Responses of Streamflow to Climate and LUCC in the Loess Plateau, China

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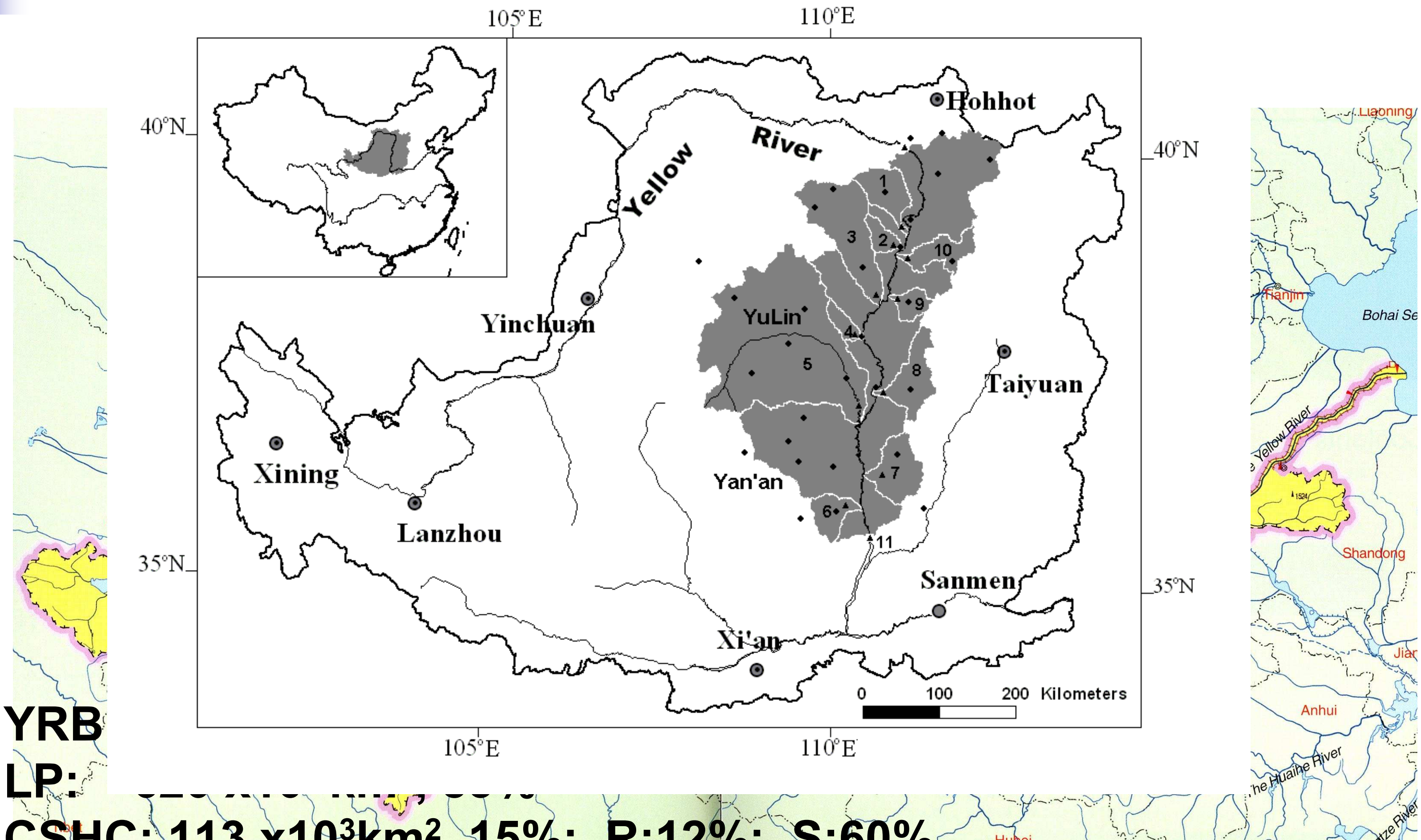
Outline of presentation

- Background: the Loess Plateau and the coarse sandy hilly catchments
- Data and methods
- Results
- Conclusions

1. The Loess Plateau and Coarse Sandy Hilly Catchments (CSHC)



YRB

LP:

CSHC: 113 x10^3km^2, 15%; R:12%; S:60%

1. The Loess Plateau and (CSHC)

Characteristics:

