Guideline to derive the Flow Persistence (FlowPer) Metric

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INTRODUCTION

The Flow Persistence (FlowPer) metric of temporal autocorrelation of empirical or simulated river flow is key to a simple model. The basic form of the Flowper model is a recursive relationship between river flow Q on subsequent days: $Q(t+1) = F_p\, Q(t) + \varepsilon$, where $Q(t)$, $Q(t+1)$ = river flow on subsequent days, F_p = flow persistence value ($[0< F_p <1]$), ε = random variate reflecting inputs from recent rainfall.

The FlowPer metric provides two functions:

1. Summarize the key parameters that can be observed on the flow pattern to assess the watershed condition,

2. Drive, in combination with a random ε generator a parsimonious "null model" that allows quantification of the gain in skill in predicting river flow patterns for spatially explicit models that respond to changes in land cover/land use parameters.

MINIMUM MODEL REQUIREMENT

1. The FlowPer calculations can be run in Microsoft Excel and the model can be downloaded in World Agroforestry Centre website in http://www.worldagroforestry.org/output/flowper-flow-persistence-model. While the FlowPer metric derivation for a R platform is being developed.
2. Any time-series of daily river discharge data can be used, but preferably covering at least one year. If station-level daily rainfall data is available it can support the interpretation of apparent variation in F_p based on rainfall persistence patterns.

GETTING STARTED WITH FLOWPER MODEL IN EXCEL

1. Open the excel file of FlowPer model (FlowPer Model.xlsm), and you will find the interface of FlowPer model.

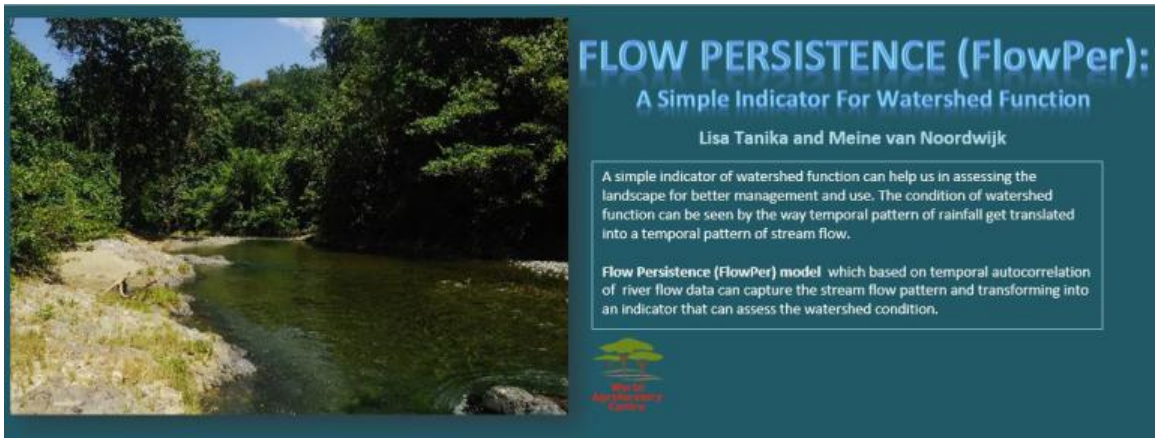


Figure 1. The interface of Flow Persistence model

2. Click in the title of 'FLOW PERSISTENCE (FlowPer)' that will bring you to the 'Read Me' page as the main page of FlowPer model.

