How sensitive are rainfall interception models to the canopy parameters of semi-arid forests?

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Introduction:

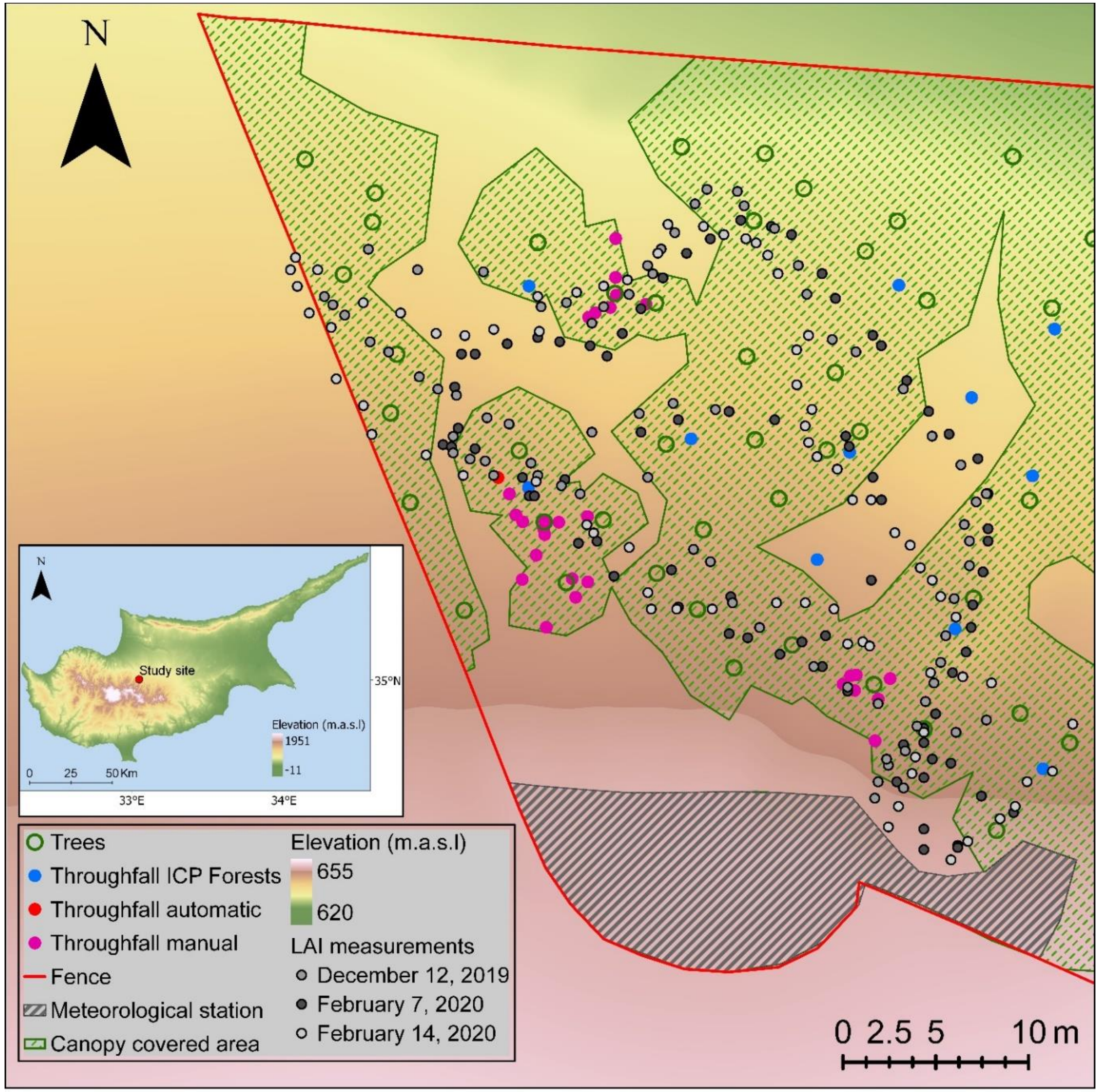
- Rainfall interception: 6 – 45% of the gross rainfall
- Rainfall interception models: rely on plant parameters
- Canopy storage capacity (*S*)
- Canopy cover fraction (*c*)
- Objective: Examine the sensitivity of three commonly used rainfall interception models (Rutter, Gash and Liu) to the canopy storage capacity (S) and to the canopy cover fraction (c)

