Quantifying the contribution of land use and climate change to stream flow alteration in tropical catchments

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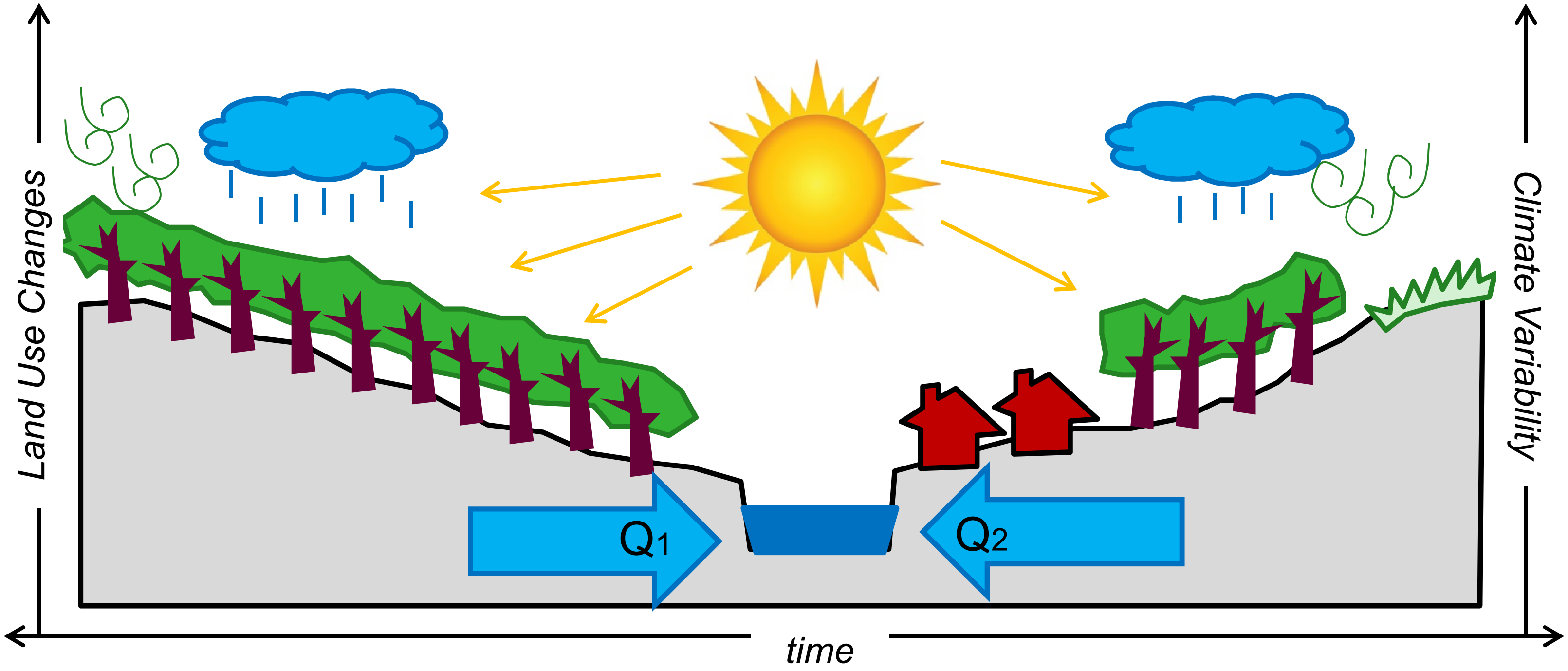
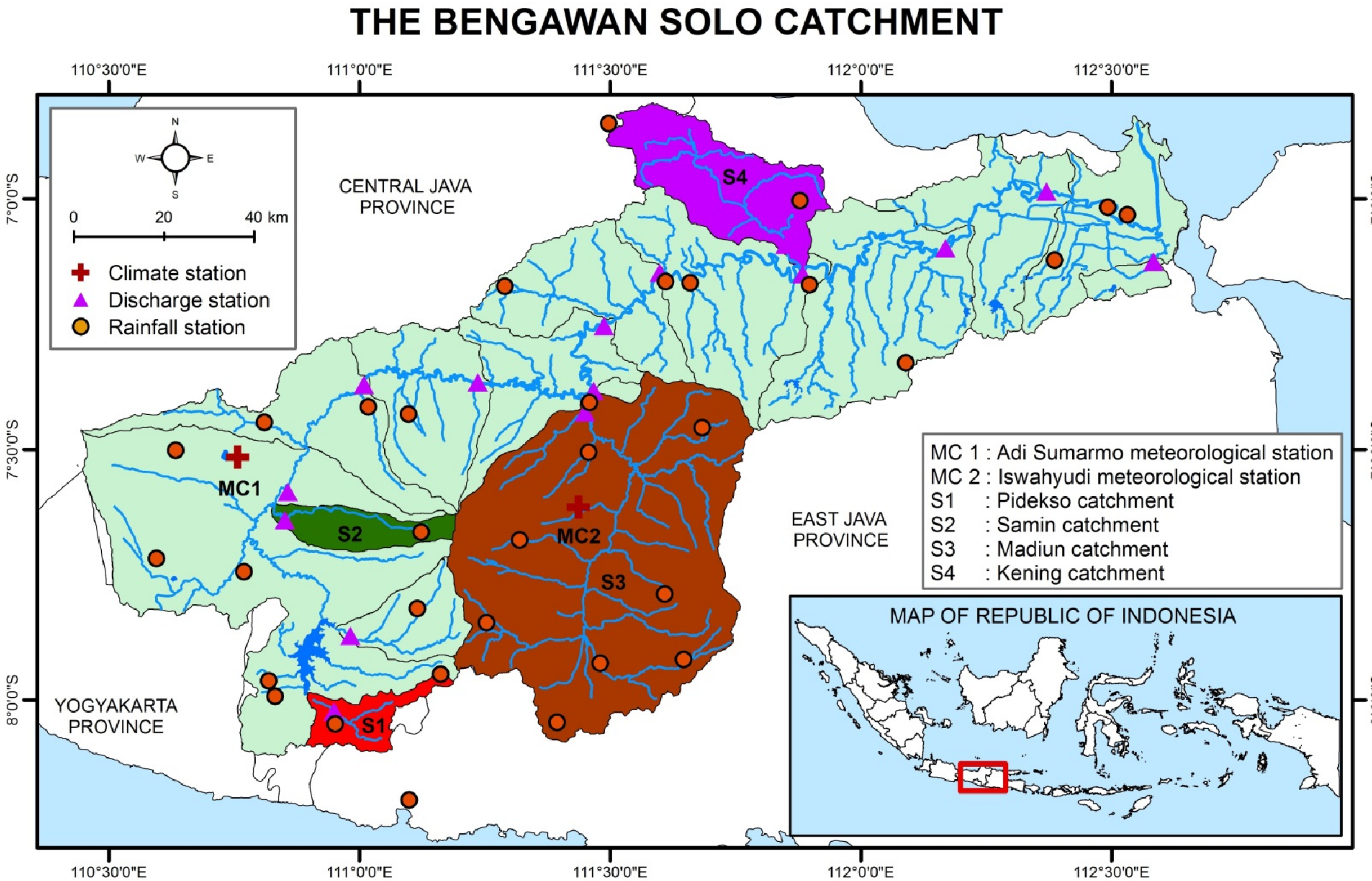
Background



