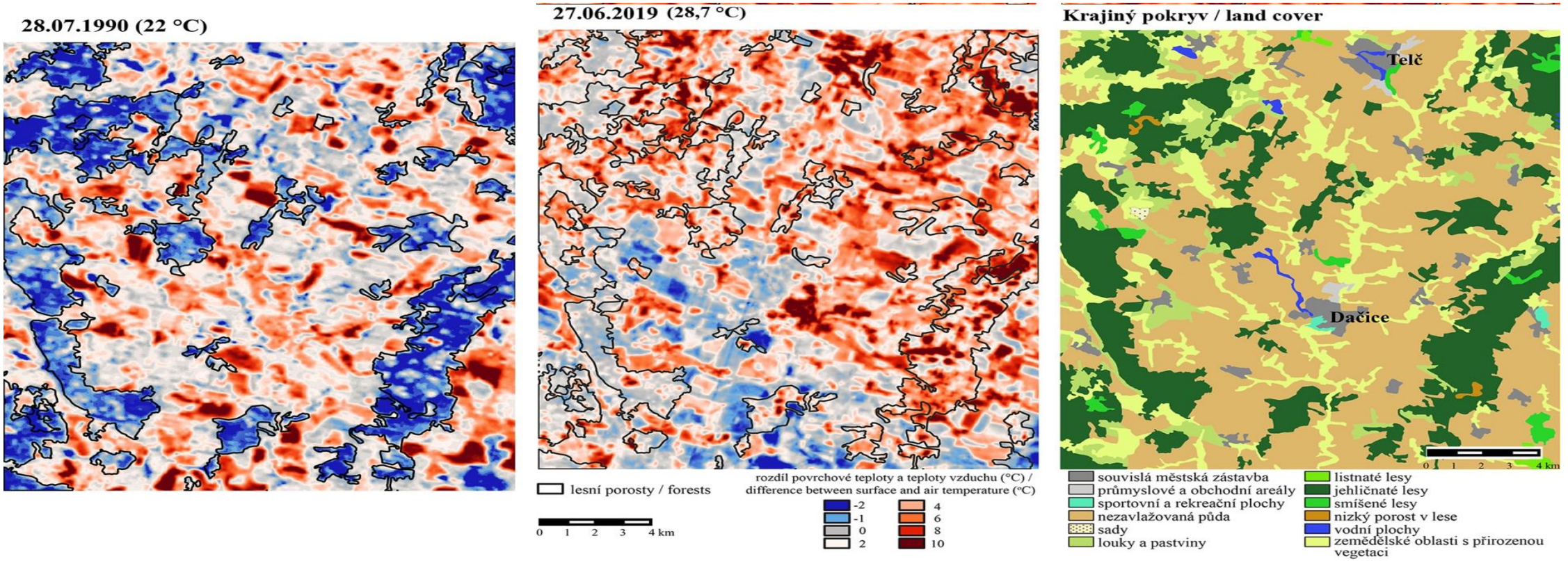
Sensible heat (W.m^{-2})



Ground heat flux (W.m^{-2})

The field block with an area of 65.37 ha is situated in the south-eastern suburb of Telč. The NW-SE transect is about 1.1 km long.

Other assessed dates: 14.7.2020; 30.7.2020



Rozdíly povrchové teploty a modelované teploty vzduchu v zájmovém území. V závorce je uvedena teplota vzduchu na stanici Kostelní Myslová.

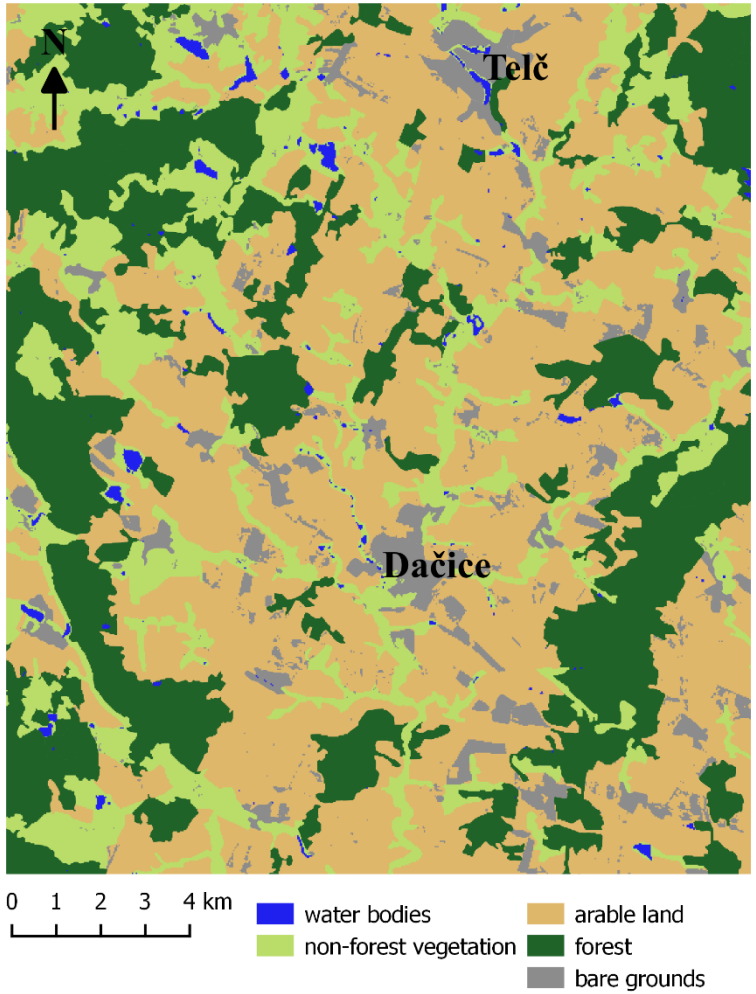
V roce 1990 byly nejchladnější lesní porosty. V roce 2019 po kůrovcové kalamitě mají lesní porosty podobnou teplotu jako zemědělská krajina. Teplota uschlých lesů se zvýšila

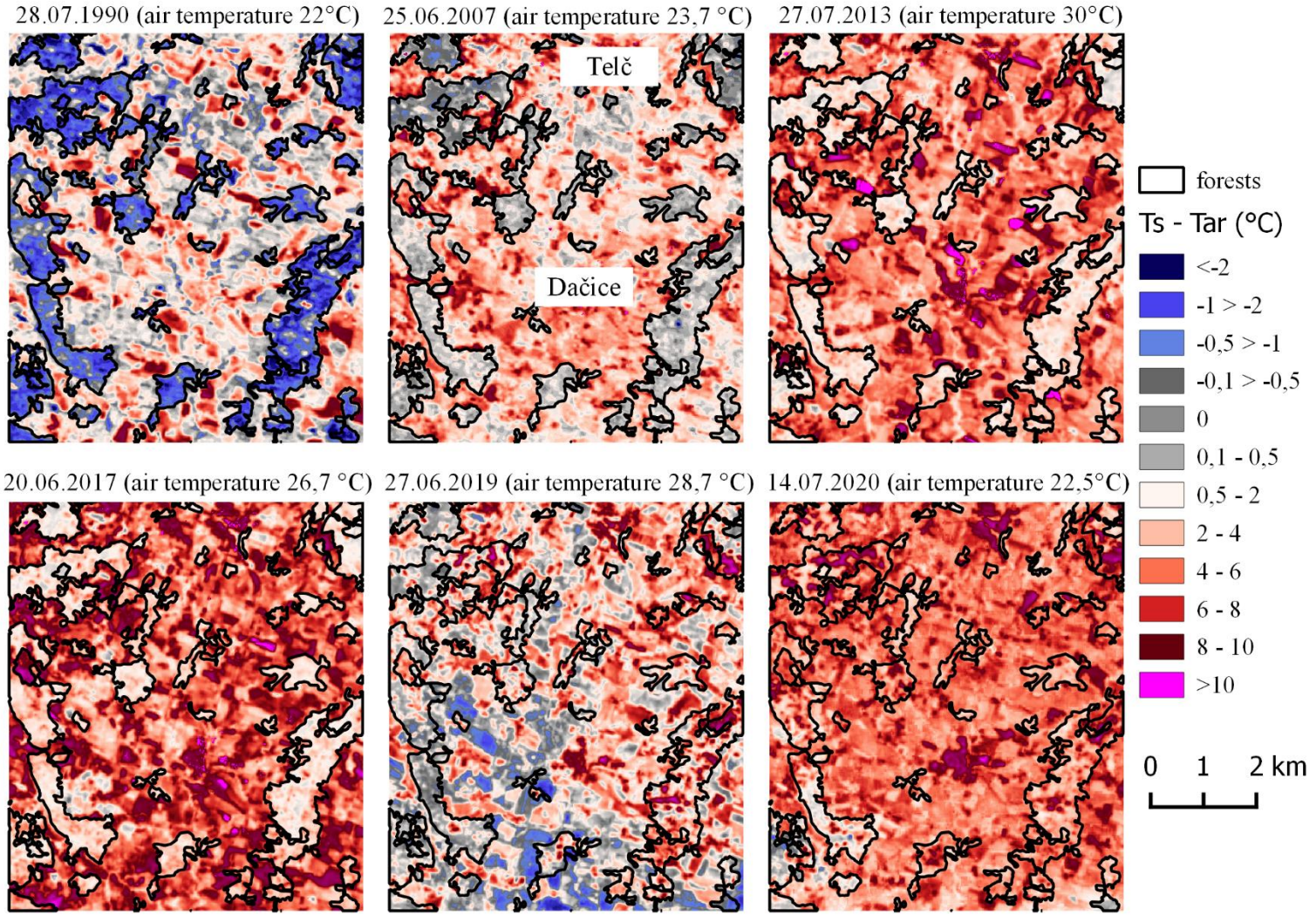
Družice Landsat snímá povrchovou teplotu kolem 10h SEČ,

