Response to comments by RC1 (dr. Giovanni Ravazzani)

This paper presents an analysis of methods to assess potential evaporation and transpiration using data across the globe coming from the FLUXNET database. This is the first time I read this paper even though authors mention the existence of an earlier version of the manuscript in the acknowledgement section. Probably due also to this fact, I found this paper very interesting and well written. My only concern is about the choice of methods to compute evaporation. They present analysis results for methods based on radiation and temperature, methods based on radiation, methods based on temperature. Surprisingly, among these latter, the Hargreaves-Samani method is not included. To my knowledge the Hargreaves-Samani method is widely used and has given satisfactory results in several biomes. So my question is how the methods to assess evaporation have been chosen and why Hargreaves-Samani equation is not included.

Reply:

Dear professor Ravazzani,

First of all, thank you very much for your kind appreciation of our work.

As to the selection of methods, we originally didn't want to include too many methods in the paper, and selected the two temperature-based methods we believed were most successful today – Although the Hargreaves-Samani (HS) method has been used much more than Oudin's method, Oudin's method is very similar to HS and performed better in Oudin's study (Oudin et al., 2005), and was picked up by several researchers.

However, we understand the comment, and have now redone the analyses to include the HS method. It was calculated as (Oudin et al., 2005; Raziei and Pereira, 2013):

$$\lambda E_{\mathrm{p}} = \alpha_{\mathrm{HS}} \, \mathrm{R_e} \, (\mathrm{T_a} + 17.8)\sqrt{T_{max} - T_{min}} \quad (1)$$

With α_{HS} a constant, T_a the daily mean air temperature, T_{max} the daily maximum and T_{min} the daily minimum air temperature. As for the other temperature-based methods, two versions were calculated. In the standard version, α_{HS} =0.0023; in the biome-specific version, α_{HS} was calibrated per biome.

We then re-did all calculations and analyses. The results are summarized in the tables 1-3 (mean correlation, unbiased RMSE and bias for the energy balance criterion) and 4-6 (same variables, but for the soil moisture criterion.

All in all, the HS method performs best of the three temperature-based methods, but clearly does not perform as good as the simple radiation-based (Milly and Dunne) method or the Priestley and Taylor method, and this for both unstressed subset selection criteria. Other analyses (ie S6-S11 in Supplement of original document) were also performed and are in line with these observations. Hence, the overall conclusions of the paper will not be affected by including the Hargreaves-Samani method.

In the revised version of the text, we will include the Hargreaves-Samani method.

Kind regards,

Wouter Maes,

On behalf of the co-authors

Table 1 – Mean correlations per biome between the measured E_{unstr} and the different E_p methods. The methods with the highest correlation per biome are highlighted in bold and underlined. Based on unstressed days only defined using the energy balance criterion. Different colours are used to group biomes into broader ecosystem types (in descending order: croplands, grasslands, forests, savannah ecosystems, wetlands).

