Estimating crop evapotranspiration of managed alpine grassland using remotely sensed LAI

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Assessing grassland water loss

Why do we need to know how much water a grassland is losing?

- Indicator of drought
- Hydrological models
- Growth models
- Biomass production
- …

How to get the water loss of a grassland?

- Directly: e.g., **lysimeters**, eddy covariance
    - Problem: Cost/maintenance/point
- Indirectly: residual of energy balance, **ET models**
    - Problem: Assumptions/accuracy

AREC Raumberg-Gumpenstein

Penman-Monteith equation

Reference evapotranspiration ET_0 – (FAO-56)

- Input: radiation, temperature, humidity, wind
- Grass reference crop
- Crop height h_c of 0.12 m
- Fixed surface resistance r_s of 70 s m^{-1}

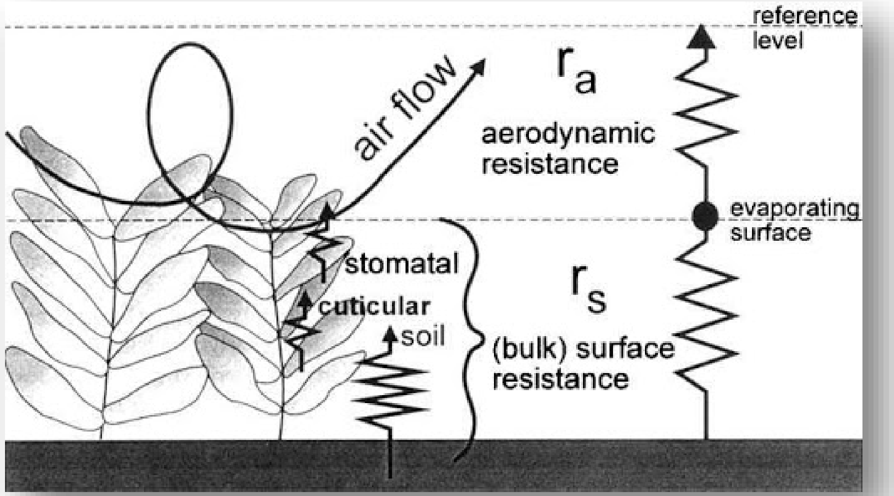
$$ET_c = \frac{\Delta(R_n - G) + \rho_a c_p (e_s - e_a)/r_a}{\lambda\left[\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)\right]}$$

Crop evapotranspiration ET_c

- Crop coefficient Kc
- Measurements of LAI and crop height h_{crop}
- Aerodynamic resistance r_a and surface resistance r_s

$$r_s = \frac{r_l}{LAI_{act}}$$

$$r_a = \frac{ln\left[\frac{z_m - 2/3\, h_c}{0.123\, h_c}\right] ln\left[\frac{z_h - 2/3\, h_c}{0.1(0.123\, h_c)}\right]}{k^2 u_z}$$



FAO-56 – Crop evapotranspiration (Allen et al. 1998)

Motivation

Compare estimated ET_c using:

1. Indirect in-situ LAI measurements (AccuPAR LP-80)
2. LAI from the proximal remote sensing approach (Field spectrometer)
   - Same LAI Retrievel Algorithm as for Sentinel-2 data

Can we estimate ET_c without in-situ measurements?

- Leaf Area Index ✓
- Crop height?
- Compare with FAO-56 reference ET

Study area: HBLFA Raumberg-Gumpenstein

Lysi-T-FACE experiment (Herndl et al., 2011) – Ambient C0T0 lysimeter

- High precision weighable lysimeter
- Soil water fluxes (ET, Precipitation, Seepage) **(Forstner et al. 2020)**
- Crop height collected using ultrasonic sensors
- 3-cut system
- Data availability: vegetation period 2016-2019

Data collection of Leaf Area Index (LAI) (Klingler et al., 2020)

