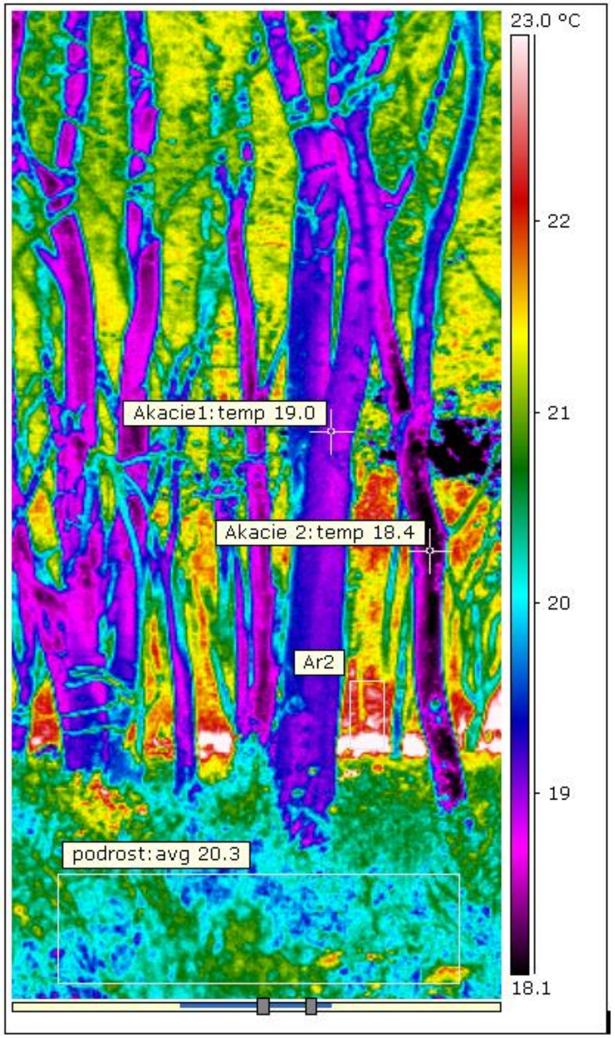
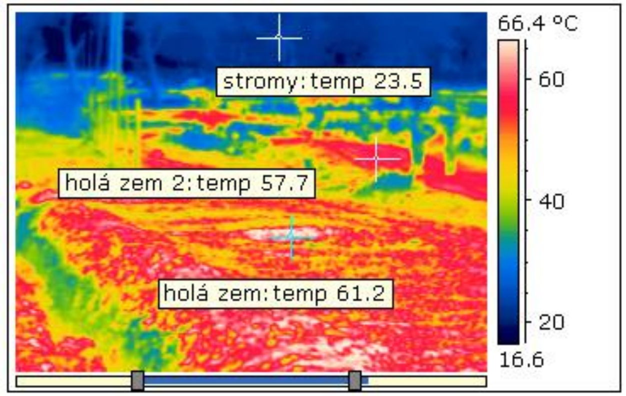
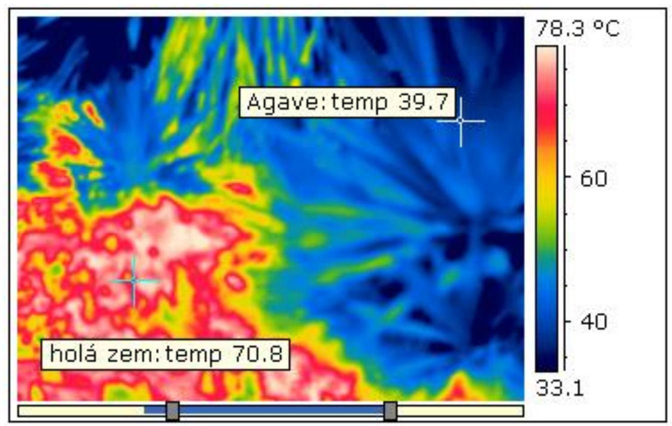
Role of wetlands and vegetation in water cycle and climate

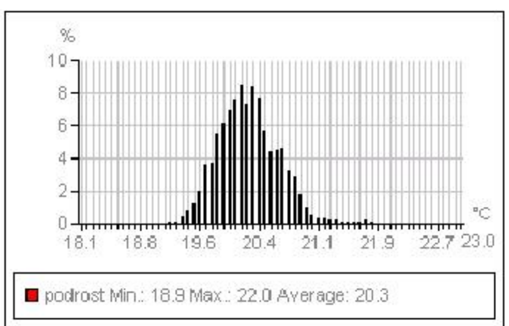
Jan Pokorný

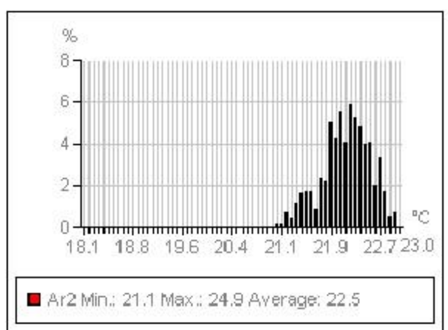




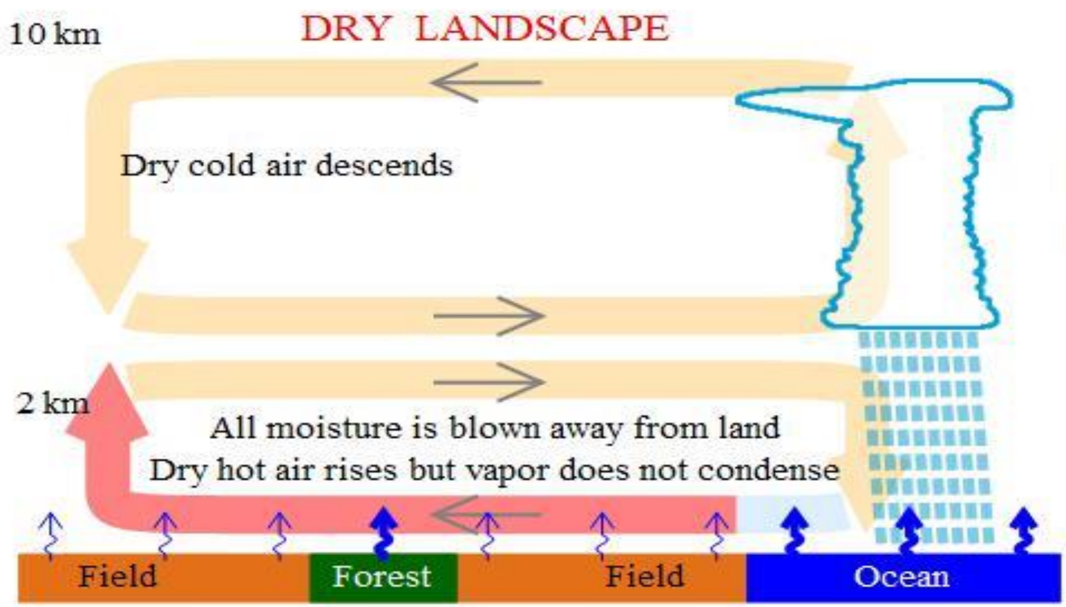
Sand has lowest albedo but highest temperature

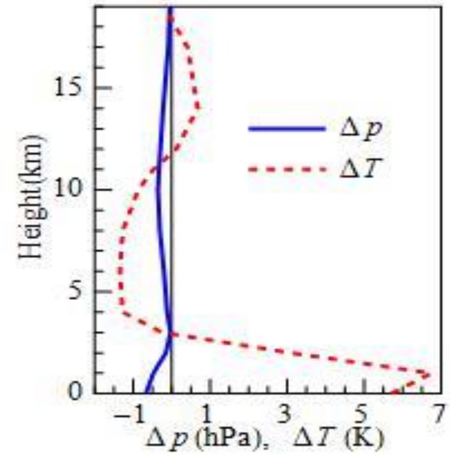




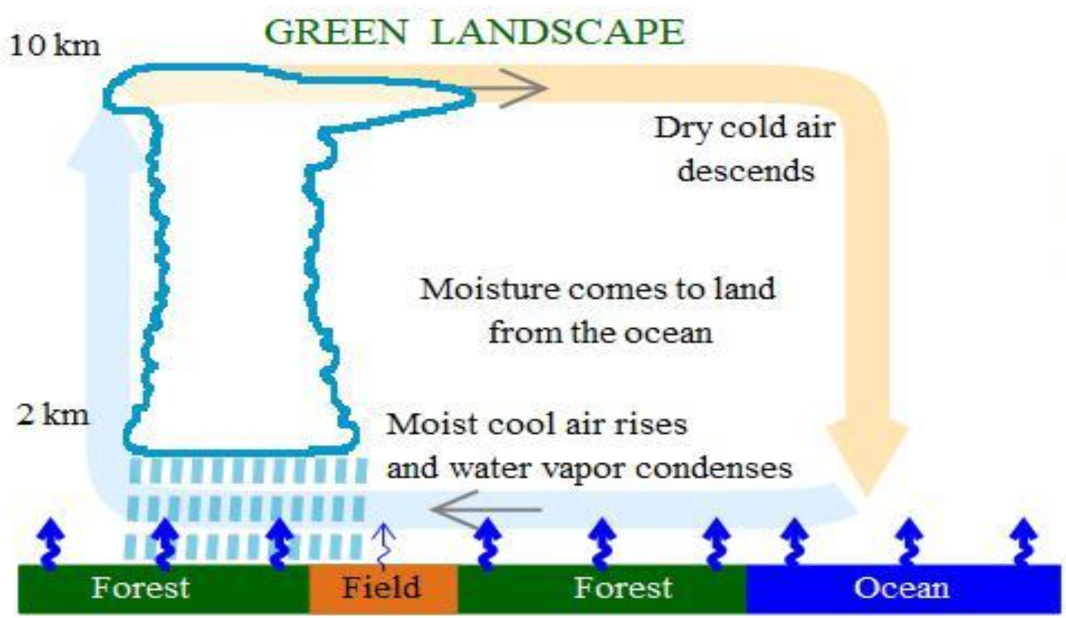


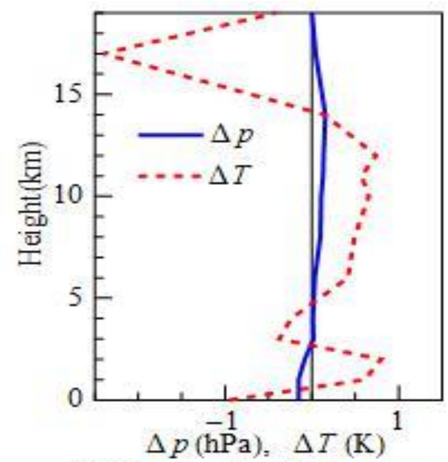
Accacia forest about 20 C
bare land up to 70 C



