S.1 Rainfall correction

The measured rainfall was corrected in 2011 for two months due to the tipping bucket's poor performance during high-intensity rainfall, which is evident from the short total rainfall time and large soil moisture changes. The annual rainfall estimate based on daily soil moisture changes was at least 100 mm higher for the year 2011 compared to any other year, while the total time of measured rainfall was the lowest in the year 2011. The measurement site precipitation was lower than the precipitation at the nearby weather station in Potchefstroom (NCEI, 2015) for most days from December 2011 to February 2012 (Fig. S1). Therefore, the rainfall measurement was corrected from December 1st to February 13th by replacing the measured rainfall with 1.044 times the Potchefstroom rainfall. This scaling factor was estimated from the relationship between monthly rainfall at the two stations (Fig. S2). On February 14th, the logging interval of the rainfall data was changed from 10 min to 1 min, and while no missing data periods were evident before this date, the lower logging frequency may have caused lost tip counts during high-intensity rainfall.

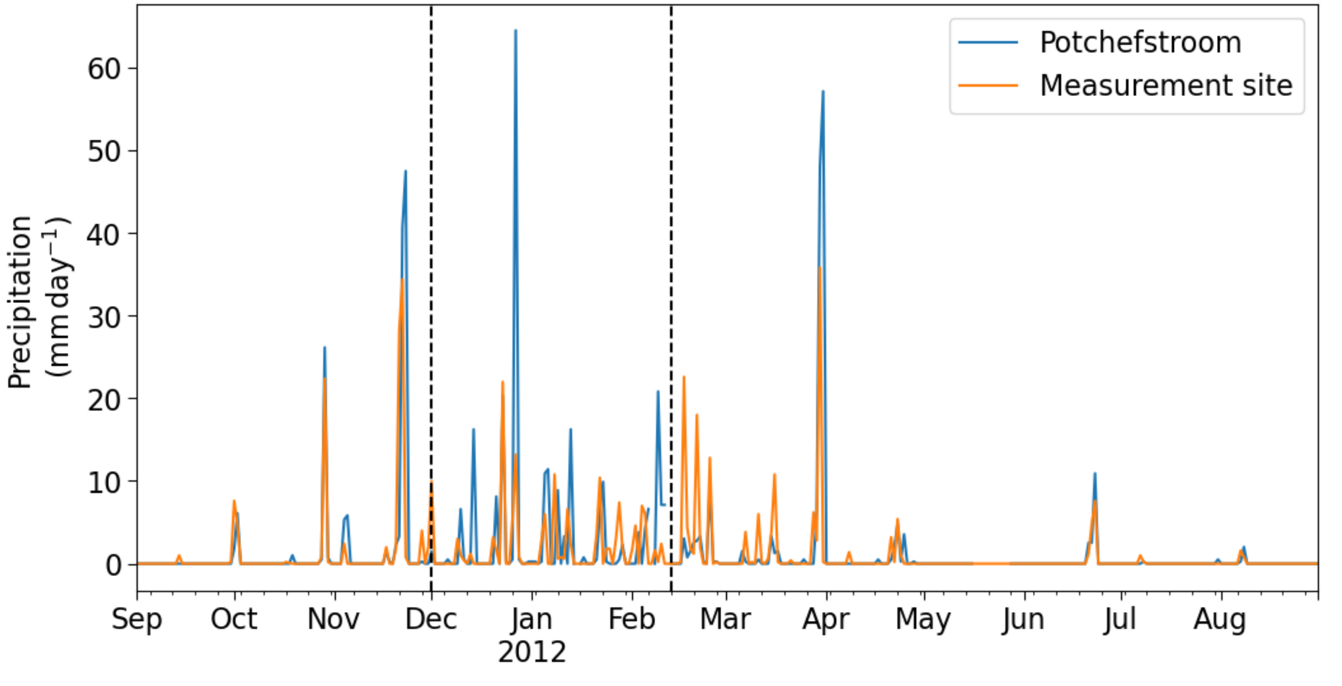

Figure S1. Time series of daily rainfall at the measurement site and nearby weather station in Potchefstroom. The dashed lines mark the period when the measurement site rainfall was corrected using the Potchefstroom rainfall.