Study site[1,2]: *Pinus brutia* forest, Cyprus

Elevation (m)	620 -655
Mean slope (degrees)	25
Aspect	North
Forest density (trees ha^{-1})	200
Average annual rainfall (mm)	425
Minimum annual rainfall (mm)	169 (2007/2008)
Maximum annual rainfall (mm)	725 (2018/2019)
Daily max. temperature (C°)	34 (July)
Daily min. temperature (C°)	4 (January)

[1]Eliades, M., Bruggeman, A., Lubczynski, M.W., Christou, A., Camera, C., Djuma, H., 2018. J. Hydrol. 562, 712–724.
[2]Eliades, M., Bruggeman, A., Djuma, H., Lubczynski, M., 2018. Water 10, 1039.

Methodology:



Period 2016 -2019

- 1 meteorological station (hourly)
- 28 manual throughfall gauges (after rainfall)
- 1 automatic throughfall gauge (hourly)
- Leaf area index
- 80 test runs per model: examine the effect of S and c onto the model performance
- Optimized parameters - Sensitivity analysis
- Model evaluation: Kling-Gupta efficiency (KGE) and percent bias (%)

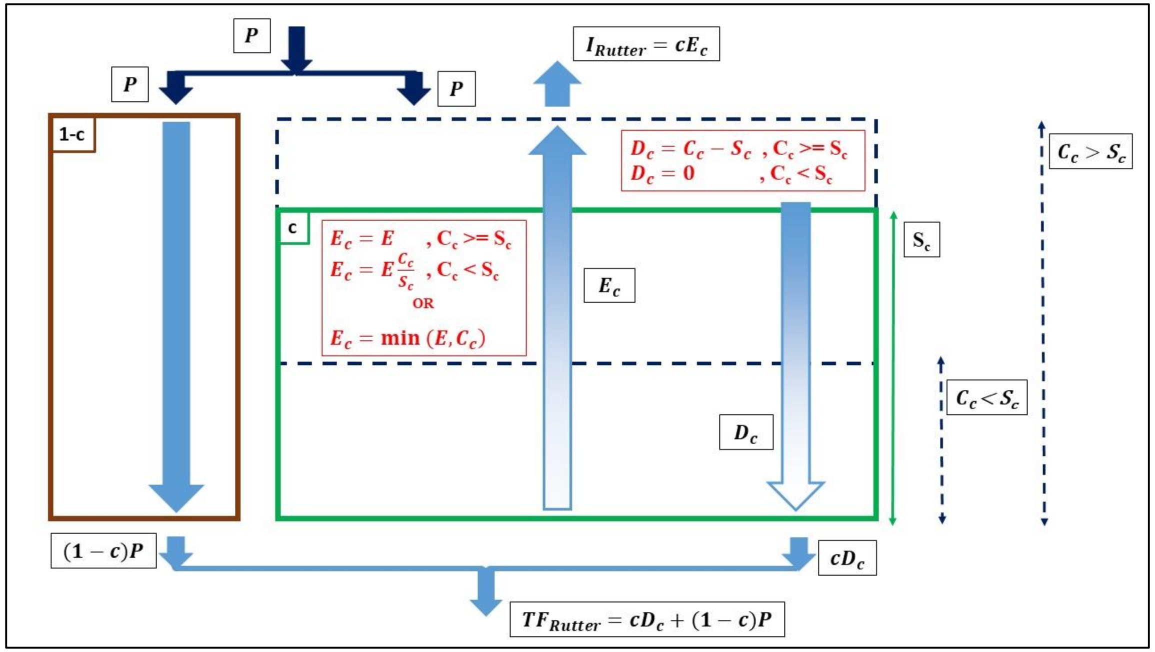
Period 2008 - 2018

- 15 ICP forests[1] throughfall gauges (weekly)
- Rainfall (daily)