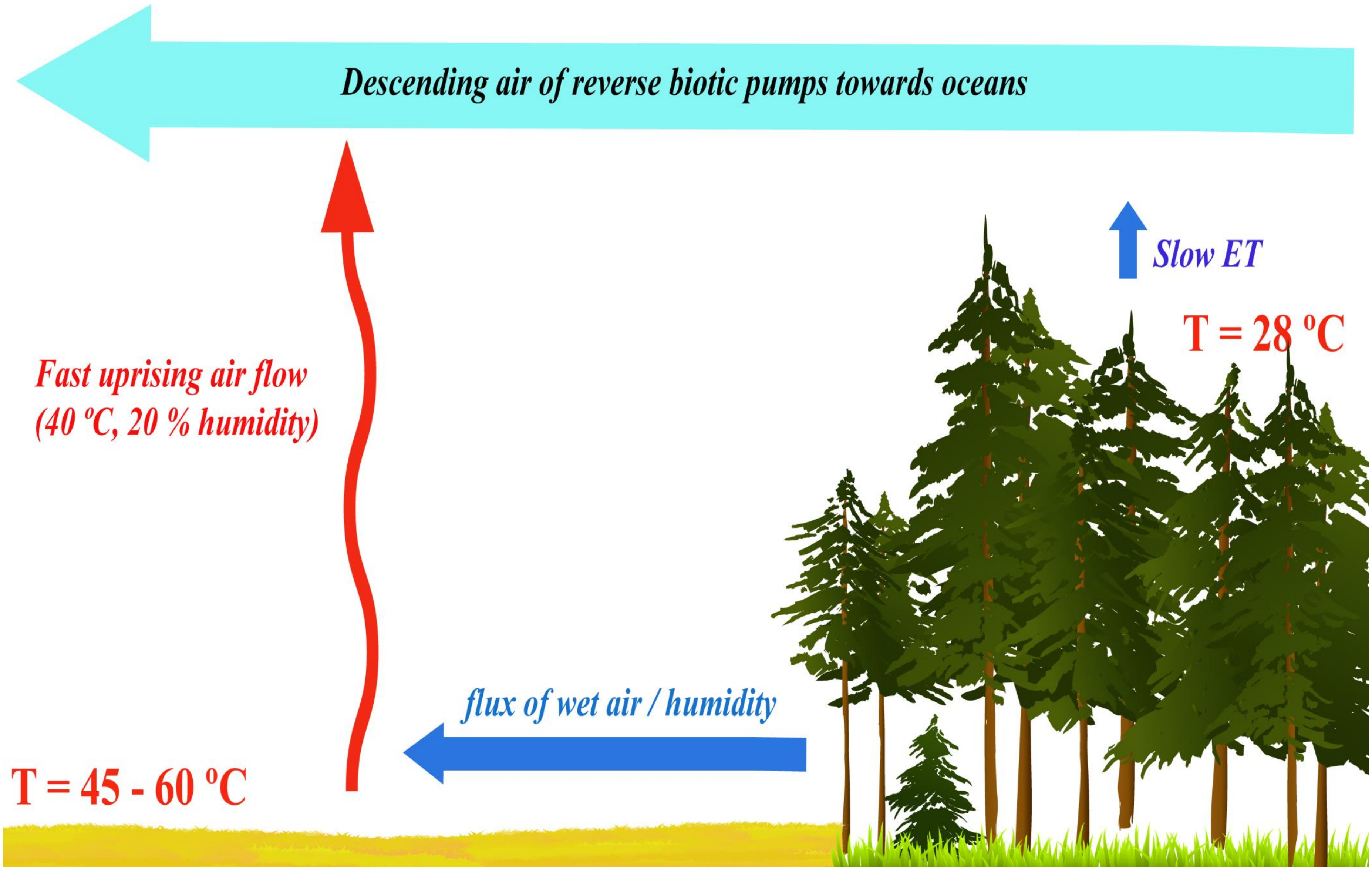


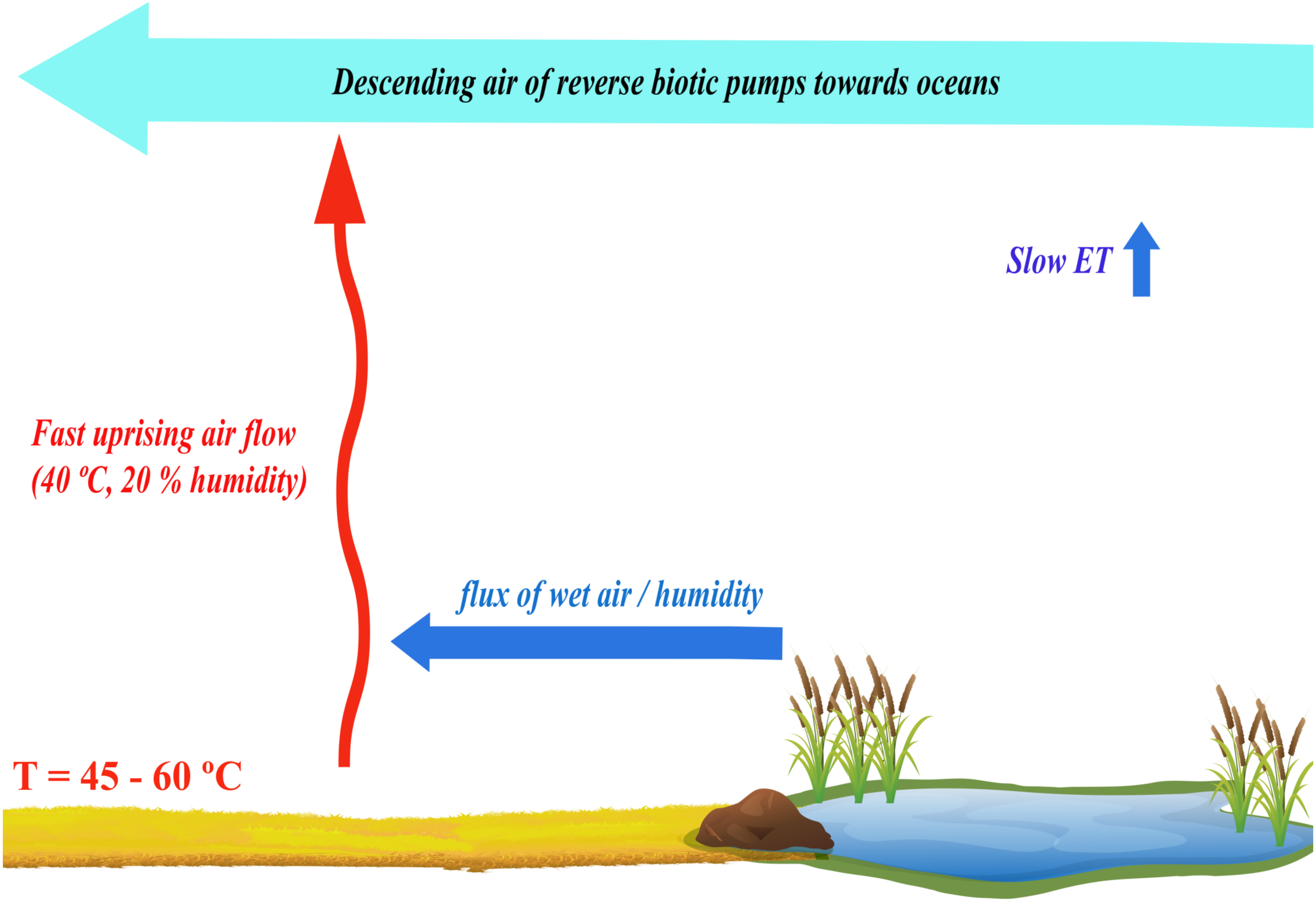
Differences in air pressure and temperature between Sahara and Atlantic ocean in March





Differences in air pressure and temperature between the Amazon and Atlantic ocean in February


Descending air of reverse biotic pumps towards oceans
Slow ET
T = 28 ºC
Fast uprising air flow
(40 ºC, 20 % humidity)
flux of wet air / humidity
T = 45 - 60 ºC


Descending air of reverse biotic pumps towards oceans
Slow ET
Fast uprising air flow
(40 ºC, 20 % humidity)
flux of wet air / humidity
T = 45 - 60 ºC

Landscape drying:

- It should be pointed out that air heated by warm surface and ascending into atmosphere contains water vapor. Landscape loses water with the upwards flowing warm air driven by sensible heat. The amount of water in the air transported by sensible heat high into atmosphere can be substantially higher than that released by evapotranspiration.
- For example, air of 100% relative humidity and temperature 40C contains 50 g of water vapor in 1 m3 that is, such air of 20% relative humidity contains still 10 g of water vapor in m3. Air driven by sensible heat from 1 m2 at speed 1 m/ s1 would transport into atmosphere 36 kg water during 1 h.