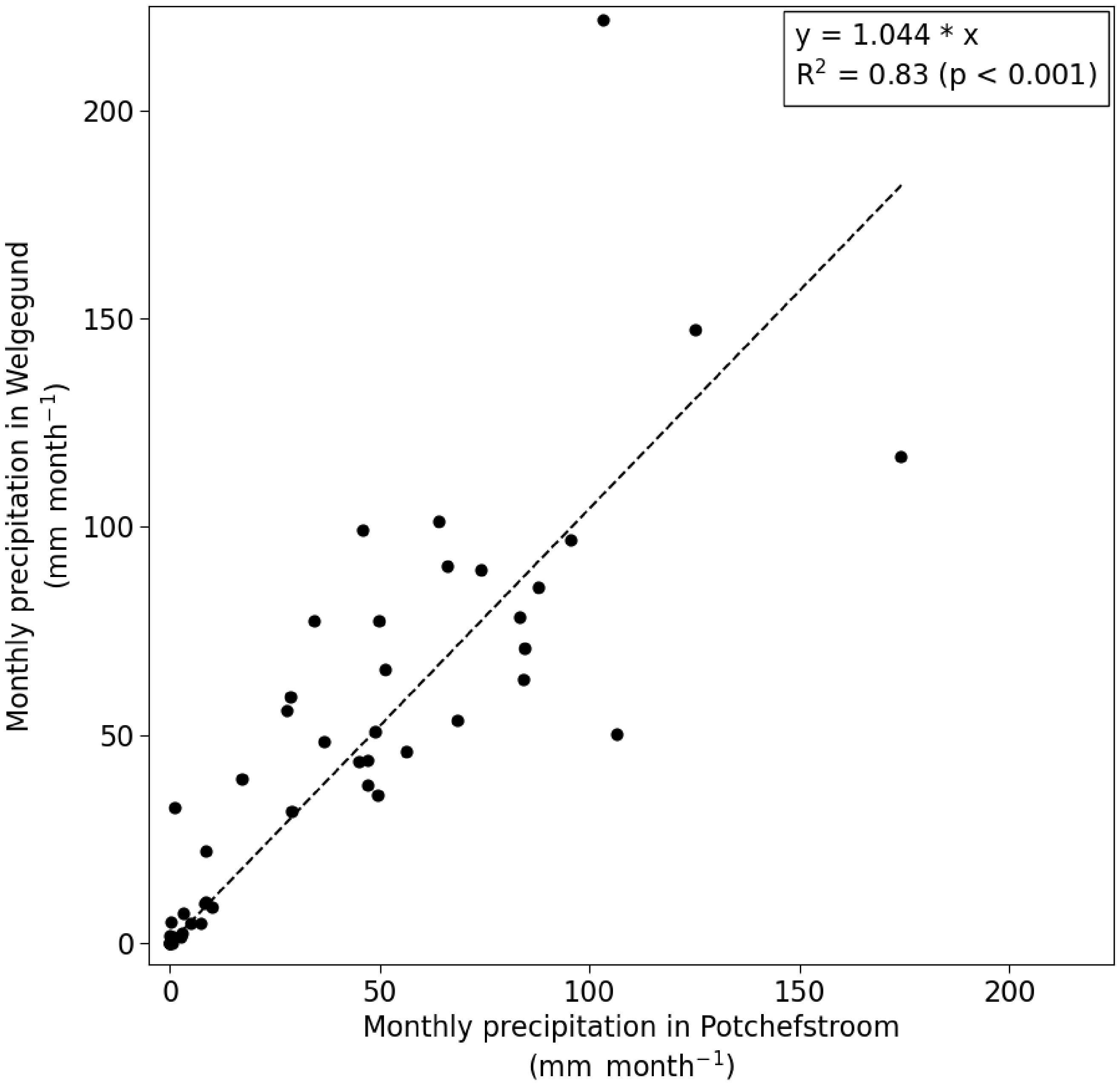

Figure S2. Relationship between monthly precipitation at the measurement site in Welgegund and at Potchefstroom station based on years 2012 to 2015.