Increase in air temperature over forests killed by the 2018-2020 bark beetle calamity
In 1990, the coldest forest stands were. In 2019, 2020, forest stands
Temperature is similar to the agricultural landscape.

Hesslerová, P., Huryna, H., Pokorný, J. and Procházka, J. (2018) The effect of forest disturbance on landscape temperature. Ecological Engineering 120, 345-354.

Hesslerová, P., Huryna, H., Pokorný, J., Kozumplíková, A., Vyskot, I., (2022) Změny klimatizační funkce lesních porostů jako následek jejich plošného odumření po gradaci lýkožrouta smrkového. Zprávy lesnického výzkumu 67 (1) : 311 - 320

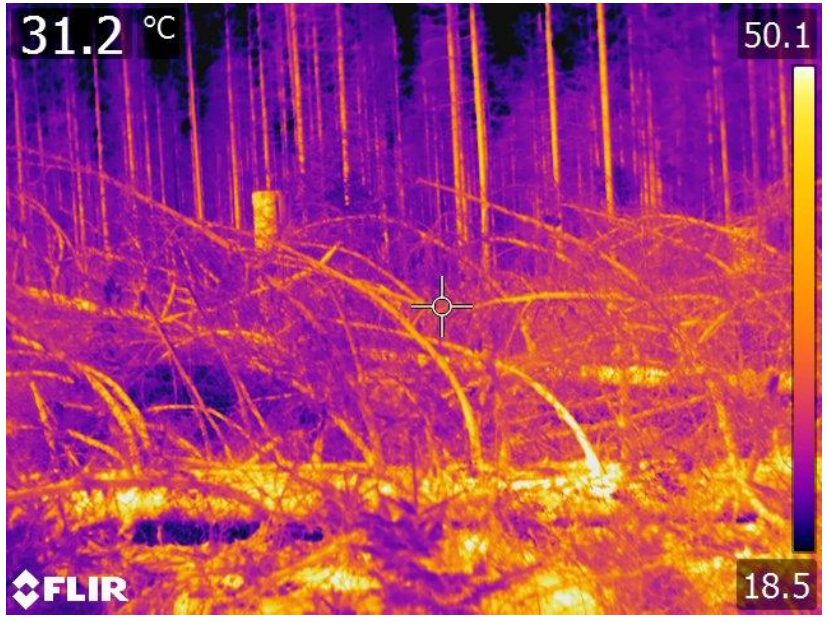


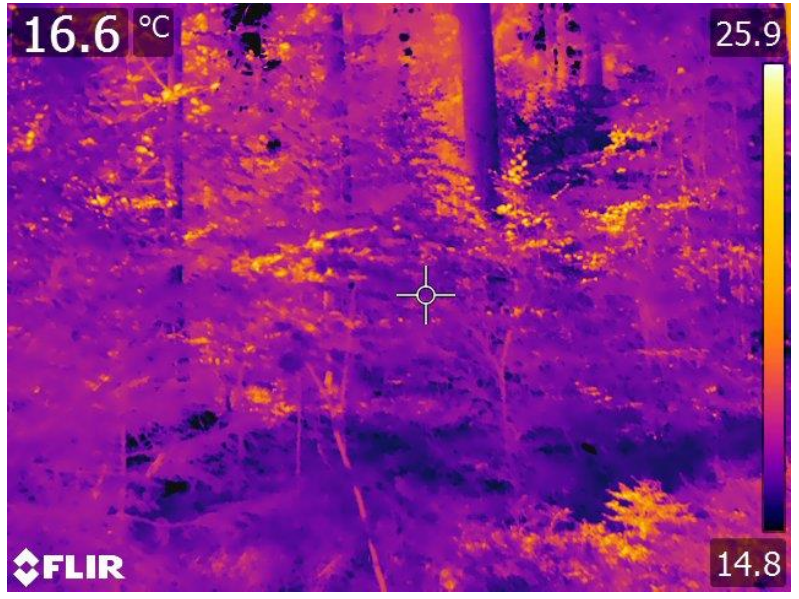


Dry forest on sunny days has high temperature (no horizontal precipitation, no cooling effect)

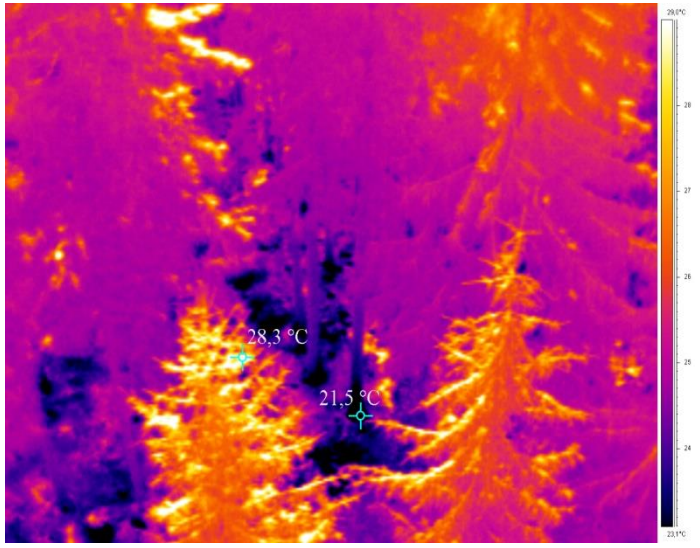
up to 50 °C

max 26 °C



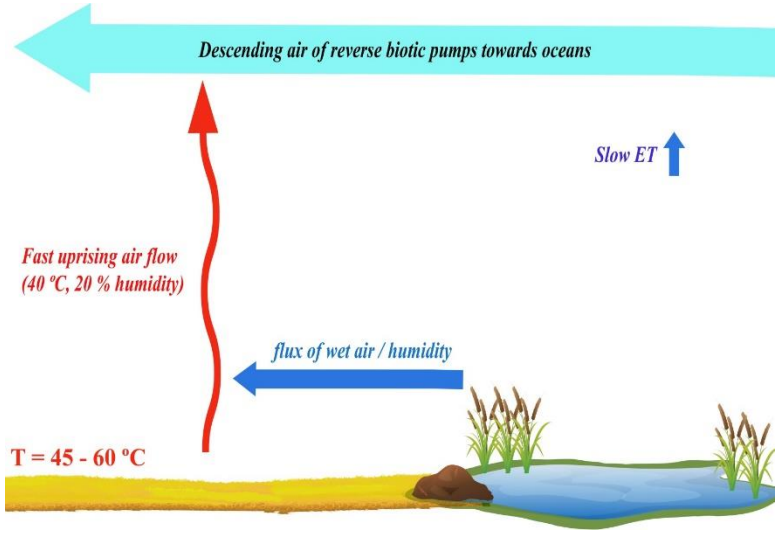


The crown surface of trees is warmer (28.3 °C than shrubs on the ground (21.5 °C)
Wet air remains in the forest canopy
Cool air is heavier



Pokorný, J., & Hesslerová, P. (2019, 14.2.2019). ***Jak vysycháme*** *– aneb, opravdu „kazí rybníky hydrologickou bilanci“?* . Odborná konference rybářského sdružení České republiky, České Budějovice. How we dry out. Are ponds really "spoiling the hydrological balance"?