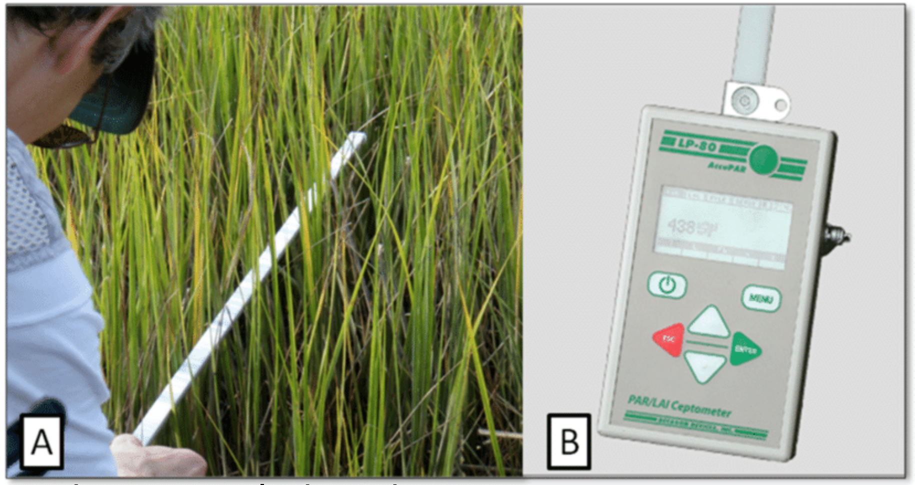
Indirect in-situ measurements

- AccuPAR LP-80 Ceptometer (Decagon Devices)

Proximal remote sensing approach

- Field spectrometer HandySpec Field VIS/NIR 1.7 (tec5 AG)
- Same LAI Retrievel Algorithm as for Sentinel-2 data

AccuPAR LP-80

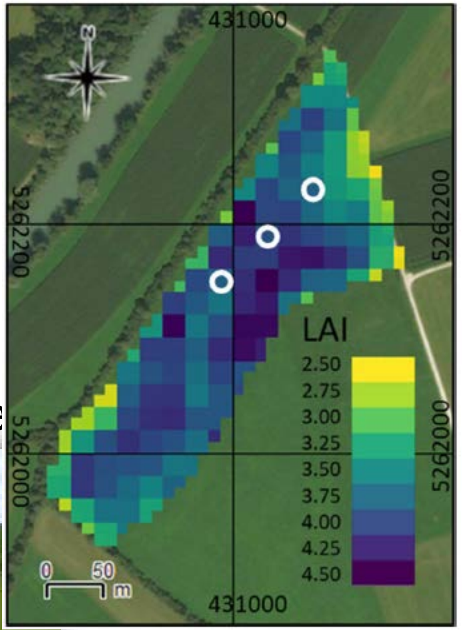


Bachmann et al. (2012)

Field spectrometer HandySpe

Schaumberger et al. (2020)

Sentinel-2



Klingler et al. (2020)

Klingler, A., Schaumberger, A., Vuolo, F., Kalmár, L.B., Pötsch, E.M., 2020. Comparison of Direct and Indirect Determination of Leaf Area Index in Permanent Grassland. PFG–Journal Photogrammetry Remote Sensing Geoinformation Science 88 (5)

Comparing crop *ET* (ET_c) with lysimeter *ET* (ET_a)

Water stress:

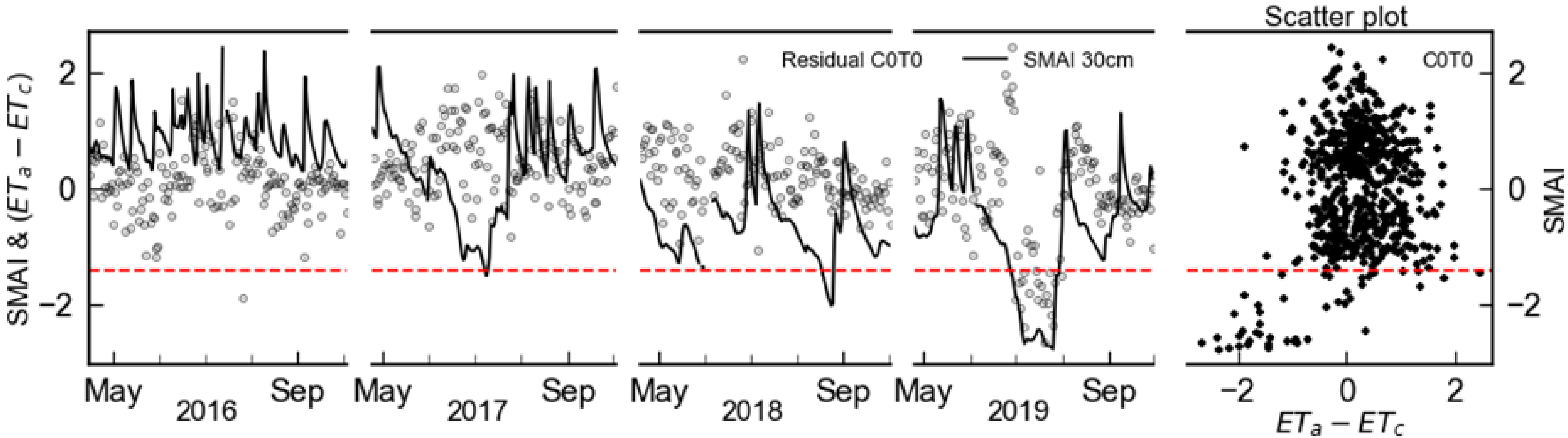
1. $ET_a - ET_c \approx 0$; no water stress
   $ET_a - ET_c \ll 0$; water stress

