Remote sensing based evapotranspiration mapping:

Applications

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Background on CREMAP

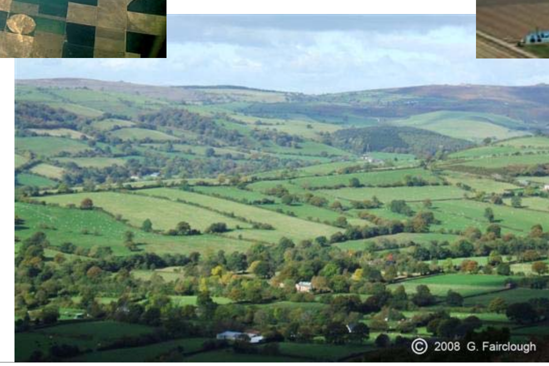
- ET cools the surface very effectively → land surface temperature (T_s) must be related to ET rate

- From observations (included in SEBAL, METRIC models): near surface air temperature gradient (d_zT_a) is directly proportional to T_s

- If there is a suitable spatial scale over which surface properties do not change significantly → net energy at the surface and aerodynamic resistance (r_a) are near constant → ET is directly proportional to T_s ← sensible heat flux (d_zT_a / r_a) is directly proportional to T_s

US

Germany



UK

The MODIS scale

The 1km spatial scale of MODIS T_s data (from 2000 on) is ideal:

- surface albedo typically changes minimally among the cells in temperate regions (for Nebraska: 17±1.2%) → net energy at the surface can be near constant for flat or rolling terrain
- is large enough to have various cover types within most of the cells → r_a may become near constant for time periods of days or longer (under neutral conditions r_a relates to the logarithm of the roughness height)Slide 4
- is small enough to give good resolution at the watershed scale

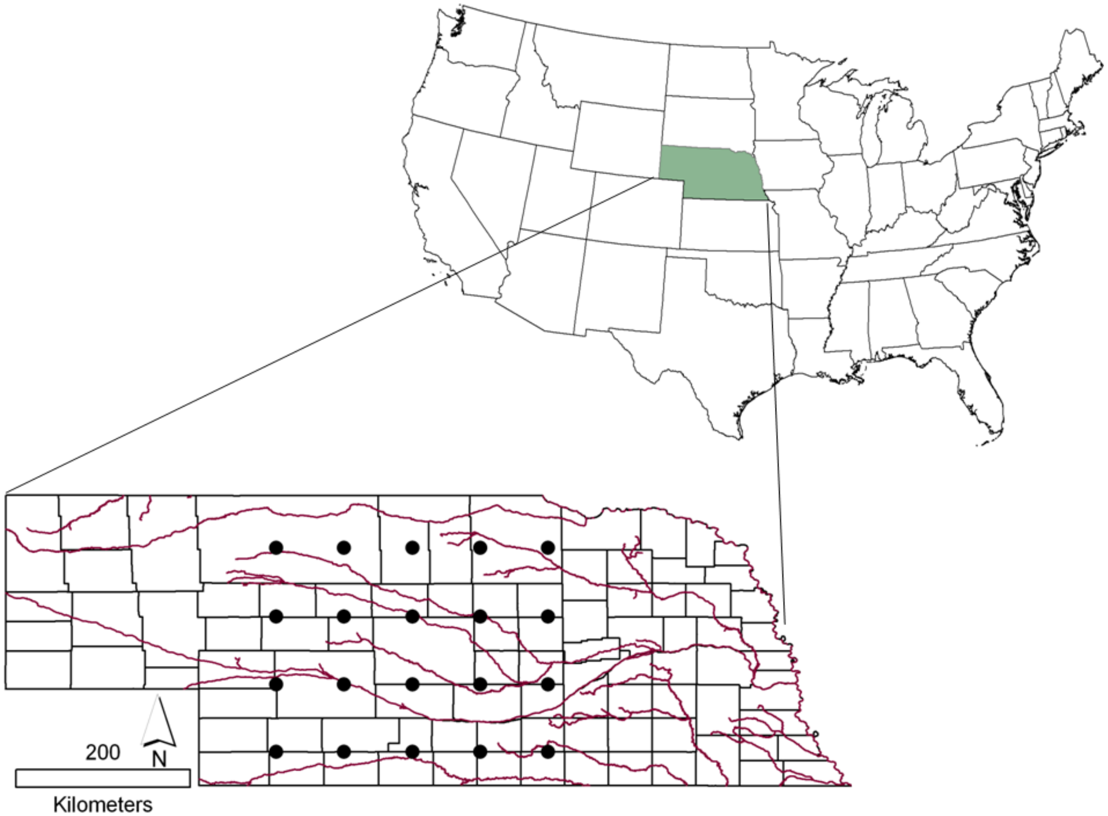
$$r_a = \ln(z_2/z_1) / u_*k$$

$$u_*=ku_{200} / [\ln(200/z_{0m})]$$

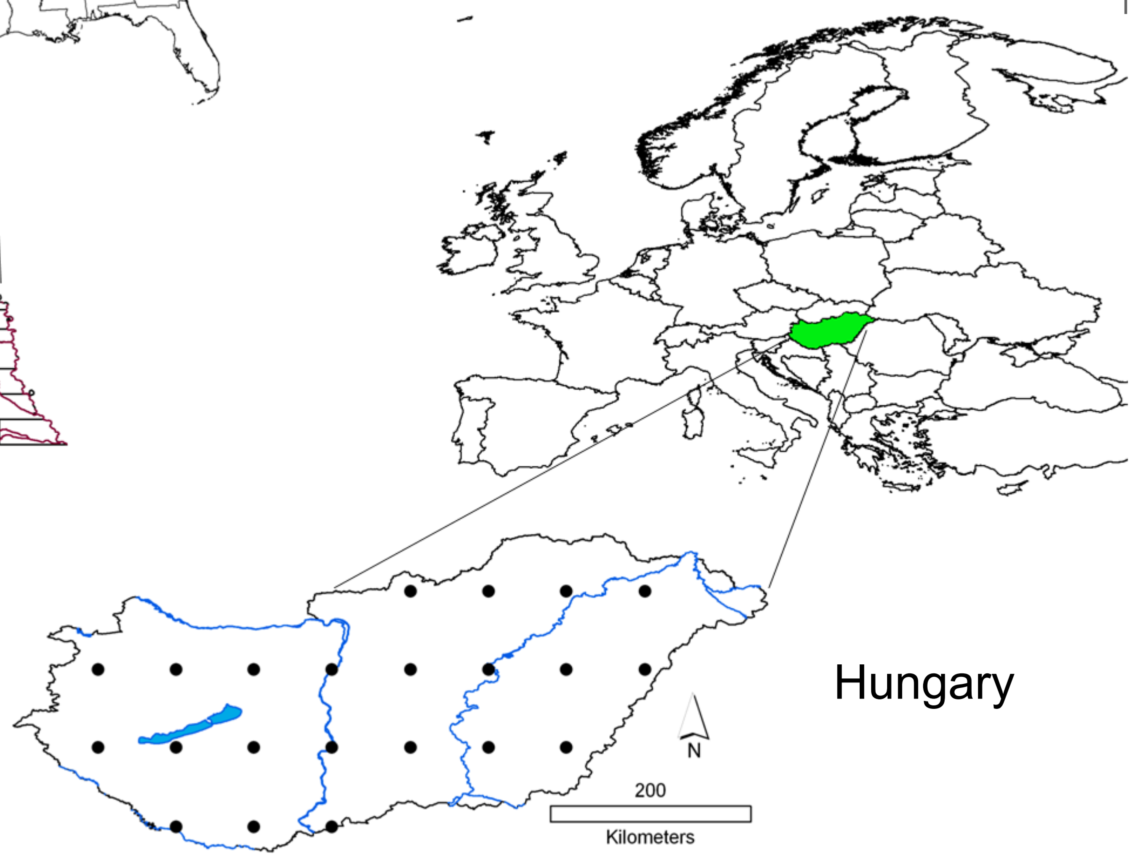
after Allen et al. (2007)

T_s – **ET direct proportionality:** empirical evidence

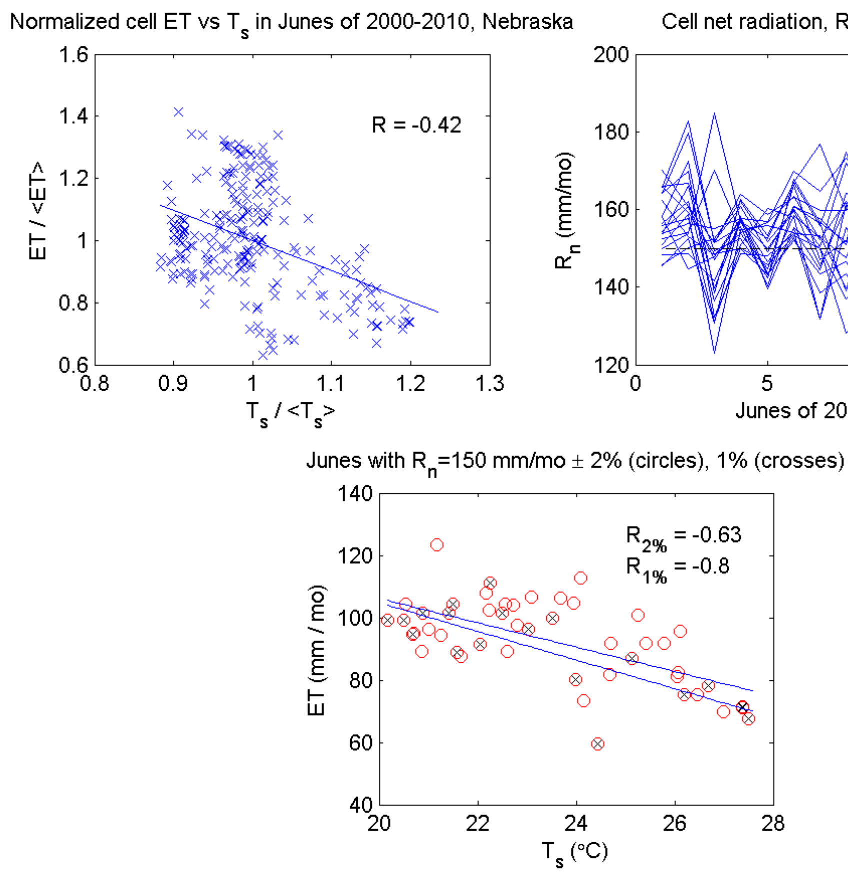
ERA-Interim reanalysis cells (~70 km)