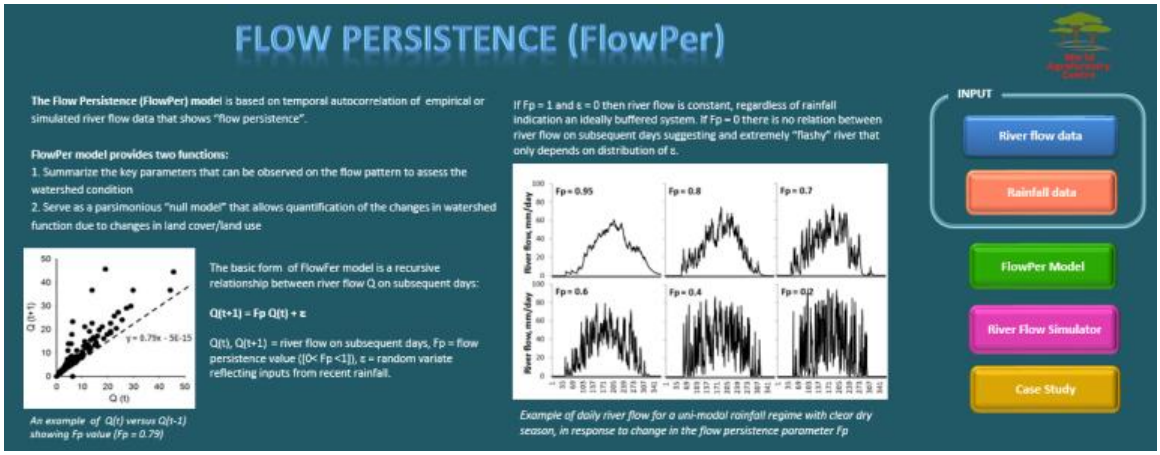


Figure 2. The 'Read Me' page of FlowPer model

3. Click 'River Flow data' to entry the daily river flow data. Adjust 'Start Year' based on your daily river flow data. Then back to the 'Read Me' page.

River Flow Data

Back To READ ME

The minimum input for FlowPer Model, at least one year data

Start Year 1989

You should only change value in blue

DOY	MOY	Period		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	23.0	15.72	13.9	19.65	17.82	9.25	20.62	21.3	18.1	14	6.9	20.78	18.63	17.8	25
2	1	1	1.01	22.6	15.4	13.9	19.3	17.4	9	20.24	21.3	18.1	14	6.9	20.29	17.81	17.4	26.8
3	1	1	1.02	22.6	15.08	13.6	18.6	16.26	9	20.24	21.3	18.1	13.6	6.4	20.29	17.42	16.7	31
4	1	1	1.03	22.1	14.76	13.6	18.25	15.5	9	19.48	21.3	17.26	13.6	6.65	20.29	17.81	16.7	29.8
5	1	1	1.04	21.7	14.44	13.6	17.9	14.36	9	18.72	20.85	17.26	13.2	6.65	19.38	17.81	16.7	27.4
6	1	1	1.05	21.7	14.44	13.6	17.2	14.36	9	18.72	20.85	16.84	12.8	6.65	18.12	17.81	16.7	50.25
7	1	1	1.06	21.7	14.44	13.6	16.85	14.36	8.6	18.72	20.85	16	12.4	6.4	18.12	17.81	16.3	43.5
8	1	1	1.07	21.2	14.12	13.3	16.5	13.98	8.8	18.72	20.85	16	12	6.4	18.12	17.42	15.9	34
9	1	1	1.08	20.8	13.8	12.4	16.15	13.98	8.8	18.34	20.4	16	12	6.4	18.12	16.64	15.5	29.8
10	1	1	1.09	20.4	13.18	12.1	16.15	13.98	8.6	18.34	19.95	16.42	12.4	6.15	18.12	16.64	15.5	27.4
11	1	1	1.1	19.9	12.56	12.4	15.8	13.6	8.6	18.34	19.5	17.26	12.4	6.15	18.12	16.64	15.1	25.6
12	1	1	1.11	19.5	12.56	12.1	16.15	13.6	8	17.58	19.5	16.42	12	6.15	17.7	16.64	14.7	24

Figure 3. Page of River Flow Data

4. If you have daily rainfall data, you can click ‘Rainfall data’ to entry the data in the same way when entering the river flow data. Then back to the ‘Read Me’ page.

Rainfall Data (mm)

Back To READ ME

Daily rainfall data as the supporting input for FlowPer

You should only change value in blue font !

DOY	MOY	Period		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	1	1	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2376	
2	1	1	1.01	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8416	
3	1	1	1.02	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	1	1	1.03	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5	1	1	1.04	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.208	
6	1	1	1.05	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0198	
7	1	1	1.06	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
8	1	1	1.07	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
9	1	1	1.08	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
10	1	1	1.09	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
11	1	1	1.1	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
12	1	1	1.11	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
13	1	1	1.12	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0.802	0	

Figure 4. Page of Rainfall Data

5. Click ‘FlowPer model’ to run the model. If you only want to run a certain year, enter the year in the ‘Year’ then click ‘Go’. The result will be shown both in the form of value and graph.