2. $SMAI < -1.42$ severe drought event (Mckee, 1993)

Soil moisture anomaly index (SMAI):

$$SMAI = \frac{\theta - \bar{\theta}}{\sigma_\theta}$$

θ - soil water content at 30 cm,
$\bar{\theta}$ - long-term avareage soil water content,
σ_θ - standard deviation.

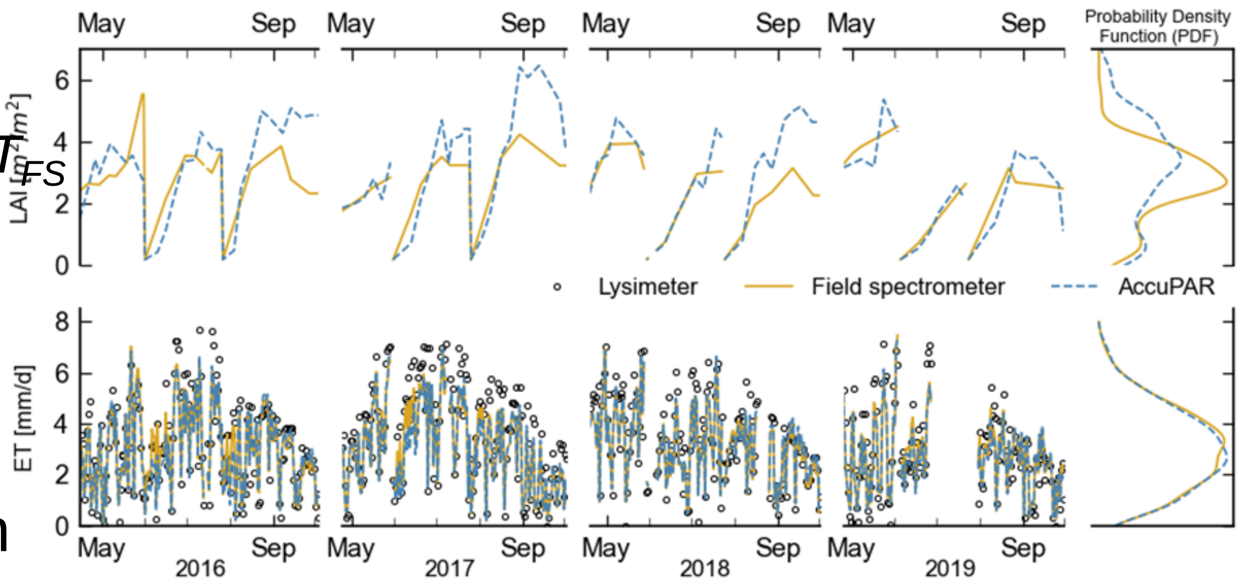


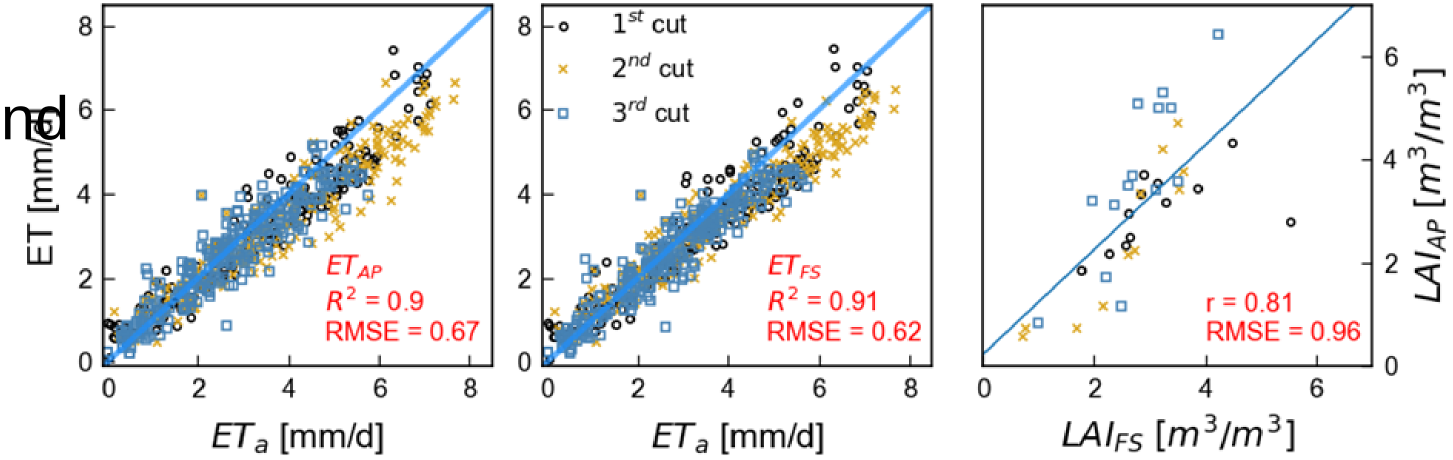
ET_c estimated with ACCUPAR vs Field spectrometer

ET_c estimated using AccuPAR (***LAI_{AP}***) = ET_{AP}

ET_c estimated using Field spectrometer (***LAI_{FS}***) = ET_{FS}