S.2 Partitioning ET

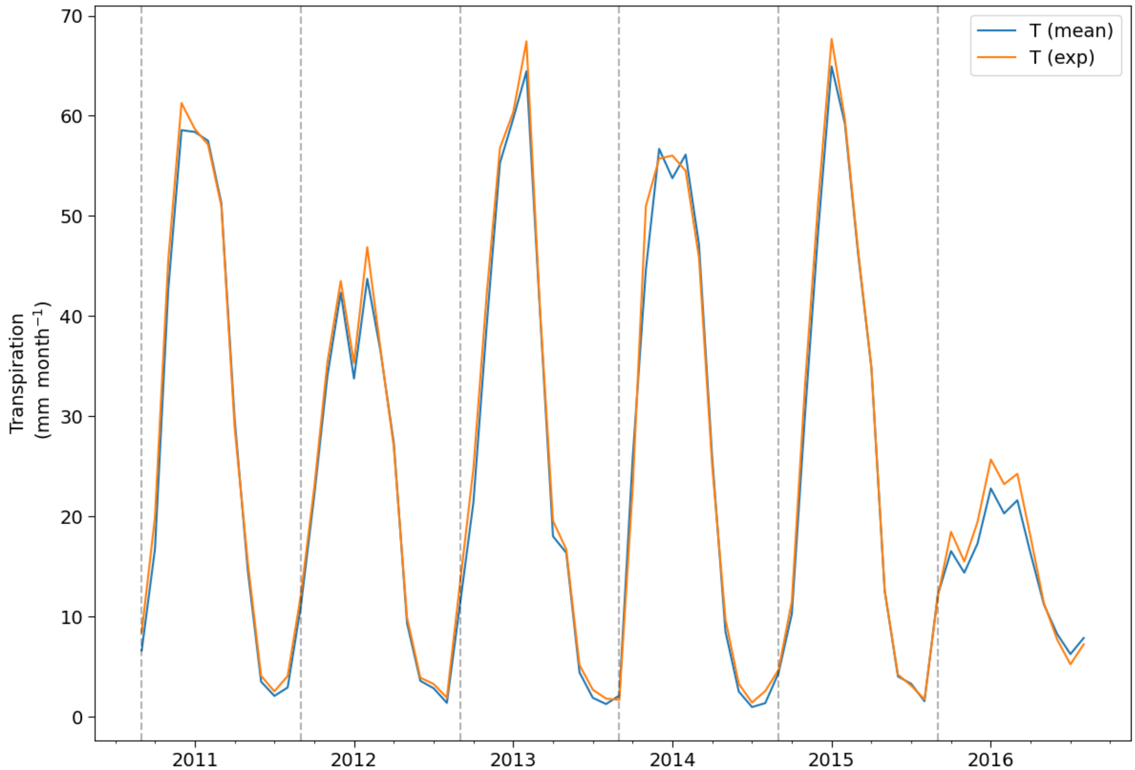

Figure S3. Monthly transpiration estimated using the Berkelhammer method with mean night-time respiration (blue) and with exponential temperature function (orange) used to determine daytime respiration (Räsänen et al., 2017).

