2016 International SWAT Conference

Changes in climate and land use, and their impacts on water and sediment yields in the Huangfuchuan River baisn, China

Depeng Zuo
Beijing Normal University

July 27, 2016

目 录
CONTENTS

1 Introduction

2 Study Area and Data Description

3 Methodology

4 Results and Discussion

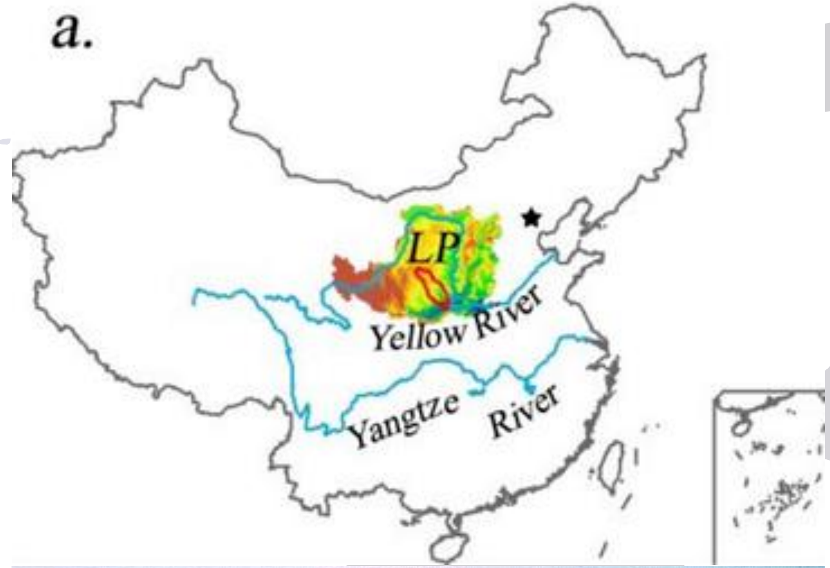
5 Conclusions

1 Introduction

Introduction

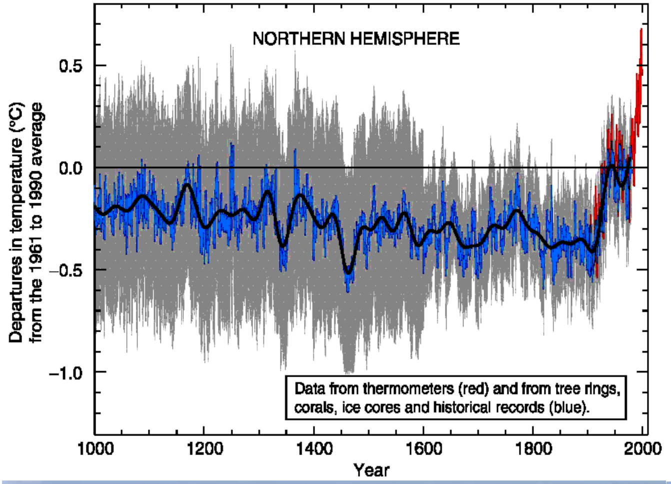
- The Yellow River is well known for its relatively low water yield compared with its huge sediment yield. The latter contributes about 6% of the sediment yield from all river systems globally.
- However, the recent runoff and sediment loads have decreased significantly, with abrupt changes occurring from the late 1980s to the early 1990s.
- Human interventions and climate changes are responsible for the dramatic reductions in runoff and sediment load.

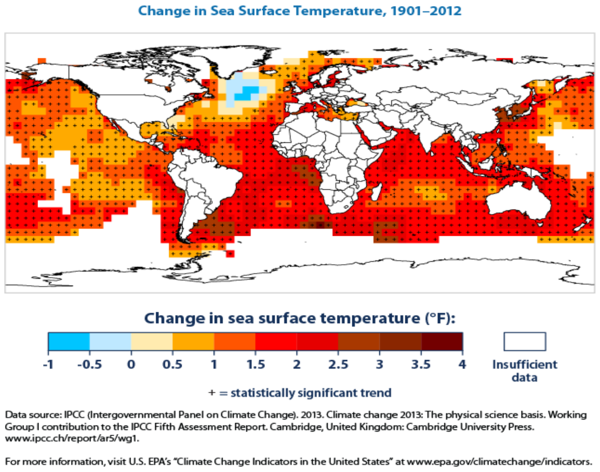
Introduction



- The Loess Plateau, located in the middle reaches of the Yellow River, occupies an area of approximately 380,000 km^2.
- The water from this region accounts for 44.3% of the Yellow River streamflow, whereas the sediment accounts for 88.2% of the river’s.
- This phenomenon makes the Loess Plateau the area with the most severe soil erosion worldwide.