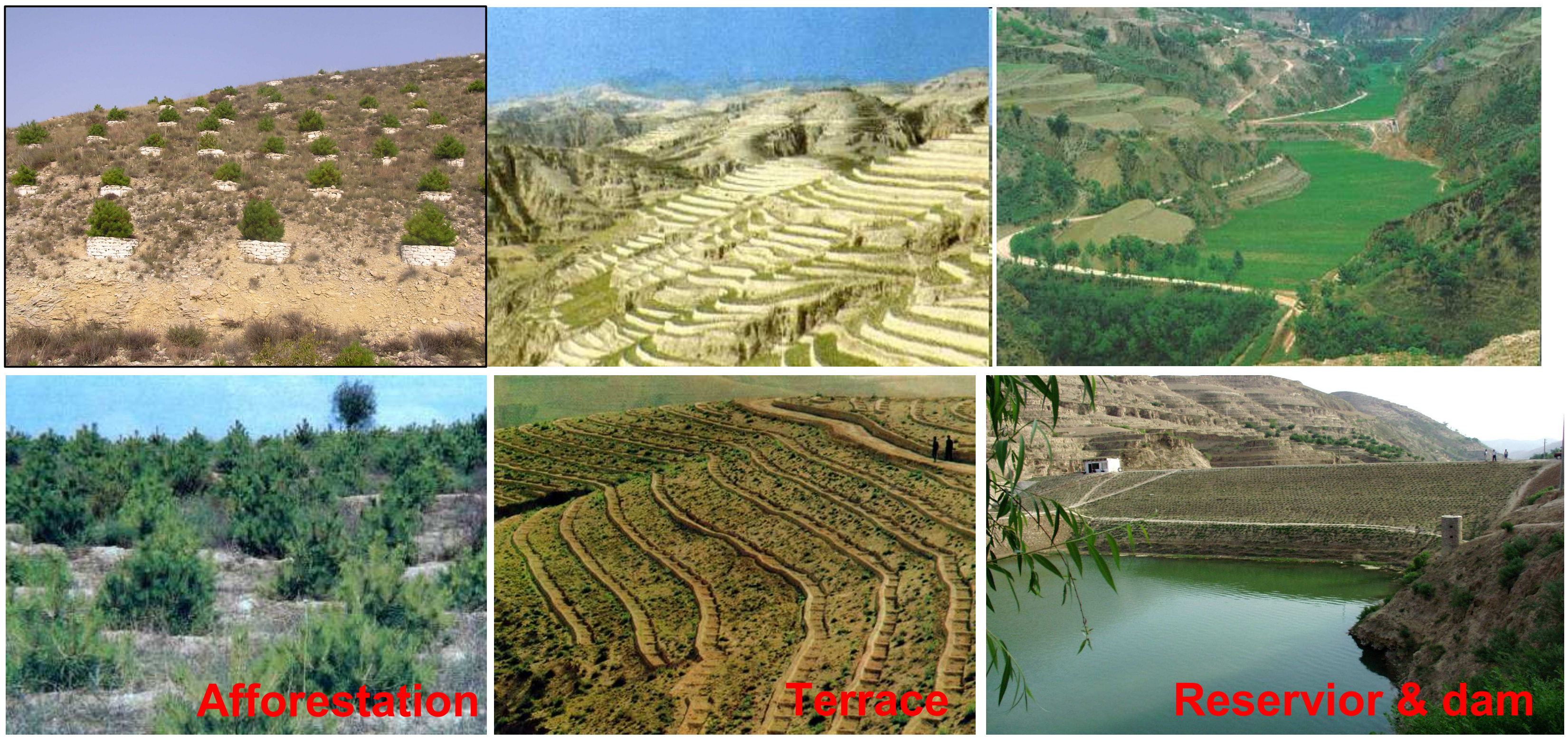
- Long civilization history
  (6,000 years)
- Densely populated
  (80-120 people/km^2)
- Heavily dissected with deep gullies

- Lack of water
- Highest erosion rates
  average 5,000-10,000
  extremely
  20,000-30,000
  $t.\ km^{-2}.a^{-1}$