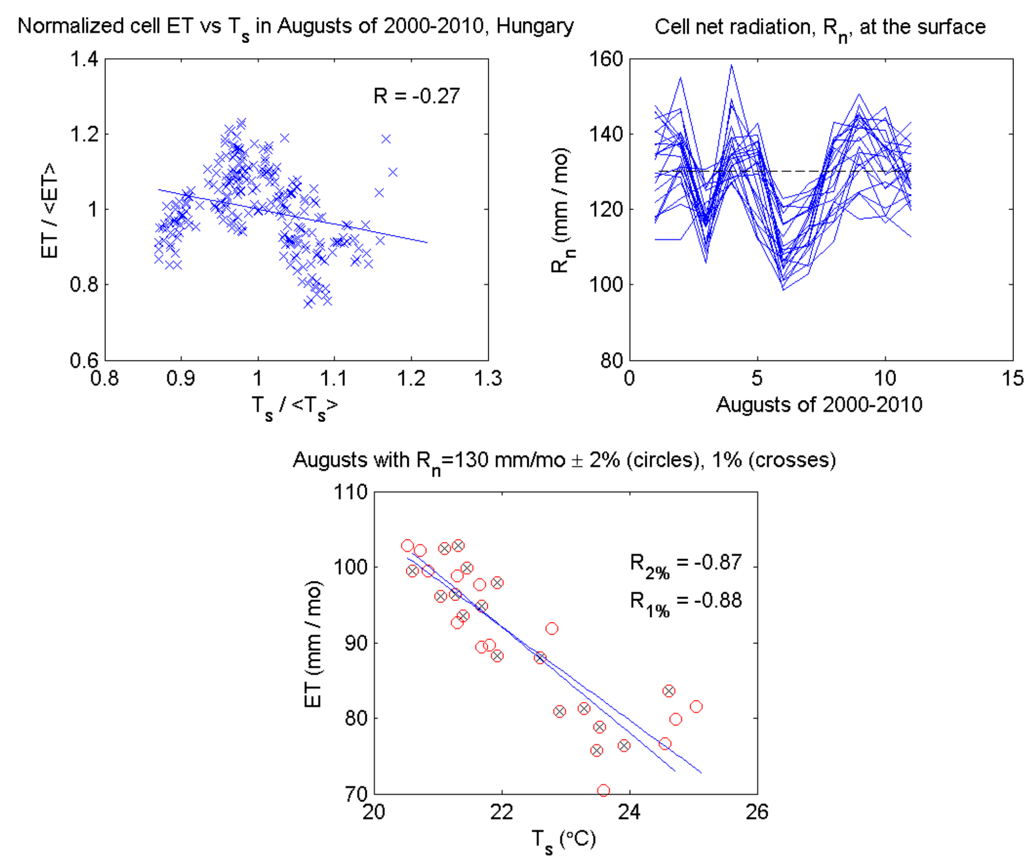


Nebraska, USA



Hungary





(Szilagyi, 2014)

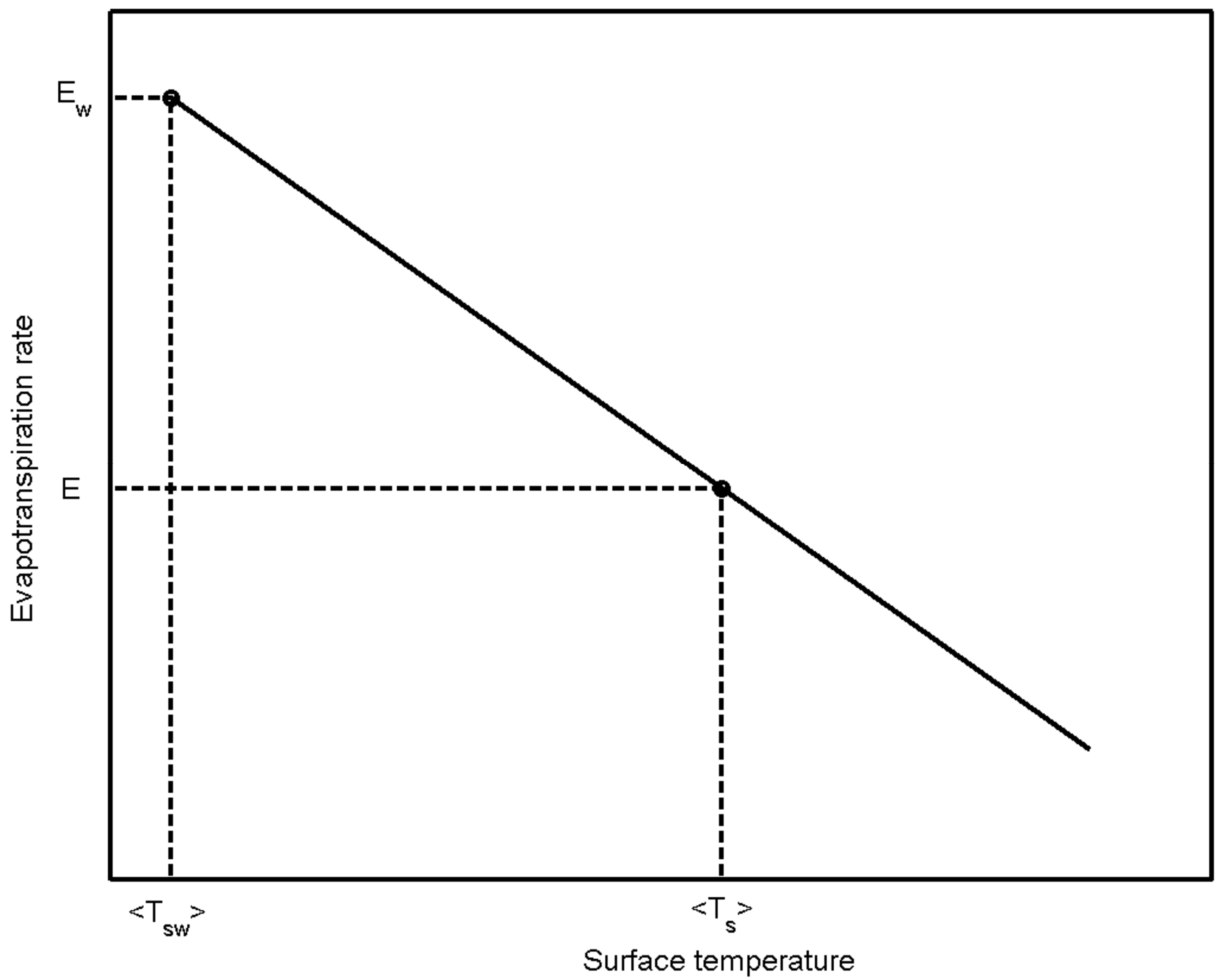
Transformation of T_s into ET

Definiton of two anchor points for the linear transformation:

-- Mean T_s ($\langle T_s \rangle$) of a region plus mean ET (E) from the Complementary Relationship (CR) of evaporation by WREVAP of Morton

-- T_s ($\langle T_{sw} \rangle$) of the coldest surface area which cools itself at the maximum rate of ET (E_w) which derives from the Priestley-Taylor (1972) equation since the 1km scale is the effective lower scale for P-T (Brutsaert, 1982)

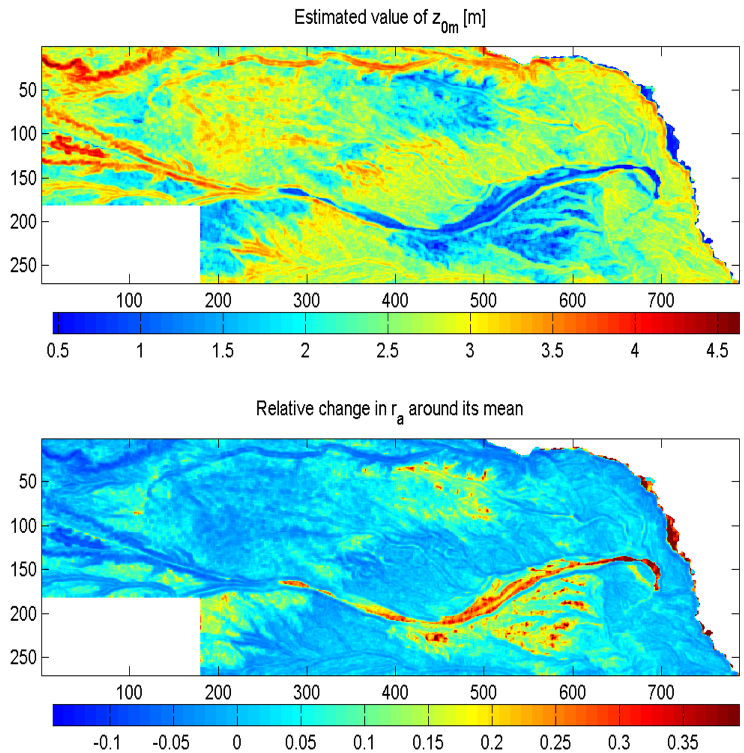
CREMAP is a **calibration-free** method



(Szilagyi et al., 2011a)

Application of the transformation equation

- The T_s – ET transformation is done on a *monthly basis*: it eliminates cloud contamination of the MODIS pixels
- It is the typical time-step of hydrologic models
- It can be simply adjusted for rough terrain
- Input data: T_s (MODIS), T_a, T_d, R_s (from PRISM & GEWEX)