	Radiation, Temperature, VPD					*Radiation, Temperature*			*Radiation*			*Temperature*					
	Penman-Monteith			**Penman**		**Priestley and Taylor**			**Milly and Dunne**			**Thornthwaite**		**Oudin**		**Hargreaves-Samani**	
	Ref. crop	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Ref. crop**	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**
CRO (10)	0.84	0.91	0.90	0.76	0.81	0.86	0.96	0.96	0.82	**0.96**	**0.96**	0.77	0.77	0.74	0.74	0.76	0.76
GRA (20)	0.79	0.87	0.87	0.77	0.84	0.82	0.93	0.93	0.80	**0.94**	**0.94**	0.55	0.54	0.55	0.55	0.66	0.66
DBF (15)	0.78	0.87	0.88	0.79	0.85	0.78	0.91	0.91	0.75	**0.91**	**0.91**	0.57	0.56	0.57	0.57	0.62	0.62
EBF (9)	0.88	0.89	0.88	0.86	0.85	0.87	**0.91**	**0.91**	0.83	0.90	0.90	0.71	0.79	0.57	0.57	0.75	0.75
ENF (26)	0.89	0.90	0.91	0.88	0.86	0.90	0.95	0.95	0.88	**0.95**	**0.95**	0.77	0.79	0.76	0.76	0.82	0.82
MF (4)	0.90	0.93	0.93	0.90	0.93	0.90	**0.94**	**0.94**	0.88	0.93	0.93	0.79	0.75	0.74	0.74	0.79	0.79
CSH (2)	0.90	0.94	0.93	0.89	0.90	0.90	0.95	0.95	0.89	**0.95**	**0.95**	0.80	0.78	0.75	0.75	0.79	0.79
WSA (5)	0.76	0.78	0.78	0.73	0.73	0.80	0.89	0.89	0.79	**0.90**	**0.90**	0.41	0.41	0.46	0.46	0.51	0.51
SAV (6)	0.79	0.82	0.81	0.77	0.79	0.83	**0.91**	**0.91**	0.81	0.91	0.91	0.52	0.52	0.56	0.56	0.71	0.71
OSH (5)	0.72	0.80	0.78	0.64	0.78	0.79	0.90	0.90	0.77	**0.90**	**0.90**	0.54	0.53	0.56	0.56	0.64	0.64
WET (5)	0.87	0.81	0.76	0.87	0.66	0.79	0.83	0.83	0.68	**0.85**	**0.85**	0.50	0.45	0.61	0.61	0.65	0.65
Overall (107)	**0.83**	**0.87**	**0.87**	**0.81**	**0.83**	**0.84**	**0.92**	**0.92**	**0.81**	**0.93**	**0.93**	**0.62**	**0.63**	**0.63**	**0.63**	**0.71**	**0.71**

CRO=cropland; DBF=Deciduous Broadleaf Forest; EBF=Evergreen Broadleaf Forest; ENF=Evergreen Needleleaf Forest; MF=Mixed Forest; CSH=Closed Shrubland; WSA=Woody Savanna; SAV=Savanna; OSH=Open Shrubland; GRA=Grasslands; WET=Wetlands.

Table 2 - Unbiased Root Mean Square Error (UnRMSE) (in mm day^{-1}) for the E_p methods per biome. The methods with the lowest UnRMSE per biome are indicated in bold and are underlined. Based on unstressed days only defined using the energy balance criterion. Different colours are used to group biomes into broader ecosystem types (in descending order: croplands, grasslands, forests, savannah ecosystems, wetlands).

	Radiation, Temperature, VPD					*Radiation, Temperature*			*Radiation*			*Temperature*					
	Penman-Monteith			**Penman**		**Priestley and Taylor**			**Milly and Dunne**			**Thornthwaite**		**Oudin**		**Hargreaves-Samani**	
	Ref. crop	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Ref. crop**	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**
CRO (10)	1.16	0.79	1.04	1.60	2.88	1.27	0.62	0.58	1.21	0.57	<u>**0.55**</u>	1.24	1.24	1.29	1.27	1.24	1.28
GRA (20)	1.22	0.70	0.81	1.75	1.04	1.40	0.58	0.47	1.13	0.44	<u>**0.44**</u>	1.07	1.03	1.05	1.04	0.97	0.97
DBF (15)	1.14	0.88	0.89	1.21	1.36	1.29	0.75	<u>**0.72**</u>	1.20	0.72	0.72	1.41	1.42	1.37	1.32	1.32	1.33
EBF (9)	0.84	0.62	0.93	1.07	1.33	1.09	0.75	0.59	0.96	0.55	<u>**0.54**</u>	1.04	0.98	1.15	1.14	1.00	1.03
ENF (26)	0.98	0.78	0.99	1.20	14.89	1.26	0.84	0.52	1.09	0.59	<u>**0.50**</u>	0.94	0.91	0.96	0.97	0.88	0.92
MF (4)	1.23	0.69	0.69	1.58	1.11	1.64	0.86	<u>**0.58**</u>	1.26	0.64	0.59	1.11	1.03	1.03	0.99	1.04	1.03
CSH (2)	0.82	0.59	0.59	0.98	0.92	1.12	0.75	<u>**0.48**</u>	0.91	0.55	0.49	0.90	0.96	0.83	0.81	0.91	0.87
WSA (5)	1.15	0.93	0.80	1.41	1.68	1.27	0.67	0.52	1.00	0.53	<u>**0.51**</u>	1.10	1.10	0.99	0.99	1.03	1.02
SAV (6)	1.22	1.02	0.83	1.53	1.88	1.39	0.76	0.52	1.07	0.58	<u>**0.52**</u>	1.22	1.21	1.10	0.97	1.02	0.94
OSH (5)	1.37	0.73	0.63	1.94	0.92	1.63	0.67	<u>**0.43**</u>	1.28	0.48	0.44	1.12	1.03	0.90	0.80	0.90	0.75
WET (5)	1.27	1.25	1.38	1.38	4.14	1.72	1.28	1.13	1.91	1.14	<u>**1.10**</u>	2.20	2.29	1.65	2.01	1.53	1.55
Overall (107)	**1.11**	**0.80**	**0.91**	**1.41**	**4.86**	**1.34**	**0.75**	**0.57**	**1.16**	**0.60**	<u>**0.56**</u>	**1.16**	**1.14**	**1.12**	**1.11**	**1.05**	**1.06**

