The impact of irrigation on Budyko framework hypothesis in Neyshaboor watershed, Iran

Ameneh Mianabadi[1,2,3], Amin Alizadeh[1], S. Hossein Sanaeinejad[1], Bijan Ghahraman[1], Kamran Davary[1], A.M.J. Coenders-Gerrits[3]

[1]Department of Water Engineering, College of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran

[2]Graduate University of Advanced Technology, Kerman, Iran

[3]Department of Water Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands

(A.mianabadi@tudelft.nl)

This poster participates in OSP

Outstanding Student Poster Contest

Introduction

In hydrology, Budyko curves are used as a first estimation of actual evapotranspiration (ET) as a function of the aridity index (∅):

$$\frac{ET}{P} = \frac{\emptyset}{1+f(\emptyset)} = F(\emptyset)$$

However, Budyko curves do not work to estimate ET in areas with lots of irrigation (Figure 1a).

To investigate the impact of irrigation, we divided the watershed into two parts including mountainous area (without irrigation) and plain area (with irrigation) (Figure 1b & 1c, respectively). As shown in the figures, in the plain area with irrigation, the amount of evaporation ratio exceeds one.

Here we aim to find a solution for areas with lots of irrigation and still use the Budyko curve framework.

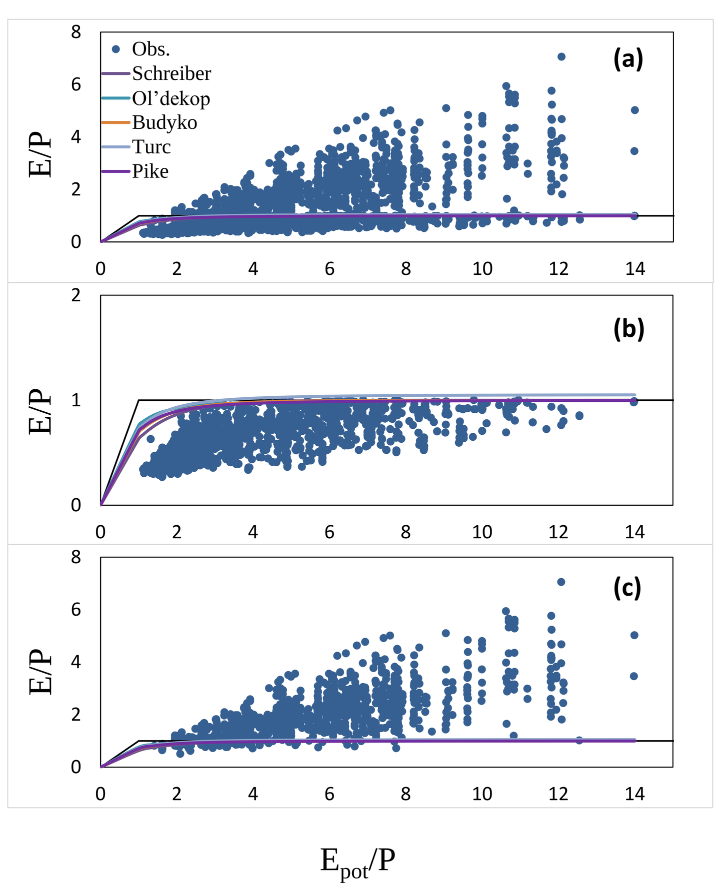

Figure 1- Plots of evaporation ratio vs aridity index showing Budyko curves and data points for 248 HRU, (a) Whole area of Neyshaboor watershed, (b) Non-irrigated area and (c) Irrigated area .

Methods

- Four solutions will be tested to calibrate and validate two kinds of Budyko curves: the Fu and Yang equation:

Fu: $$\frac{E}{P} = 1 + \emptyset - [1 + (\emptyset)^{\alpha}]^{\frac{1}{\alpha}}$$

Yang: $$\frac{E}{P} = \frac{\emptyset}{(1+\emptyset^{n})^{1/n}}$$

- The parameters α and n were calibrated by minimizing the root mean square errors (RMSE) of the estimated actual evapotranspiration in comparison to SWAT output.
- The four solutions will be compared with each other for the period 2001-2012. The study area is the Neyshaboor waterscheed in Iran.