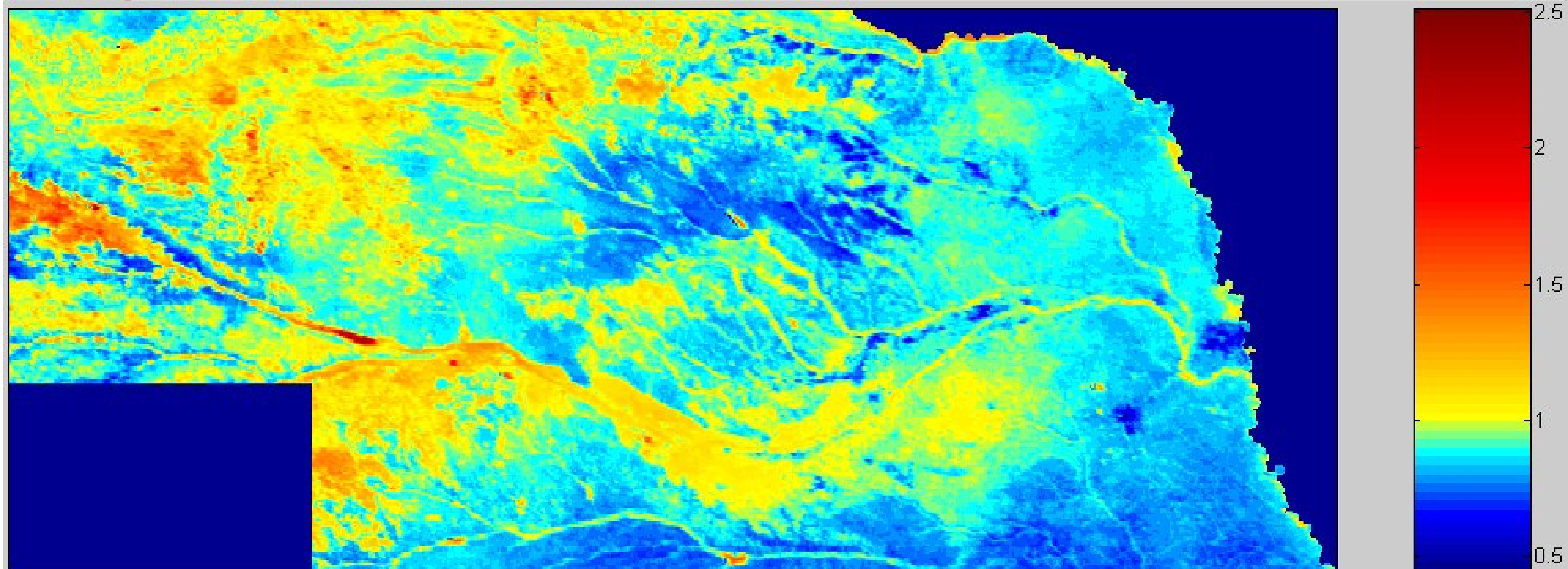


Pine Ridge, Nebraska, USA

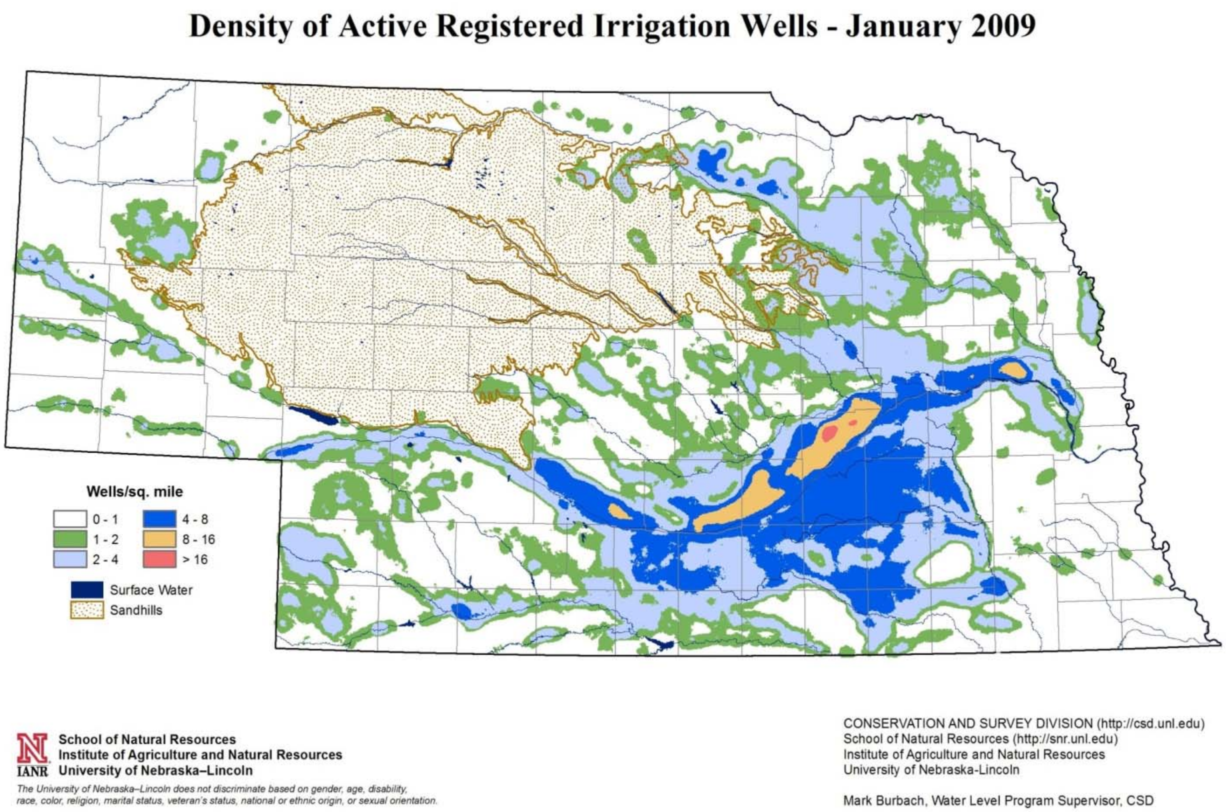
(Szilagyi, 2013)

1) Nebraska: Mean annual ET / P, 2000-2009

Check out the eastern outlines of the Sand Hills and the two largest cities: Omaha and Lincoln!



(Szilagyi et al., 2011a)


Density of Active Registered Irrigation Wells - January 2009
Wells/sq. mile
0 - 1
1 - 2
2 - 4
4 - 8
8 - 16
> 16
Surface Water
Sandhills
School of Natural Resources
Institute of Agriculture and Natural Resources
University of Nebraska–Lincoln
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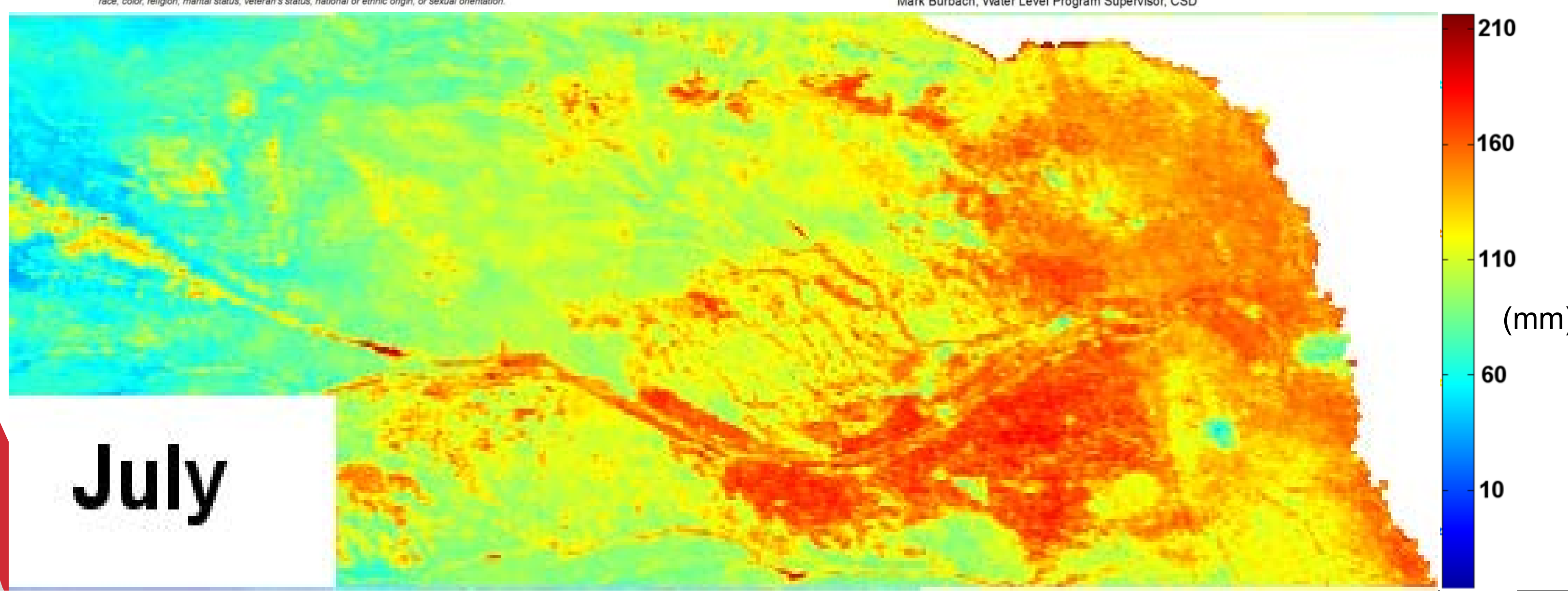
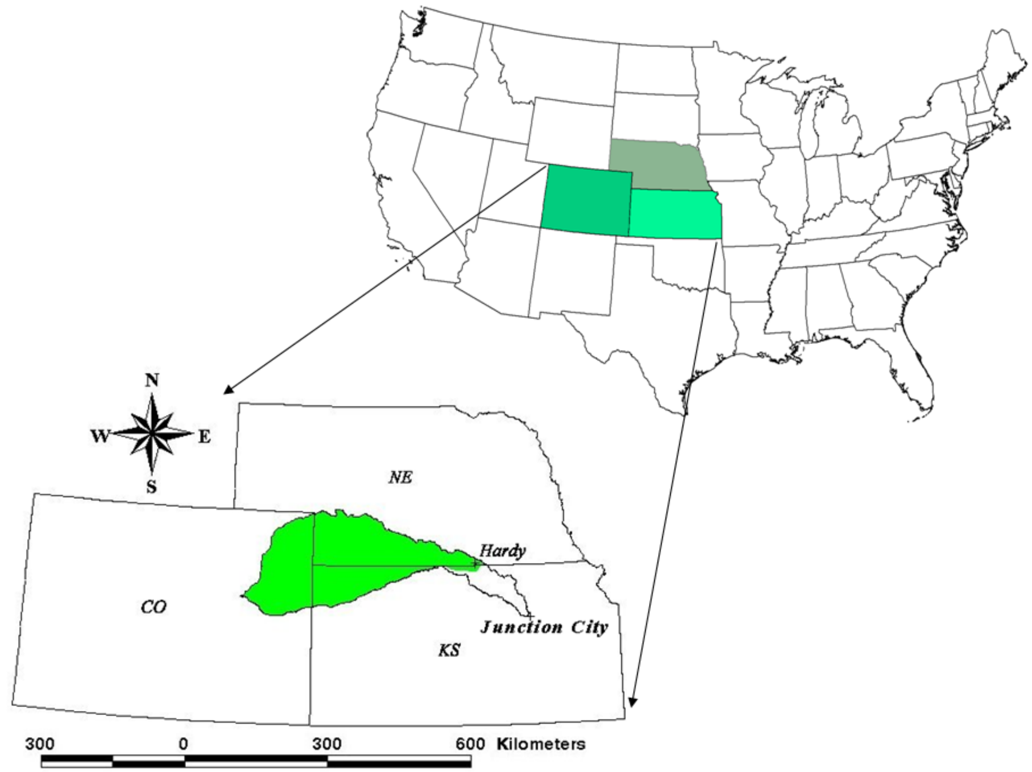
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
Mark Burbach, Water Level Program Supervisor, CSD