RQ : What is the attribution of changes in stream flow (ΔQ) to land use change and climate change?

Study Area



- ✓ the largest catchment area on Java, Indonesia i.e. ±16,000 km^2
- ✓ Frequently devastated by floods
- ✓ Selected catchments represent the upstream (S1, S2), the mid-stream (S3) and the downstream (S4)

Id	Catchment	Area (km^2)	Av. slope (%)
S1	**Pidekso**	**234.1**	**15.8**
S2	**Samin**	**281.2**	**10.2**
S3	**Madiun**	**3759.2**	**9.9**
S4	**Kening**	**837.2**	**5.8**

Data Availability

- Hydrological Data

Id	Discharge	Rainfall	Nr Rainfall St	Climate	Nr Climate st
S1	1975-2012	1975-2013	4	1975-2013	2
S2	1983-2012	1975-2013	4	1975-2013	
S3	1982-2012	1975-2013	9	1975-2013	
S4	1982-2012	1975-2013	4	1975-2013	

- Spatial Data

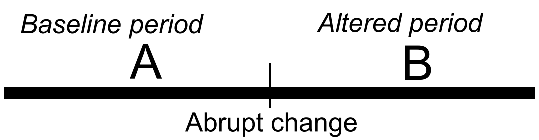
Name of data	Scale/ resolution	Acquisition date	Source
Landsat MSS	57 m	27/09/1972	USGS
Landsat TM	30 m	01/09/1994	USGS
Landsat ETM+	30 m	30/08/2002	USGS
Landsat 8	30 m	20/08/2013	USGS

Methods (1) : A non-modelling approach

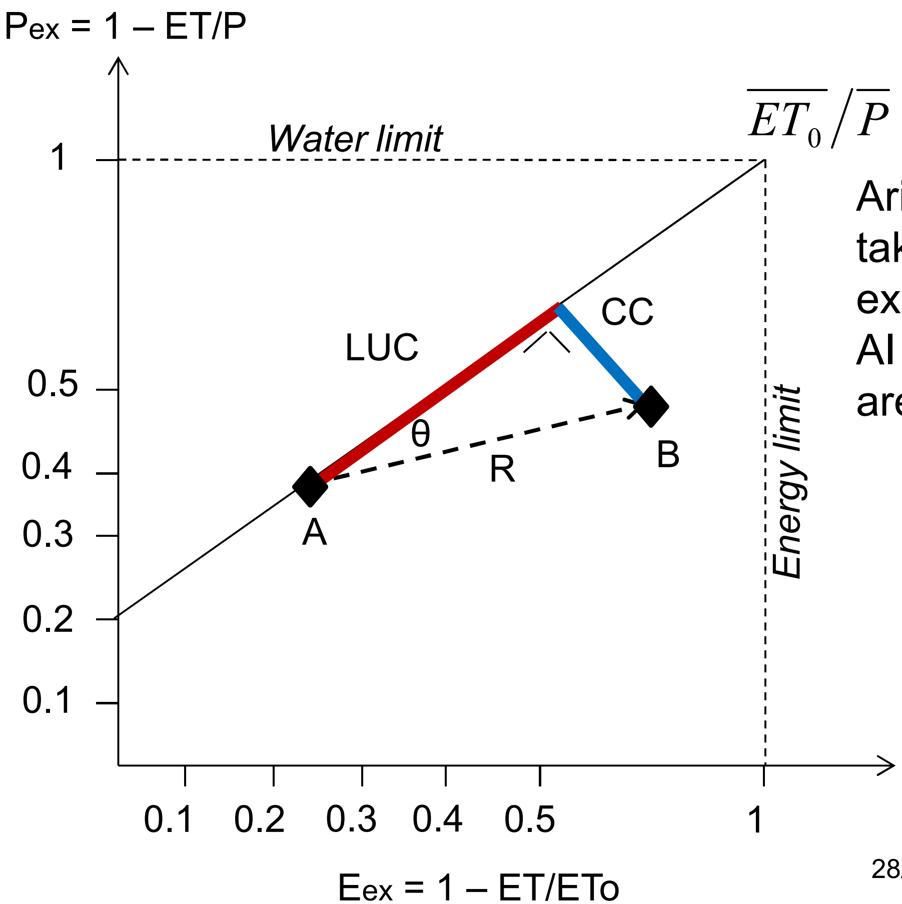
1. Performing abrupt change detection on annual stream flow using statistical homogeneity test analysis i.e. Pettitt's test
2. Calculating the proportion of excess water and the proportion of excess energy for the period before and after the abrupt change of the stream flow
3. Calculating the quantitative contribution of land use and climate change to stream flow changes
4. Validating the results with the statistical trend analysis i.e. Mann-Kendall test (for P and ETo), and the land use change analysis i.e. Max-likelihood classification on multi-temporal LANDSAT imageries