Table 3 - Mean bias (in mm day^{-1}) for the E_p methods per biome. The best performing method per biome is indicated in bold and is underlined. Based on unstressed days only defined using the energy balance criterion. Different colours are used to group biomes into broader ecosystem types (in descending order: croplands, grasslands, forests, savannah ecosystems, wetlands).

	Radiation, Temperature, VPD					*Radiation, Temperature*			*Radiation*			*Temperature*					
	Penman-Monteith			**Penman**		**Priestley and Taylor**			**Milly and Dunne**			**Thornthwaite**		**Oudin**		**Hargreaves-Samani**	
	Ref. crop	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Ref. crop**	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**
CRO (10)	1.14	-0.49	0.84	2.83	2.64	2.20	0.47	**-0.01**	1.43	-0.24	0.12	-0.65	-0.59	-1.62	-0.62	-1.01	0.11
GRA (20)	2.65	0.53	1.16	4.37	1.90	3.69	1.11	**0.02**	2.57	0.22	-0.10	-0.14	-0.44	-0.61	-0.73	0.07	0.11
DBF (15)	0.30	-0.48	0.89	1.30	2.63	1.81	0.94	**-0.06**	0.74	-0.13	-0.15	-1.94	-2.03	-2.44	-0.71	-1.99	0.19
EBF (9)	0.70	**0.04**	0.95	1.39	1.74	1.39	0.79	0.16	0.79	0.17	-0.13	-0.83	-0.27	-0.53	-0.36	-0.84	0.20
ENF (26)	1.28	0.45	1.23	2.03	1.04	2.06	1.17	-0.05	1.88	0.90	**0.02**	-0.15	-0.05	-0.73	-0.54	-0.30	0.26
MF (4)	2.22	0.65	0.30	3.31	2.04	3.26	1.46	-0.07	2.53	0.87	-0.04	0.73	0.19	-0.01	-0.99	0.31	0.16
CSH (2)	1.01	0.49	**0.00**	1.61	1.79	1.46	1.10	-0.04	0.92	0.51	-0.14	0.18	0.39	0.14	-0.56	0.18	-0.18
WSA (5)	2.67	1.16	0.17	3.68	3.88	3.63	1.42	-0.03	2.33	0.40	-0.22	-0.14	-0.23	-0.20	-0.39	0.08	**-0.02**
SAV (6)	2.56	1.30	0.31	3.57	3.78	3.34	1.47	-0.15	2.21	0.54	-0.13	0.03	**0.00**	0.40	-0.93	0.53	-0.25
OSH (5)	4.32	1.68	0.37	6.20	2.73	5.08	2.00	0.10	3.89	1.15	**0.00**	1.13	0.84	0.81	-0.44	1.45	0.06
WET (5)	2.34	1.28	1.74	4.17	4.51	3.45	2.00	1.04	3.29	1.43	1.12	1.42	0.29	-0.52	-2.79	0.36	**-0.11**
Overall (107)	**1.69**	**0.40**	**0.93**	**2.88**	**2.21**	**2.67**	**1.14**	**0.04**	**1.92**	**0.45**	**0.00**	**-0.38**	**-0.45**	**-0.80**	**-0.72**	**-0.37**	**0.12**

Table 4 - Mean correlations per biome between the measured E_{unstr} and the different E_p methods. The methods with the highest correlation per biome are highlighted in bold and underlined. Based on unstressed days only defined using the soil moisture criterion.