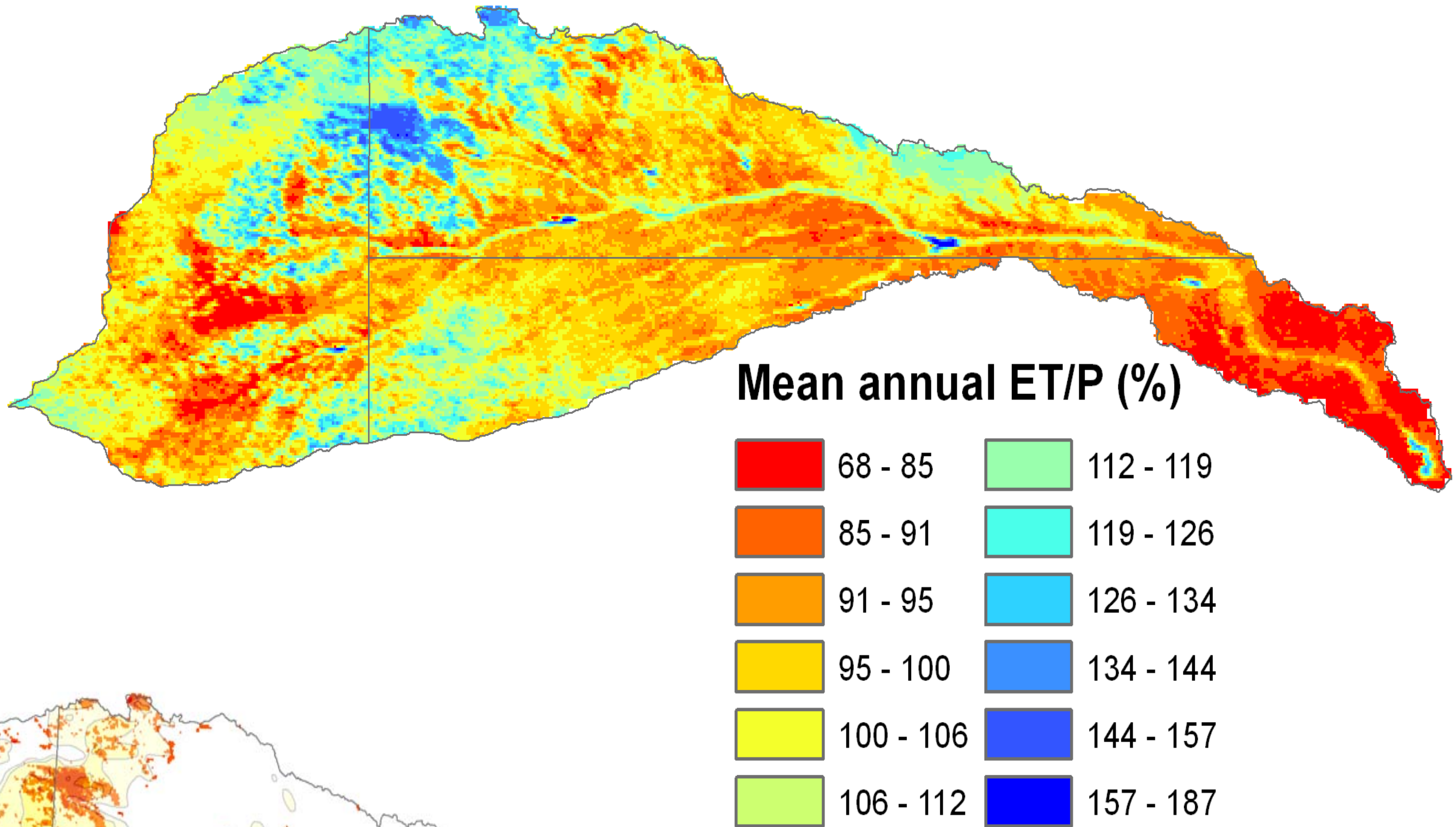

July
210
160
110
(mm)
60
10

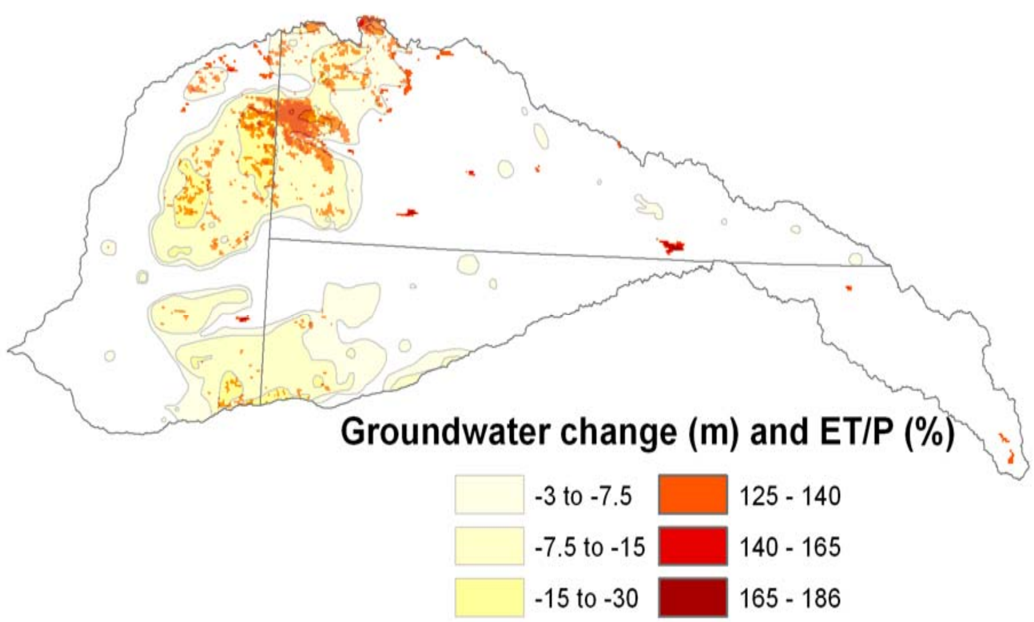
2) The Republican River basin



-- The <u>quantity of water</u> each state <u>irrigates</u> is <u>unknown</u> since irrigation wells are not metered

-- <u>Interstate litigation</u> has been going on for decades about whether each state complies with the compact or not

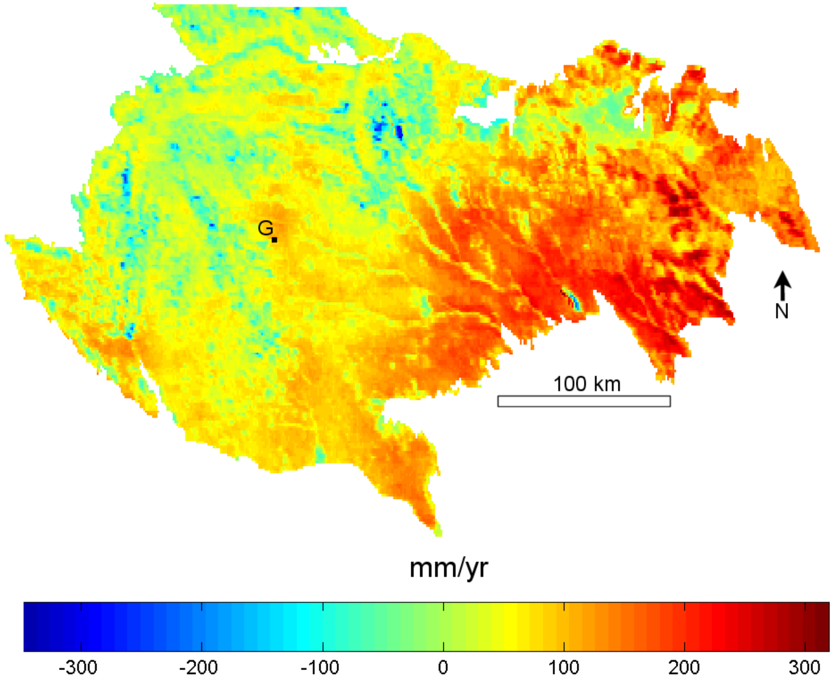

Mean annual ET/P (%)
68 - 85
85 - 91
91 - 95
95 - 100
100 - 106
106 - 112
112 - 119
119 - 126
126 - 134
134 - 144
144 - 157
157 - 187