[1]International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

Methodology:

- Rutter model



- Gash model

$$I_{Gash} = c\sum_{j=1}^{m} P_j + c(nP_s) + c\frac{\bar{E}_c}{\bar{R}}\sum_{i=1}^{n}(P_i - P_s)$$

- Liu model

$$I_{Liu} = c\left\{S_c\left[1 - exp\left(-\frac{c}{S}P\right)\right]\left[1 - \frac{\bar{E}_c}{\bar{R}}\right] + \frac{\bar{E}_c}{\bar{R}}P\right\}$$

C_c: Water storages on the canopy surface (mm)

P: Rainfall (mm)

E: Potential evaporation (mm)

E_c: Actual evaporation (mm)

D_c: Canopy drainage (mm)

S_c: Storage capacity of the canopy cover area (S /c) (mm)

c: Canopy cover fraction

P_j : Rainfall - m small rain events, insufficient to saturate the canopy ($P < P_s$)

P_i: Rainfall - n large events that saturate the canopy ($P \geq P_s$)

P_s: Amount of water needed to saturate the canopy (mm)

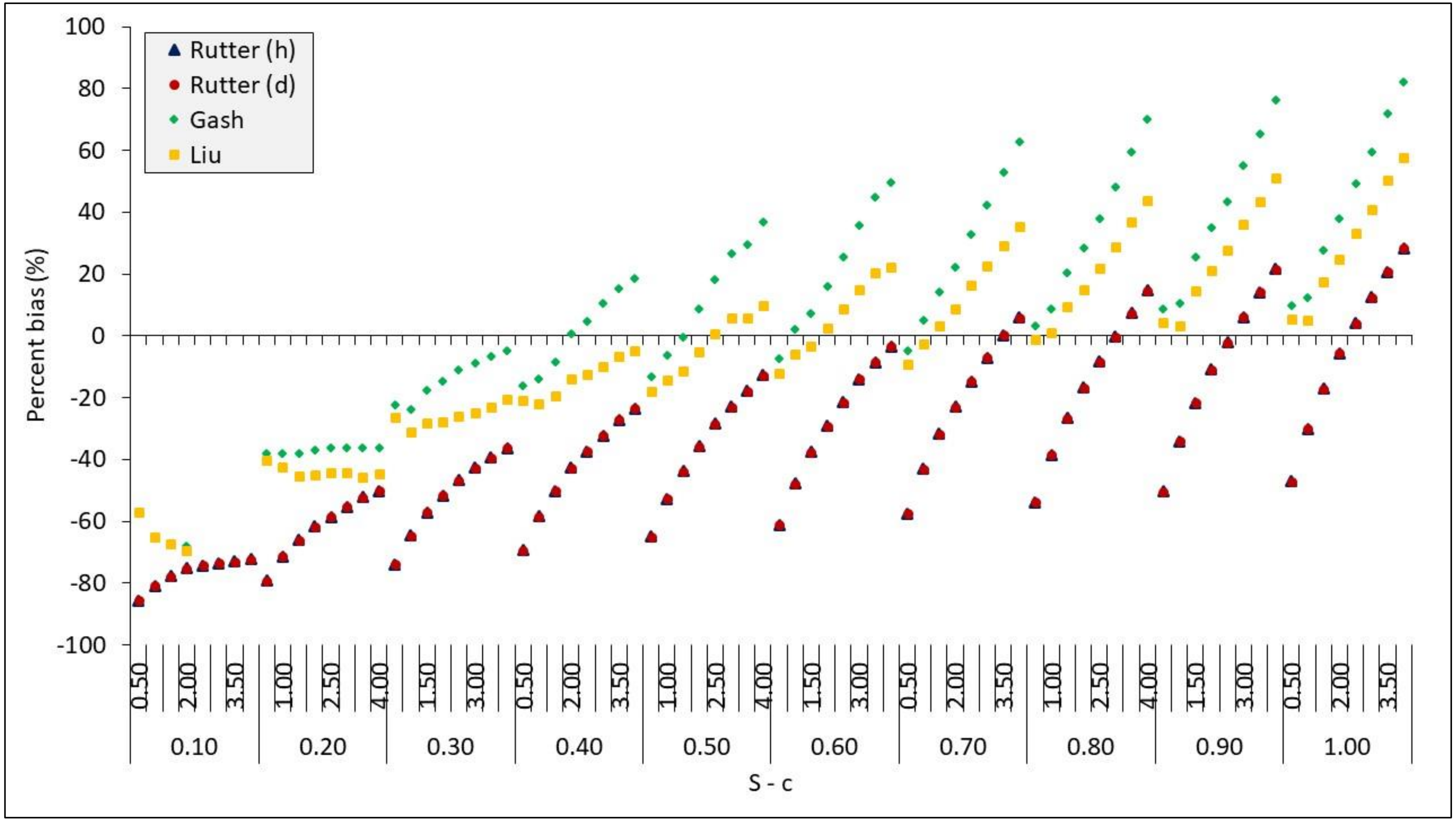
$\bar{R}$: Mean rainfall rate (mm h^{-1})