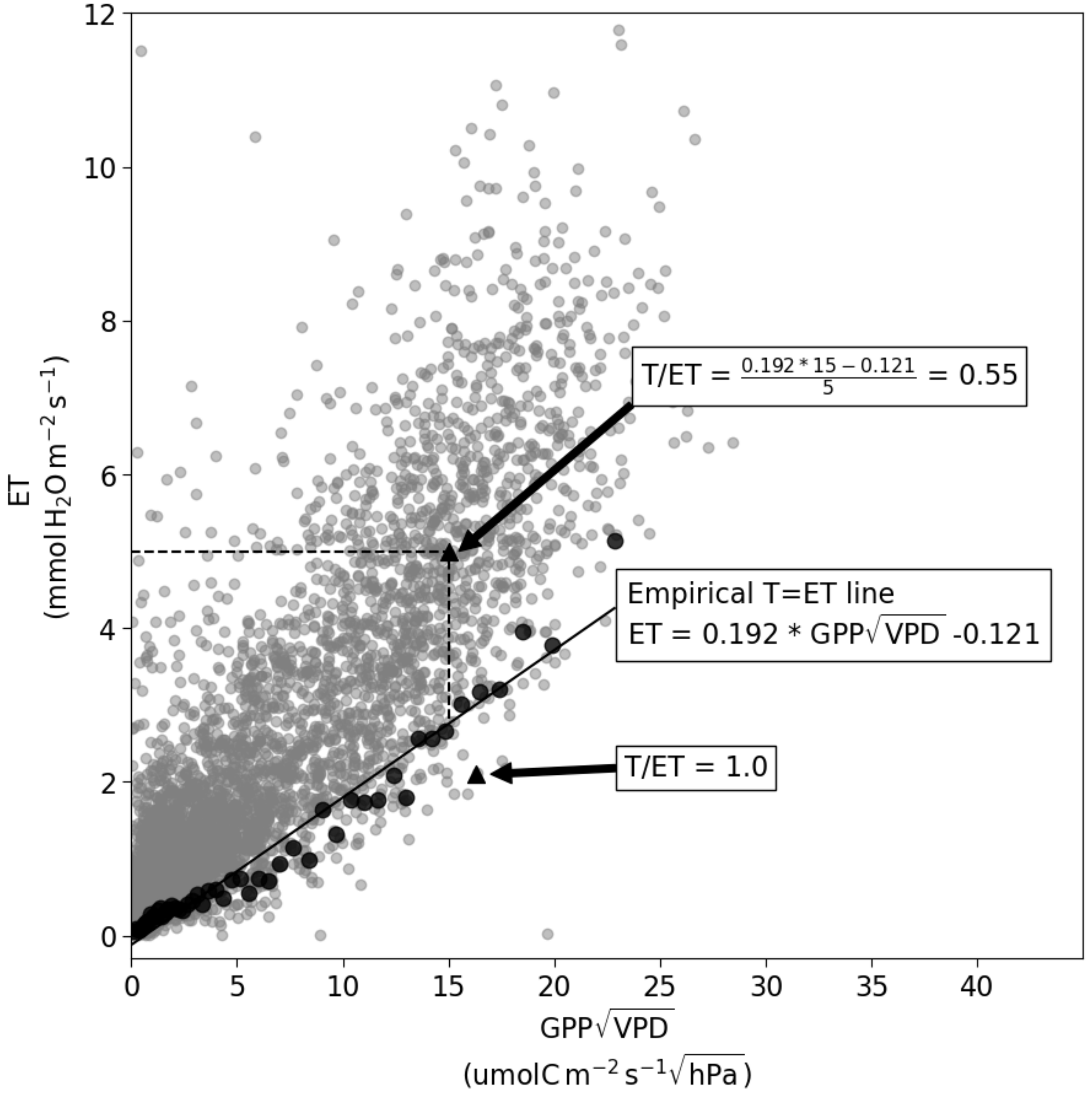

Figure S4. A fit of an annual *T*=ET line for the year 2010 and an example calculation of half-hour *T*/ET values for points indicated by triangles. The gray circles indicate all half-hour values, and black dots indicate fifth percentile points of each GPP × $VPD^{0.5}$ bin. The binning of x-axis values was conducted by dividing the values into 50 bins with an equal number of data points. The empirical *T*=ET line is a linear fit to the 5th percentile points.

S.3 Soil desorption

The mean daily estimate of evaporation calculated using Berkelhammer method from the half-hour estimates of *T*/ET allows indirect testing of whether estimated cumulative E scales linearly with $t_d^{1/2}$, where t_d is a single-event dry-down duration in days. This scaling is expected for what is termed as stage-2 evaporation rate starting from the day after the rainfall event. During this stage, the daily E is limited by soil moisture conditions and soil physical properties (desorptivity) described elsewhere (Brutsaert and Chen, 1995). The daily evaporation rate can be expressed as $E = (1/2)D_E t_d^{-1/2}$ and the cumulative daily E can be expressed as $D_E t_d^{1/2}$, where D_E is the soil desorptivity to be determined. The expected range of D_E based on several experiments is about 3 to 6 mm $d^{-1/2}$ as discussed elsewhere (Parlange et al., 1992) for sandy soils. By regressing cumulative daily E inferred from the aforementioned partitioning methods upon $\sqrt{t_d}$ for a single dry-down period, the D_E can be computed and compared to literature values. Dry season precipitation events were selected from June to August each year with the condition of at least an 8-day long dry-down and 0.02 $m^3 m^{-3}$ increase in surface soil moisture at 0.1 m depth. The wet season precipitation events were identified from April of each hydrological year. In five hydrological years, there were 8-days long dry-down period after precipitation in April with continuous daily evaporation estimate. April is also the month with the lowest coefficient of variation in monthly value of EVI, excluding the dry season months. By sampling from the late wet season, any differences in soil surface conditions may be seen in the late wet season evaporation events if ambient atmospheric variables do not exert stronger controls on the soil evaporation (as expected in stage-2 evaporation). The first day of fitting of the soil desorption was set to a day when soil evaporation decreased. This varied from 2 days to 6 days after the rainfall event. In April, the soil is dry enough for stage-2 conditions, unlike in mid-wet season when P frequency is higher, and surface soil is wet. The stage-2 soil evaporation after precipitation events was modeled with two different estimates of soil desorption. First, the soil evaporation was calculated using the aforementioned D_e from the regression of cumulative soil evaporation. This represents the eddy covariance scale, and the calculated daily evaporation should match with the partitioned soil evaporation estimate if the conditions for stage-2 evaporation are met. The second estimate is a linearized solution for soil desorptivity based on initial surface soil moisture conditions (Black et al., 1969)

$$D_{e,\theta} = 2(\theta_i - \theta_0)\left(\frac{\overline{D}}{\pi}\right)^{\frac{1}{2}}, \quad (6)$$

where θ_i is initial soil moisture, θ_0 is the soil moisture at surface and $\overline{D}$ is the weighted-mean diffusivity that was set to 394 $mm^2\ d^{-1}$ (Brutsaert, 2014). The first-day soil moisture value at 0.1 m depth was used for θ_i and θ_0 was set to zero as a first approximation.