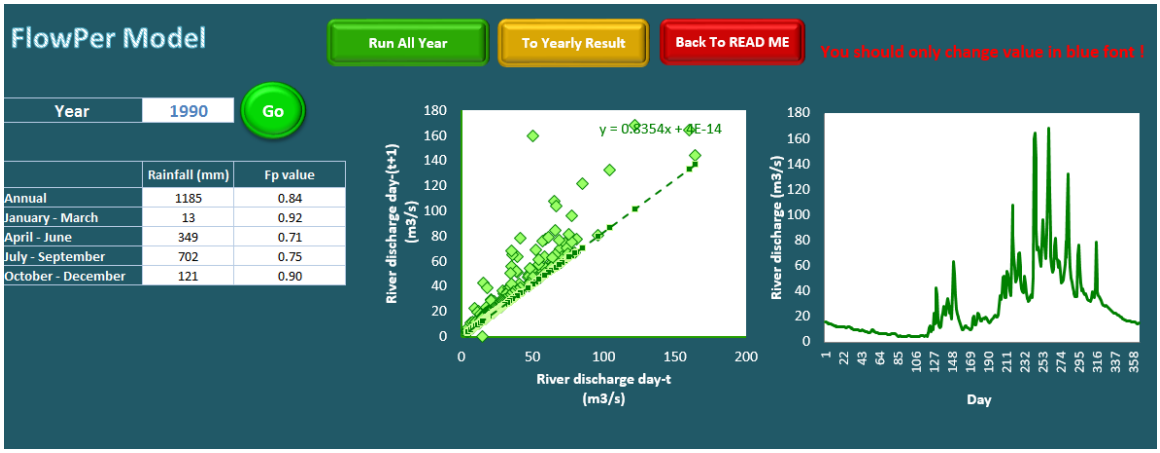
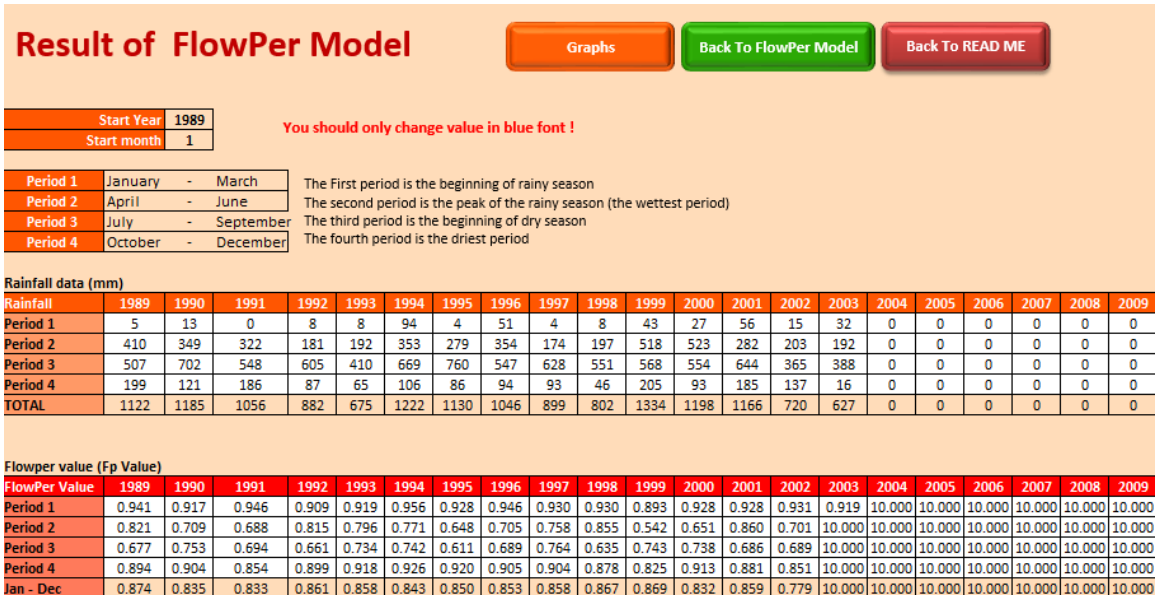


Figure 5. The page of 'FlowPer model'