Makarieva, A.M., Nobre, A., Nefiodov, A.V. Sheil, D., Nobre, P., Pokorny, J., Hesslerova, P. Li B.-L. 2022 Vegetation Impact on Atmospheric Moisture Transport in a Climate with Increasing Land-Ocean Temperature Contrasts. Heliyon , Volume 8, Issue 10, October 2022, e11173 https://doi.org/10.1016/j.heliyon.2022.e11173



Parking and market

Surface temperature up to 60 °C

11 hectares of farmland disappear every day in the Czech Republic of which half is being converted into impermeable surfaces

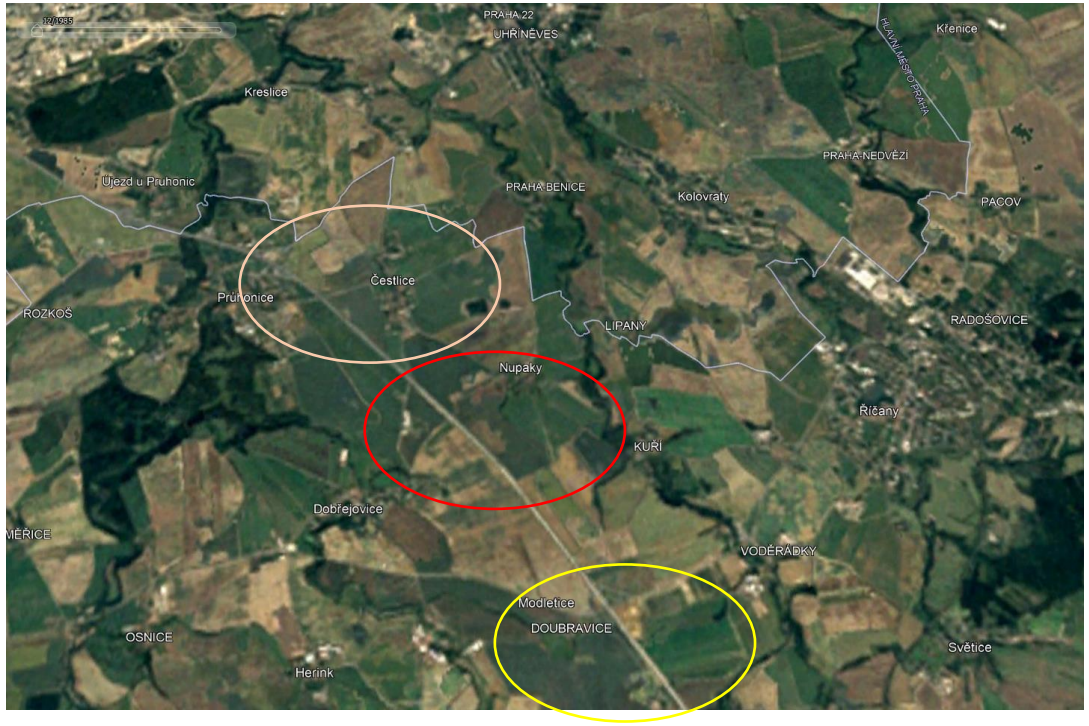
Change in landscape cover and increase in solid surfaces near Prague (Čestlice, Křeslice, Průhonice) according to the Corine Land Cover Methodology

In 1990, the area of paved surfaces was 300 ha (11.6% of the total land area).In 2018, the area of paved surfaces was 730 ha (28% of the total area).

From 1990 to 2018, 430 ha of built-up areas were added at the expense of arable farmland.

Evaporation rate $100 mgm^{-2}s^{-1} = 240 Wm^{-2}$ shifted to sensible heat

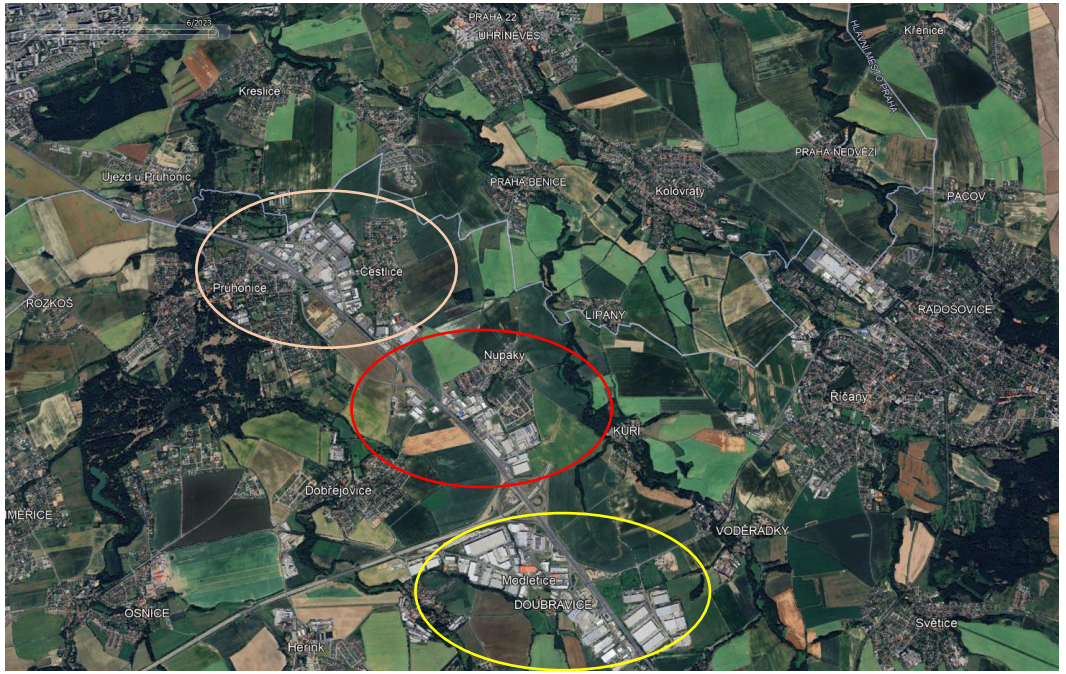
430 ha (4,3 km^2) = 1032 MW = 1.03 GW heat



Year
1985

Shift from evaporation cooling to heat production is not considered in EIA proces