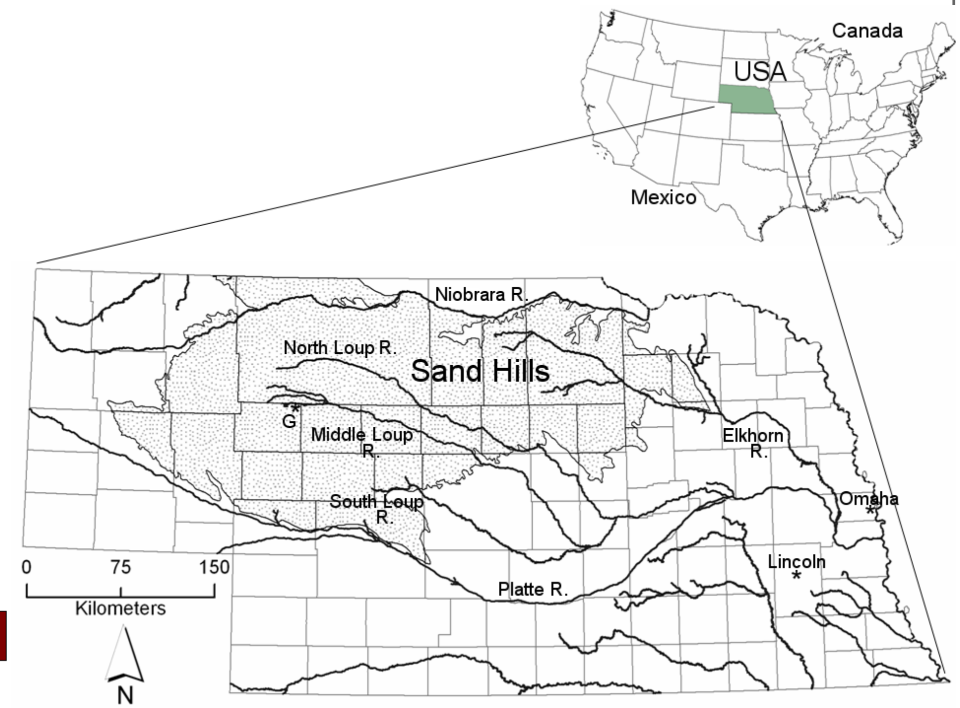

Groundwater change (m) and ET/P (%)
-3 to -7.5
-7.5 to -15
-15 to -30
125 - 140
140 - 165
165 - 186

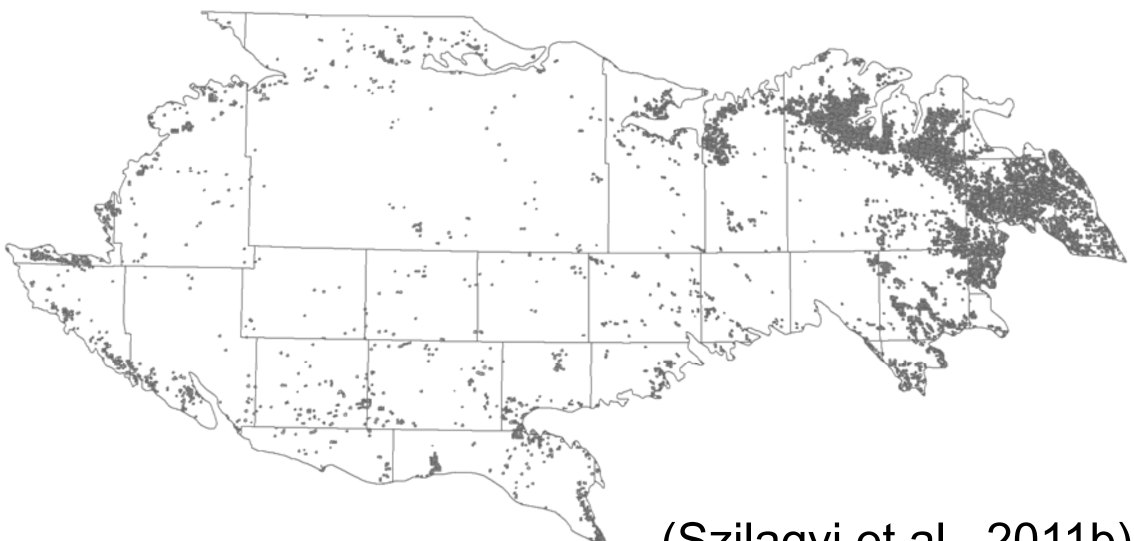
Basin area	Undisturbed ET (mm)	Present ET (mm)	P (mm)	ET / P (%) undisturbed	ET / P (%) present	Change in ET / P (%)
CO	424	444	430	97.92	103.26	5.34
NE	551	575	563	98.57	102.13	3.56
KS	555	565	596	93.91	94.8	0.89
KS upstream of Hardy, NE	527	535	536	96.34	99.81	3.47

The extent each state disturbs the natural hydrologic cycle is expressed by the change in precipitation recycling (ET / P) relative to undisturbed (native prairie) conditions

3) Sand Hills net recharge: P - ET





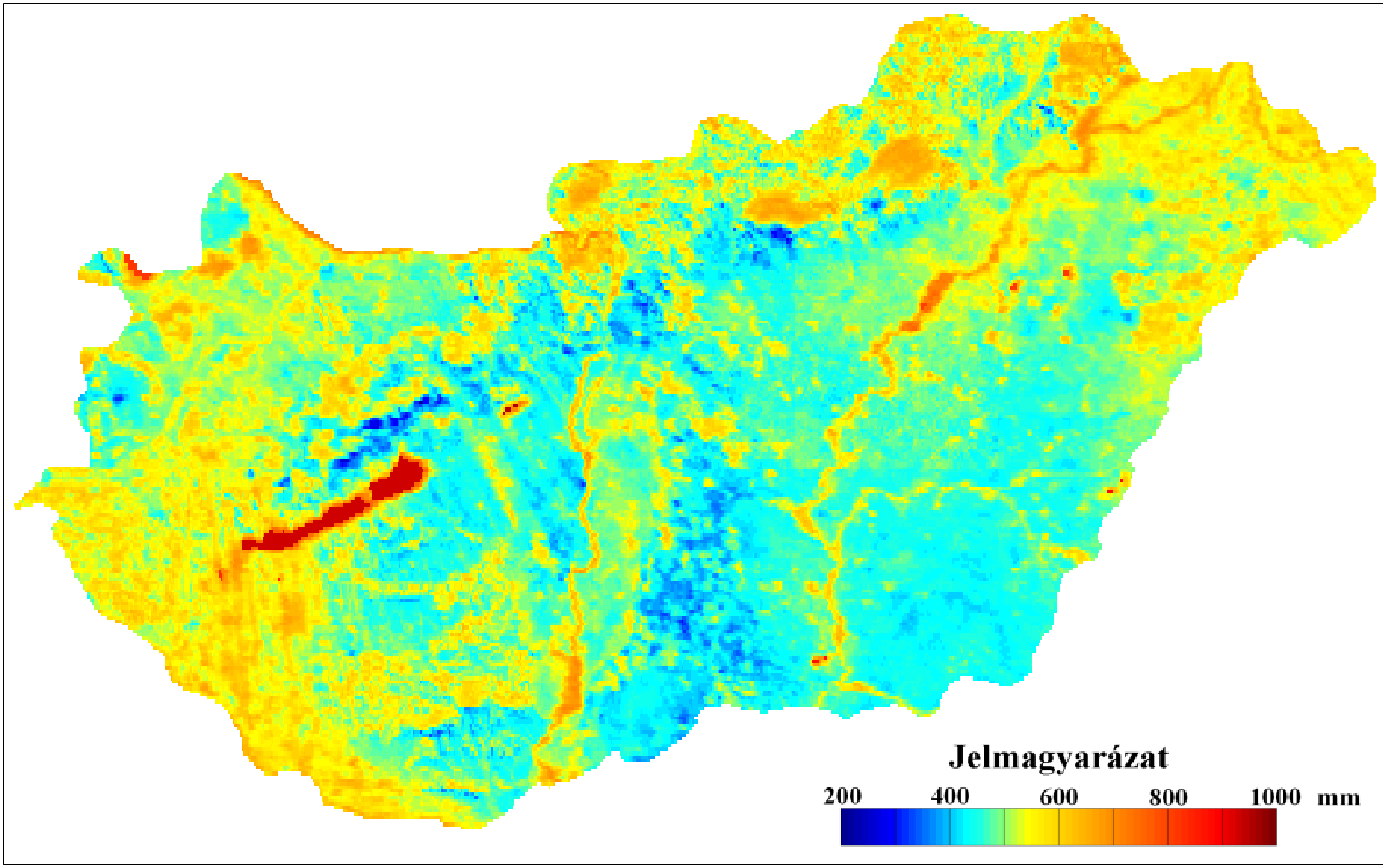


(Szilagyi et al., 2011b)