The estimated cumulative E scaled linearly with $t_d^{1/2}$ ($R^2 > 0.97$) during five late wet season events and four dry season precipitation events allowing us to check estimated E dry-down trend to expected stage-2 evaporation and compare to soil moisture based estimate of E (Fig. S5, Table S1). For the dry season 2012, there was no precipitation event from June to

August, and in dry season 2013 there was one precipitation event, but the soil moisture at 0.1 m did not register that event. For these years, the dry season soil desorptivity was not estimated. In 2010 late wet season, there was no 8-day dry-down period, and hence no estimate of desorption was possible for the late wet season. The late wet season soil desorption estimated from partitioned evaporation (D_e) ranged from 2.6 to 7.5 mm $\mathrm{d}^{-1/2}$. The mean soil moisture based $D_{e,\theta}$ ranged from 2.0 to 3.5 mm $\mathrm{d}^{-1/2}$. The late wet season soil desorption (D_e) increases linearly with increasing initial daily evaporation (Table S1, $R^2 = 0.85$, p = 0.025) and for all events ($R^2 = 0.55$, p = 0.016). The D_e values were not correlated with first-day air temperature or water vapor deficit, but there was a significant correlation with soil moisture at 0.2 m depth ($R^2 = 0.60$, p = 0.023). The wet season $D_{e,\theta}$ estimated from soil moisture is similar to D_e, except in 2010 and in 2013 when the precipitation event was only 7.1 mm. For 2014 and 2015 the dry season $D_{e,\theta}$ is higher than D_e. One possible explanation for this difference is a potential drift in the dry season surface soil moisture sensor (due to changing sensor-soil contact). Evidence supporting this slight drift is that the minimum soil moisture value is approximately 0.04 higher in later years than in 2011. The much larger $D_{e,\theta}$ in 2015 shows that the 'small scale' estimate can be much larger than the eddy covariance scale estimate, although the overall mean D_e is higher than $D_{e,\theta}$. Despite different initial conditions primarily controlled by the first day E, the wet and dry season estimated soil desorption are in a similar range, and the D_e estimate of wet season dry-downs matches estimated daily E from the partitioning methods (Fig. S5). The lowest wet and dry season D_e values were estimated during the drought year 2015, characterized by grass regrowth and reduction in annual transpiration.

Table S1. Late wet season (April) and dry season soil desorption estimated from partitioned evaporation (D_e) and surface soil moisture ($D_{e,\theta}$). $E_{t,day1}$ is the evaporation of the first day of soil desorption fit.

Year	Start date	P amount	D_e	$D_{e,\theta}$	$E_{t,day1}$	θ_i
		(mm)	(mm $\mathrm{d}^{-1/2}$)	(mm $\mathrm{d}^{-1/2}$)	(mm)	($\mathrm{m^3 m^{-3}}$)
Wet season						
2011	2012-04-01	49.2	7.5	3.1	2.7	0.14
2012	2013-04-26	50.5	3.8	3.5	1.9	0.16
2013	2014-04-24	7.1	3.2	2.0	1.9	0.09
2014	2015-04-26	14.9	3.6	2.8	1.6	0.13

2015	2016-04-23	11.8	2.6	2.7	1.2	0.12
Dry season						
2010	2011-06-09	24.5	2.8	-	0.7	-
2011	2012-06-24	14.9	2.8	2.1	0.5	0.10
2014	2015-09-06	45.1	4.4	4.6	0.8	0.21
2015	2016-07-26	55.6	2.4	5.2	0.6	0.25