	Radiation, Temperature, VPD					*Radiation, Temperature*			*Radiation*			*Temperature*					
	Penman-Monteith			**Penman**		**Priestley and Taylor**			**Milly and Dunne**			**Thornthwaite**		**Oudin**		**Hargreaves-Samani**	
	Ref. crop	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Ref. crop**	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**
CRO (5)	0.73	0.80	0.79	0.69	0.77	0.74	**0.85**	**0.85**	0.68	0.85	0.85	0.68	0.68	0.69	0.69	0.71	0.71
GRA (15)	0.62	0.79	0.79	0.50	0.73	0.69	**0.88**	**0.88**	0.56	0.87	0.87	0.66	0.66	0.66	0.66	0.69	0.69
DBF (8)	0.74	0.85	0.85	0.70	0.72	0.74	**0.87**	**0.87**	0.58	0.81	0.81	0.78	0.77	0.80	0.80	0.79	0.79
EBF (3)	0.71	0.82	0.82	0.71	0.80	0.71	**0.83**	**0.83**	0.64	0.80	0.80	0.66	0.66	0.60	0.60	0.63	0.63
ENF (18)	0.68	0.77	0.77	0.65	0.72	0.70	**0.81**	**0.81**	0.56	0.74	0.74	0.77	0.77	0.76	0.76	0.77	0.77
MF (2)	0.65	0.73	0.73	0.63	0.71	0.68	0.78	0.78	0.58	0.75	0.75	**0.80**	0.80	0.75	0.75	0.76	0.76
CSH (2)	0.82	**0.85**	0.83	0.80	0.81	0.77	0.81	0.81	0.73	0.83	0.83	0.46	0.49	0.48	0.48	0.52	0.52
WSA (3)	0.60	0.74	0.76	0.50	0.57	0.65	**0.86**	**0.86**	0.54	0.84	0.84	0.65	0.66	0.65	0.65	0.70	0.70
SAV (3)	0.57	0.68	0.64	0.58	0.72	0.59	0.77	0.77	0.57	**0.78**	**0.78**	0.45	0.45	0.42	0.42	0.50	0.50
OSH (3)	0.58	0.80	0.85	0.35	0.66	0.64	**0.86**	**0.86**	0.46	0.84	0.84	0.68	0.73	0.73	0.73	0.72	0.72
Overall (62)	**0.67**	**0.78**	**0.78**	**0.61**	**0.72**	**0.70**	**0.84**	**0.84**	**0.58**	**0.81**	**0.81**	**0.69**	**0.69**	**0.70**	**0.70**	**0.71**	**0.71**

Table 5 - Unbiased Root Mean Square Error (UnRMSE) (in mm day^{-1}) for the E_p methods per biome. The methods with the lowest UnRMSE per biome are indicated in bold and are underlined. Based on unstressed days only defined using the soil moisture criterion.

	Radiation, Temperature, VPD					*Radiation, Temperature*			*Radiation*			*Temperature*					
	Penman-Monteith			**Penman**		**Priestley and Taylor**			**Milly and Dunne**			**Thornthwaite**		**Oudin**		**Hargreaves-Samani**	
	Ref. crop	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Ref. crop**	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**
CRO (5)	1.30	1.03	1.25	1.77	1.65	1.57	1.00	0.85	1.44	0.86	**0.84**	1.24	1.24	1.21	1.18	1.16	1.16
GRA (15)	1.55	0.91	0.89	2.27	1.27	1.65	0.76	**0.74**	1.62	0.74	0.85	1.02	1.07	1.00	0.99	1.02	1.00
DBF (8)	1.52	1.20	1.19	1.77	2.20	1.74	1.17	1.26	2.01	1.32	1.53	1.15	**1.14**	1.35	1.43	1.44	1.48
EBF (3)	0.89	0.65	0.67	1.10	0.91	1.06	0.84	**0.59**	1.03	0.77	0.62	0.73	0.72	0.71	0.76	0.68	0.77
ENF (18)	1.30	1.08	0.98	1.63	2.19	1.60	1.18	**0.73**	1.64	1.10	0.85	0.86	0.86	0.84	0.83	0.86	0.85
MF (2)	1.59	1.21	1.05	1.83	1.57	1.89	1.25	0.92	1.67	1.12	1.03	**0.72**	0.73	0.94	0.94	0.92	0.92
CSH (2)	0.73	0.60	0.56	0.95	0.98	1.16	0.90	**0.54**	1.13	0.78	0.55	0.94	0.97	0.82	0.73	0.74	0.72
WSA (3)	1.25	0.84	0.74	1.63	1.95	1.42	0.70	**0.58**	1.40	0.64	0.65	0.89	0.89	0.81	0.79	0.74	0.73
SAV (3)	1.33	0.94	0.80	1.67	1.66	1.56	0.84	**0.57**	1.31	0.67	0.57	0.97	0.94	0.98	0.87	0.97	0.87
OSH (3)	1.35	0.69	0.54	2.16	1.06	1.57	0.62	**0.53**	1.55	0.55	0.63	1.03	1.00	0.74	0.63	0.73	0.65
Overall (62)	**1.36**	**0.98**	**0.94**	**1.80**	**1.71**	**1.58**	**0.97**	**0.78**	**1.59**	**0.93**	**0.89**	**0.96**	**0.97**	**0.97**	**0.96**	**0.98**	**0.97**