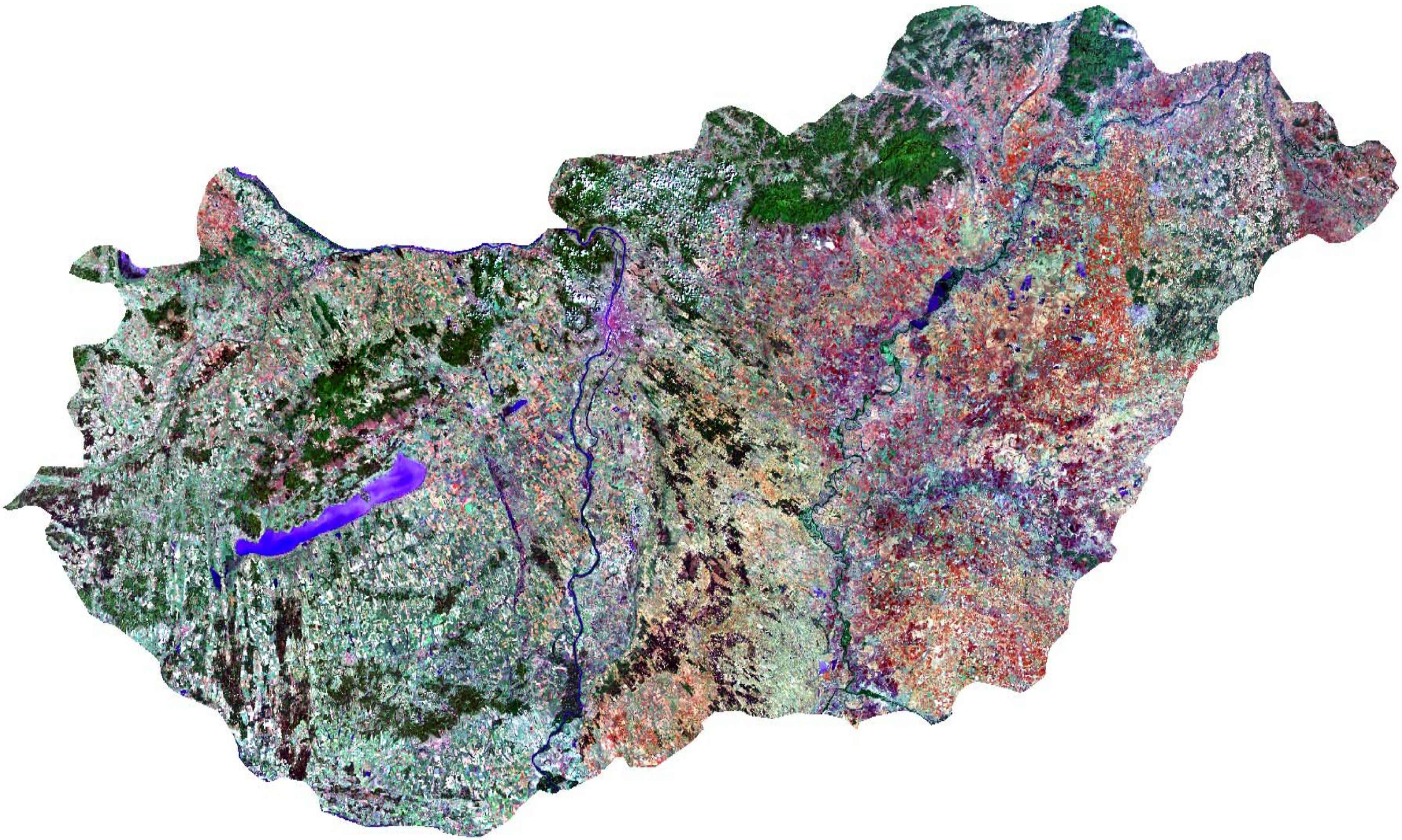
MODIS-derived net recharge rate of 75 mm/yr equals chloride mass balance derived rate

4) Mean annual ET (2000-2008) in mm

(Szilagyi & Kovacs, 2010,2011)



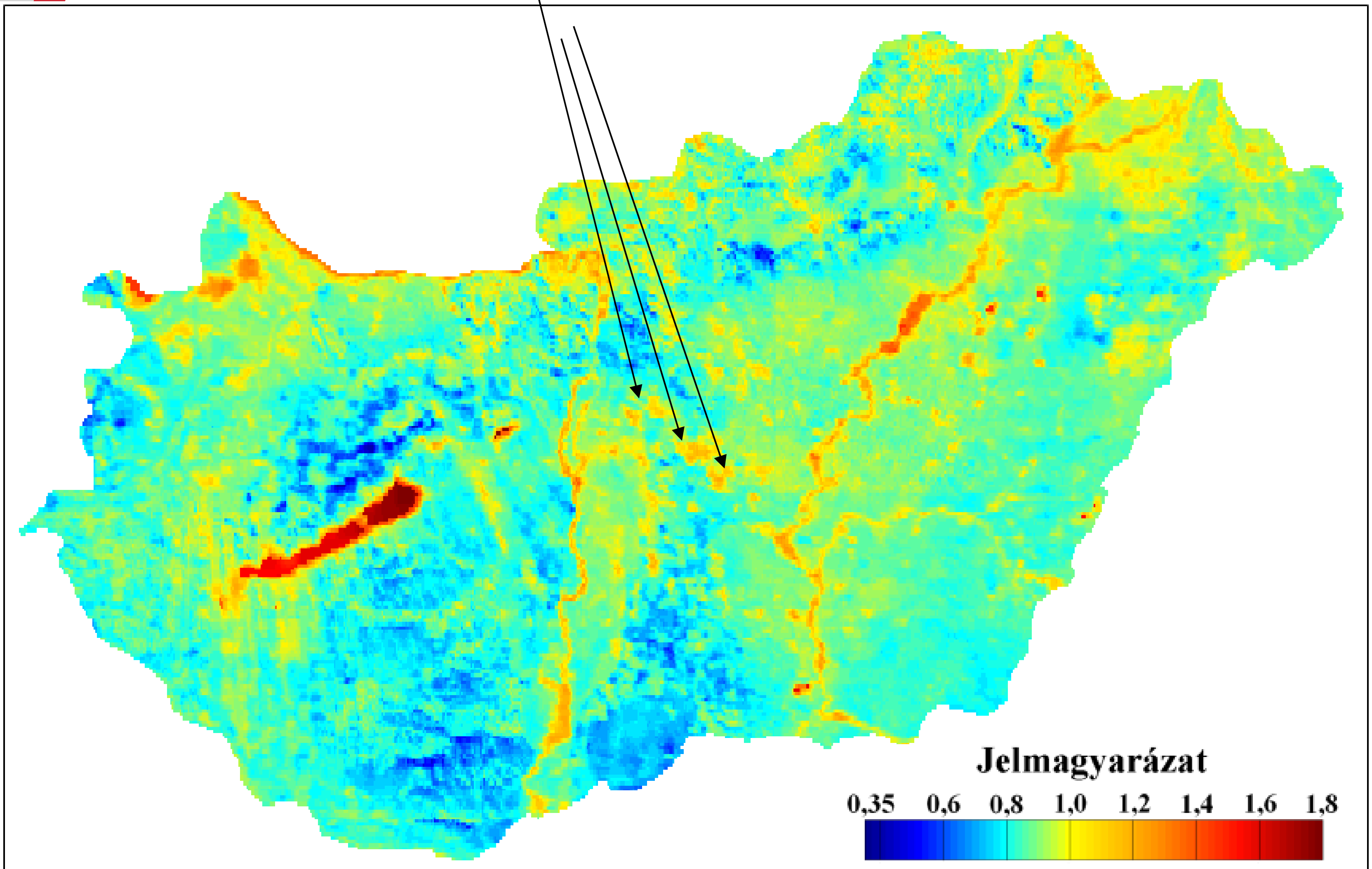
150-m resolution vegetation cover



Ratio of mean annual ET and precipitation

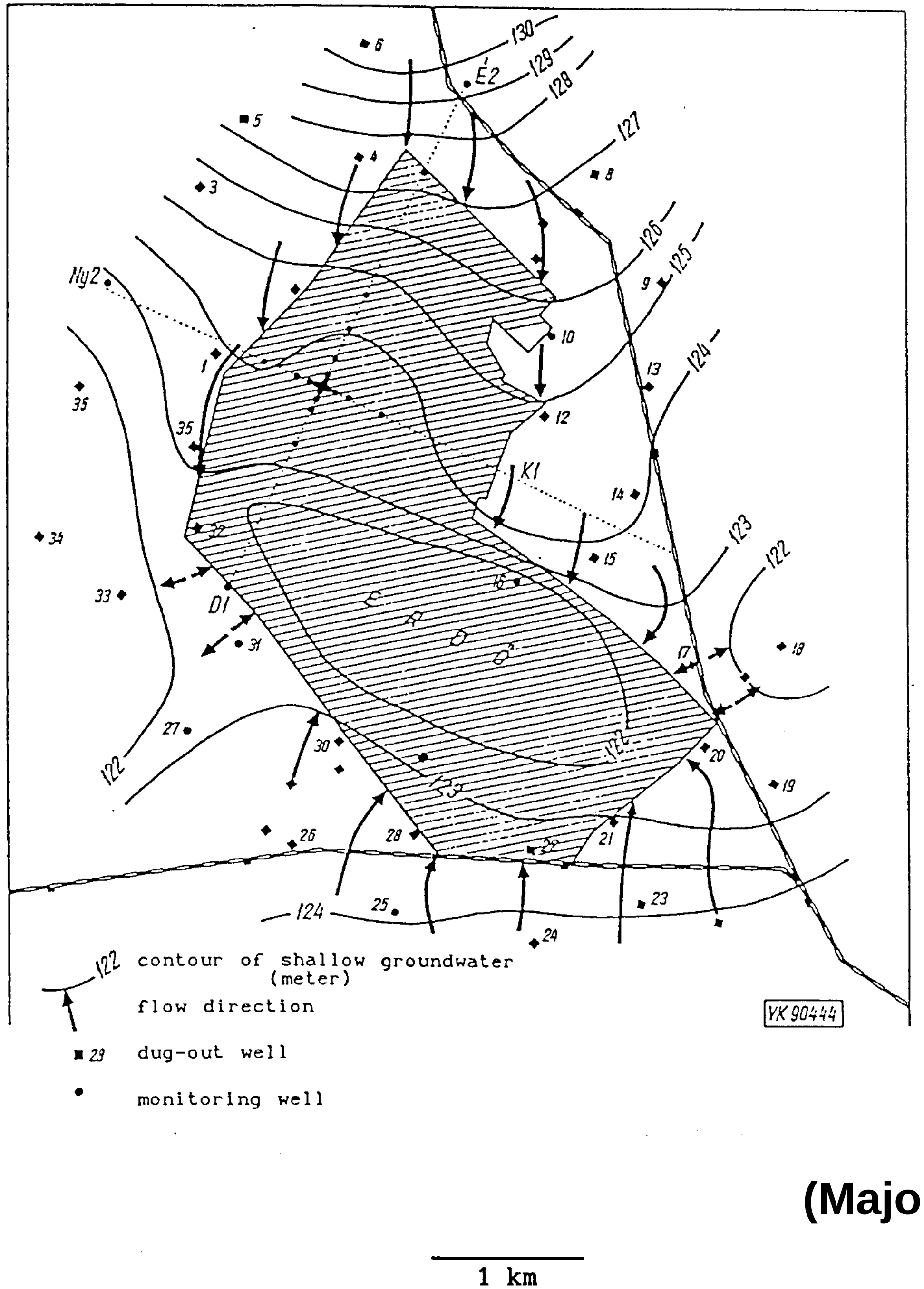
Estimated areal average: 89.2%, water-balance derived mean: 89.6%