- High correlation between LAI_{AP} and LAI_{FS} for the 1st and 2nd cut
- ET_{FS} showed overall better agreement with lysimeter ET as ET_{AP}
- Overestimation of LAI_{AP} in the second and third cut seems to affect the estimation of ET_c **negatively**

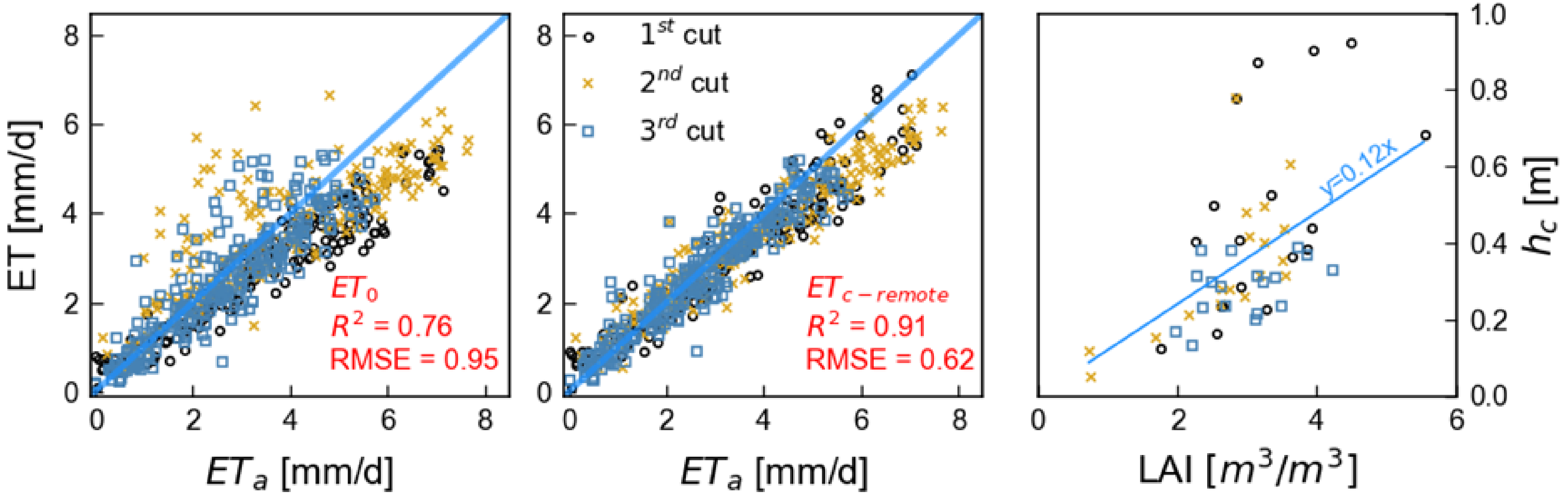




Estimation of ET_c using an LAI/h_c relationship

A relationship between *LAI* and h_c was obtained by fitting a simple linear function $y = k*x$ to the ultrasonic crop height data from the lysimeter plot.