Introduction



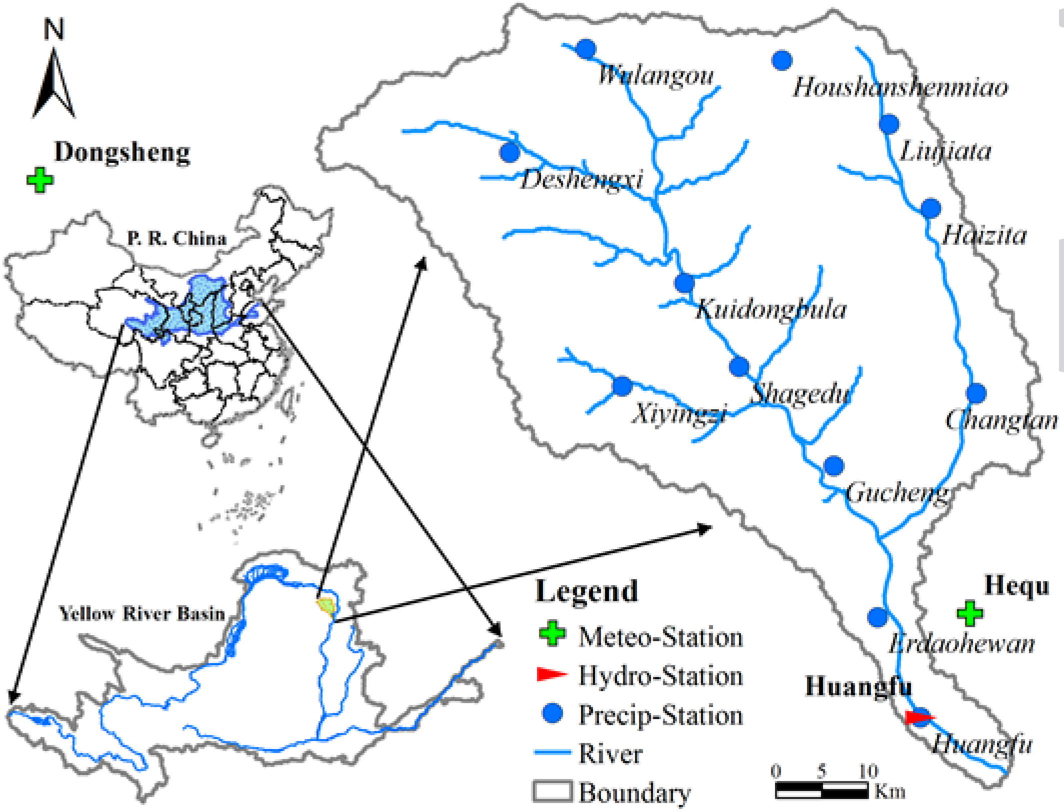


- Air temperature increase alters regional weather circulation, changes the patterns of precipitation, and intensify the hydrological cycle. Soil erosion is mainly the result of extreme but short precipitation events; therefore, changes in the frequency and intensity of precipitation influence soil erosion processes.

- Land use change such as afforestation, desertification, urbanization, and reclamation of wetlands have resulted in increases of flooding and drought occurrences, land degradation related to soil erosion, reduced agricultural productivity, and deterioration of fragile natural ecosystems.

2 Study Area and Data Description

Study Area Description



- A first-order tributary of the Yellow River
- The Loess Plateau and Inner Mongolian grassland
- Area of 3246 km^2
- The main stream is 137 km
- Two main tributaries: the Nalin and Changchuan rivers
- Transitional belt of warm temperate and mesothermal zones
- Average annual precipitation of about 380 mm
- Southeastern monsoonal conditions in summer
- Semi-arid continental climate.
- Frequently occurring floods in July and August often cause substantial soil erosion
- Average annual runoff: 1.269×10^8 m^3
- Average annual sediment load: 0.408×10^8 ton
- Nearly 80% of which was concentrated during the rainy season from June to September

Data Description

Input Data	Resolution	Source
DEM	30 m	International Scientific & Technical Data Mirror Site, Computer Network Information Center, Chinese Academy of Sciences
Land-use map	100 m	Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences
Soil-type map	330 m	Institute of Soil Science, Chinese Academy of Sciences
Meteorological data	Daily	China Meteorological Administration
Hydrological data	Daily	Yellow River Conservancy Commission