Solutions

S1: Separating actual evapotranspiration (E) coming from rainfall (E_P) and irrigation (E_I) and calibrate Fu and Yang equations for the evapotranspiration coming from rainfall only (with E_{pot} potential evapotranspiration , P precipitation, and I irrigation).

$$\frac{E_P}{P} = \frac{\emptyset}{1+f(\emptyset)} = F(\emptyset) = F(\frac{E_{pot}}{P})$$

The amount of evapotranspiration from irrigation water can be estimated as follow (RC is recharge as estimated with a SWAT model):

$$E_I = I - RC \quad \text{in dry season}$$

$$E_I = 0 \quad \text{in wet season}$$

S2: Including irrigation in the Budyko framework and incorporating irrigation water inflow in water availability (E_{P+I} is total evapotranspiration from both irrigation and precipitation).

$$\frac{E_{P+I}}{P+I} = \frac{\emptyset}{1+f(\emptyset)} = F(\emptyset) = F(\frac{E_{pot}}{P+I})$$

S3: Using water footprint definition, estimating effective rainfall (part of rainfall stored in the root zone and can be used by the plants by SWAT model.

$$E_P = \min(E_{P+I}, P_{effective})$$

S4: Using water footprint definition, estimating effective rainfall by USDA.

$$P_{effective} = 125 + 0.1P \quad if\ P > 250\ mm/year$$

$$P_{effective} = \frac{P}{125}(125 - 0.2P) \quad if\ P \le 250\ mm/year$$

Results & Discussion

According to the Table 1, S4 shows the highest R^2 and the lowest RMSE. But, since the USDA estimated a very low amount for effective rainfall, the amount of parameters α and n for S4 are less than those for other solutions.

Figure 2 shows the plotted data and fitted model for whole area of the watershed for S4. S1 and S3 showed similar results.

Table 1. Statistical comparisons of two Budyko frameworks using three solutions for Neyshaboor watershed.

Area	Solution	Fu				Yang			
		α	R^2	$RMSE_C$*	$RMSE_V$**	n	R^2	$RMSE_C$	$RMSE_V$
Total	S1	1.60 (1.59, 1.62)***	0.35	0.15	0.15	0.85 (0.84, 0.87)	0.36	0.15	0.15
	S2	1.73 (1.71, 1.74)	0.06	0.18	0.18	0.99 (0.97, 1.01)	0.05	0.18	0.18
	S3	1.60 (1.59, 1.61)	0.35	0.15	0.15	0.85 (0.84, 0.87)	0.37	0.15	0.15
	S4	1.319 (1.316, 1.322)	0.69	0.08	0.08	0.568 (0.565, 0.571)	0.75	0.07	0.07
Irrigated	S1	1.84 (1.81, 1.86)	0.49	0.10	0.15	1.08 (1.06, 1.10)	0.49	0.10	0.15
	S2	2.30 (2.27, 2.32)	0.33	0.08	0.08	1.60 (1.57, 1.62)	0.32	0.08	0.08
	S3	1.84 (1.81, 1.86)	0.49	0.10	0.15	1.08 (1.06, 1.10)	0.50	0.10	0.15
	S4	1.338 (1.334, 1.343)	0.67	0.07	0.07	0.585 (0.581, 0.589)	0.74	0.06	0.06
Non-irrigated	-	1.56 (1.55, 1.57)	0.38	0.15	0.15	0.81 (0.80, 0.83)	0.40	0.15	0.14

*RMSE for calibration data, ** RMSE for validation data, ***Confidence interval (95%) shown in parenthesis.

Conclusion & future research

- Although the S4 solution showed the highest R^2 and the lowest RMSE, we prefer the S1, because of more reliable results and similar behavior to Schreiber, Oldekop, Budyko and Pike equations.
- Although S1 and S3 showed nearly similar results, S1 is preferred, because it needs less data than S3.
- For the catchments with adequate data, it is better to investigate the solutions and calibrate the equations using ground-based data, especially actual ET.