Evapotranspiration x drying

- Common value of ET is several millimeters (several liters per m2 per day). Very high value of ET is about 10 mm. From this point of view, ET can be considered as a process of slowing down evaporation water losses from landscape on regional level.
- ET binds surplus of solar energy into latent heat of water vapor and reduces release/production of sensible heat, water vapor is not driven up it stays close to the canopy.

Plants are perhaps the most advanced instrument yet evolved for degrading incoming solar radiation. A corollary to nature´s abohorrence of a gradient is that when a gradient is imposed on a system it can develop processes and structure that will hold material and energy from going to equilibrium immediately while degrading the imposed gradient as thoroughly as possible.

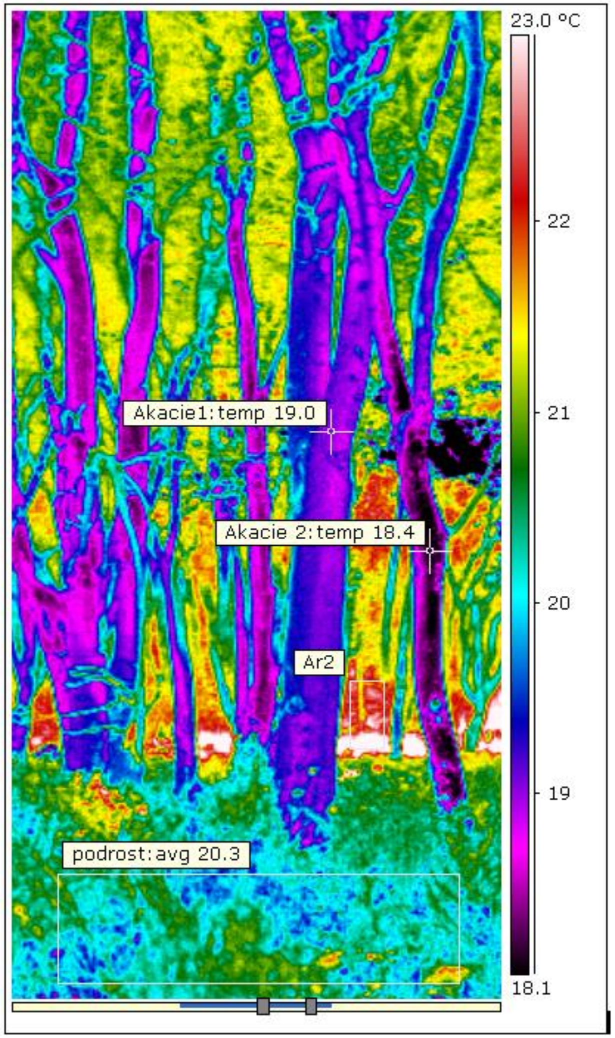
In the Cool – Energy Flow, Thermodynamics, and Life. Eric Schneider, Dorion Sagan, University of Chicago Press, 2005

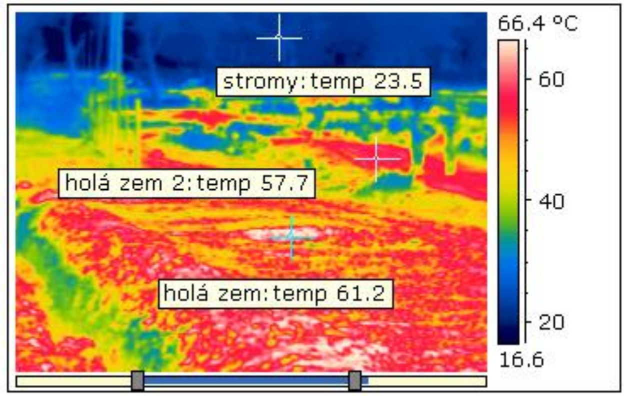
It is often claimed that evapo-transpiration from papyrus „wastes“ water because it is greater than evaporation from open water surface (e.g. motivation behind draining of the Sudd swamp of South Sudan to „save“ Nile water for Egypt). Some experimental researchers maintain that they proved that papyrus enhances water loss, however other claim opposite using similar experimental set ups.
It is an open issue. It depends on the surrounding climate and perhaps on the status of the papyrus swamp.

- Does wetland waste water? When?
- Sand or papyrus/reed, wetland?
- Our logic says: wetlands plants tranpirates they deprive land from water.
- Dead tree spends less water than living tree

Thermal pictures show cooling by evapotranspiration

- Papyrus stand
- Phragmites
- Forest
- Culture landscape





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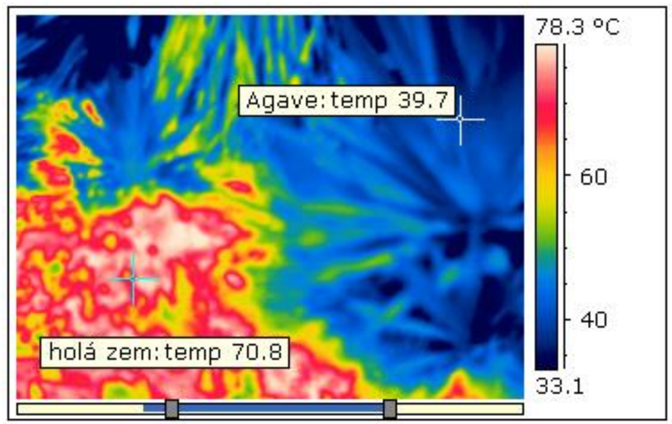
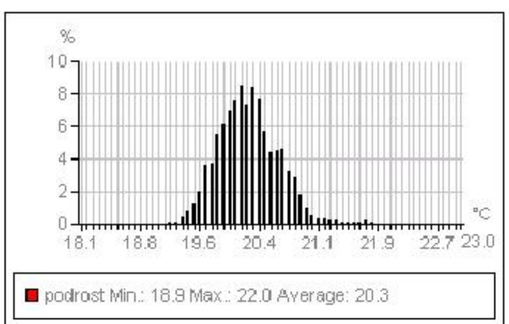
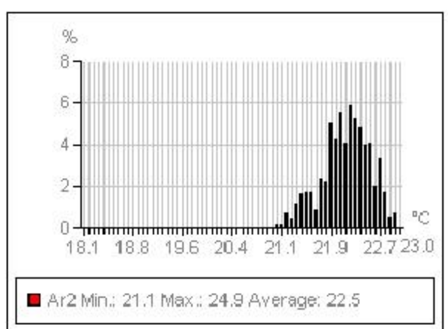






Accacia forest about 20 C
bare land up to 70 C

- t

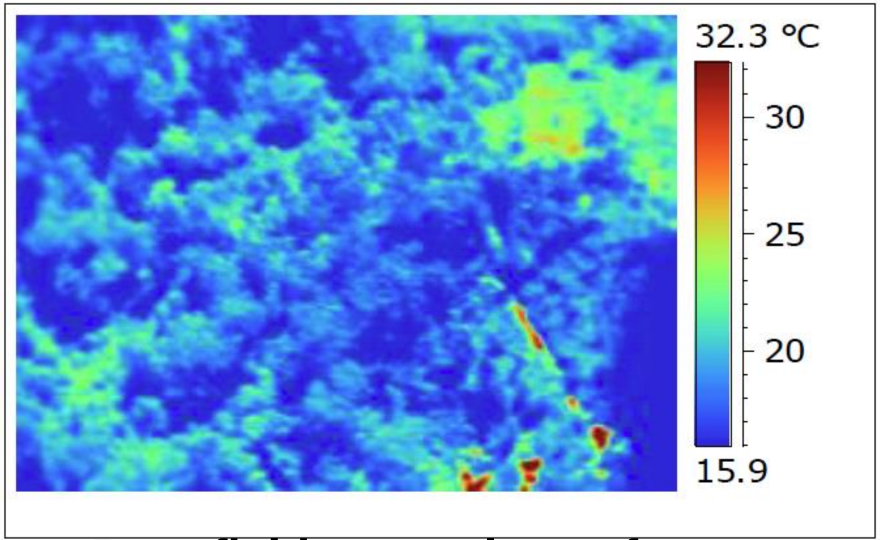
Thermopictures of MauForest

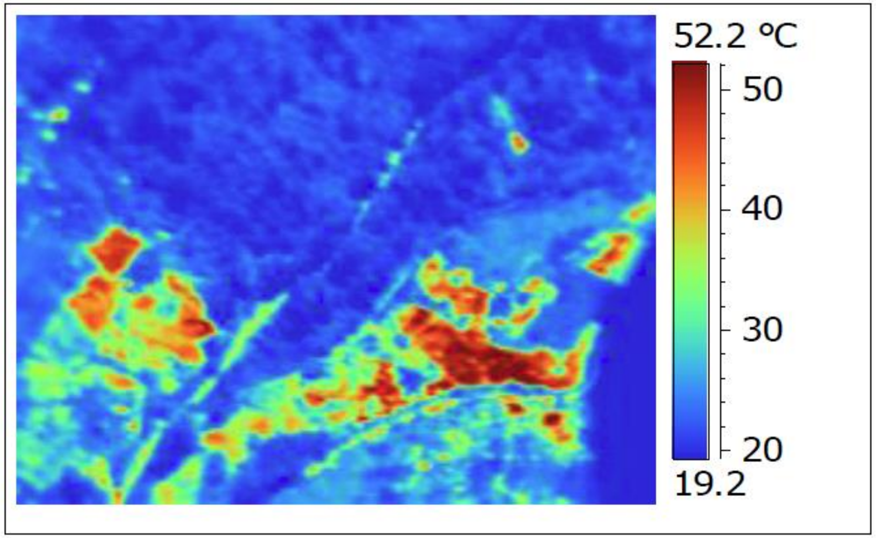
Taken from an aircraft
and from land
Altitude c. 3000m