$\bar{E}_c$: Mean evaporation rate from the canopy area ($\bar{E}/c$), (mm h^{-1})

Gash, J.H.C., 1979. Q. J. R. Meteorol. Soc. 105, 43–55.
Gash, J.H.C., Lloyd, C.R., Lachaud, G., 1995. J. Hydrol. 170, 79–86.
Carlyle-Moses, D.E., Price, A.G., 2007. Hydrol. Process. 21, 2572–2580.
Liu, S., 1997. Ecol. Modell. 99, 151–159.
Rutter, A.J., Kershaw, K.A., Robins, P.C., Morton, A.J., 1971. Agric. Meteorol. 9, 367–384.
Valente, F., David, J.S., Gash, J.H., 1997. J. Hydrol. 190, 141–162.

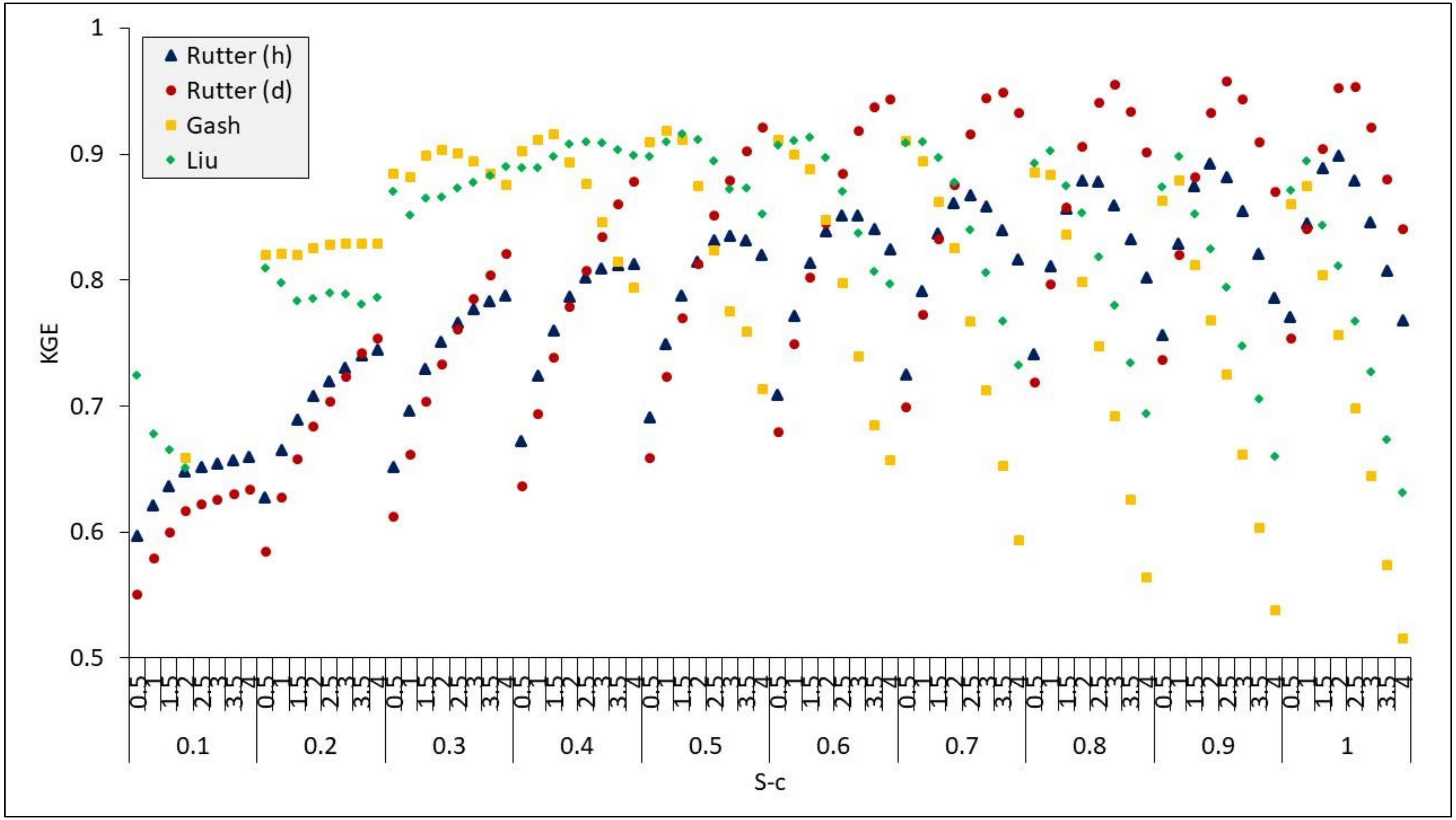
Results:

- Model performance (given by the KGE) of the three models (Rutter hourly and daily, Gash and Liu) with changing canopy cover fraction (c) and storage capacity (S)



Results:

- Percent bias between modelled and observed interception loss of the three models (Rutter hourly and daily, Gash and Liu) with changing canopy cover fraction (c) and storage capacity (S)



Results:

- Sensitivity analysis:

Percent change of the input parameter S (dS/S) and c (dc/c) and the relative change to the model output for S (O(S)) and c (O(c))

%	Rutter		Gash		Liu	
dS/S, dc/c	O (S)	O (c)*	O (S)	O (c)	O (S)	O (c)
20	8		6	11	3	7
10	4		3	6	1	5
5	2		1	4	1	4
-5	-2	-3	0	-2	1	-1
-10	-5	-6	-1	-5	0	-2
-20	-10	-12	-3	-13	0	-7