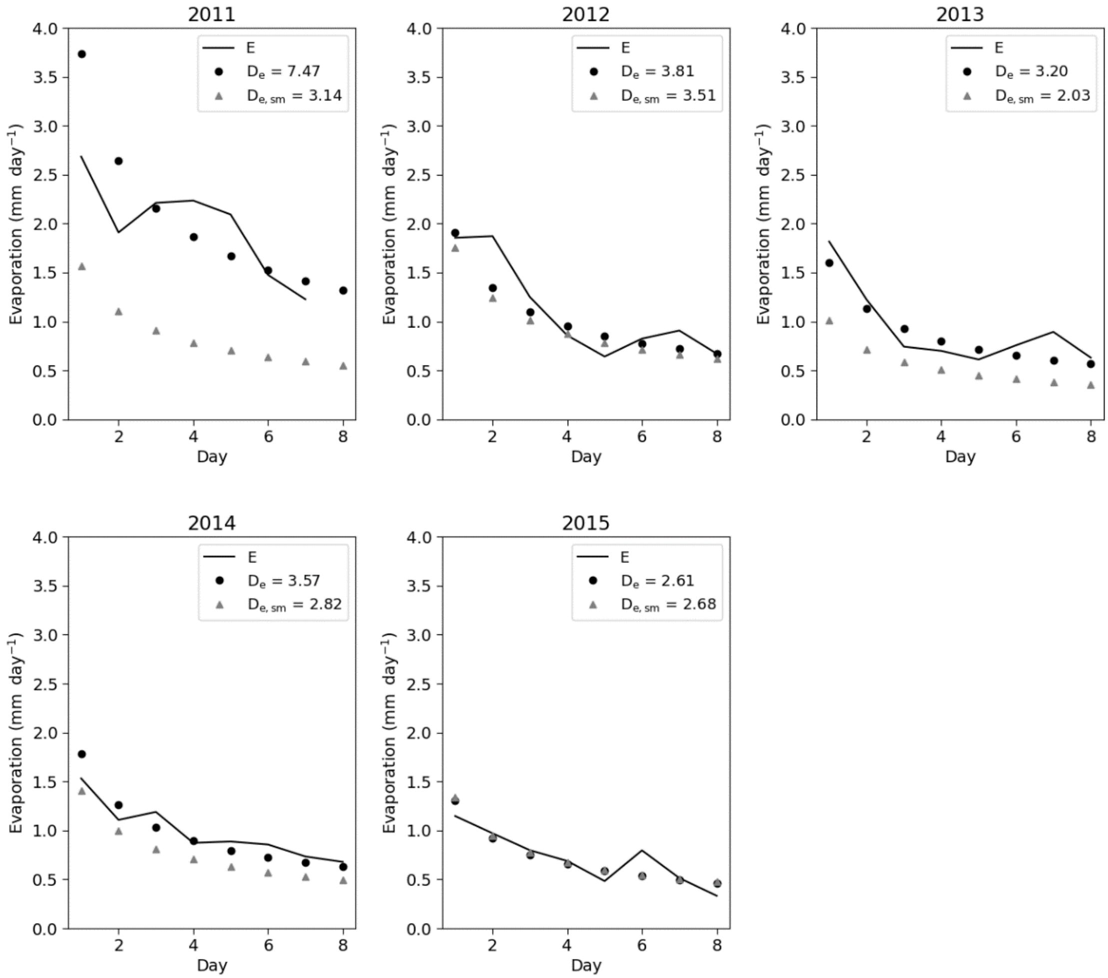

Figure S5. Daily evaporation after rainfall event in April except in year 2010. The line is estimated daily evaporation calculated using daily mean *T*/ET from Berkelhammer method. The dots indicate daily evaporation estimated from cumulative daily evaporation, and triangles indicate daily evaporation estimated from initial surface soil moisture.

Despite the majority of the *T*=ET moments concentrated at the wet season, the analysis of soil desorption from wet and dry season shows that the estimated daily soil evaporation under stage-2 condition had the expected characteristics of diffusion-limited soil evaporation (i.e. $1/\sqrt{t_d}$ scaling). The experimental values of the initial stage-2 evaporation vary from 1 to 3 mm day^{-1} for various soils and boundary conditions (Shokri et al., 2009). The daily evaporation rate was less than 2.7 mm d^{-1} on the first day of all wet season drying events and below 1 mm d^{-1} of all dry season events, which means that evaporation was stage-2 in all the drying events considered here. The differences in D_e values were not explained by ambient meteorological conditions but higher first-day evaporation and initial soil moisture at 0.2 m resulted in higher D_e. In laboratory conditions with full wetting of sandy soil columns, the stage-2 evaporation was shown to increase with ambient temperature (Ben Neriah et al., 2014). In the lab, the soil is dried homogeneously and continuously, whereas, in field conditions, there can be a large variance in surface soil moisture conditions and soil characteristics. The first-day evaporation control of D_e is expected due to the large spatial scale of the eddy covariance measurement, whereas small scale ambient measurements may not explain average evaporation of large spatial extent. However, the significant correlation with soil moisture at 0.2 m suggests that the soil moisture at this depth is a better representative of the column average soil moisture than the soil at 0.1 m depth. The slightly lower values of soil desorption during the dry season compared to the wet season are explained by the lower first-day evaporation and thus give confidence that the estimated evaporation in the dry season is also reasonable.

S.4 Water balance

Table S2. Dry season (Jun-Aug) sum of water balance components.