6. If you want to run the entire year, click 'Run All Year' and you can see the result by clicking 'To Yearly Result'



Rainfall	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Period 1	5	13	0	8	8	94	4	51	4	8	43	27	56	15	32	0	0	0	0	0	0
Period 2	410	349	322	181	192	353	279	354	174	197	518	523	282	203	192	0	0	0	0	0	0
Period 3	507	702	548	605	410	669	760	547	628	551	568	554	644	365	388	0	0	0	0	0	0
Period 4	199	121	186	87	65	106	86	94	93	46	205	93	185	137	16	0	0	0	0	0	0
TOTAL	1122	1185	1056	882	675	1222	1130	1046	899	802	1334	1198	1166	720	627	0	0	0	0	0	0

FlowPer Value	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Period 1	0.941	0.917	0.946	0.909	0.919	0.956	0.928	0.946	0.930	0.930	0.893	0.928	0.928	0.931	0.919	10.000	10.000	10.000	10.000	10.000	10.000
Period 2	0.821	0.709	0.688	0.815	0.796	0.771	0.648	0.705	0.758	0.855	0.542	0.651	0.860	0.701	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Period 3	0.677	0.753	0.694	0.661	0.734	0.742	0.611	0.689	0.764	0.635	0.743	0.738	0.686	0.689	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Period 4	0.894	0.904	0.854	0.899	0.918	0.926	0.920	0.905	0.904	0.878	0.825	0.913	0.881	0.851	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Jan - Dec	0.874	0.835	0.833	0.861	0.858	0.843	0.850	0.853	0.858	0.867	0.869	0.832	0.859	0.779	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Figure 6. Page of FlowPer result

EXAMPLE OF FLOWPER MODEL ANALYSIS

The result of FlowPer model is a value (F_p) in the range between 0 and 1. If $F_p = 1$ and $\varepsilon = 0$ then river flow is constant, regardless of rainfall indication an ideally buffered system. If $F_p = 0$ there is no relation between river flow on subsequent days suggesting and extremely "flashy" river that only depends on distribution of ε.

The analysis of F_p value can be done in two stages, the annual F_p and quarterly F_p. The annual F_p show the watershed condition based on one year data. The quarterly F_p show the F_p for each three months data. The purpose of the quarterly F_p analysis is see the condition of watershed during wet and dry season.

The F_p-value can also be analyzed against the year and rainfall. F_p value against the year to see the changes of F_p value from time to time whether increased, decreased or stable. The up-trend of F_p means that the watershed condition is going better and better, while the down-trend means the degradation of watershed. The F_p analysis against rainfall is to see the relationship between watershed condition and climate change. If there is relation between F_p value and rainfall, it means that that watershed is vulnerable to climate change.

The example of FlowPer analysis in this guideline is from Mae Chaem watershed (3740 km^2), as part of the upper Ping Basin, Thailand. The rainfall data was an interpolation from six rainfall stations that obtained from Water resource Department, Meteorology Department and Royal Project. The daily river flow data was obtained from the Royal Irrigation Departement (RID) river gauge station P.14 in Ob Luang and was taken from ICHARM website (http://www.icharm.pwri.go.jp/html/network/pub_dabase_top_files/maecham_q.txt).

The result of FlowPer model in Mae Chaem watershed is shown by Table 1 and Figure 7. From the quarterly rainfall in the Table 1, the wet season in Mae Chaem watershed is in the period 3 (July-September) and the dry season is in the period 1 (January – March). Over 14 years (1989-2002), the result of F_p analysis shows stable trend with average of F_p 0.85 (Figure 7A). But if we look at the quarterly analysis, in the wet season (period 3) the trend line has a decline tendency (Figure 7B). It means that the ability of watershed to buffer the peak rainfall event has been decreased.

Fp analysis also shows a stable tendency towards rainfall changes (Figure 7C). But in the quarterly analysis, the trend of F_p value are decreasing (Figure 7D), the higher the rainfall amount, the smaller the F_p value. This condition is corresponding to Figure 7B.