Soil conservation measures

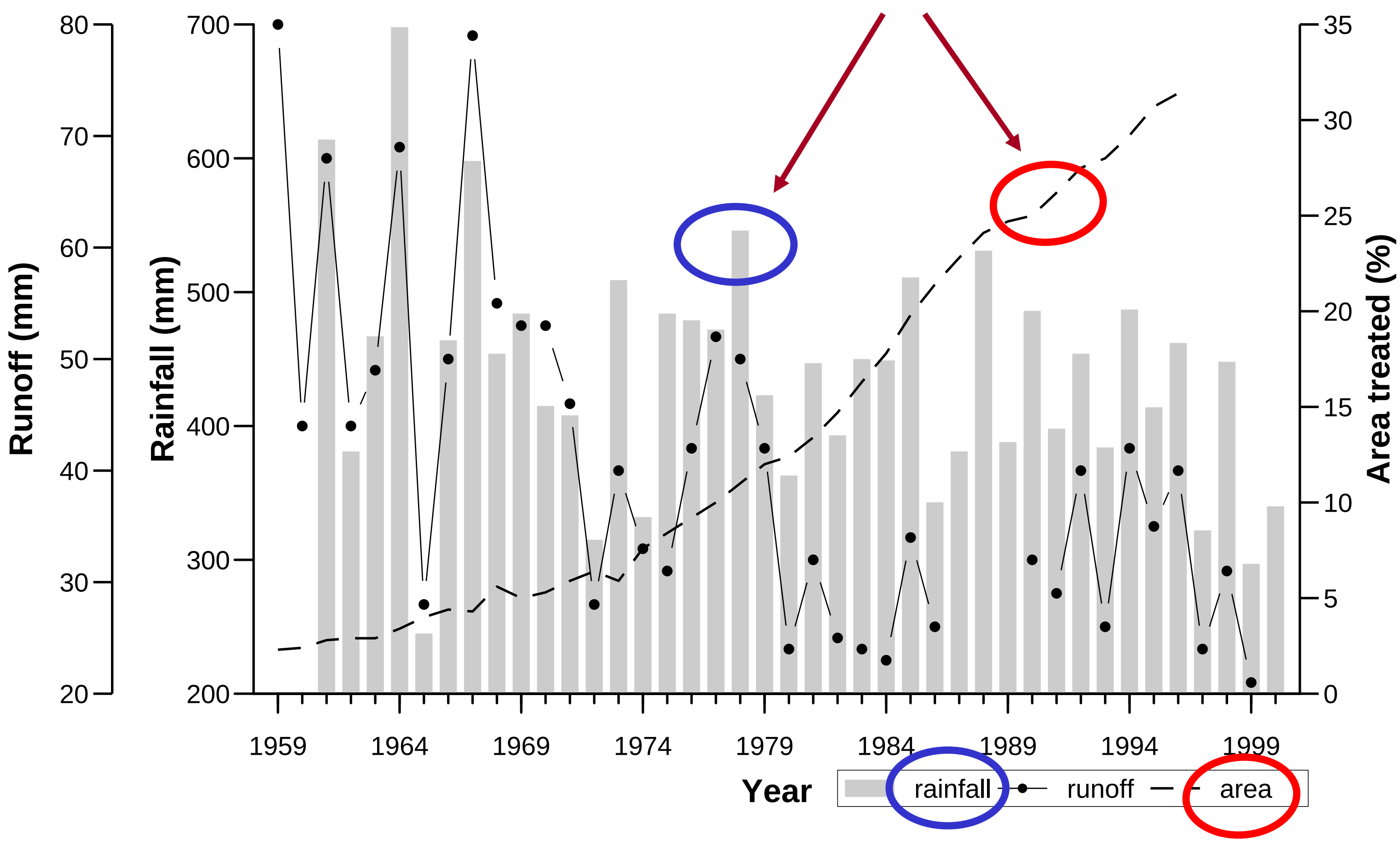
The main formations in LUCC include re-vegetation and engineering soil conservation measures, since 1950s widespread across the Loess Plateau:

- **Reforestation to increase land cover**
- **Construction of 113,500 check-dams prior to 2000**



Annual rainfall- streamflow- treated area in CSHC

Which has been more important???