Dry season	*P*	ET	*T*	*E*
	(mm)	(mm)	(mm)	(mm)
2010	25	52	8	43
2011	18	40	7	32
2012	2	33	7	25
2013	7	29	4	24
2014	13	34	8	25
2015	66	47	22	25

Table S3. Rainy season timing and tree green-up dates. The start day refers to the day of the hydrological year and the end day to the day of the subsequent year. Early wet season period spans from September to November.

Year	Tree green-up	Start of rain	End of rain	Rainy season length	Percentage of rainy season T=ET values	Mean θ_{5cm} of T=ET	Early wet season α	Early wet season λ
	(DOY)	(DOY)	(DOY)	(days)	(%)	($m^3 m^{-3}$)	(mm d^{-1})	(storms d^{-1})
2010–2011	238	309	127	183	75	0.10	5.4	0.44
2011–2012	230	302	112	176	67	0.07	7.3	0.21
2012–2013	242	250	109	224	84	0.05	6.6	0.35
2013–2014	254	294	90	161	81	0.06	7.4	0.47
2014–2015	241	298	108	175	81	0.08	7.0	0.38
2015–2016	241	247	207	326	84	0.07	6.5	0.14

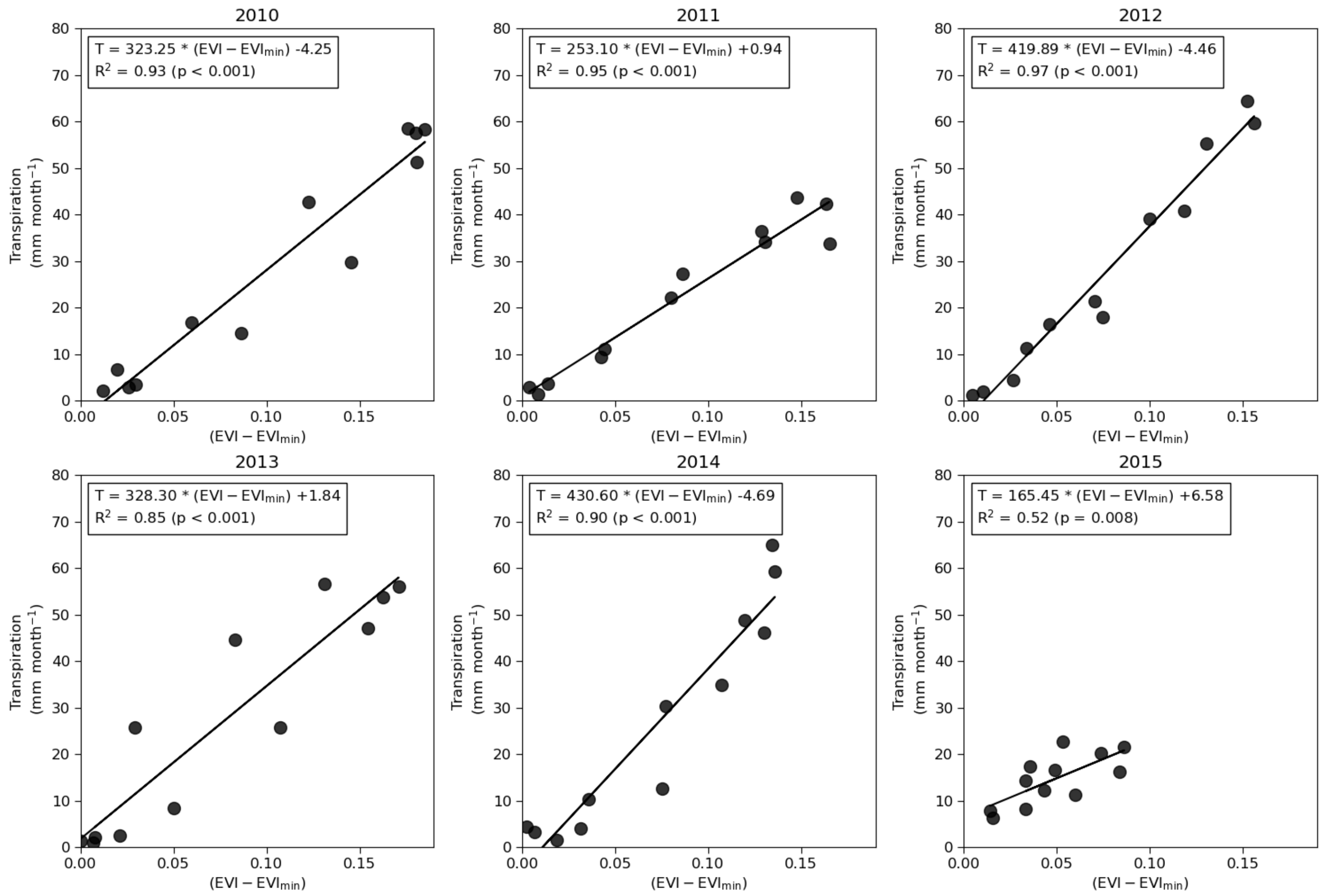

Figure S6. Relationship between monthly transpiration (Berkelhammer method) and monthly EVI.