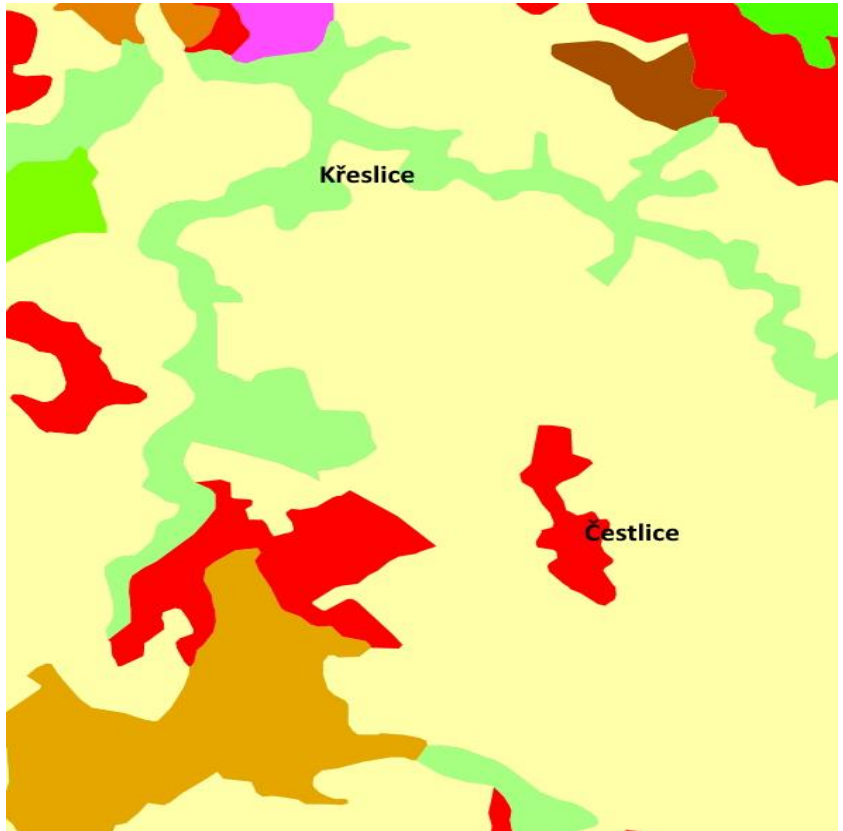
2023

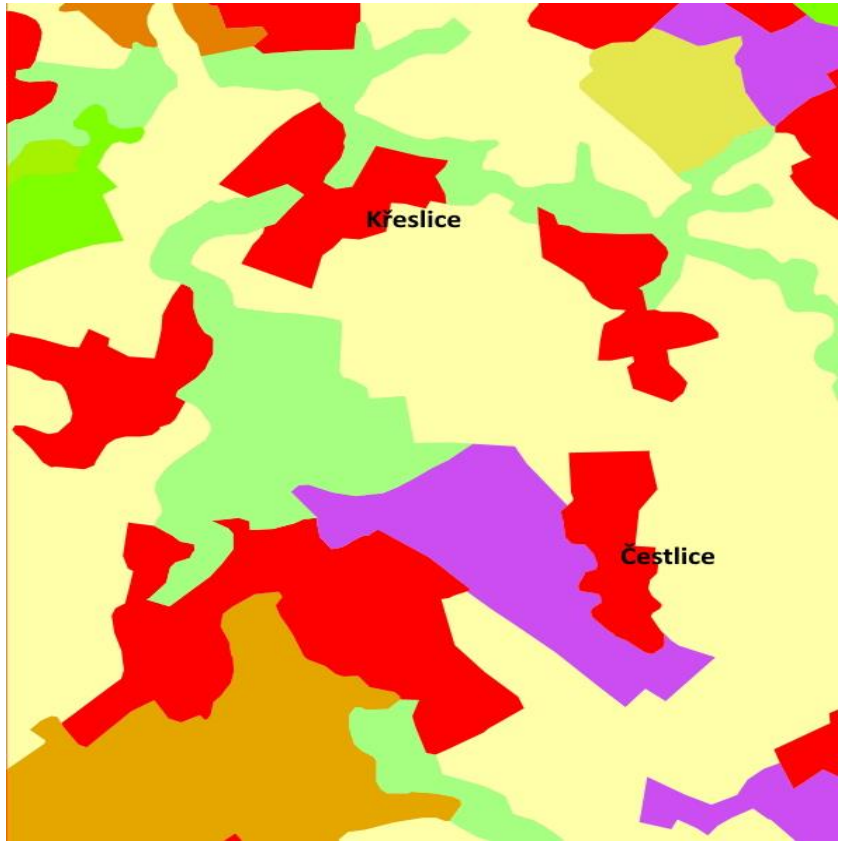


Google Earth

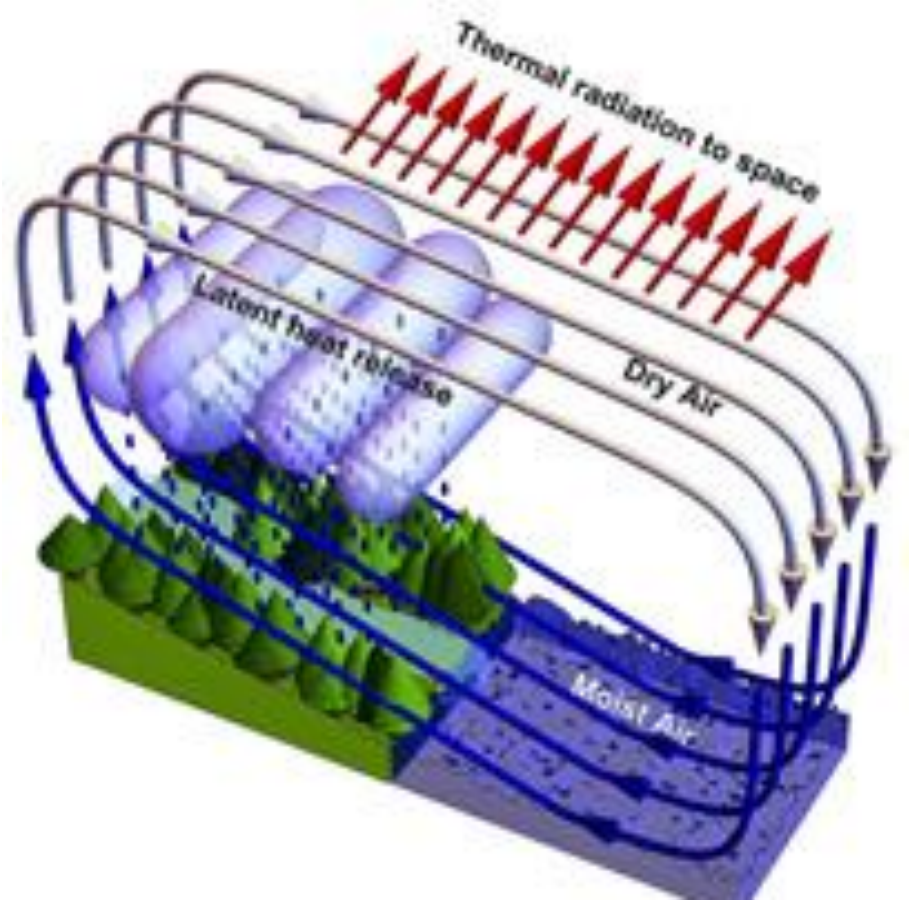
- Discontinuous urban fabric
- Industrial or commercial units
- Road and rail networks and associated land
- Dump sites
- Construction sites
- Green urban areas
- Sport and leisure facilities
- Non-irrigated arable land
- Pastures
- Land principally occupied by agriculture
- Broad-leaved forest
- Mixed forest`
- Transitional woodland-shrub
- Water bodies

1990 Land cover Corine **2018**





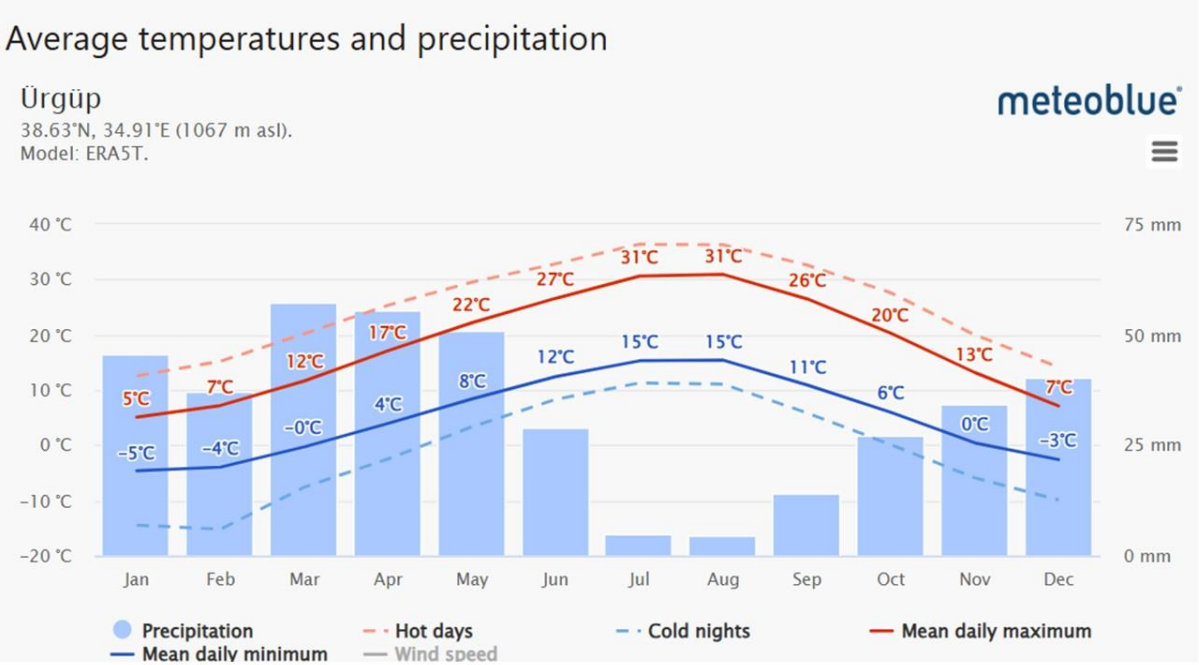
Forests evaporate water and cool, water vapour condensates, heat releases, air pressure sinks, clouds shade. (Water for Climate Healing, New Water Paradigm, **New York UNO 22.-24. 2023**)
Embracing Nature's Complexity: How to Communicate the Value of Water- and Climate-Regulating Ecosystems?" **10 – 14 April 2024, TUM-IAS Munich**, Biotic Pump Greening Group