Objectives

- **The annual streamflow has trends and change points over last 40 years?**
- **How to change in the daily streamflow?**
- **What is the proportion in streamflow changes from climate and LUCC?**

Data sources

- Annual Streamflow data (1950s-2000), Daily data: the Water Resources Committee of the Yellow River Conservancy Commission
- Precipitation and other meteorological data: the State Meteorology Bureau
- References: Ran *et al*. 2000; Zhang *et al*. 1998
- Precipitation spatially interpolated and accumulated
- E_0 estimated with Blaney-Criddle method

Identifying changes

Trend identification:

The Mann-Kendall test statistic is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}\left(x_j - x_k\right)$$

Change point identification:

The non-parametric approach of Pettitt (1979)**:**

$$U_{t,N} = U_{t-1,N} + \sum_{j=1}^{N} \operatorname{sgn}(x_t - x_j)$$

$$k(t) = Max_{1 \le t \ge N} \left| U_{t,N} \right|$$

Assessing climatic & LUCC impacts

Total change in Q:

$$\Delta Q^{tot} = \overline{Q}_2^{obs} - \overline{Q}_1^{obs}$$

Assume:

$$\Delta Q^{tot} = \Delta \overline{Q}^{c\lim} + \Delta \overline{Q}^{LUCC}$$

Impact of climate on Q:

$$\Delta \overline{Q}^{c\lim} = \beta \Delta P + \gamma \Delta E_0$$

Refer to: Milly and Dunne 2002, Li *et al* 2007, Zhang *et al*, 2001, 2007

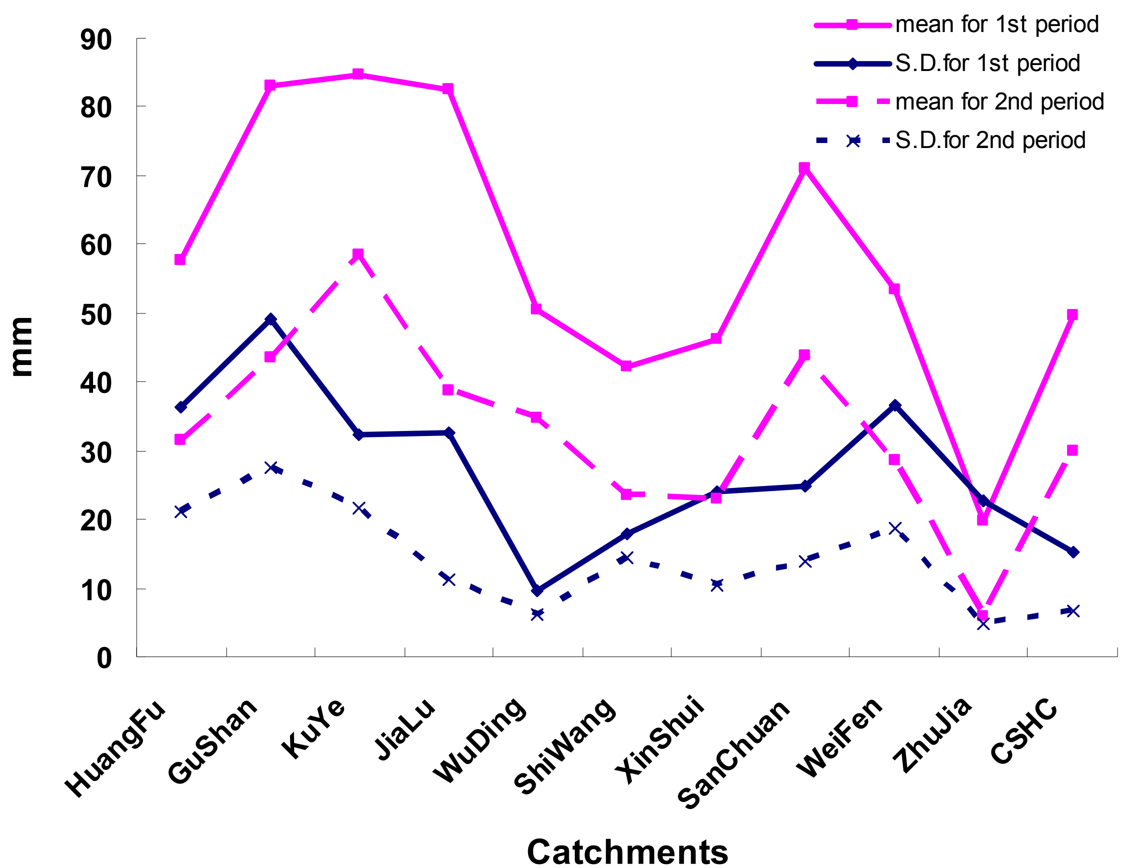
Results - 1 annual streamflow trend and change point