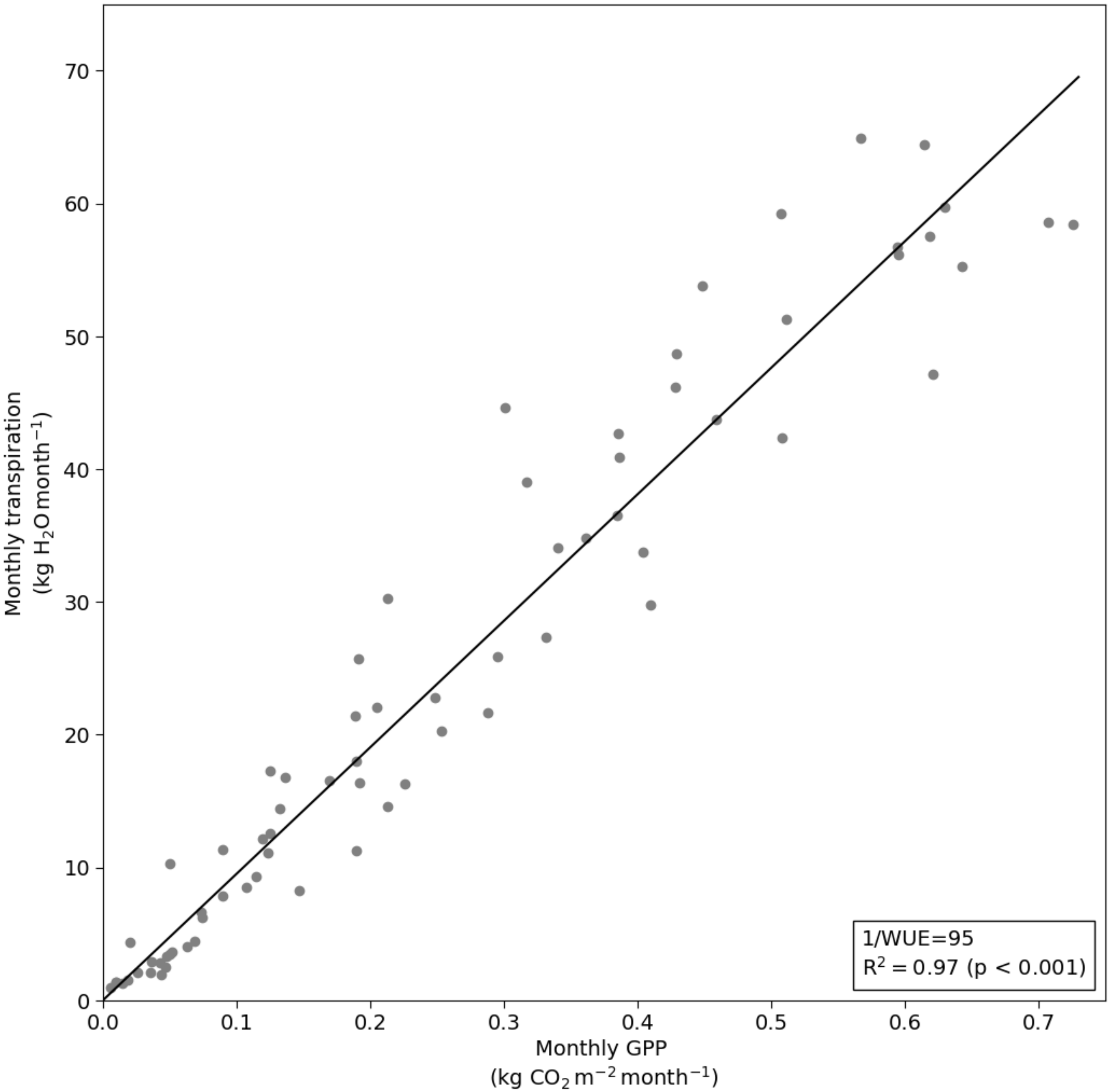

Figure S7. Inverse of water use efficiency estimated from monthly transpiration and GPP with zero intercept.

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