Method (2) : Step 2 and Step 3

- Adapted from Tomer and Schilling framework (2009), “A simple approach to distinguish land-use and climate-change effects on watershed hydrology”. They used a fraction of excess water (P_{ex}) and excess energy (E_{ex}) to assess the attribution of changes in stream flow to land use and climate change.

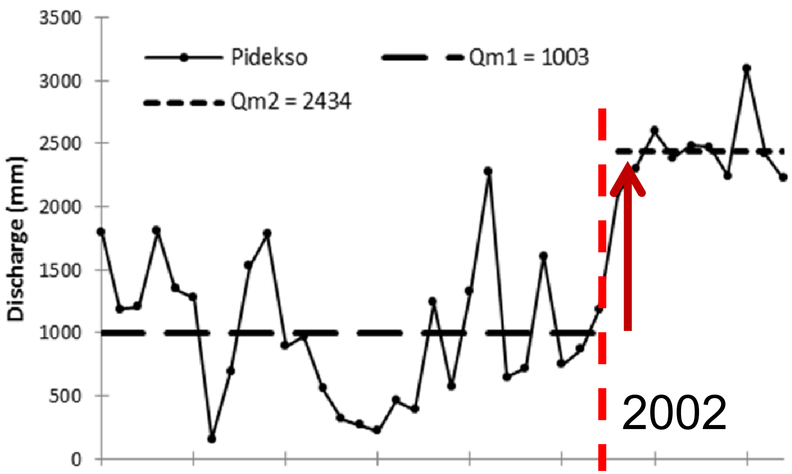


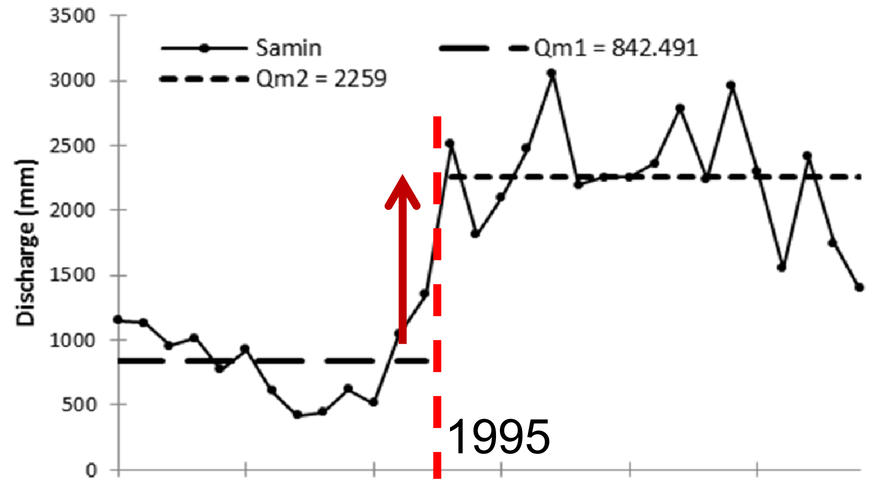
- ✓ The resultant length (R) indicates the magnitude of the changes with a higher resultant indicating a higher magnitude
- ✓ The angle of change (θ) indicates the magnitude of the contribution of LUC and CC with a higher angle reflecting a higher contribution of CC
- ✓ The relative attribution of changes in stream flow to LUC and CC in percentage (%)