Catchment	Trend analysis			Change point	
	Test Z	Signific.	Slope (mm a^{-1})	year	Signific.
HuangFu	-2.67	**	-0.855	1982	* (0.05)
GuShan	-2.95	**	-1.364	1979	** (0.001)
KuYe	-2.99	** (0.01)	-0.882	1979	**
JiaLu	-5.88	*** (0.001)	-1.583	1978	**
WuDing	-4.47	***	-0.516	1973	**
ShiWang	-3.68	***	-0.703	1985	**
XinShui	-4.54	***	-0.815	1979	**
SanChuan	-4.48	***	-0.992	1979	**
WeiFen	-2.67	**	-0.685	1979	**
ZhuJia	-2.15	* (0.05)	-0.129	1971	*
CSHC	-4.29	***	-0.791	1979	**

Statistically significant negative trends in all study catchments

Change points between 1971-1985

Results - 1 annual streamflow trend and change point



Large reduction in mean of annual streamflow from 1st period to 2nd
The ratio ranges from 0.3 to 0.68
Significant differences at 1% level

An average reduction of 52% in Standard Deviation

Coefficient of Variation reduction in 8 catchments

Results - 2 changes in streamflow regime

Normalized flow duration curves
Relative changes in three streamflow regime according to the change points in individual catchment

Catchment	High ΔQ_5 (%)	Median ΔQ_{50} (%)	Low ΔQ_{95} (%)
HuangFu	-35.1	-37.3	-
GuShan	-16.5	-36.3	-
KuYe	-5.2	-17.2	24.6
JiaLu	-31.2	-20.5	-13.3
WuDing	-33.3	-22.6	-30.5
ShiWang	5.0	-11.0	22.3
XinShui	-27.7	7.6	6.6
SanChuan	-27.9	-13.9	-4.8
WeiFen	-32.2	-16.8	-
ZhuJia	-68.4	-41.7	-
CSHC*	-36.1	-32.6	-100

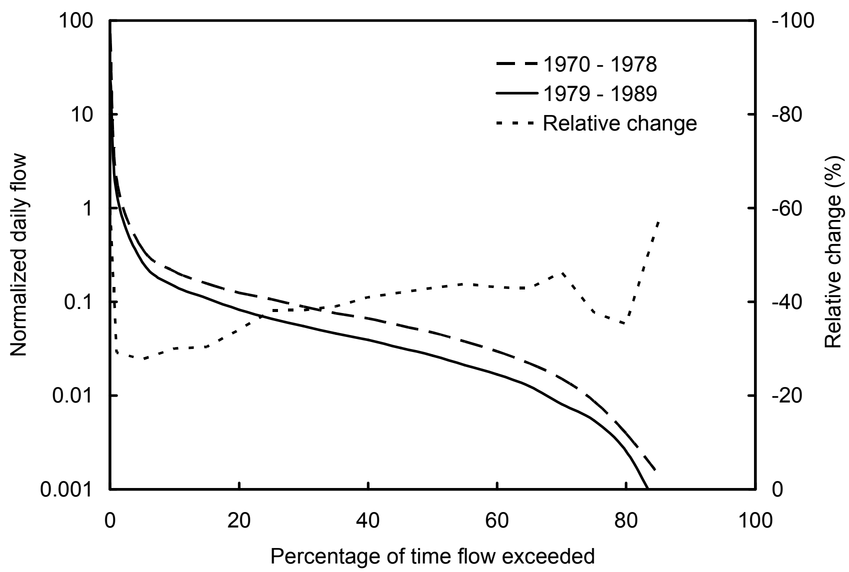
High flow lowered by 5-68%: expected to highly related to construction of engineering works

Median flow decreased by 10-42%: also reflects water extraction

Low flow more variable: related to the operation of reservoir and presence of terracing