Mountain forest atracts water
it is called „water tower“

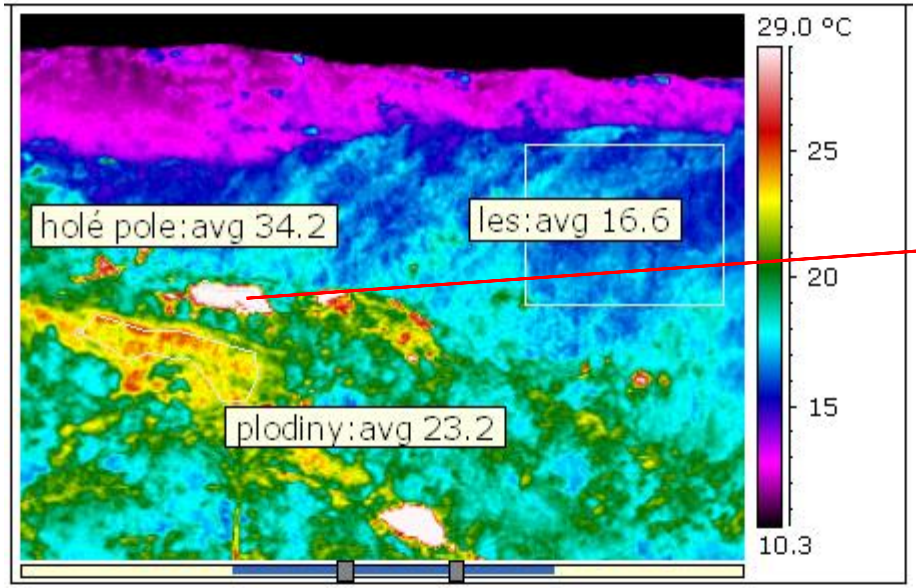
- Village Son Koi Kiminta located at cca 3000 m altitude has not allowed clearing of 600 ha forest. Local people know from experience that forest attracts due and creates mild rain.
- Forest clearing in vicinity of other villages resulted in rain shortage and early morning frost linked with crop decline.

Mau Forest (alt. c. 3000m)



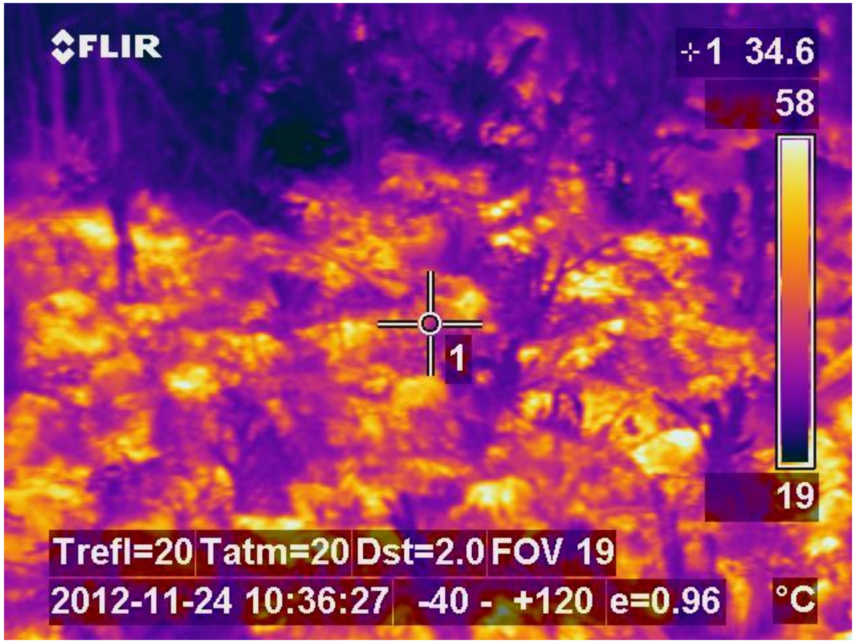


Bare field, crop plants, forest

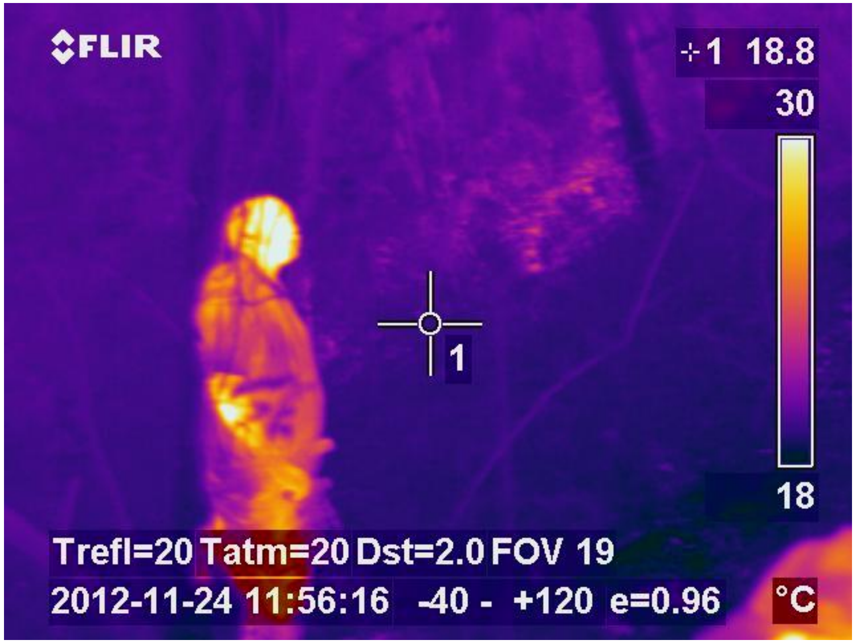


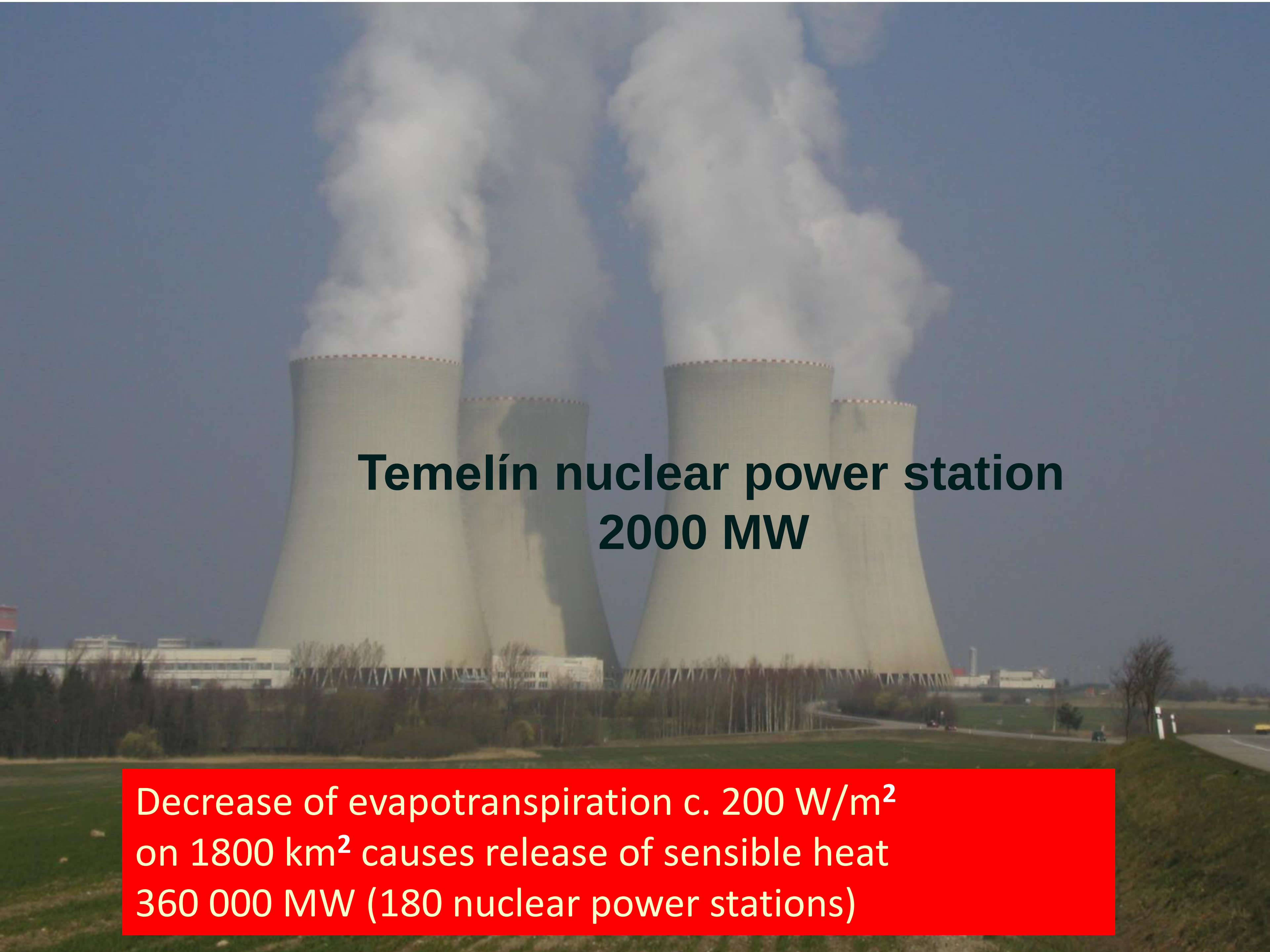
Deforested part

Surface temperature up to 58 centigrades



Temperature inside of a mountain forest
(50meters from the previous place)