Table 6. Mean bias (in mm day^{-1}) for the E_p methods per biome. The best performing method per biome is indicated in bold and is underlined. Based on unstressed days only defined using the soil moisture criterion.

	Radiation, Temperature, VPD					*Radiation, Temperature*			*Radiation*			*Temperature*					
	Penman-Monteith			**Penman**		**Priestley and Taylor**			**Milly and Dunne**			**Thornthwaite**		**Oudin**		**Hargreaves-Samani**	
	Ref. crop	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Ref. crop**	**Standard**	**Biome**	**Ref. crop**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**	**Standard**	**Biome**
CRO (5)	2.07	0.50	1.15	3.83	1.83	2.93	1.02	0.08	3.03	0.90	<u>**0.08**</u>	0.28	0.38	-0.33	-0.48	0.15	0.19
GRA (15)	3.08	0.98	0.82	4.89	2.16	4.06	1.41	-0.03	3.91	1.15	-0.13	0.21	0.48	0.11	-0.55	0.74	<u>**0.01**</u>
DBF (8)	1.92	0.84	0.60	2.96	4.15	3.14	2.13	-0.22	3.37	2.09	-0.35	-0.10	<u>**0.02**</u>	-0.44	-0.83	0.10	-0.16
EBF (3)	1.61	0.37	0.62	2.60	1.81	3.06	1.85	0.08	2.94	1.57	-0.02	-1.36	-0.74	-1.06	<u>**0.00**</u>	-0.92	0.43
ENF (18)	2.70	1.45	0.97	3.95	4.75	3.92	2.62	<u>**0.03**</u>	4.28	2.71	-0.04	0.36	0.45	-0.50	-0.52	0.29	0.13
MF (2)	3.17	1.68	0.57	4.51	3.36	4.58	2.51	-0.04	5.04	2.60	-0.15	1.03	1.01	<u>**0.01**</u>	-0.55	0.84	0.05
CSH (2)	1.93	0.85	0.04	2.87	2.35	2.74	1.62	-0.05	2.49	1.30	-0.08	-0.41	-0.14	<u>**-0.03**</u>	-0.37	0.04	-0.05
WSA (3)	2.64	1.09	<u>**0.13**</u>	3.54	3.97	3.59	1.51	-0.21	3.32	1.13	-0.32	-0.25	0.21	0.14	-0.42	0.29	-0.19
SAV (3)	2.66	1.30	0.19	3.55	3.26	3.48	1.54	-0.14	2.82	0.96	<u>**-0.10**</u>	0.56	0.53	1.15	-0.62	1.07	-0.21
OSH (3)	3.94	1.40	0.14	5.54	2.49	4.64	1.39	<u>**0.01**</u>	4.52	1.19	-0.12	0.32	0.69	0.63	-0.28	1.11	-0.02
Overall (62)	**2.64**	**1.09**	**0.72**	**4.00**	**3.33**	**3.71**	**1.89**	**-0.04**	**3.77**	**1.77**	**-0.12**	**0.12**	**0.33**	**-0.16**	**-0.52**	**0.39**	<u>**0.04**</u>

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