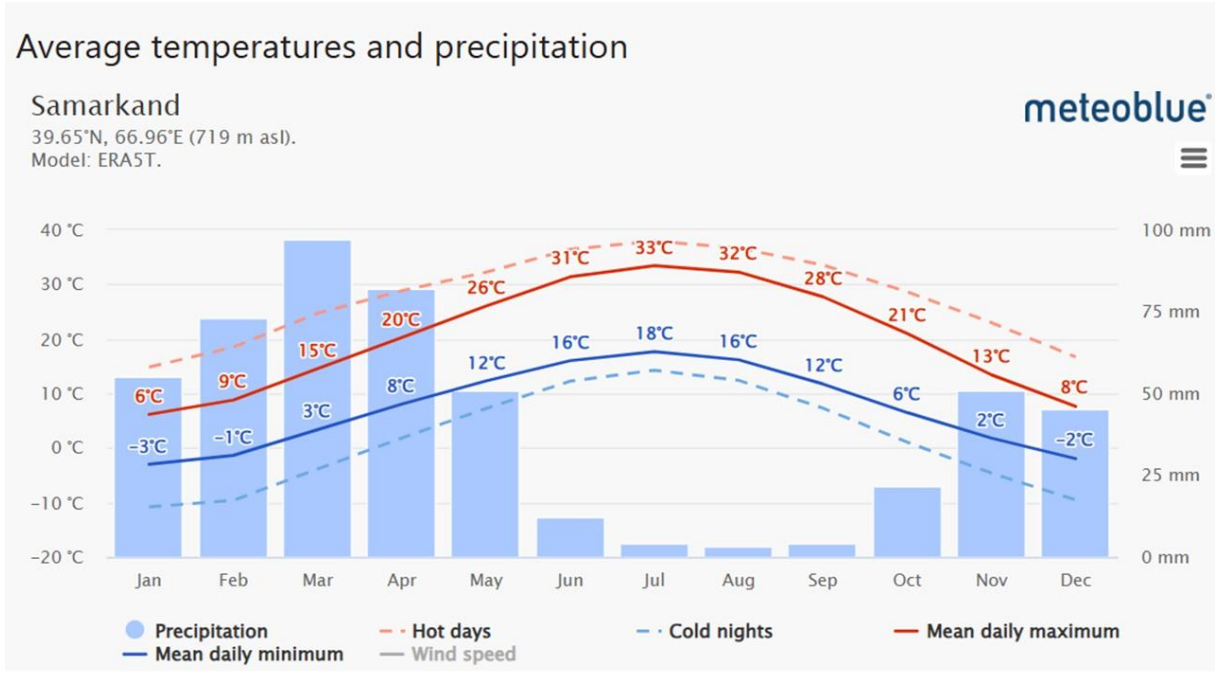


South Italy. Green houses
save water
however missing
evaporation results
in high surface
temperature,
rising heated air blocks
clouds inflow from the
sea,
(inversion biotic pump)

The landscape heats up after the harvest and rainfall stops

Michal Kravčík, People and Water, Slovakia





Evapotranspiration = evaporation of water by the plant (transpiration) + evaporation

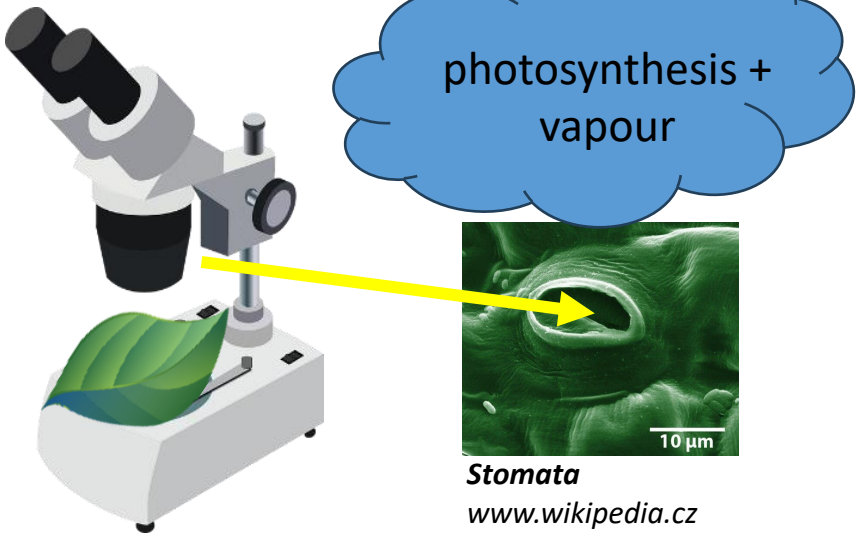
Evapotranspiration cools, balances temperatures over time and space, and attracts water

Pokorny, J., (2019) Evapotranspiration. In: Fath, B.D. (editor in chief) Encyclopedia of Ecology, 2nd edition, vol. 2, pp. 292-303. Oxford: Elsevier.© 2019 White Paper, New York UN Conference on Water 22-24 March 2023

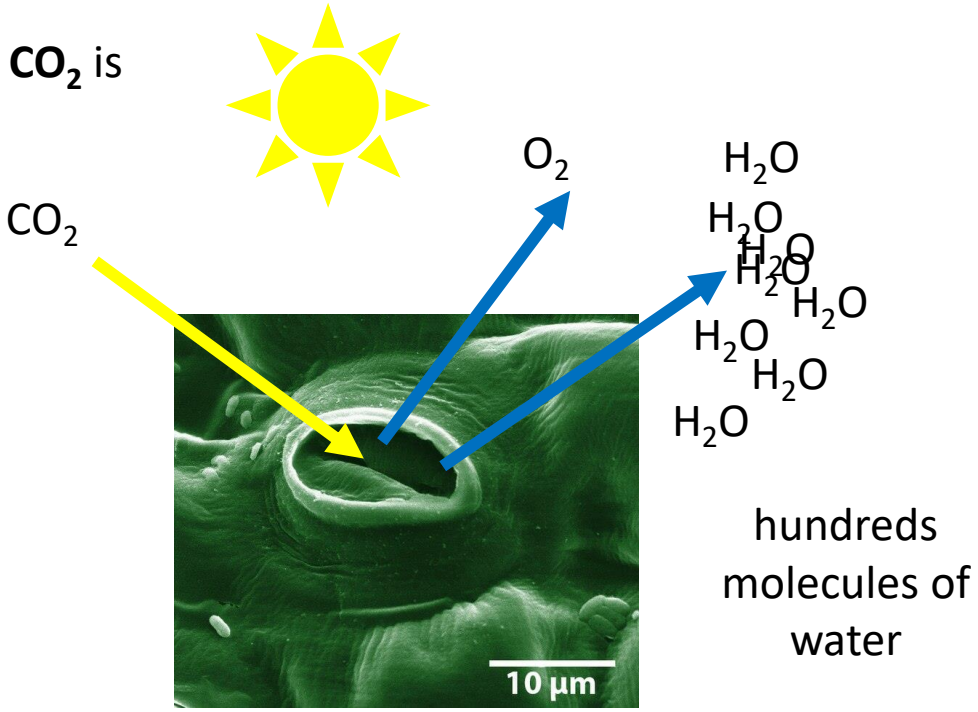
Evapotranspiration is linked with promary production.It is a fundamental process of solar energy distribution, balancing temperature and pressure differences (gradients), fog formation, cloud formation, and short and long water cycle.