Table 1. Annual and quarterly of rainfall and F_p value

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Avg*
Period	Rainfall (mm)														
1	5	13	0	8	8	94	4	51	4	8	43	27	56	15	24
2	410	349	322	181	192	353	279	354	174	197	518	523	282	203	310
3	507	702	548	605	410	669	760	547	628	551	568	554	644	365	576
4	199	121	186	87	65	106	86	94	93	46	205	93	185	137	122
TOTAL	1122	1185	1056	882	675	1222	1130	1046	899	802	1334	1198	1166	720	1031

Period	Fp-value														
1	0.94	0.92	0.95	0.91	0.92	0.96	0.93	0.95	0.93	0.93	0.89	0.93	0.93	0.93	0.929
2	0.82	0.71	0.69	0.82	0.80	0.77	0.65	0.71	0.76	0.86	0.54	0.65	0.86	0.70	0.737
3	0.68	0.75	0.69	0.66	0.73	0.74	0.61	0.69	0.76	0.64	0.74	0.74	0.69	0.69	0.701
4	0.89	0.90	0.85	0.90	0.92	0.93	0.92	0.90	0.90	0.88	0.83	0.91	0.88	0.85	0.891
Jan - Dec	0.87	0.84	0.83	0.86	0.86	0.84	0.85	0.85	0.86	0.87	0.87	0.83	0.86	0.78	0.848

*Avg = average

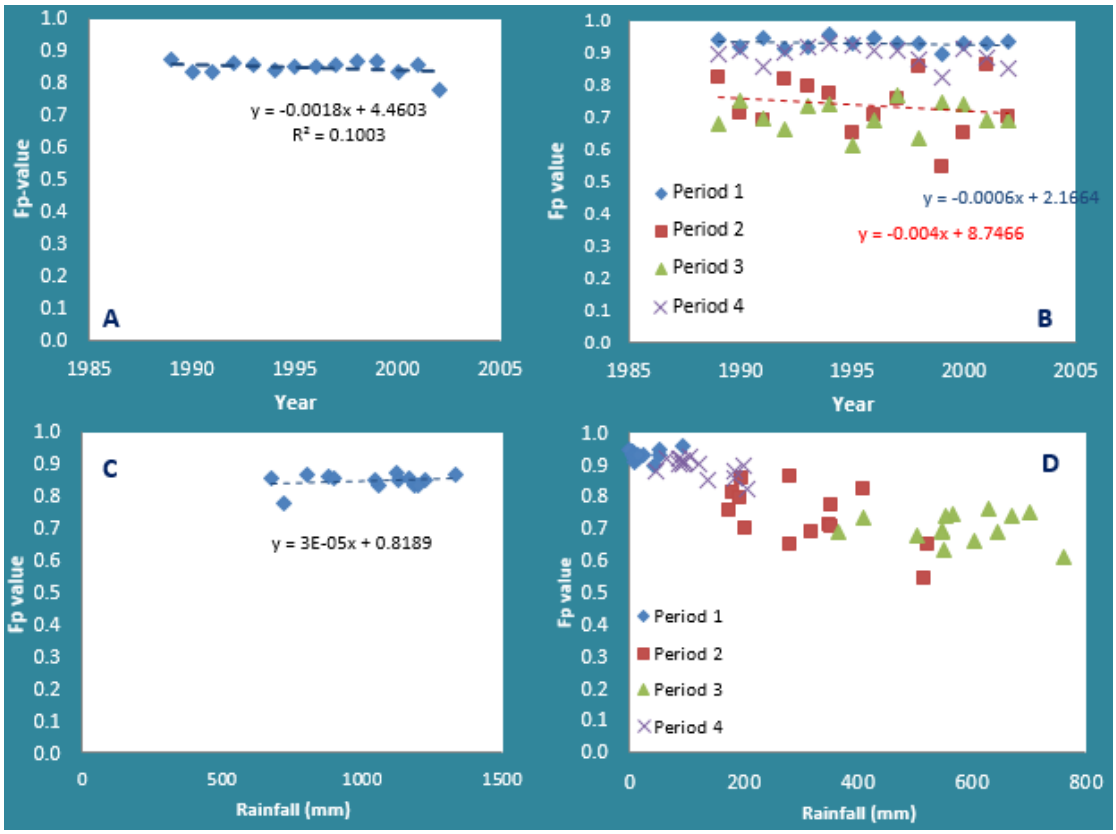


Figure 7. The example of the result of FlowPer model in Mae Chaem watershed. (period 1 = January – March, period 2 = April – June, period 3 = July – September, period 4 = October – December)