Future research:

- Calibration of the equations using modified SEBAL algorithm.
- Calibration of the equations with the real data for the catchment and for other catchment.
- Estimation of runoff using the ET estimated using Budyko curves.

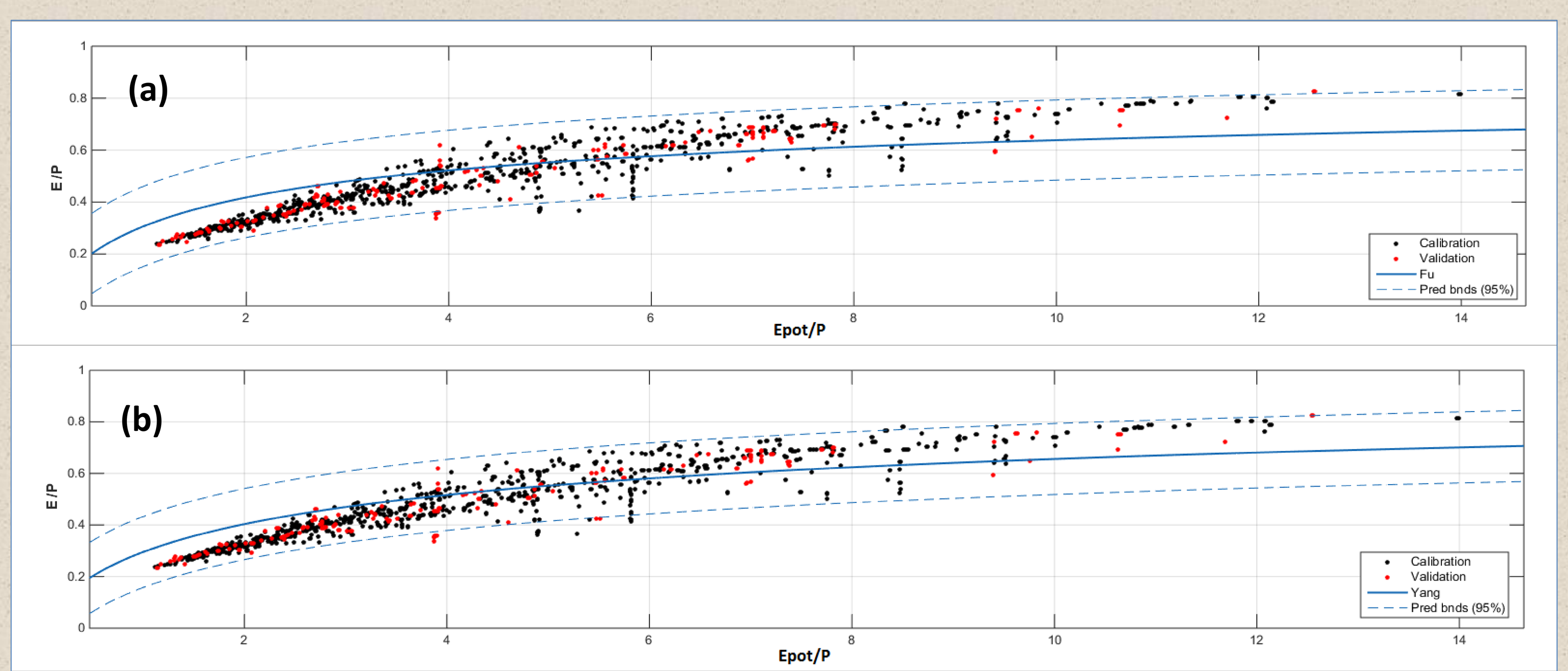

Figure 2- Plotted data and fitted model for whole area of the watershed for S4 (a) Fu equation and (b) Yang equation.