Forest ET (620 mm) ca. 15% larger than precipitation



Forests draw down the groundwater table creating local gw catchments

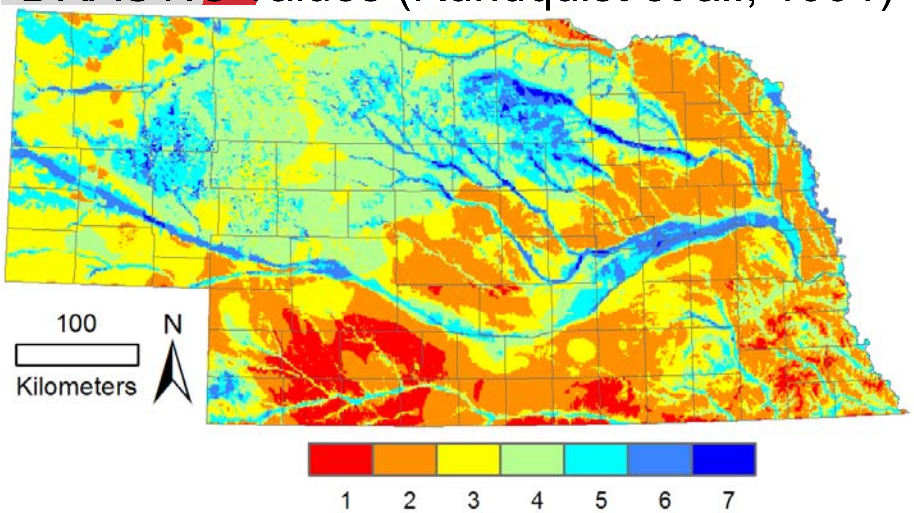
(Szilagyi & Kovacs, 2010,2011)



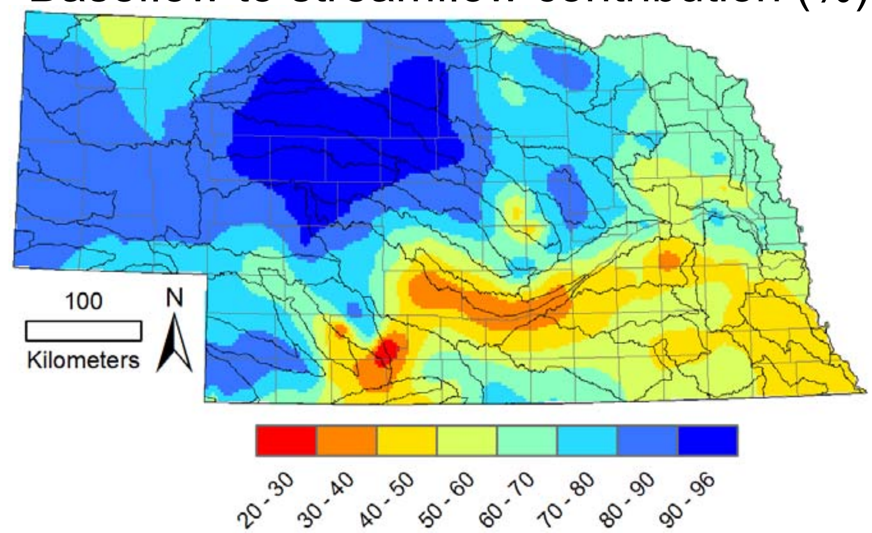
(Major & Neppel, 1988)

4) State-wide net groundwater recharge

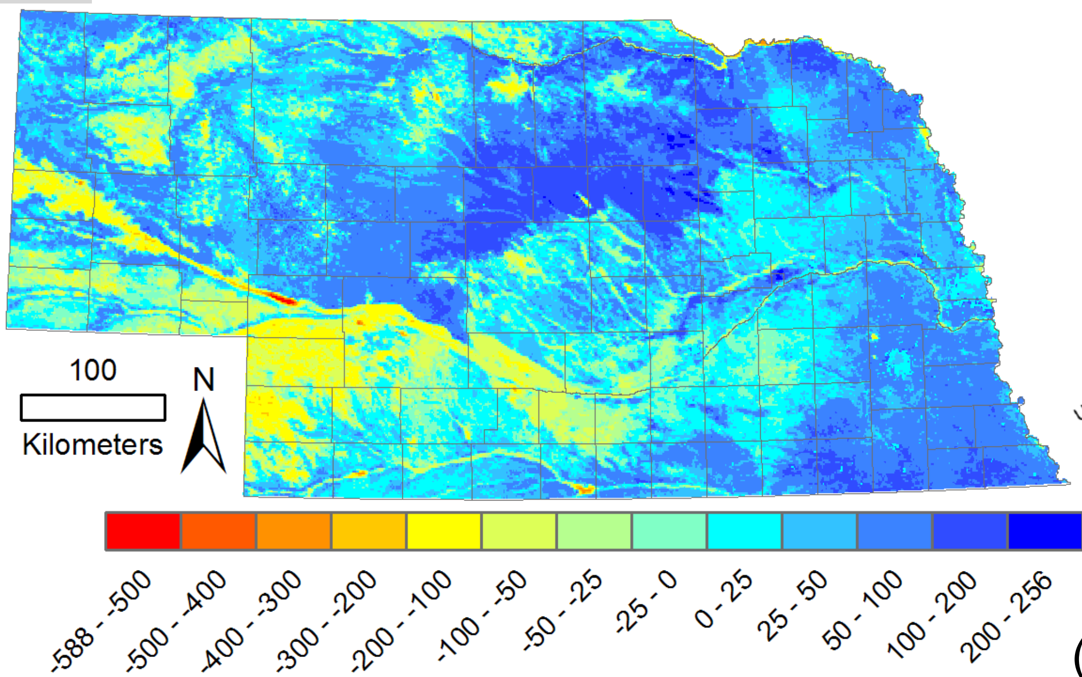
DRASTIC values (Rundquist et al., 1991)

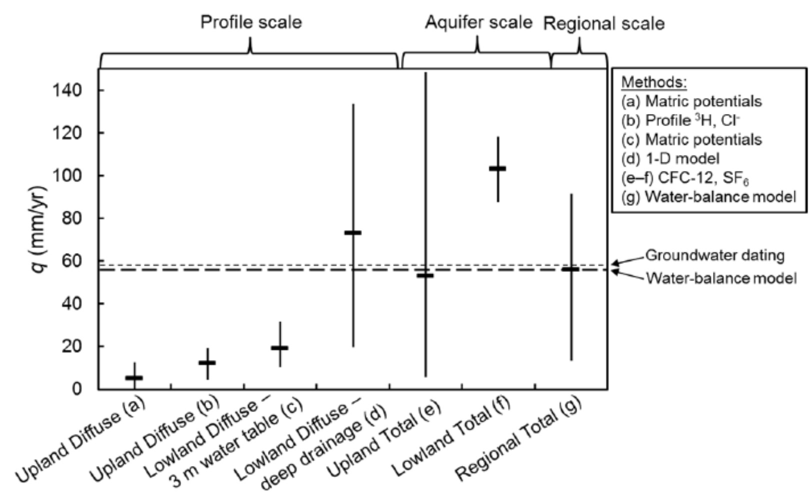


Baseflow to streamflow contribution (%)