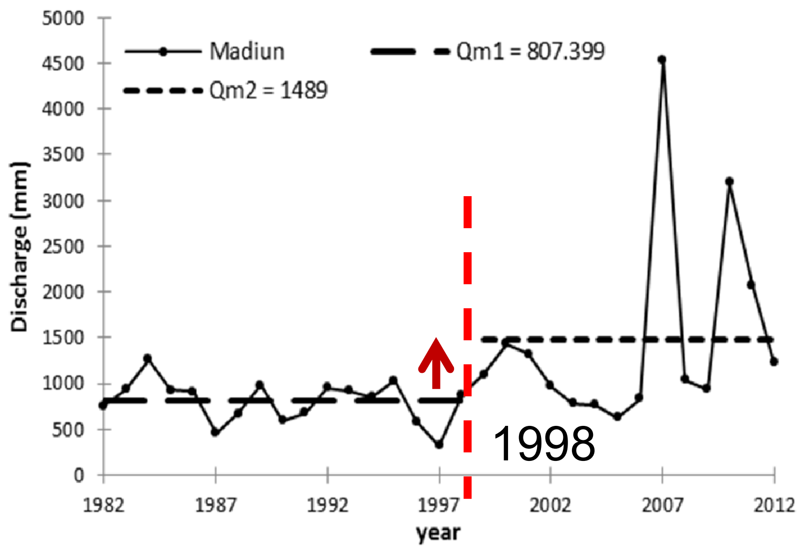


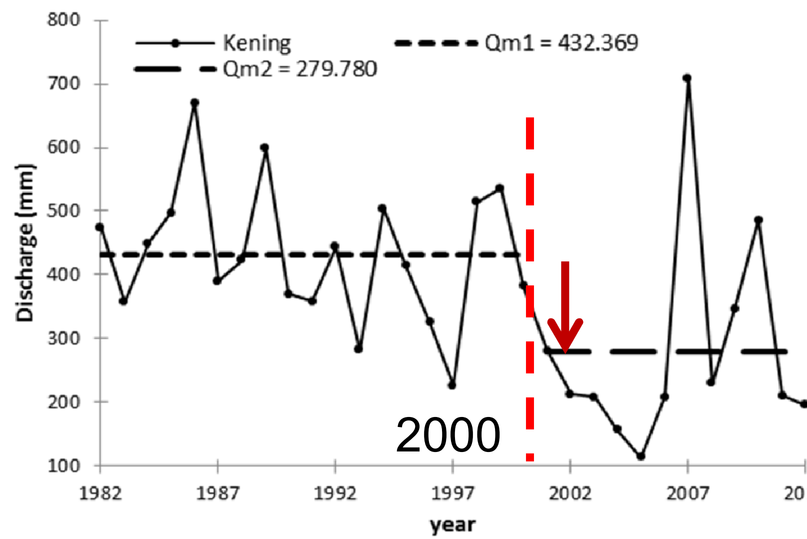
Aridity index, taking an example the AI of the area is 0.8

