World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Watersheds degrade and this makes river flow less predictable: bigger floods and lower dry season flow – but how to quantify?

A parsimonious null model of flow persistence (FlowPer) links local knowledge to hard data

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Landscapes translate a temporal pattern of rainfall into a temporal pattern of stream flow, which aggregates up to a river. Downstream stakeholders start from what they want to see ('perfectly regular flow of clean water') and observe a pattern of stream and river flow that doesn't match their expectations. They search for interventions on the 'anthropogenic' groups of causes ('deforestation', 'degradation'), but need to understand the potential reach of such interventions, given the geological and climatic background. In the absence of knowledge of what happens upstream, an observer of river flow can deduce a fair amount of information from a time series of river flow data.

The FlowPer Model

The FlowPer model is focused on what a downstream observer can infer about conditions upstream, without knowing the rainfall. It can also serve as a parsimonious (parameter-sparse) 'null model' based on temporal autocorrelation or an empirical 'flow persistence' in the river flow data that allows quantification of the increments in model prediction that is achieved with spatially explicit models (with *a priori* parameterization rather than parameter tuning to the data).

The basic form:

$$Q_{t+1} = f_p \, Q_t + Q_{add}$$

where Q_t and Q_{t+1} represent the river flow on subsequent days, f_p is the flow persistence factor ([0< f_p <1]) and Q_{add} is a random variate that reflects inputs from recent rainfall.

$$Q_{add} \text{ and } f_p \text{ are related, as } \sum Q_{add\,i} = (1 - f_p) \sum Q$$

Ideally buffered system → if $f_p = 1$, $Q_{add} = 0$ and river flow is constant, regardless of rainfall .

Very poorly buffered watershed → If $f_p = 0$ there is no relation between river flow on subsequent days and the river is extremely 'flashy', alternating between high and low flows without temporal predictability within the frequency distribution of Q_{add}.

A spreadsheet with algorithms that turn any timerseries of riverflow into a corresponding f_p estimate is now available for wider testing. We look for further datasets to test it.

The term $Q_{add,i}$ can be described as a statistical distribution with a probability of a non-zero value, a mean and a measure of variance, plus two parameters that describe a seasonal pattern (peak and shape of the distribution, e.g. Weibull). This makes for 5 parameters for $Q_{add,i}$ (and six for the whole model) that are derived from the data. It leaves many degrees of freedom for more specific models that, for example, make use of measured rainfall.

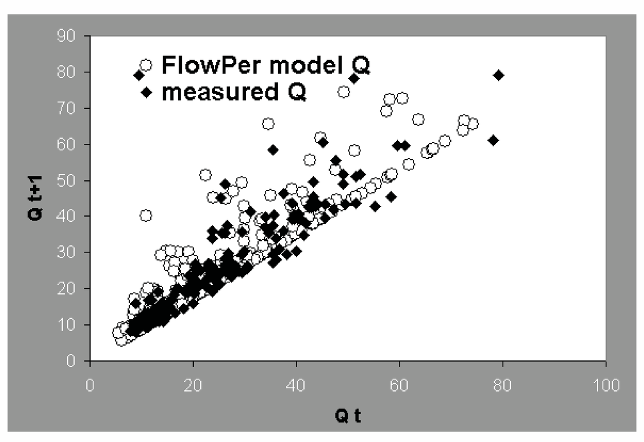
Partitioning the total flow Q_{tot} into water flow by three pathways (surface runoff, interflow and groundwaterflow):

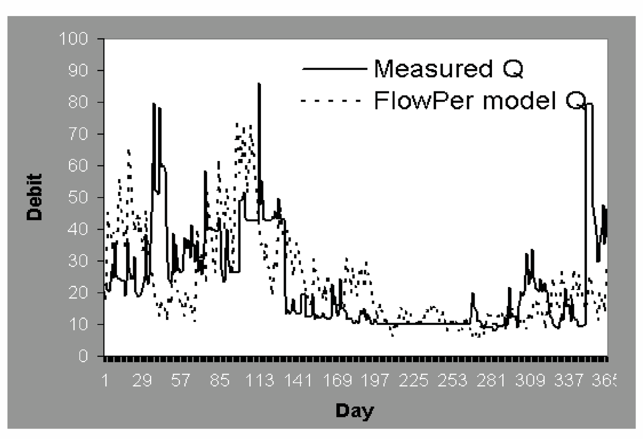
$$Q_{tot} = Q_{runoff} + Q_{interflow} + Q_{gwflow}$$