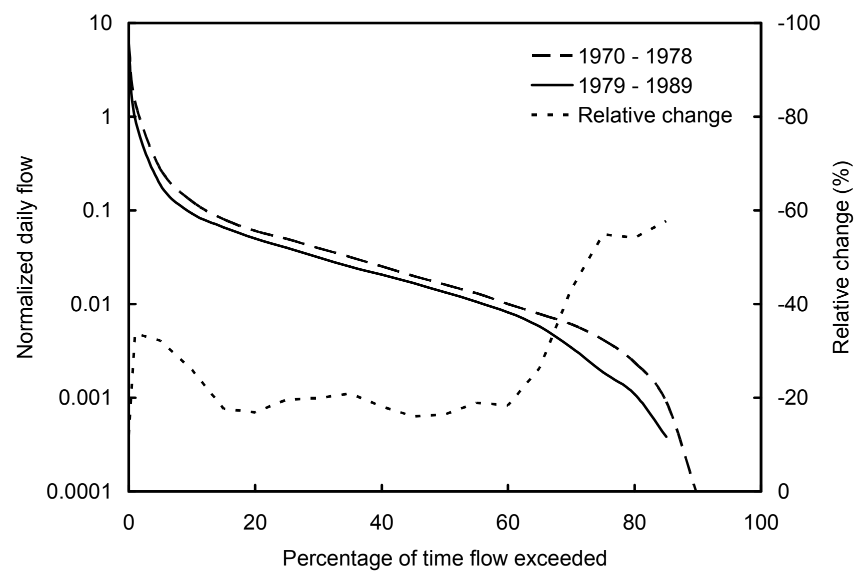
Results - 2 changes in streamflow regime

Relatively constant reduction occurred across most flow quantiles



Gushan River catchment

Weifen River catchment



Area, P, Changing point

Results - 3 impacts of climate or LUCC

Caused by climatic variable?

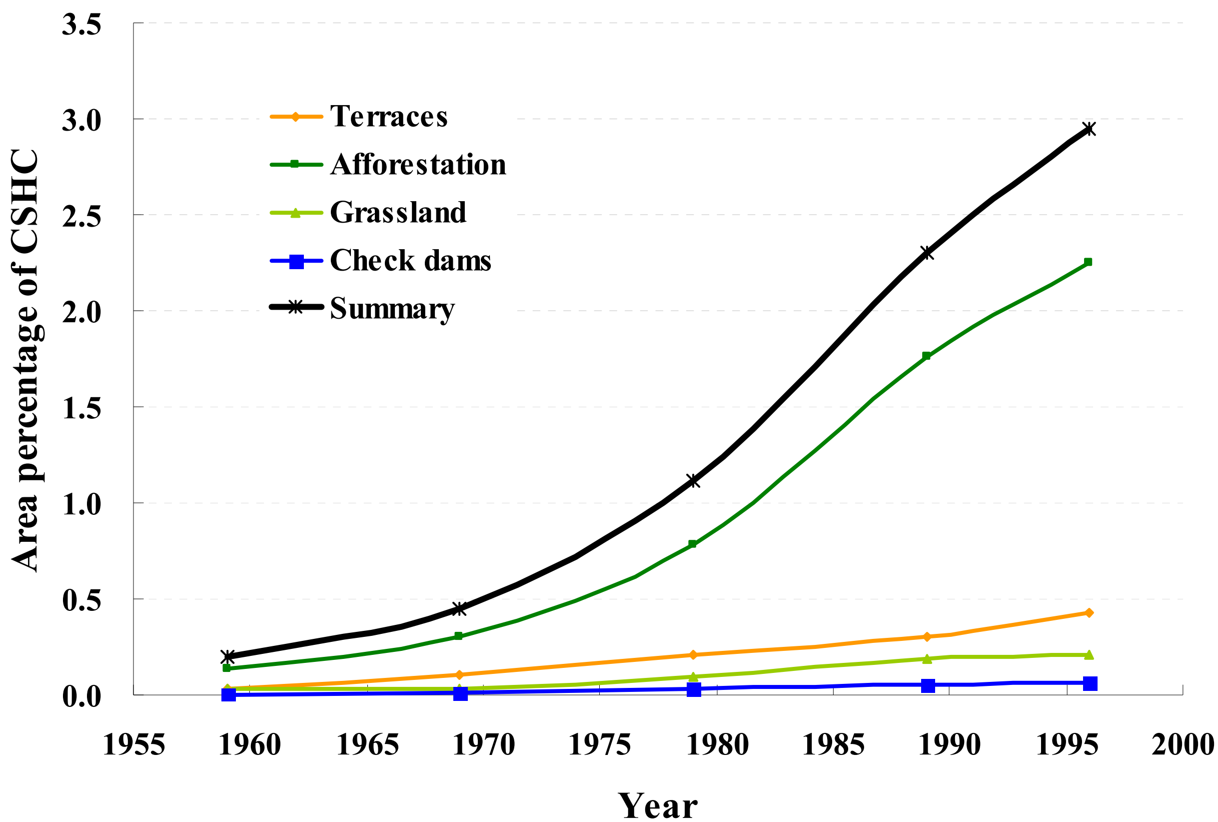
Catchment	Annual precipitation			Annual PET		
	Test Z	Signific.	Slope *(b)* (mm a^{-1})	Test Z	Signific.	Slope (*b)* (mm a^{-1})
HuangFu	-0.59	*ns*	-1.150	-2.39	*	-4.256
GuShan	-0.74	*ns*	-1.306	-1.24	*ns*	-1.319
KuYe	-0.39	*ns*	-0.764	-1.49	*ns*	-1.642
JiaLu	-1.59	*ns*	-2.283	0.18	*ns*	0.817
WuDing	-0.48	*ns*	-0.500	-1.32	*ns*	-1.517
ShiWang	-2.35	*	-2.932	-0.20	*ns*	-0.332
XinShui	-2.38	*	-4.334	-0.27	*ns*	-0.264
SanChuan	-1.24	*ns*	-2.302	0.93	*ns*	0.976
WeiFen	-0.73	*ns*	-1.115	0.28	*ns*	0.400
ZhuJia	-0.50	*ns*	-0.721	-1.63	*ns*	-1.933
CSHC	-1.97	*	-2.478	-0.65	*ns*	-0.765