Temelín nuclear power station
2000 MW

Decrease of evapotranspiration c. 200 W/m^2
on 1800 km^2 causes release of sensible heat
360 000 MW (180 nuclear power stations)

… few numbers

- consider air at temperature 25 ° C contains approx. 22 grams/ m^3; at 40 ° C has a doubled capacity (50 g / m^3)
- Deforestation and the consequent rise of temperature lead to a transport of warm and relatively dry air into the upper atmosphere
- Hot air = higher capacity to suck up water = the transport of water vapour by the overheated air out of short water cycle
- Decrease in evapotranspiration of about 2 mm/ km2/day = decrease in evaporation of 2 000 000 litres
- To evaporate 1 liter we need 0,7 kWh (2 500kJ)
- Latent heat of vaporisation of 2 000 000 litres of water = 1.4 million kWh
- If there is no water = no latent heat - release of 1.4 million kWh of sensible heat/ day

- The Mau Forest complex has lost 1800 km^2 in 23 years

- This means 2,6 billion kWh of sensible heat released from this area a day

- For comparison, a quarterly production of the well-known Czech nuclear power plant Temelin (2000 MW) in 2012 was 4,4 billion kWh

Monitoring temperature changes across landscapes as a result of forest losses

Infrared images document how vegetation regulates the temperature and the water cycle in a tropical catchment

Pokorný, J., Hesslerová, P., Pacini, N., Morrison, E.H.J., Harper, D. M.

Imarisha Scientist-Citizens WorkshopNaivasha, November 2013

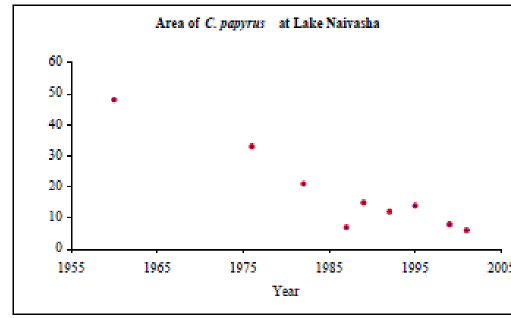
Locality: Naivasha

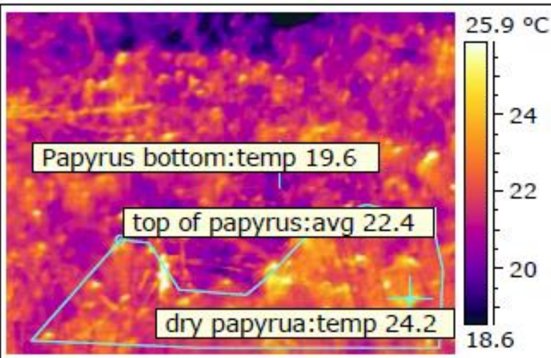
Estimated air temperature: 22 - 26 °C, relative humidity 85%