Net recharge (mm/yr), 2000-2009



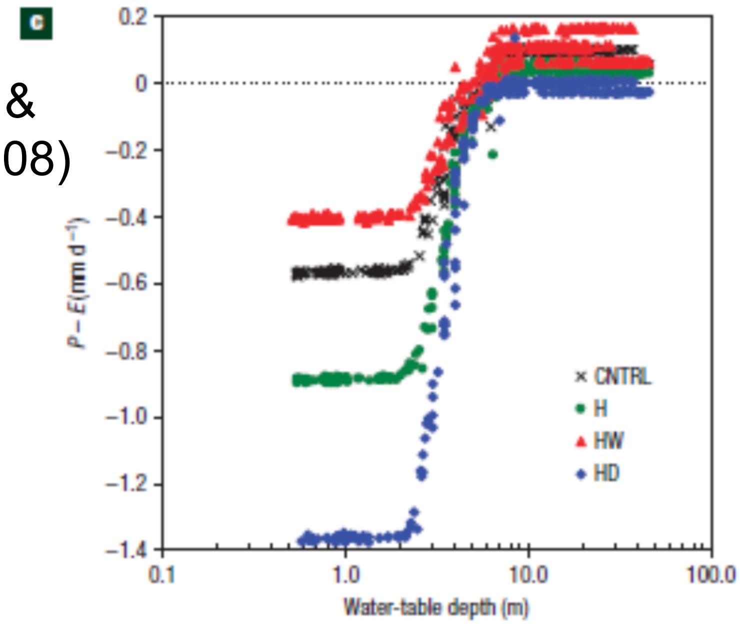


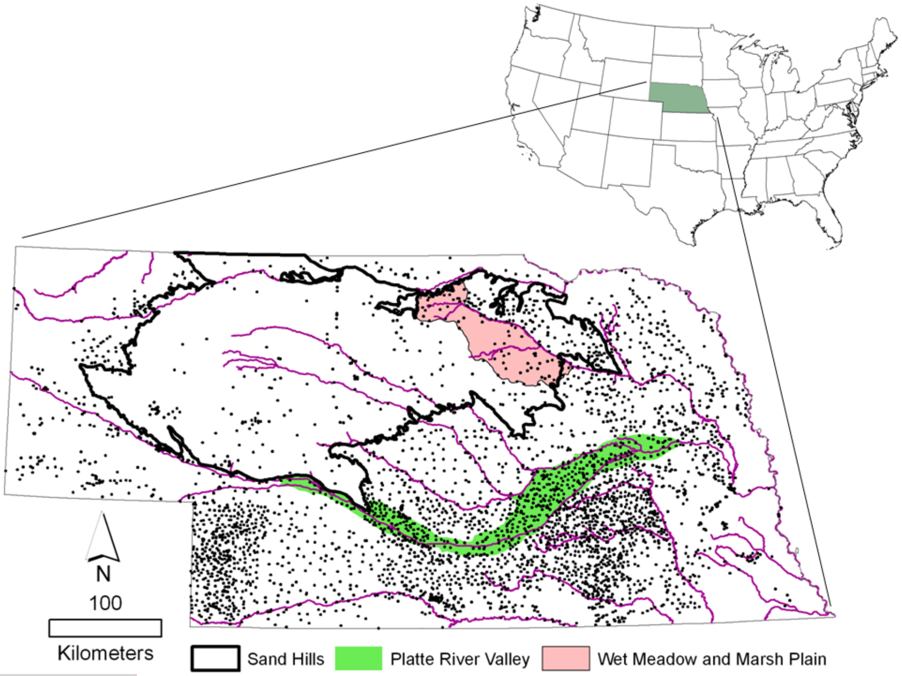
(Gates et al., 2014)

(Szilagyi-Jozsa, 2013)

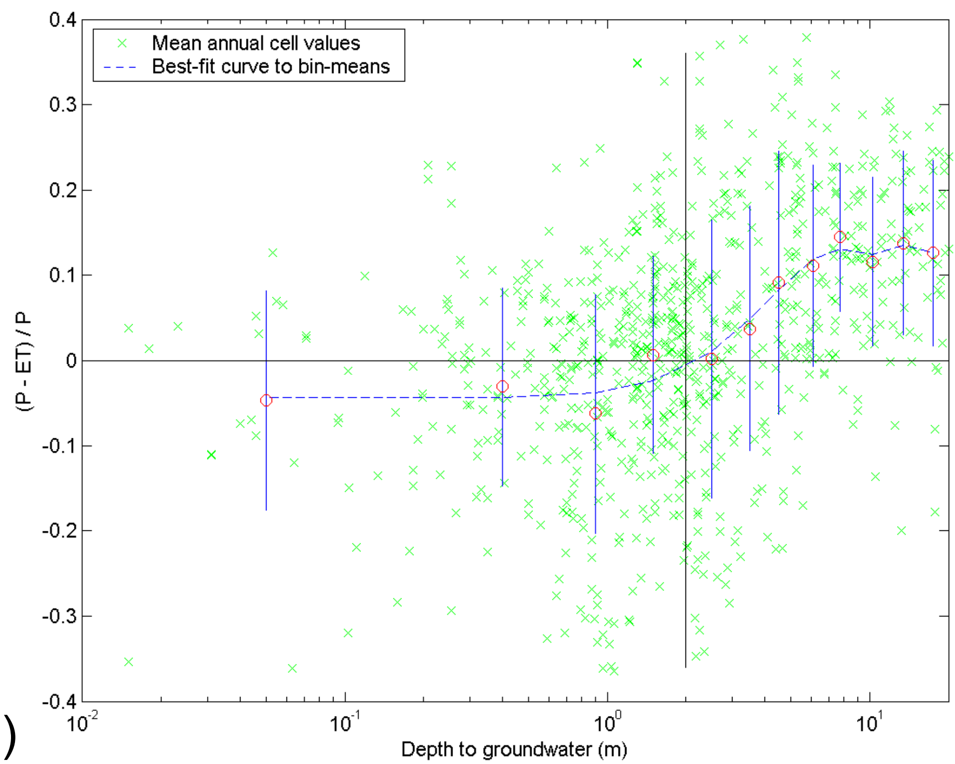
5) Net groundwater recharge vs depth to groundwater

(Maxwell & Kollet, 2008)





Groundwater wells in Nebraska



Net recharge to precipitation, Platte River valley (2000-2009)

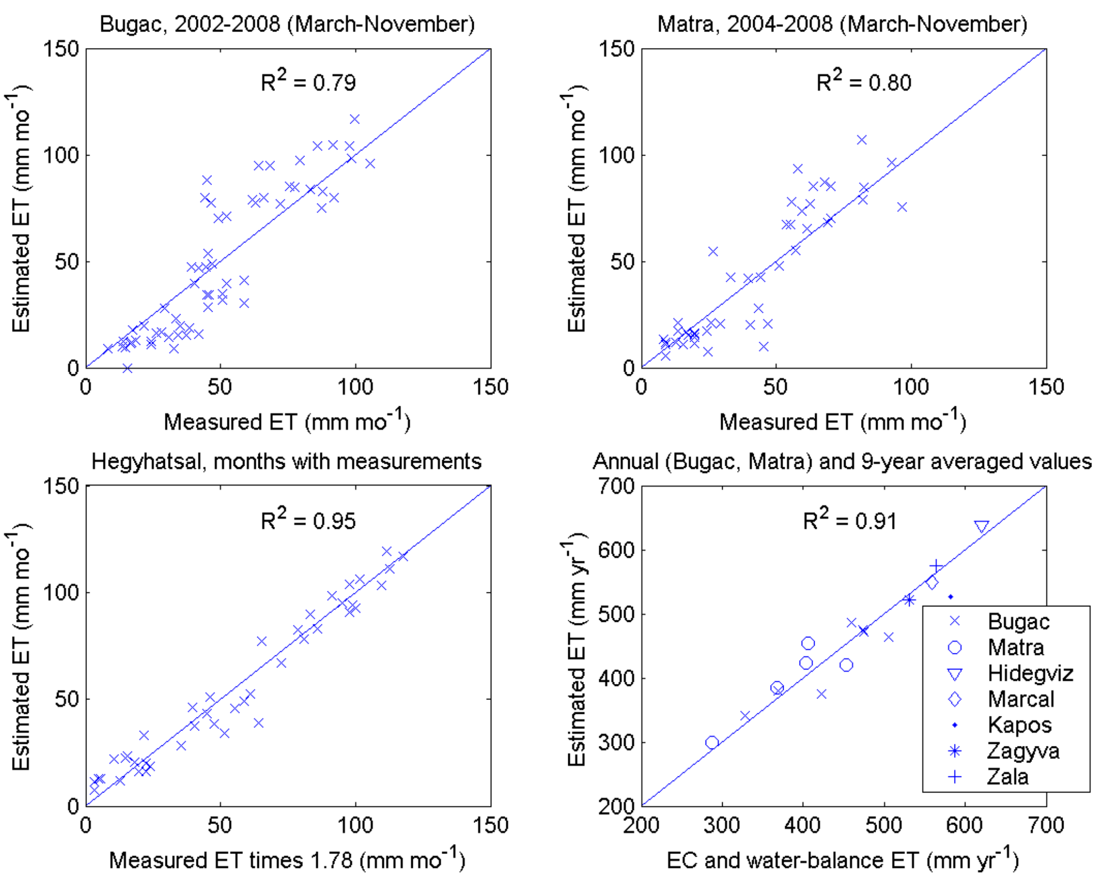
(Szilagyi et al., 2013)

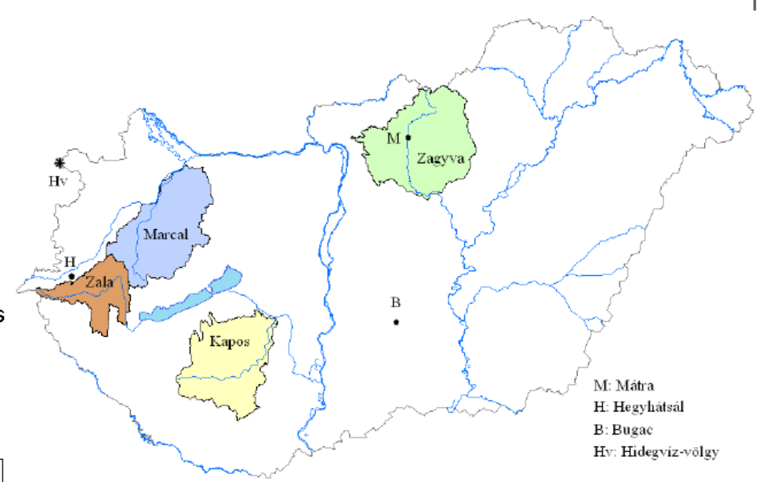
Summary

- CREMAP is a simple, **calibration-free** ET estimation method that requires minimal data (T_s, T_a, T_d, R_s) and works at a spatial scale of 1km or larger, and at a temporal scale of week or longer

- It is best suited for well vegetated surfaces of a flat/rolling terrain (ideal for the Great Plains of the US)

- CREMAP ET rates are within 10% of EBBR, EC or water-balance derived ET rates





<u>References:</u>

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