No statistically significant trends in annual P and E_0

No change points either

Results - 3 impacts of climate or LUCC

Caused by soil conservation measures?



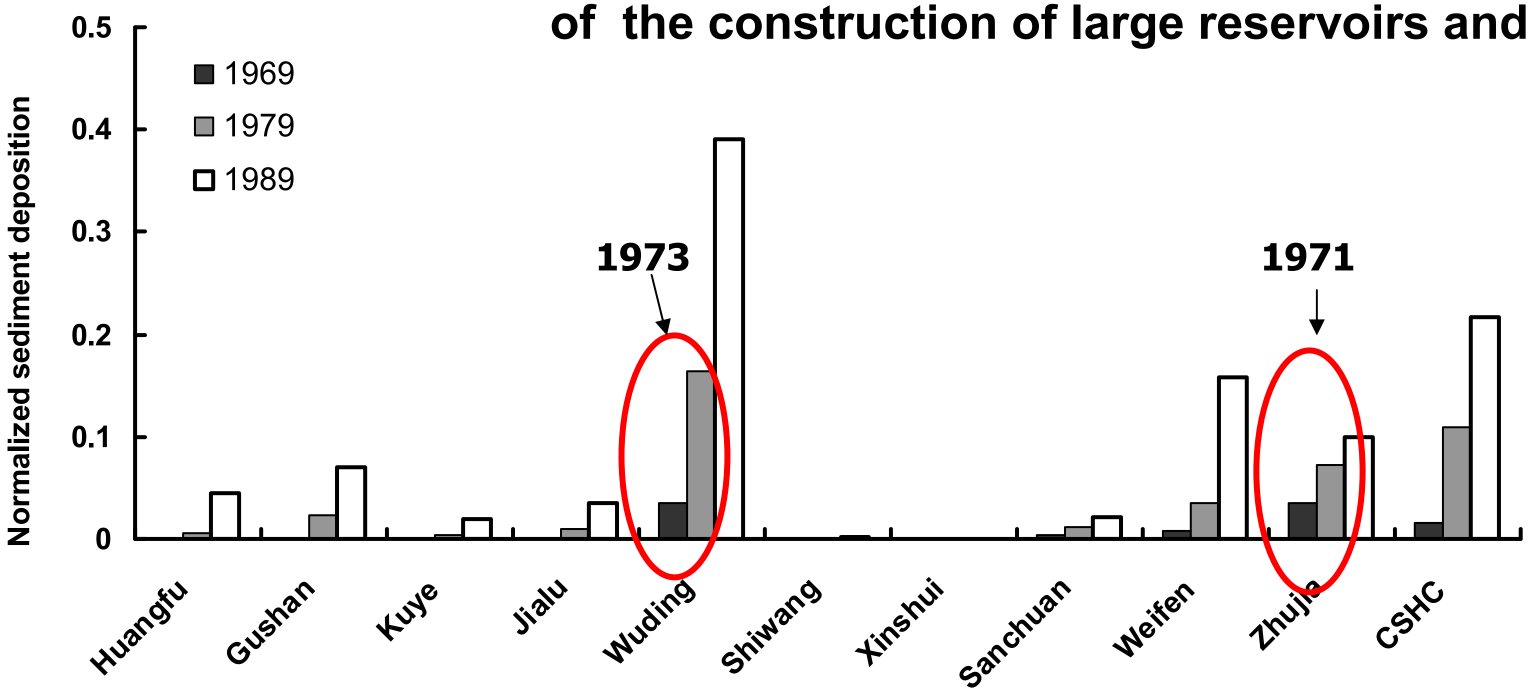
Biological measures:
Area and timing of plantation in CSHC
May not be very strong to the change of annual streamflow