Each type of flow pathway will typically have a different flow persistence, $f_{p,runoff}$, $f_{p,interflow}$ and $f_{p,gwflow}$, respectively.

$$Q_{tot,t+1}/Q_{tot,t} = f_{p,runoff}\,(Q_{runoff,t}/Q_{tot,t}) + f_{p,interflow}\,(Q_{interflow,t}/Q_{tot,t}) + f_{p,gwflow}\,(Q_{gwflow,t}/Q_{tot,t}) + Q_{add,t}/Q_{tot,t}$$

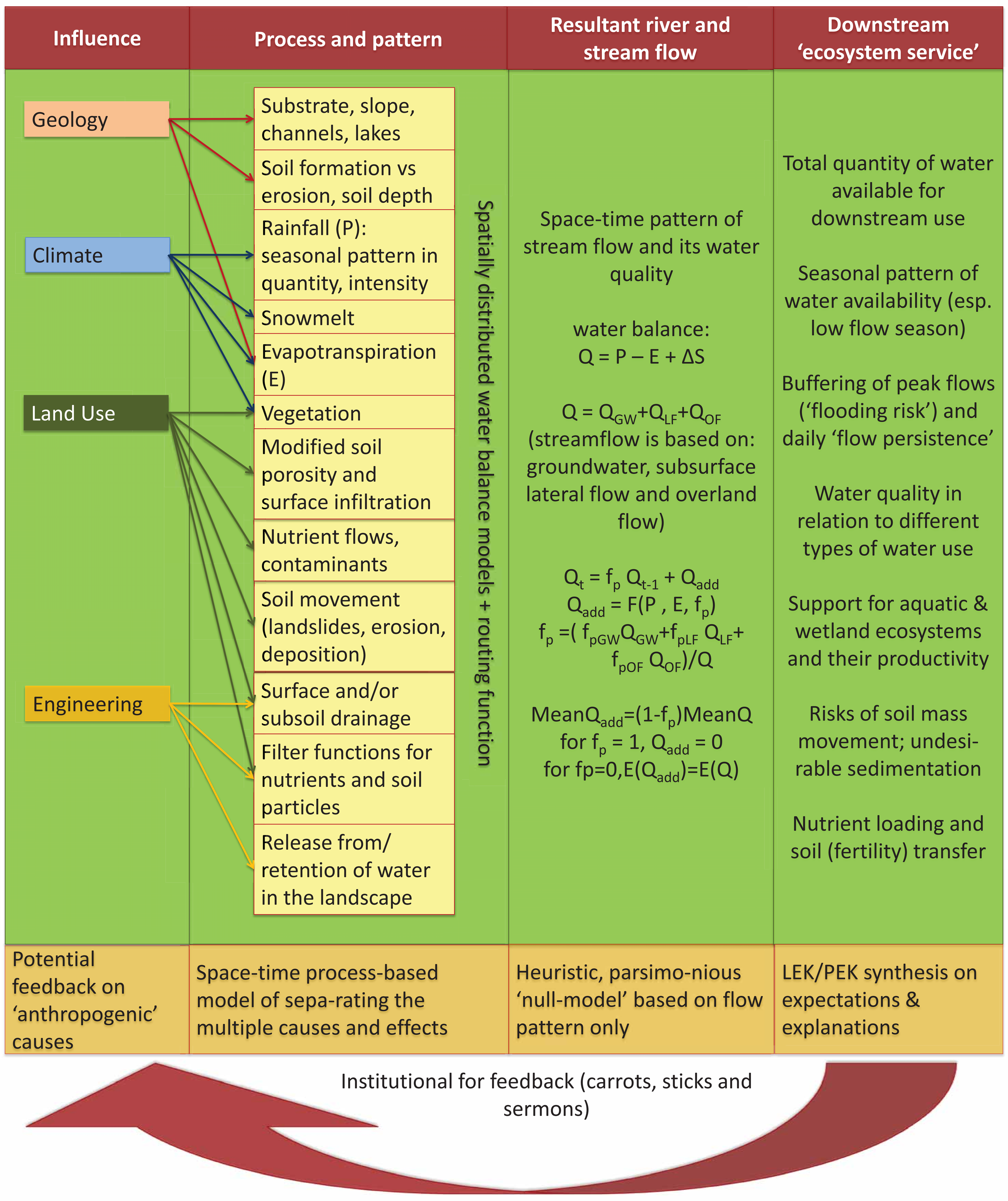
As we can expect values for $f_{p,runoff}$, $f_{p,interflow}$ and $f_{p,gwflow}$ of about 0, 0.5 and close to 1, respectively, we can interpret the relative contributions of the 3 flow pathways from the overall f_p value.