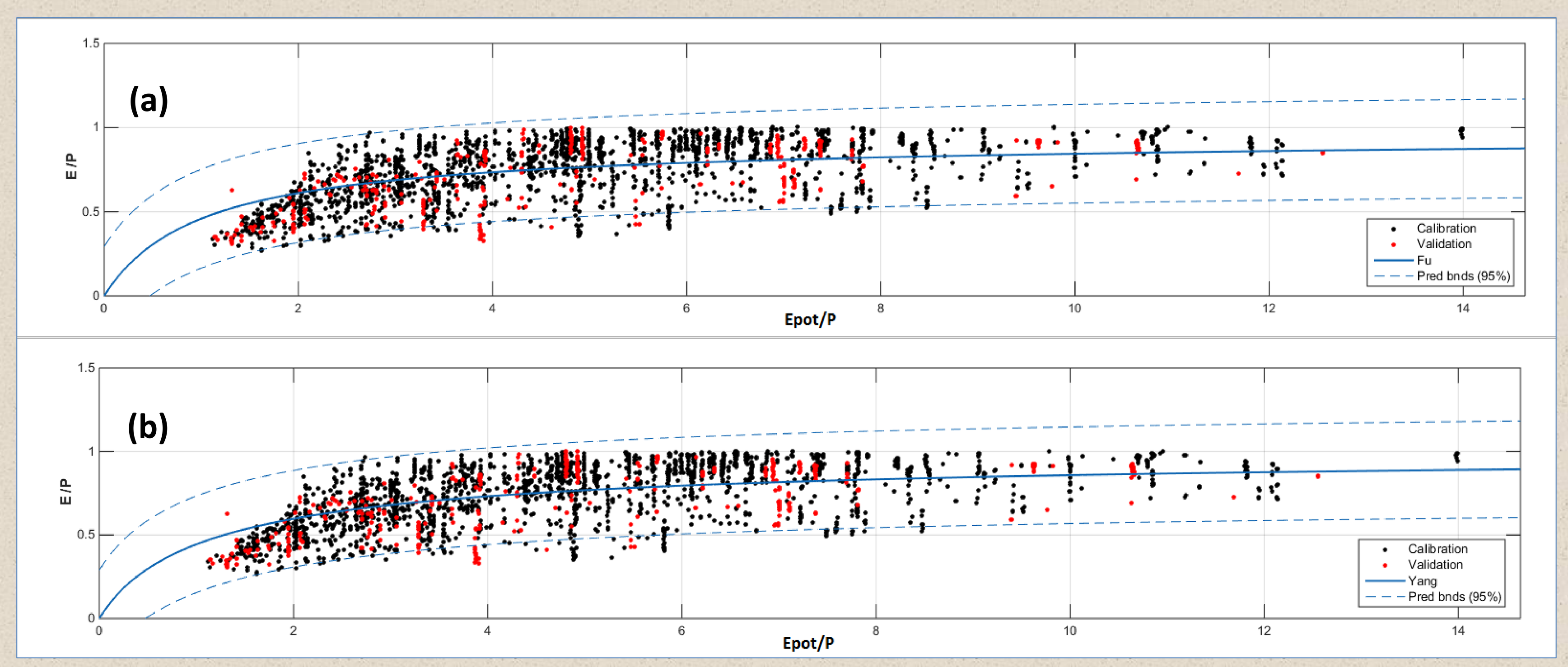

Figure 3- Plotted data and fitted model for whole area of the watershed for S1 (a) Fu equation and (b) Yang equation.

References

Arora, V. K., 2002, The use of the aridity index to assess climate change effect on annual runoff, Journal of Hydrology, 265, 164–177.

Songjun, H., Heping, H., Dawen, Y., Qunchang, L., 2011, Irrigation impact on annual water balance of the oases in Tarim Basin, Northwest China, Hydrology Processes, 25, 167–174.

Zhang, L., Dawes, W.R., Walker, G.R., 2001, Response of mean annual evapotranspiration to vegetation changes at catchment scale, Water Resources Research, 37, 701–708.

Zhang, L., Hickel, K., Dawes, W.R., Chiew, F.H.S., Western, A.W., Briggs, P.R., 2004, A rational function approach for estimating mean annual evapotranspiration, Water Resources Research 40, W02502. doi:10.1029/2003WR002710.

Poster presented at the EGU General Assembly, Vienna, Austria, 12–17 April, 2015.