Engineering measures:
Although small area
Effects are substantial

Results - 3 impacts of climate or LUCC

Normalized sediment deposition: deposited sediment volume by catchment average runoff

The change points are consistent with the year of the construction of large reservoirs and check dams



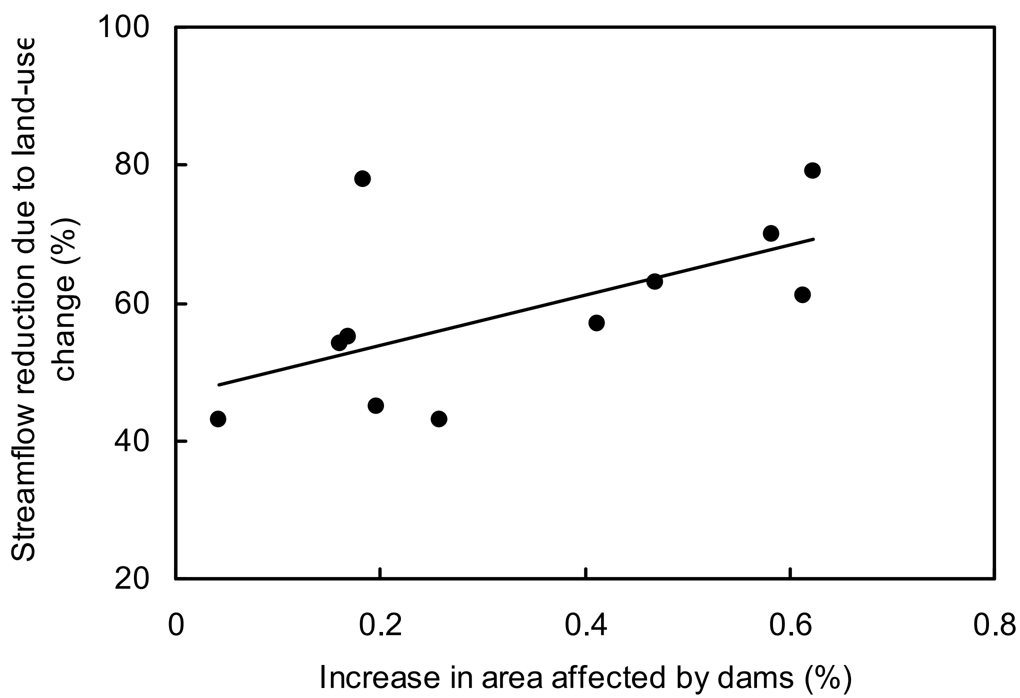
Results - 3 relative impacts of climate and soil conservation measures on streamflow

Impact (%)	Catchment										
	HuangFu	GuShan	KuYe	JiaLu	WuDing	ShiWang	XinShui	SanChuan	WeiFen	ZhuJia	CSHC
Climate	21	39	22	37	43	57	55	30	57	45	46
LUCC	79	61	78	63	57	43	45	70	43	55	54

Soil conservation measures / LUCC contributed 43-79% of the change in average annual streamflow for the catchments studied

For whole CSHC, climate and LUCC estimated equally to the streamflow reduction

Results - 3 relative impacts of climate and soil conservation measures on streamflow



The proportional streamflow reduction positively correlated with the increase in area of of sediment trapping dams

But no correlation against the other land use/cover changes

Conclusions

- The annual streamflow detected with statistically significant decreasing trends of 0.13-1.58 mm/a in CSHC

- Significant change points occurred between 1971-1985 with most of the catchments showing changing points around 1979

- No significant trends identified in precipitation and potential evapotranpiration

Conclusions

•Daily flow duration curves showed relatively constant reductions across most flow quantiles

•In most catchments the soil conservation measures were the dominant control on the streamflow reduction compared to the precipitation change. The measures responsible for 43-79% of the streamflow reduction

•Among the measures, construction of reservoirs and check dams be most correlated with the reduction in streamflow

Thank You

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