Results (1) : Change point detection on Streamflow

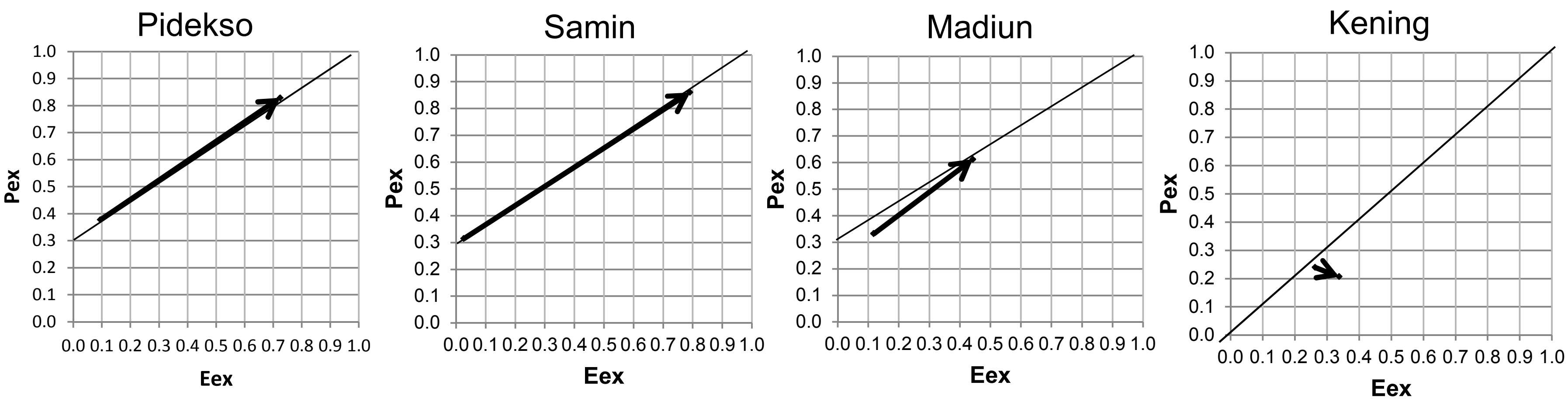








Results (2) : Attribution Analysis



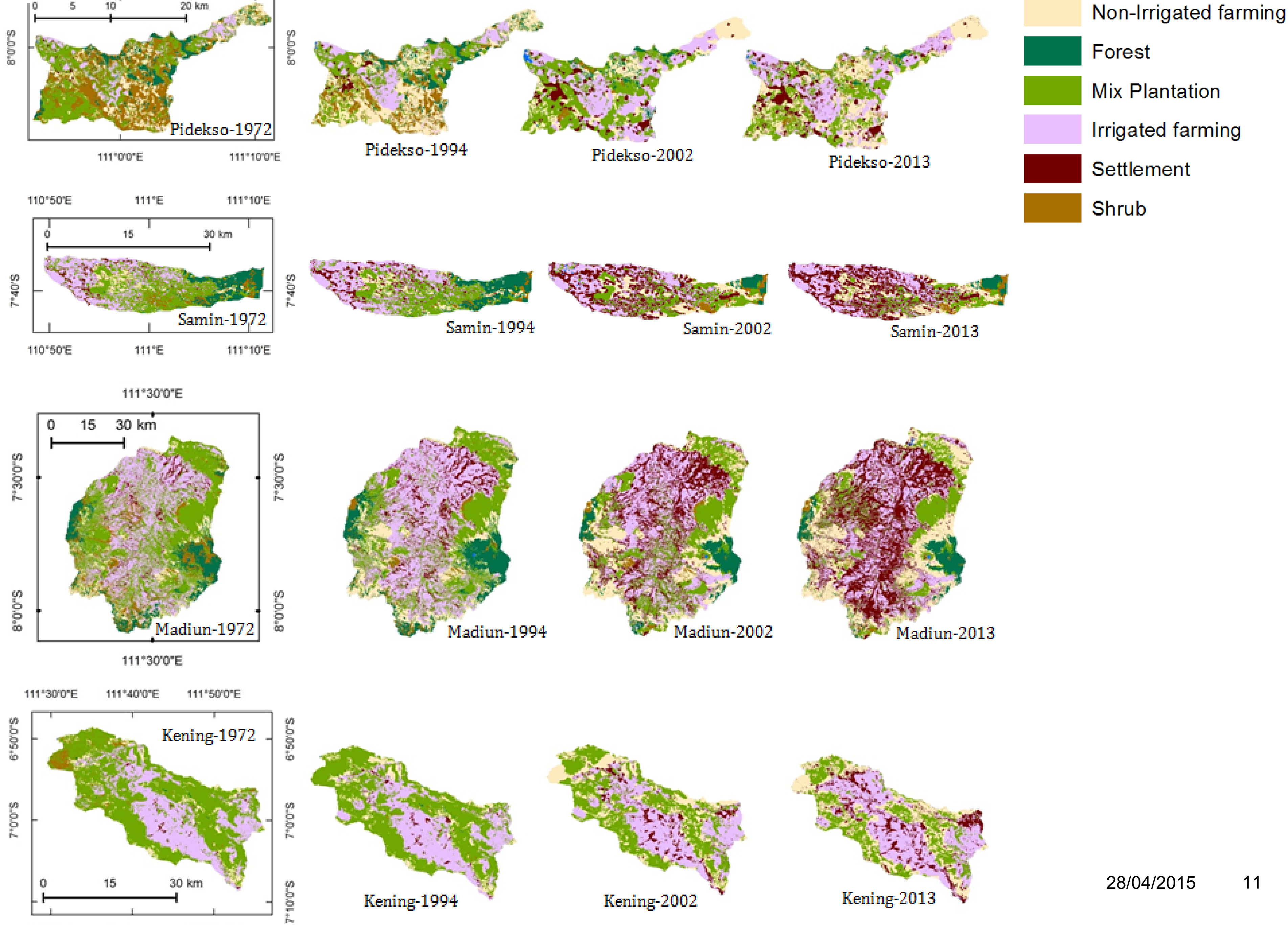
Catchment	Abrupt change	$\overline{ET_0}/\overline{P}$	Period		P_{ex}	E_{ex}	R	θ	LUC	CC
Pidekso	2002	0.67	(1)	1975-2002	0.38	0.09				
			(2)	2003-2012	0.83	0.72	0.8	1.8	97.0	3.0
Samin	1995	0.69	(1)	1983-1995	0.31	0.03				
			(2)	1996-2012	0.86	0.79	0.9	0.8	98.6	1.4
Madiun	1998	0.69	(1)	1982-1998	0.33	0.12				
			(2)	1999-2012	0.61	0.44	0.4	6.0	90.5	9.5
Kening	2000	1.0	(1)	1982-2000	0.24	0.26				
			(2)	2001-2012	0.21	0.34	0.1	67.0	26.7	73.3