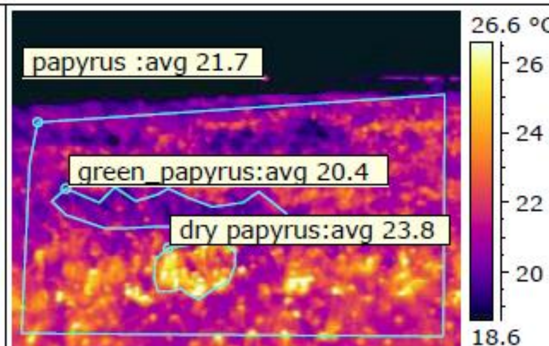
Sunshine, partly cloudy

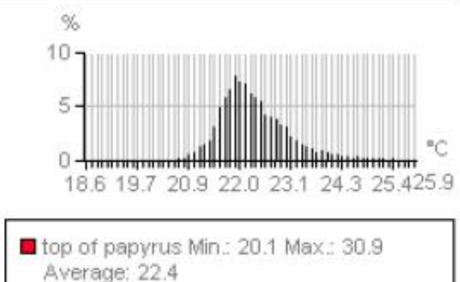
Location: S 0°49´34,38 E 36°20´22,32

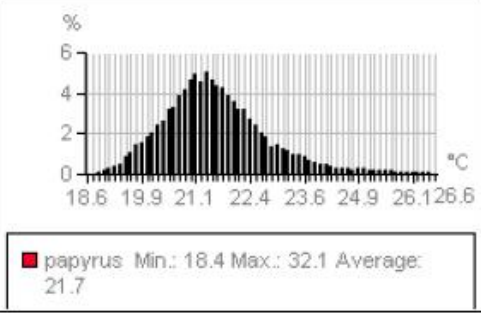
Date: 30 July 2012; Local time: 14:00

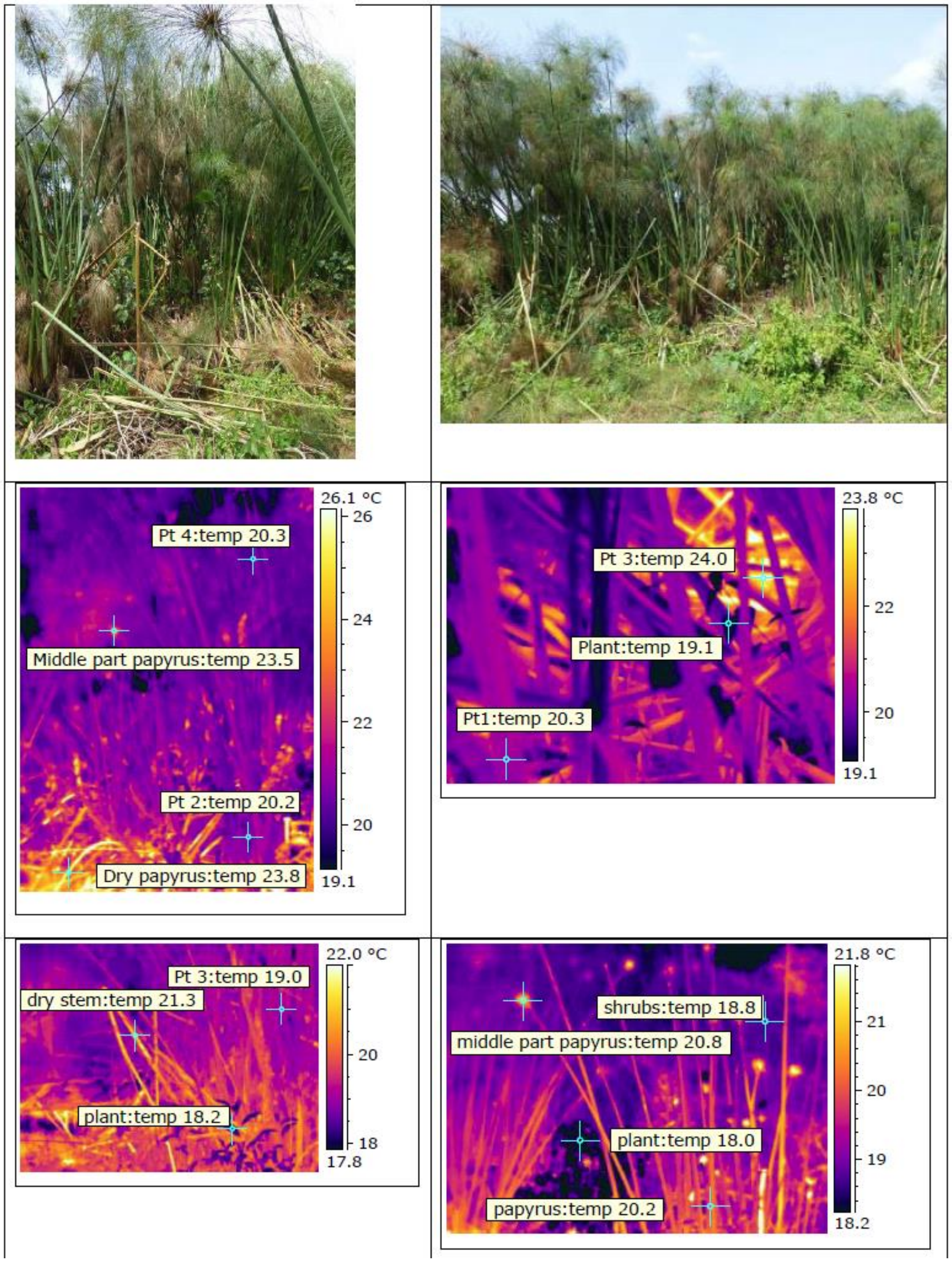








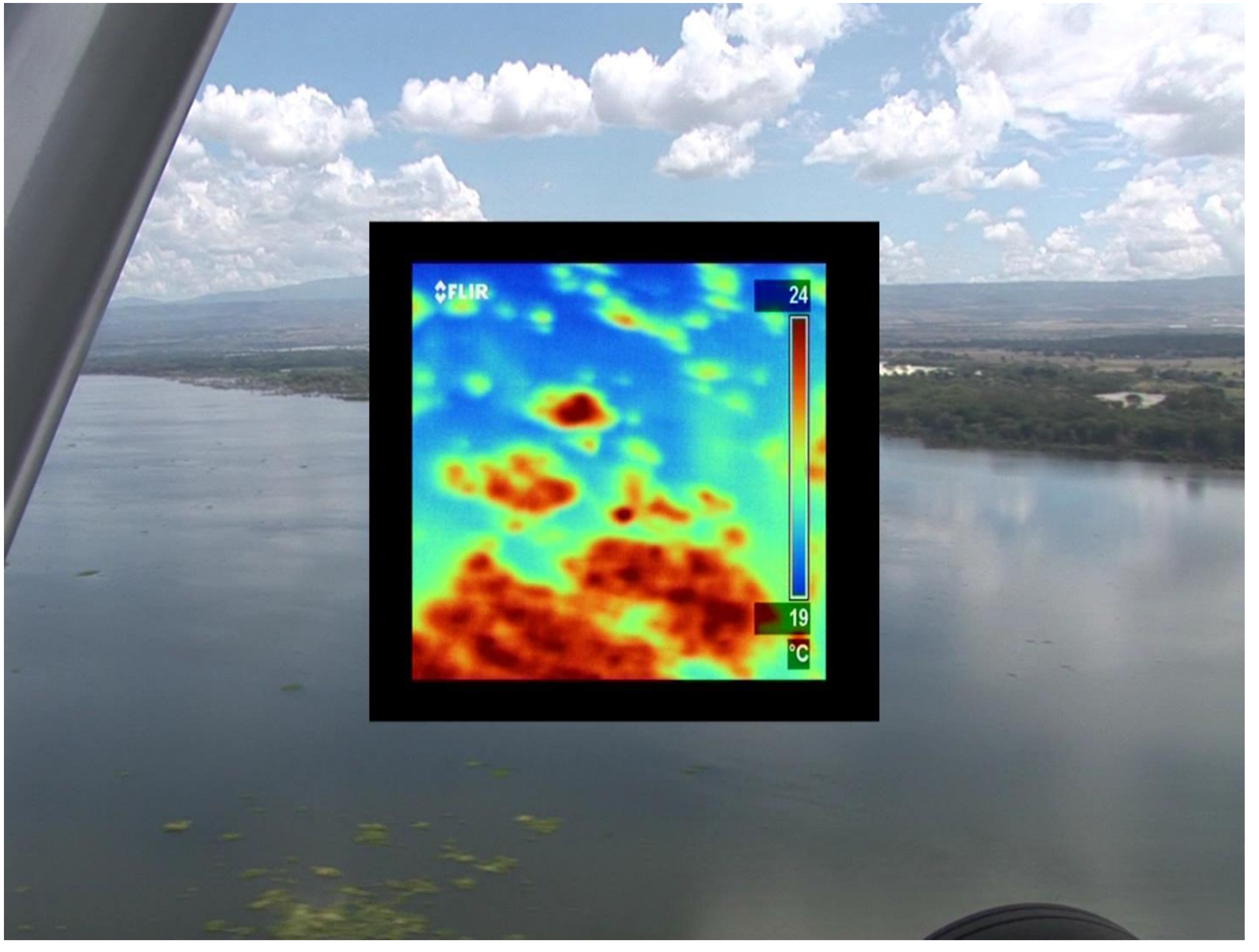


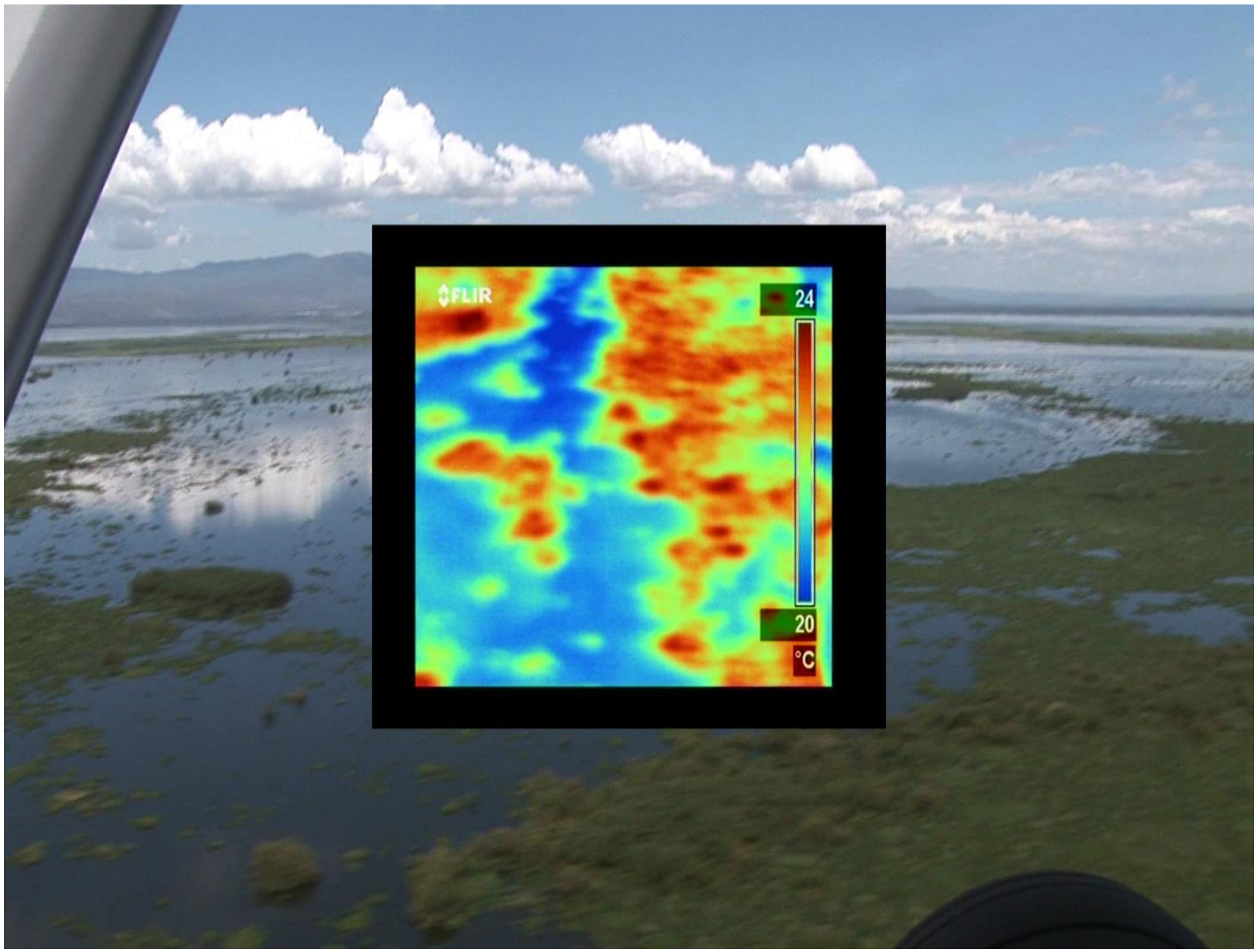

26.1 °C
26
24
22
20
19.1
Pt 4:temp 20.3
Middle part papyrus:temp 23.5
Pt 2:temp 20.2
Dry papyrus:temp 23.8
23.8 °C
22
20
19.1
Pt 3:temp 24.0
Plant:temp 19.1
Pt1:temp 20.3
22.0 °C
20
18
17.8
Pt 3:temp 19.0
dry stem:temp 21.3
plant:temp 18.2
21.8 °C
21
20
19
18.2
shrubs:temp 18.8
middle part papyrus:temp 20.8
plant:temp 18.0
papyrus:temp 20.2