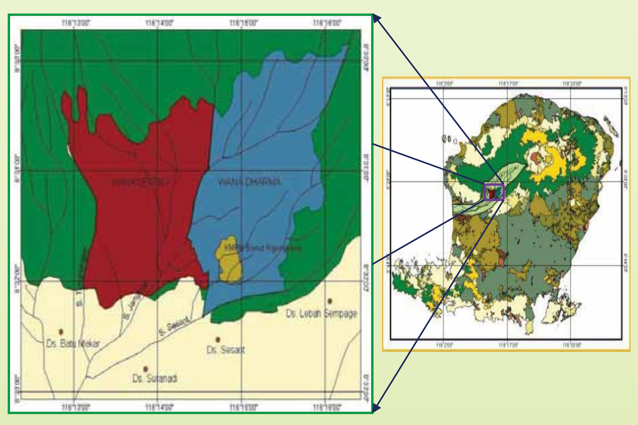
Example of the type of 'fit' that can be achieved for the 6-parameters FlowPer model

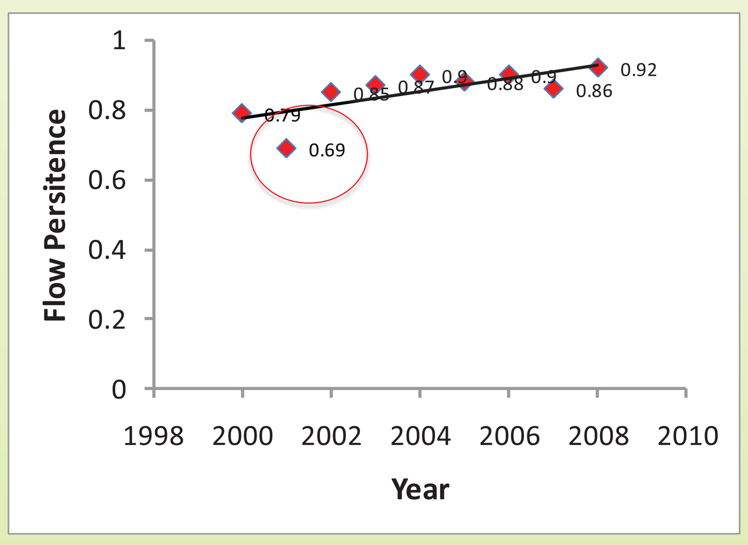
A FlowPer value of above 0.8 may reflect good watershed conditions; values below 0.4 indicate poorly buffered watershed. These values are tentative and need further testing. Further data sets to do are welcome!



Case Study: Jangkok sub-watershed, Lombok, Indonesia

The total area of Sesaot forest is 5 950 ha. It is up-stream of the Jangkok sub-watershed, west Lombok. Agroforestry is major land cover, serving economical and ecological functions. The Jangkok sub-watershed is categorized as a priority watershed in local plans (Rencana Pembangunan Jangka Menengah /RPJM of theForestry Department), since the area is a source of water for people living in west Lombok, central lombok and Maratam.





Buffer capacity of the sub-watershed was analyzed using FlowPer model. The flow persistence value tend to increase with an average value of 0.85 reflecting good watershed conditions. The lowest value was found for the 2001 data, at a time widespread (illegal) logging was associated with high flow during wet season and low flow during dry season. The Flow Persistence parameter is a good candidate for a performance measure.

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