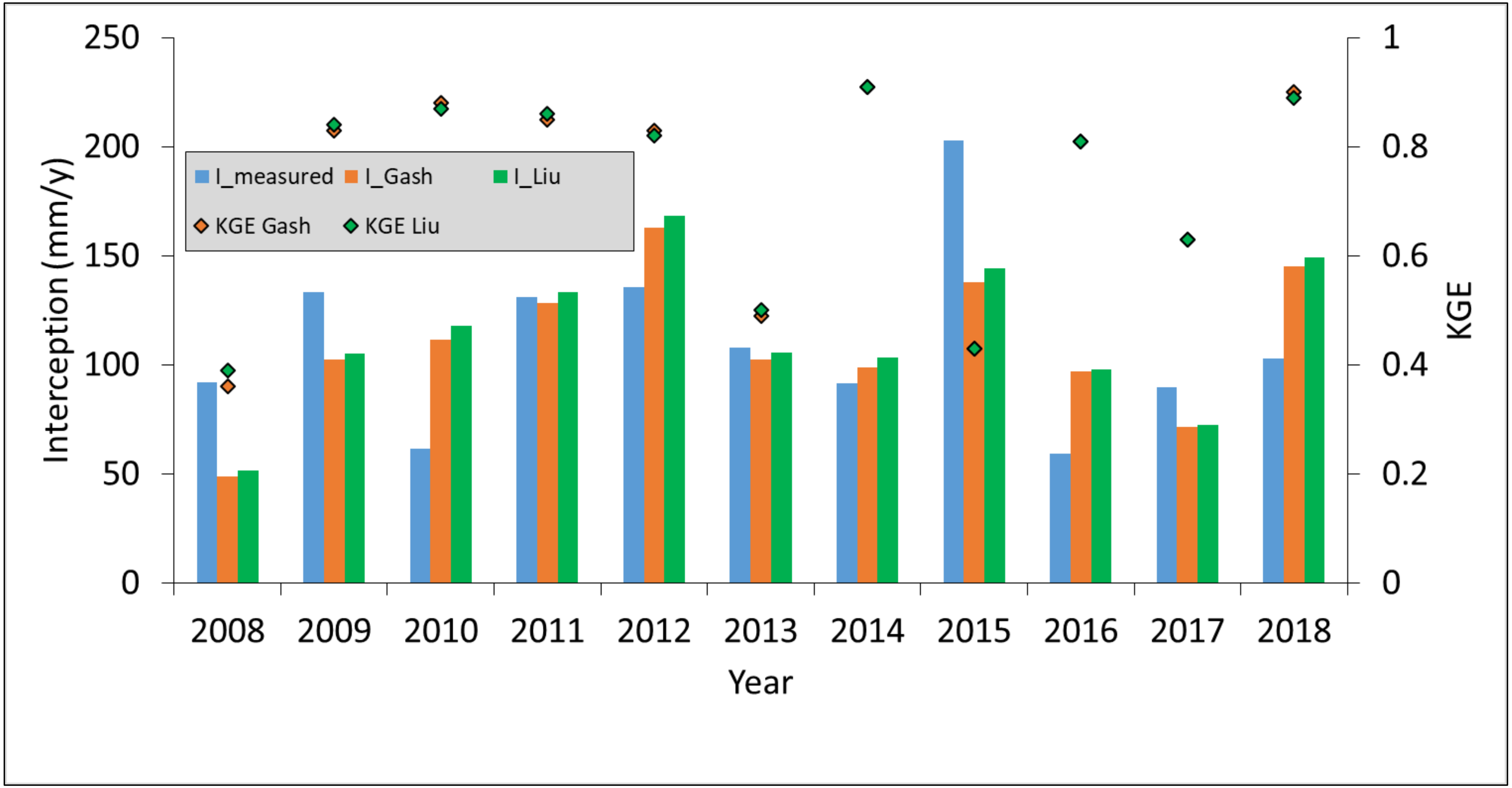
*Positive changes to the model output were not computed because the optimum c was at the maximum (1).

- Optimized parameters

Parameters	Rutter	Gash	Liu
S	2.23	1.43	1.37
c	1.00	0.40	0.57
E	0.07	0.07	0.07
R	0.37	0.44	0.40

Results:

- Rainfall interception (I_measured, I_Gash and I_Liu) and model performance (KGE Gash and Liu) per year



Conclusions:

- The Rutter model outperformed Gash and Liu models
- Gash and Liu had similar long-term model performance
- All models were more sensitive to changes in c than to changes in S
- A range of canopy parameter values achieve similar high rainfall interception model performance

Thank you!

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