- the processes of photosynthesis and transpiration/evaporation of water are linked through stomata
- One molecule of oxygen is released per molecule of carbon dioxide during photosynthesis. At the same time, hundreds of molecules of water are released through open stomata in evaporation (transpiration).
- consumption of units of $W.m^{-2}$ in photosynthesis and hundreds of Wm^{-2} in transpiration.

- About **500 kg** of water is evaporated per **1 kg** of photosynthesized dry matter (4-5 kWh), which represents cooling effect of 500 x 0.68 = **340 k Wh** of latent heat.
- There **is 0.4 kg of carbon in 1 kg** of plant **biomass** and **1.4 kg** of **CO_2** is consumed



Stomata
www.wikipedia.cz



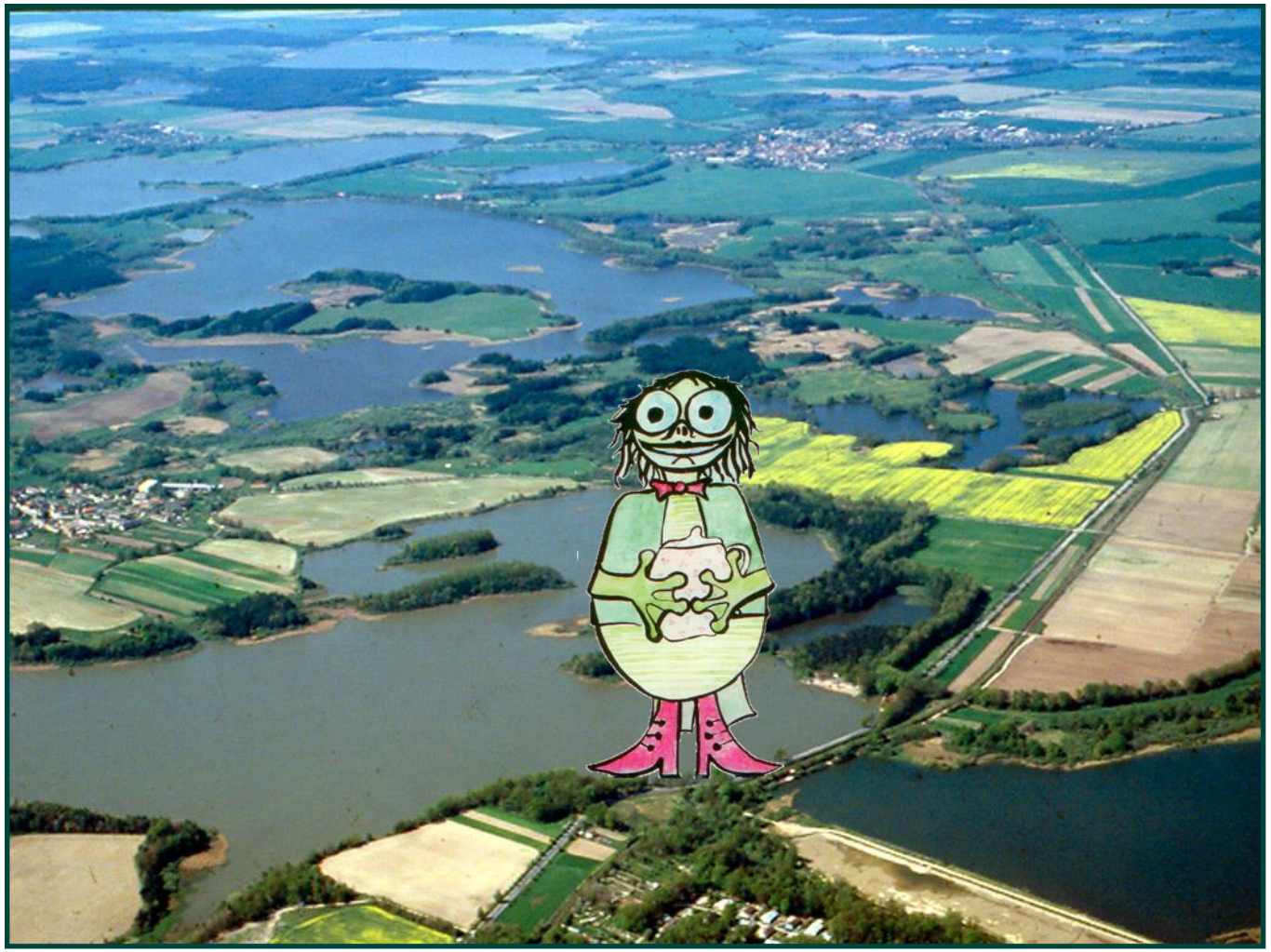
hundreds molecules of water

Farmers, foresters decide on the distribution of solar energy, the quality and quantity of water runoff. Will society recognise this role for them?

Growing crops, forages, grasslands bind carbon, nutrients, balance temperatures, shape the climate, promote water circulation, enrich the soil

Farmers' comments: Perennial forage crops are beneficial: clover, alfalfa, which enrich the soil with nitrogen and serve as cattle feed. The cattle unit in the Czech Republic is low 0,38/ha. We need more cattle to return manure to the soil, which promotes the decomposition of plant biomass and soil formation.

Man made landscape from the Middle Ages



EDUCATION needed

By managing water and vegetation, we direct flows solar energy, determine water quality and influence climate(condensation driven air mass movement)

Low level of knowledge about the role of plants in climate (distribution of solar energy), plant blindness, plant awarness

*Ryplová, R., Pokorný, J. 2020, Saving Water for the Future Via Increasing Plant Literacy of Pupils, European Journal of Sustainable Development (2020), **9**, 3, 313-323 ISSN: 2239-5938 Doi: 10.14207/ejsd.2020.v9n3p313*

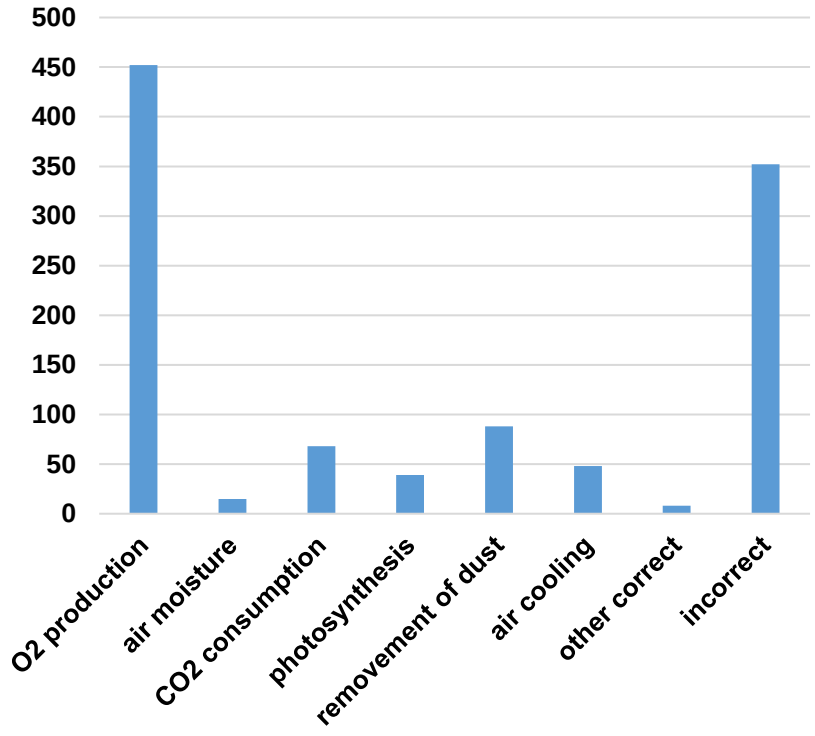
Deforestation, drainage = less clouds = more sunlight

a decrease in evaporation (evapotranspiration) means a shift from cooling to heating and drying: hundreds of watts per square meter in sunny weather

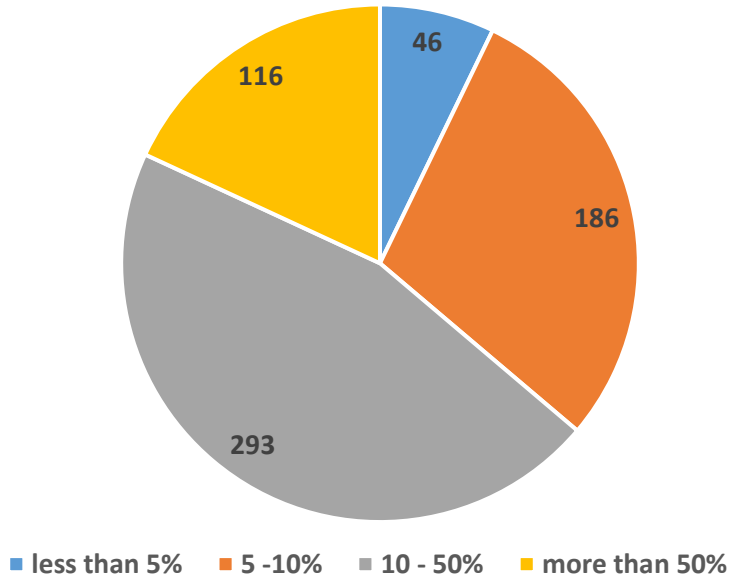
We can measure it and understand principles

Didactic survey done among 641 Czech students (15 years old) aimed on the understanding of plant – atmosphere interactions and plant physiological processes

How can plants influence our atmosphere?