Results (3) : Result Validation

- Mann-Kendall Trend test for climate variables

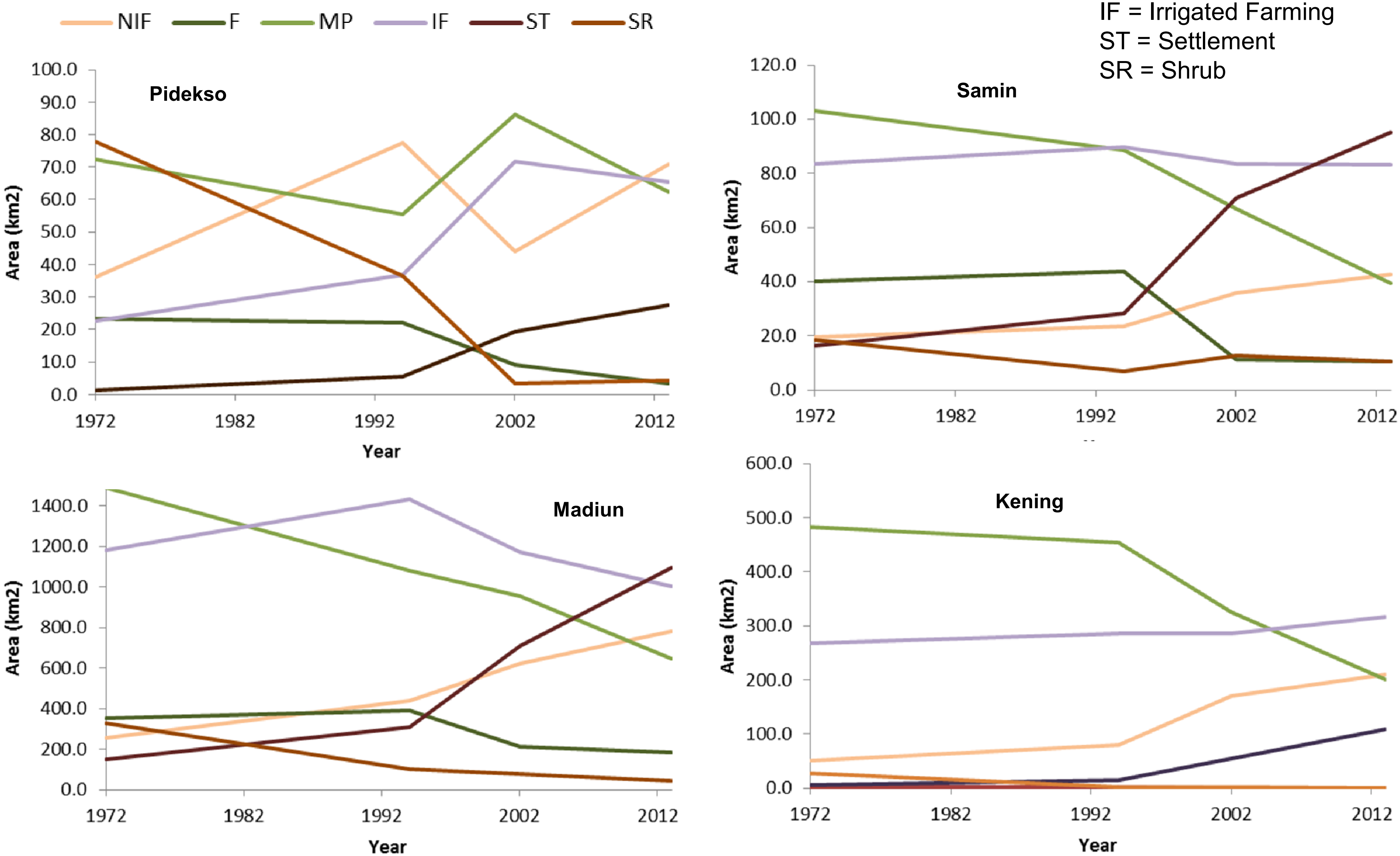
Catchment	Variables	MK_{stat}	Sig α=0.1
Pidekso	Rainfall	0.82	NS
	ETo	-0.92	NS
Samin	Rainfall	0.07	NS
	ETo	-0.92	NS
Madiun	Rainfall	-0.87	NS
	ETo	-1.09	NS
Kening	Rainfall	-2.44	S
	ETo	-1.09	NS

LUC analysis (1)



LUC analysis (2)

NIF = Non-Irrigated Farming
F = Forest
MP = Mix Plantation
IF = Irrigated Farming
ST = Settlement
SR = Shrub



- ✓ Inclining trend of settlements and seasonal-crop agricultural area (i.e. IF and NIF), declining trend of tree-dominated area (i.e. F and MP)
- ✓ Dramatic LUC was occurred for the period of 1994-2002

Conclusions

- Changes in stream flow can be mainly attributed to land use change rather than climate change for the study catchments except in the Kening catchment.
- The results are in line with the results of the Mann-Kendall trend analysis for climate variables (i.e. P has significantly changed only for Kening catchment (-) and ETo has not significantly changed for all catchments) and with the results of land use change analysis which found to be significant for all catchments in particular during the period 1994 – 2002 (i.e. when the abrupt changes in stream flow were found).
- Our three measures successfully quantified the relative attribution of changes in stream flow to land use change and climate variability.
- The proposed method needs more practical applications across different climatic regions to make the approach more reliable and robust.

Reference

- Tomer, M. D., & Schilling, K. E. (2009). A simple approach to distinguish land-use and climate-change effects on watershed hydrology. Journal of Hydrology, 376(1-2), 24-33

Further Information

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