$$h_c = 0.12\ LAI_{FS}$$



- $ET_{c-remote}$ estimated using LAI_{FS} and h_c from the above relationship outperforms the standard reference Evapotranspiration ET_0

Conclusions

- **High agreement** between ET_{AP} and ET_{FS} with ET_a
  - Small deviations of ET_{AP} with ET_a in the 2nd and 3rd cut (overestimation of LAI_{AP})
- High agreement between $ET_{c-remote}$ and ET_a
  - $ET_{c-remote}$ **outperforming** ET_0

	1st cut	2nd cut	3rd cut	Whole period
LAI_{FS}	3.32	2.19	**2.50**	2.60
LAI_{AP}	3.32	2.22	**3.39**	2.99
RMSE ET_{FS}	0.62	0.78	0.50	0.62
RMSE ET_{AP}	0.59	0.87	0.54	0.67
RMSE $ET_{c-remote}$	0.68	0.78	0.46	0.62
RMSE ET_0	1.00	1.21	0.69	0.95

Table: Mean values of the interpolated Leaf Area Index and the root-mean-square errors (mm/day).

Outlook

- ➢ High correlation between Sentinel-2 and field spectrometer LAI (Klingler, 2020)
  - same *LAI* retrieval algorithm
  - **opportunity to expand these findings on a regional scale**

Field spectrometer HandySpec

Sentinel-2 LAI satellite
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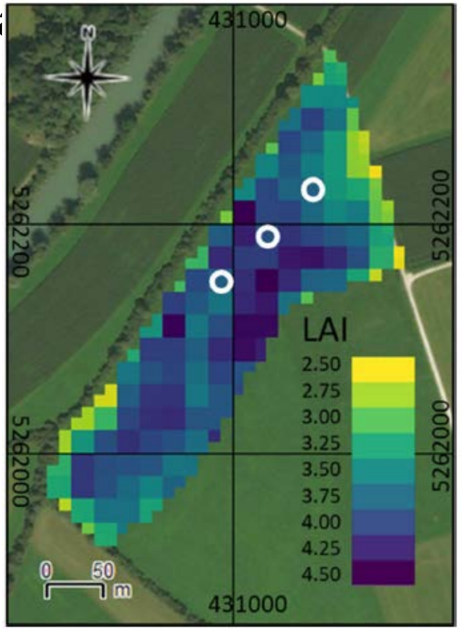

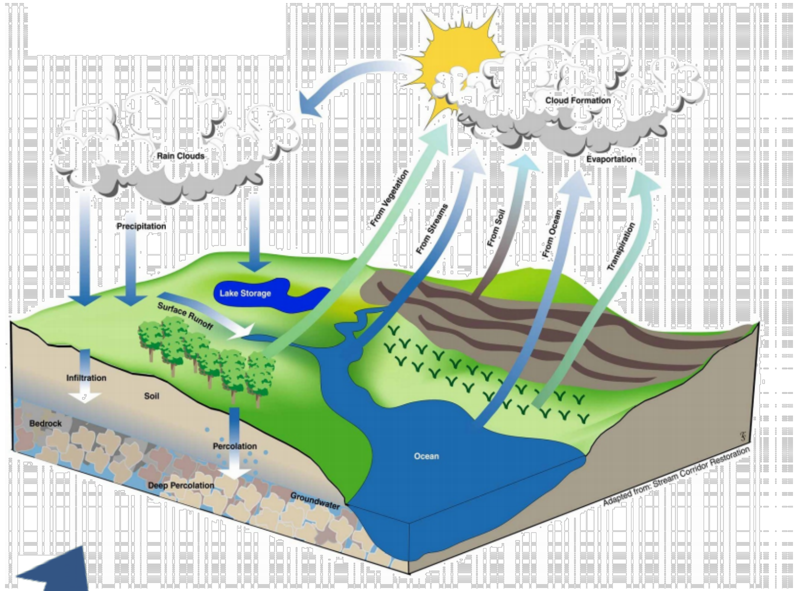

Regional hydrological models
Regional biomass pruduction

Thanks for your attention!

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