How much incoming solar energy is used for photosynthesis?



Correct answers

- Less than 1% of solar energy is fixed in plant biomass by photosynthesis. $1100 kWh.m^{-2}.year^{-1}$ $1kg\ of\ plant\ dry\ mass.m^{-2}.year^{-1}$
- 1kg dry biomass contains 4 - 5kWh energy (combustion heat)
- One molecule of CO_2 is fixed, one molecule of O_2 is released and several hundred molecules of water are evaporated (transpiration)
- On a sunny day: several $W.m^{-2}$ used by photosynthesis;

  several hundred $W.m^{-2}$ by water evaporation
- Evaporation rate $100mg.m^{-2}.s^{-1}$ = latent/hidden heat flux $240W.m^{-2}$

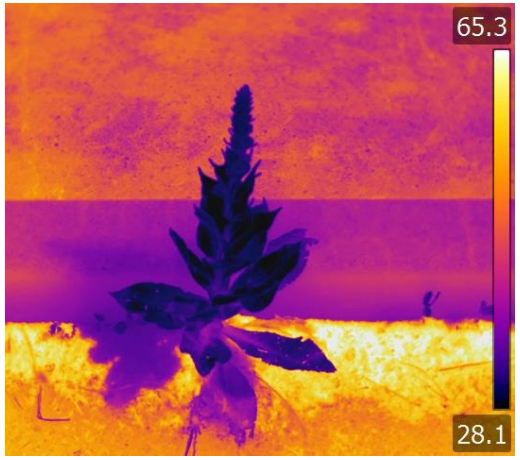
Co-funded by the Erasmus+ Programme of the European Union

Erasmus+ Project No. 2021-1-CZ01-KA220-HED-000030213

Education for Plant Literacy

https://planteducation.eu/

6 project partners 5 EU countries 4 online publications with teaching materials on plant role in our environment appearing in 2024



OUR MISSION is to improve plant literacy of general public by more efficient and attractive botany teaching at all school levels which has to be reached via education of educators, i.e. innovative teachers‘ training.

Would you like to know...?

How can a tree cool our environment by the capacity higher than common air –conditioning system?
How can the forests pump the water from the see into the continents?
Why is the shadow under a tree cooler than the shadow under an umbrella?
Why is the atmosphere above the forest smelling?
How to measure these principles at schools?
How to make botany teaching more attractive for students?
…and much more?

Jihočeská univerzita v Českých Budějovicích
University of South Bohemia in České Budějovice

ENKI o.p.s.

HOCHSCHULE FÜR Agrar- und Umweltpädagogik
Eigene Rechtspersönlichkeit

LAPIN YLIOPISTO
UNIVERSITY OF LAPLAND

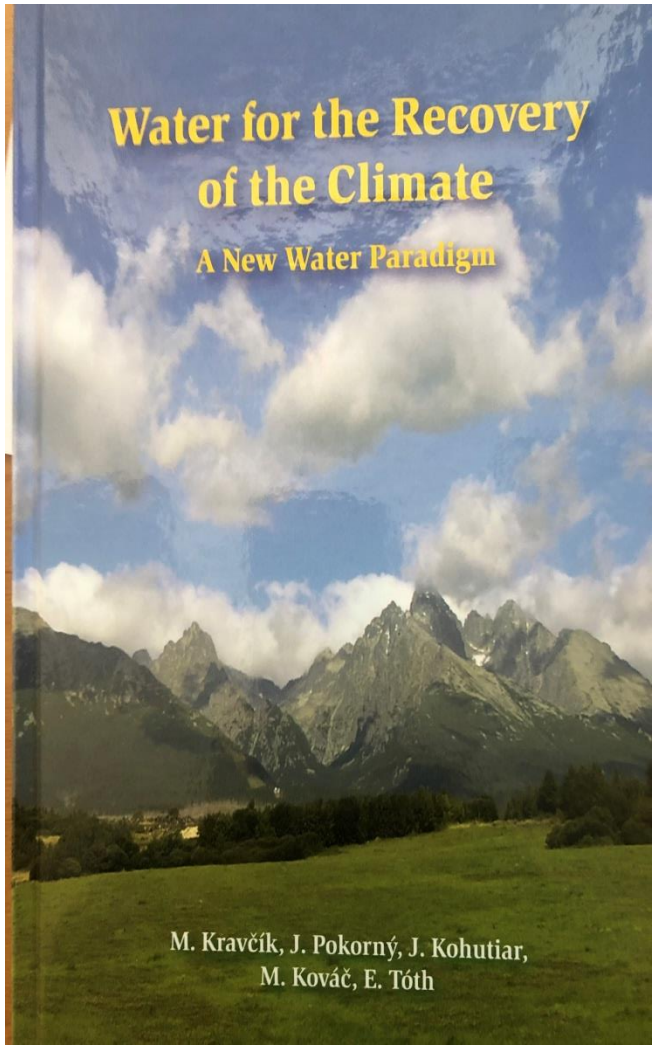
in Dialogue leadership and organisational development