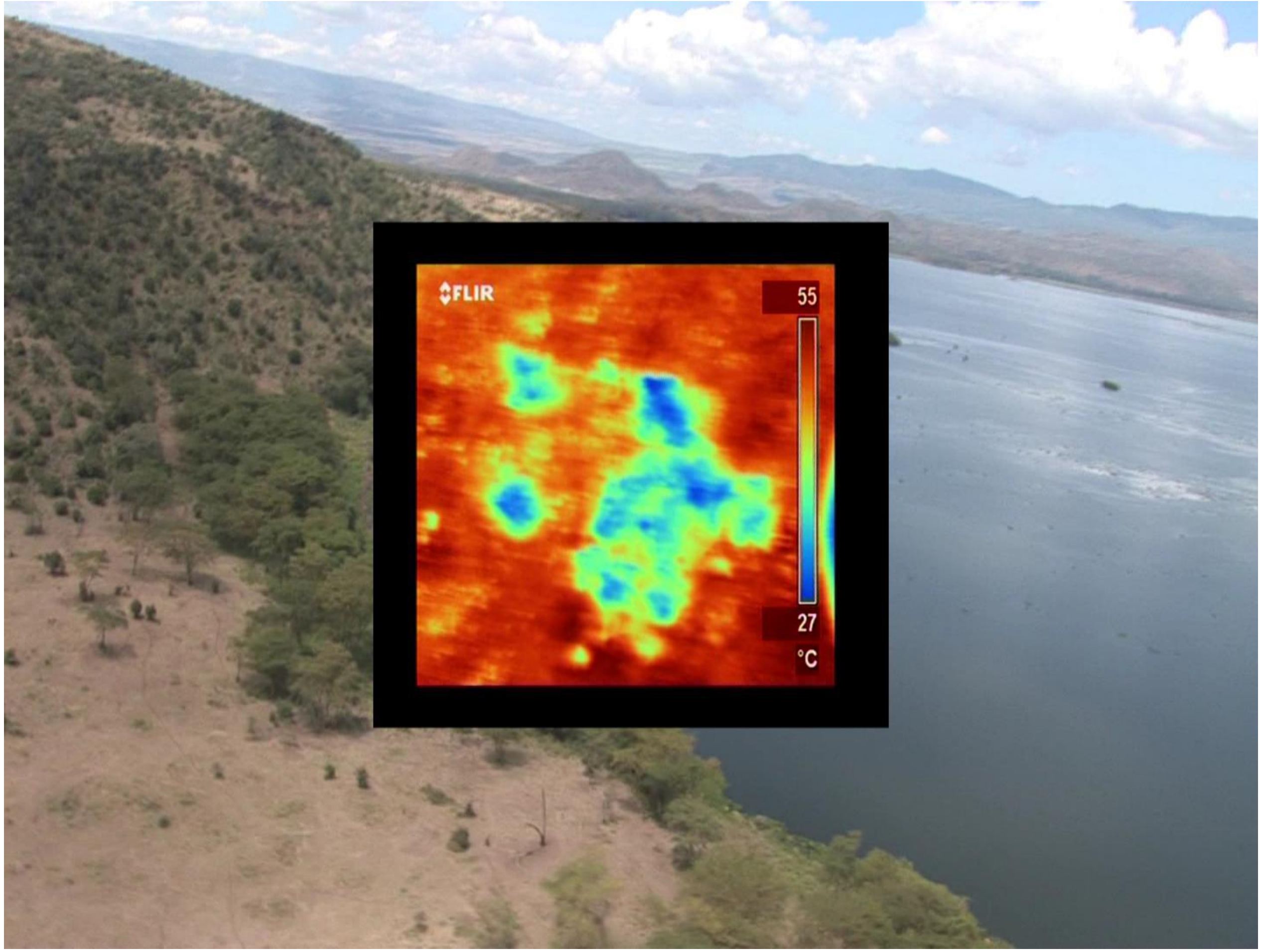
Infrared images document how vegetation regulates the temperature and the water cycle in a tropical catchment

Pokorný, J.*[1], Hesslerová, P.[1,2], Pacini, N.[3], Morrison, E.H.J.[4], Harper, D. M.[5]

SIL Budapest 8.8. 2013


FLIR
24
19
°C


FLIR
24
20
°C


FLIR
55
27
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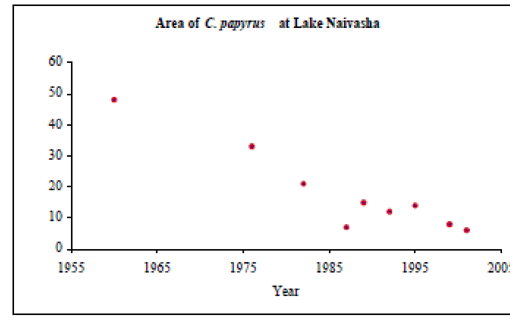
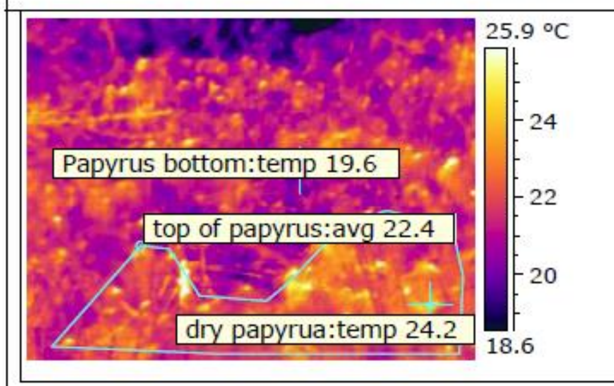
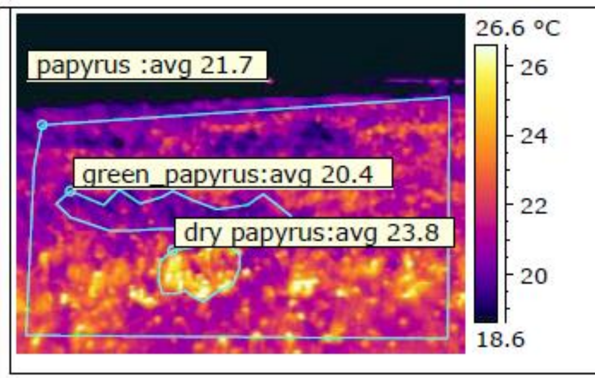
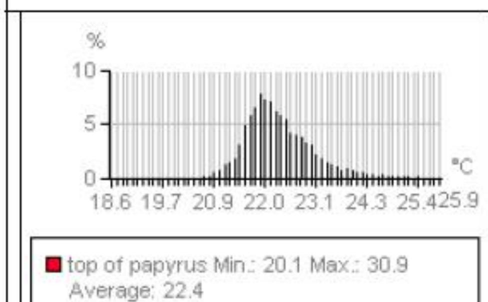
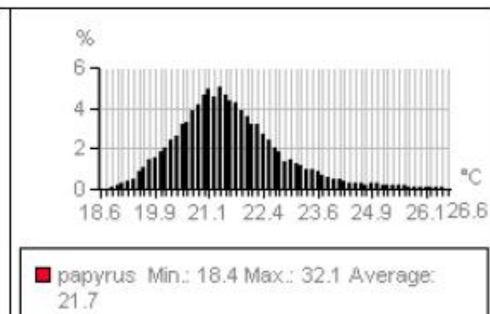
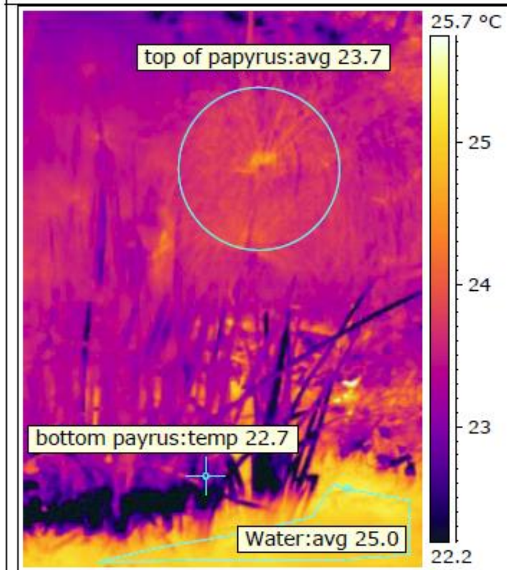