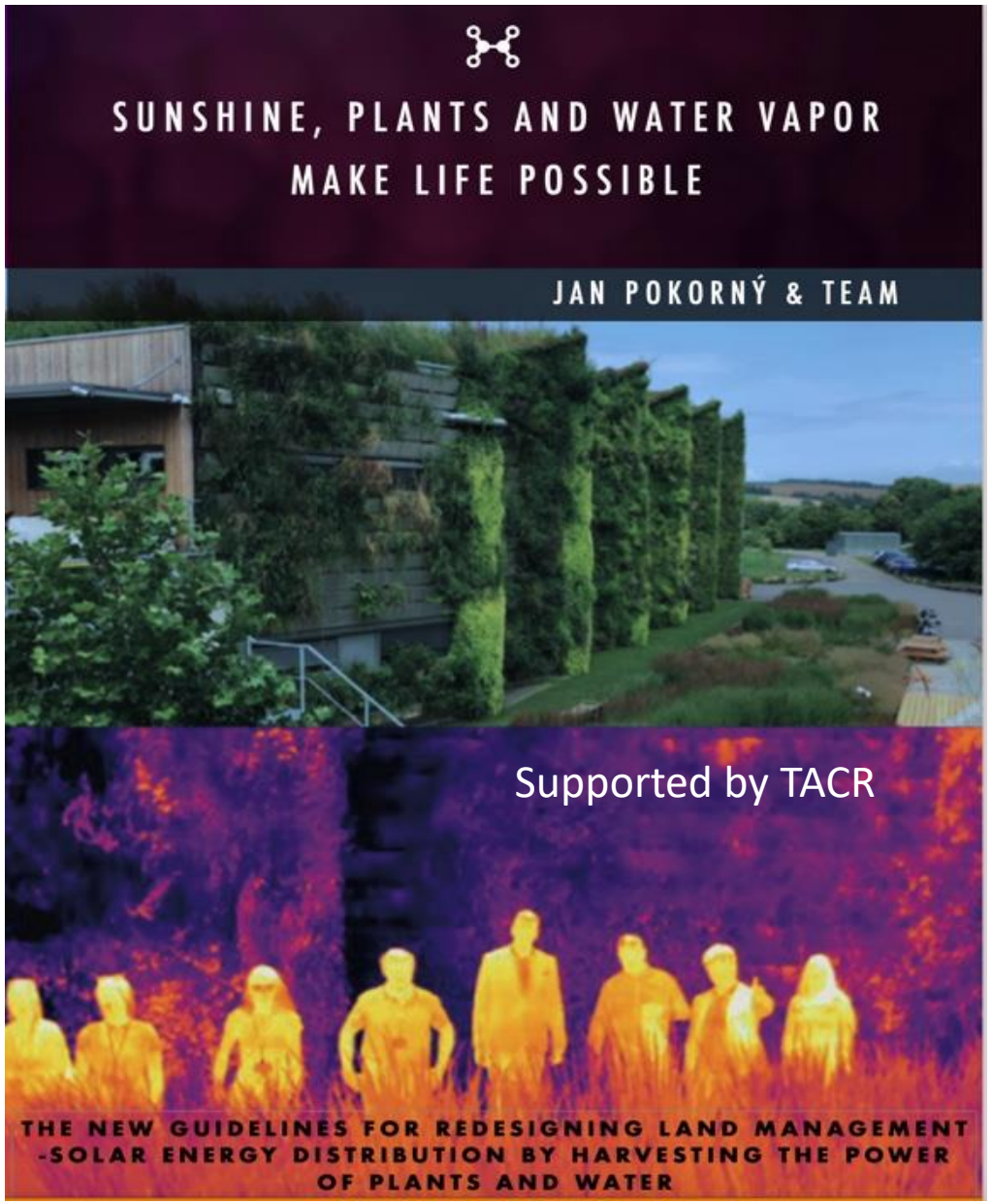
pokorny@enki.cz

ERASMUS project
Education for Plant Literacy
https://planteducation.eu

www.waterparadigm.org
Water for the Recovery of Climate
In six languages

TACR project with
Faculty of Education
University of South Bohemia in České Budějovice (in Czech)
https://projekty.pf.jcu.cz/svv/metodika_zs.php





Stop desertification and bring back water and vegetation:

- Air-conditioning via short water cycle
- More biomass, more food
- Biodiversity increase
- Carbon sequestration
- Recycling of nurients and water
- Employment
- **Any negative effect??**

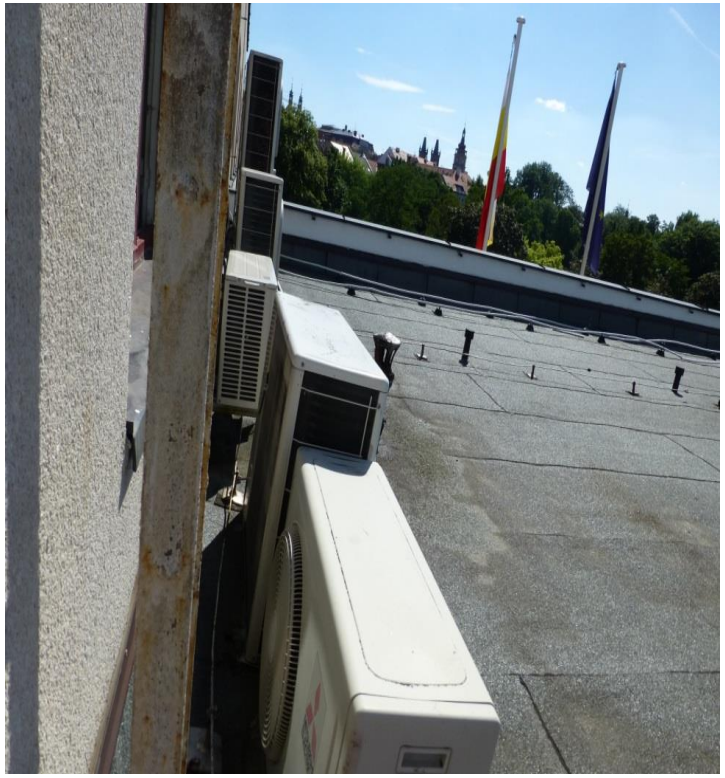
877 W/m²
51.0 °C
124 Fahrenheit

Sap flow/evaporation
20 litres/hour
14 kW cooling
Latent heat of 1kg water = 0.7kWh

Photosynthesis c. 0.2 kW

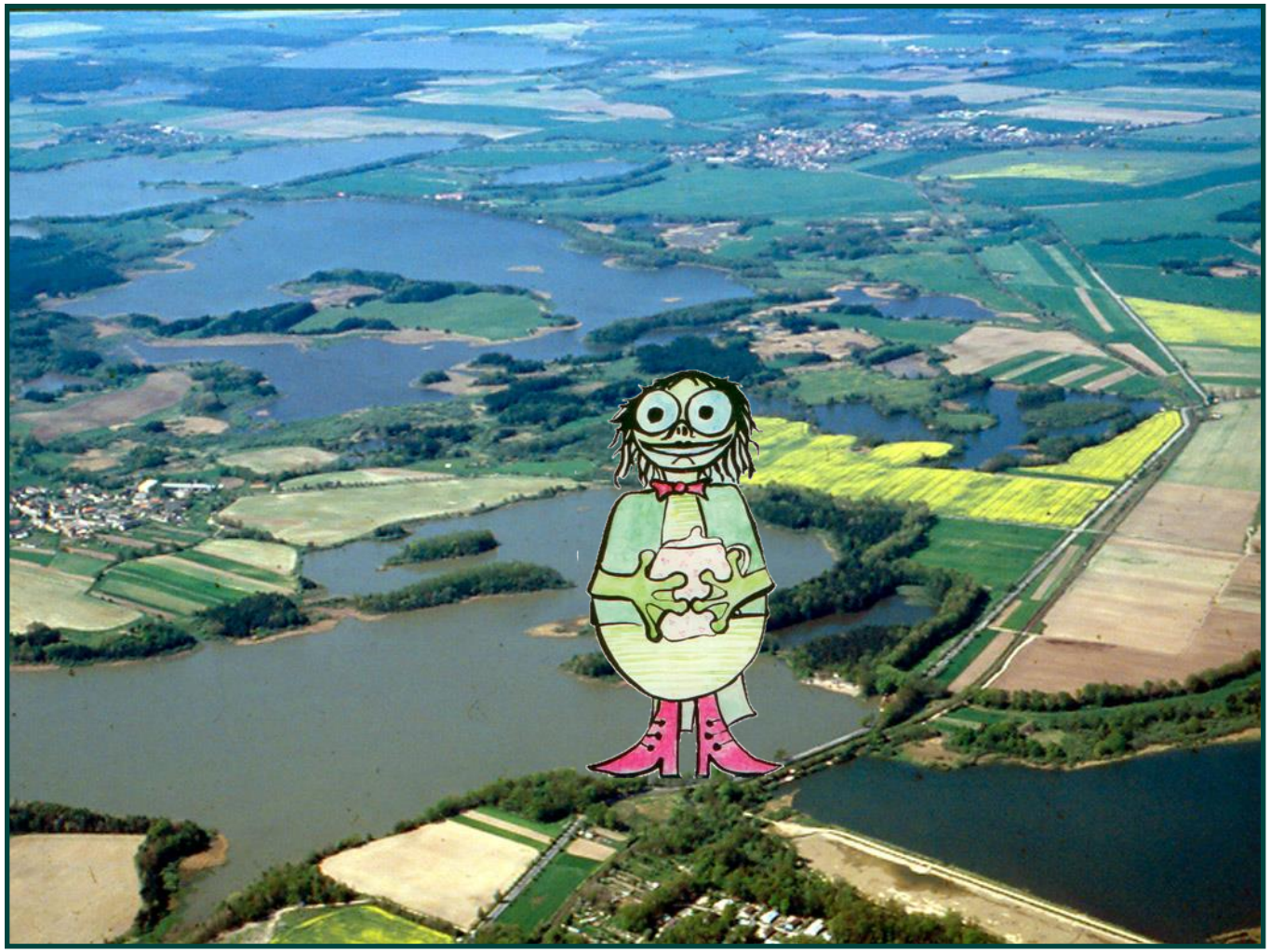
82 W/m²
26.9 °C
80 Fahrenheit

One large tree cools like 4 air conditioners.
The air conditioner cools inside and heats outside!
Where does the tree send heat?



One air conditioner consumes 3.4 kW

Man made landscape from the Middle Ages



By managing water and vegetation, we direct flows solar energy, determine water quality and influence climate(condensation driven air mass movement)