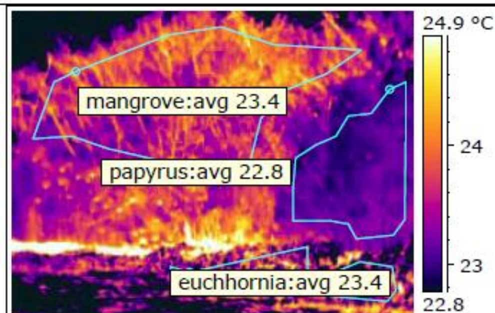


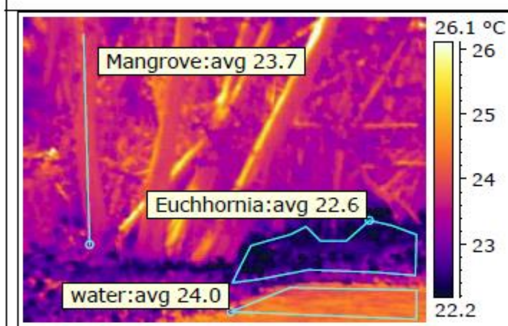


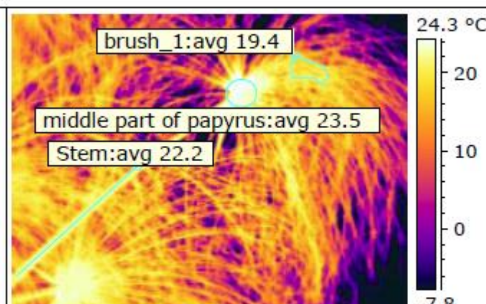












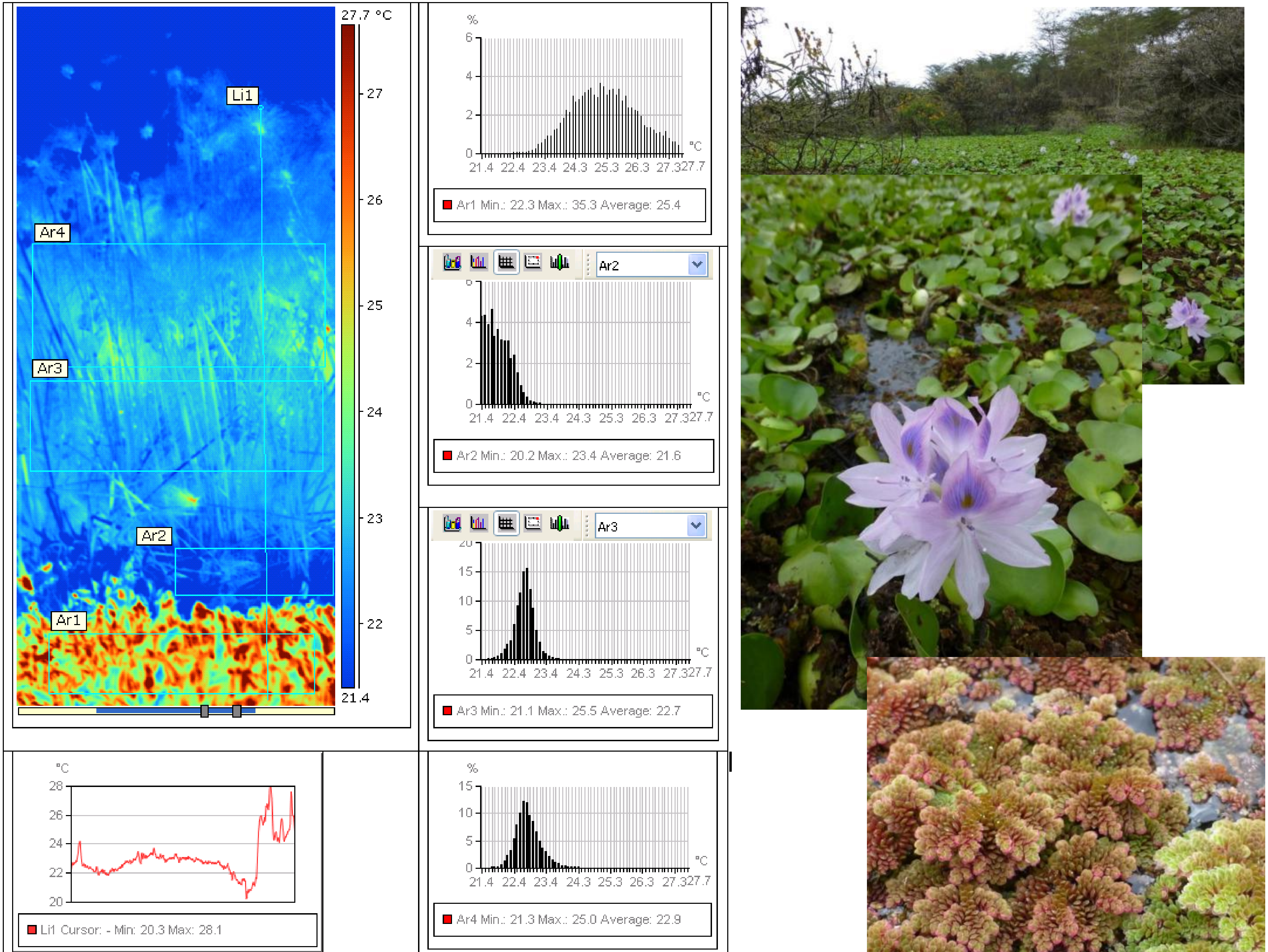
Locality: Lake Victoria

Estimated air temperature: 30 °C, relative humidity 95%

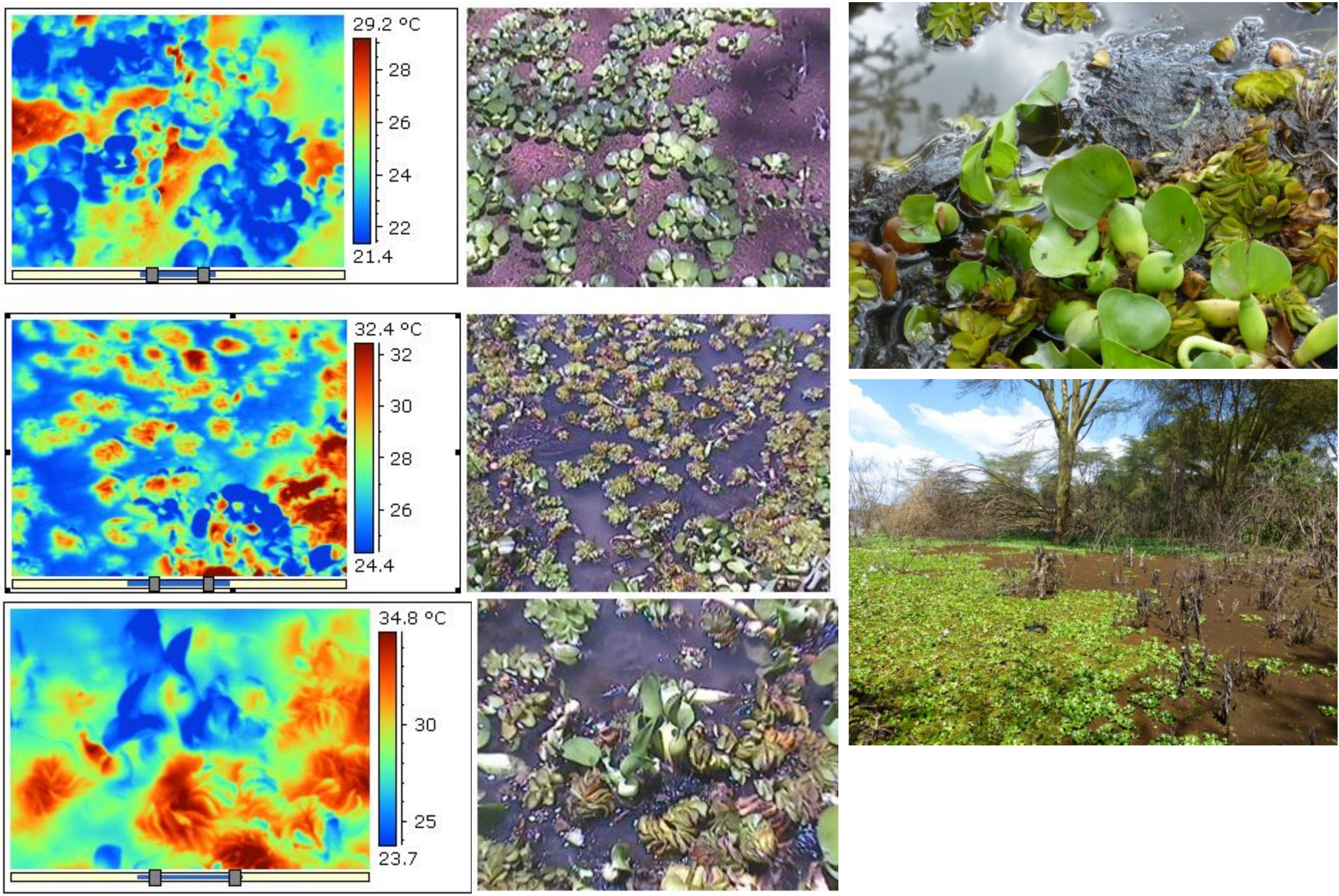
Sunshine, a light haze

Location: S 0°09´29,42 E 34°44´38,68

Date: 29 June 2012; Local time:10:30 – 12:00



27.7 °C
27
26
25
24
23
22
21.4
Li1
Ar4
Ar3
Ar2
Ar1
%
6
4
2
0
°C
21.4 22.4 23.4 24.3 25.3 26.3 27.3 27.7
Ar1 Min.: 22.3 Max.: 35.3 Average: 25.4
Ar2
Ar2 Min.: 20.2 Max.: 23.4 Average: 21.6
Ar3
15
10
5
Ar3 Min.: 21.1 Max.: 25.5 Average: 22.7
Ar4 Min.: 21.3 Max.: 25.0 Average: 22.9
28
26
24
22
20
Li1 Cursor: - Min: 20.3 Max: 28.1



Salvinia molesta, Eichhornia crassipes

- *In reality, however, a tree is best understood as a giant degrader of energy. Each new leaf, each new phototrophic rearrangement, is a new opportunity for energy degradation. In short, the Cartesian statement "I think therefore I am" becomes "I am because I dissipate". .*
-

- Plants cool themselves by evapotranspiration and equalize temperature differences within canopy. Adult forest is characterised by inversion vertical temperature: lower temperature at ground and higher temperature on surface of a canopy. Relatively cool air stays in the canopy during a sunny day and evaporation is controlled just by crowns on top. Such a forest does not lose much water in comparison with sparse vegetation or simple crops in which ground temperature is higher than temperature on top of a canopy: hot air transports water vapour fast to up to atmosphere.
-

- Plants cool themselves by evapotranspiration. Mature forest (papyrus) is characterized by vertical temperature inversion: lower temperature at ground level and higher temperature in the canopy. Relatively cool air remains under the canopy during a sunny day, while evapotranspiration involves only the top of the tree crowns

- Thus forest, well established wetland stand do not lose much water in comparison with sparse vegetation or simple crops. Under sparse vegetation conditions, a permanent ascending hot air stream is created, through which large amounts of water vapour are moved up into the atmosphere, desiccation the soil.

- Our objective was this to:
- Demonstrate whether papyrus swamps acted as a forest, maintaining an inverse (equal) temperature gradient inside, so that vegetation stands are able to maintain humidity within the ecosystem, minimizing evaporation from the water of the swamp and minimizing loss from the stand to atmosphere

Methods

- Temperature images taken inside and outside papyrus, reed, alder stands by FLIR FPA ThermaCAM™ thermo-vision camera
- Comparative images taken of natural forests, semi-natural scrubland, alien aquatic vegetation and open water

- Papyrus cools itself by evapotranspiration to 20 – 24 C. Bare land has temperature of 60 – 70 C. Hot air rises from hot bare land and takes water vapour to atmosphere. Low temperature of papyrus prevents rapid rise of air to atmosphere, air low temperature has high relative humidity (e.g. early morning fog above papyrus) and potential evapotranspiration is low. Water vapour condensates on cool surfaces of papyrus. Hot land surface serves as a donor of water vapour for other regions, cool landscape surface is acceptor of water vapour (sensu biotic pump Gorshkov Makarieva 2007)