3 Methodology

Methodology

Mann-Kendell

Non-parametric test

Temporal trend analysis

Pettitt

Non-parametric test

Change point detection

Transition Matrix analysis

Statistical analysis

land-use changes analysis

SWAT

Hydrological Model

Runoff and sediment load simulation

SUFI-2

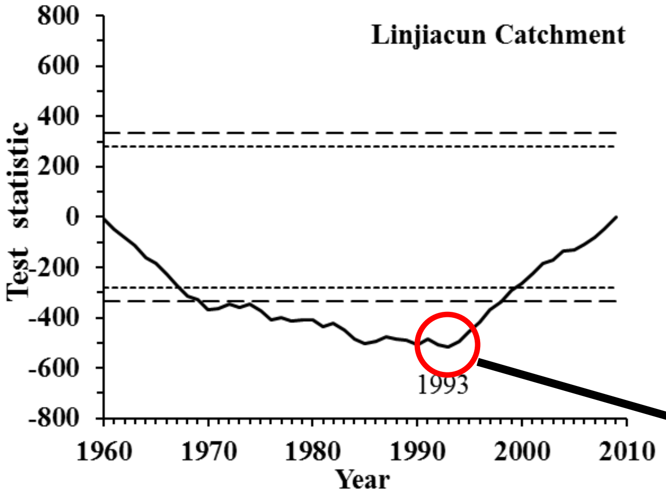
SWAT-CUP

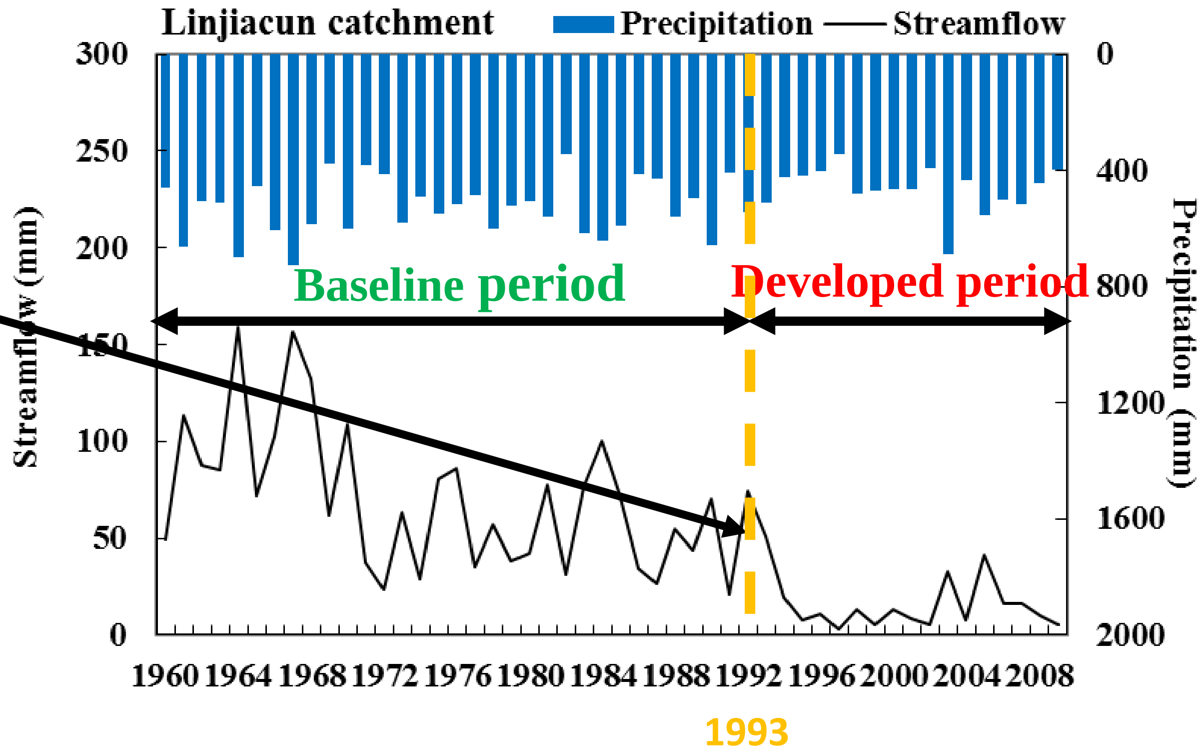
Calibration and uncertainty analysis

Methodology

Determination of Baseline and developed periods

Non-parametric Pettitt method





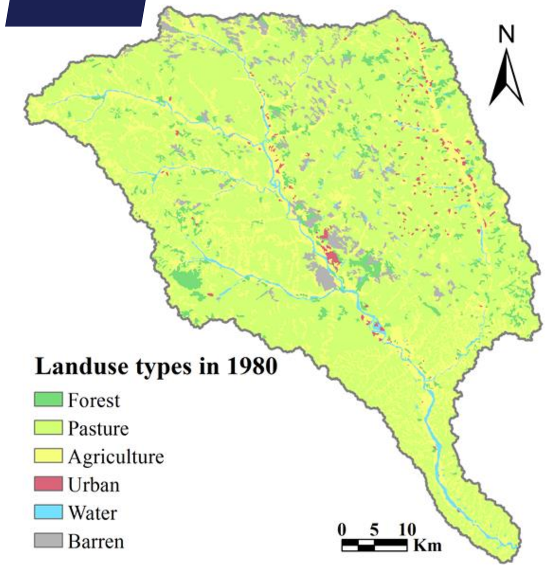
Methodology

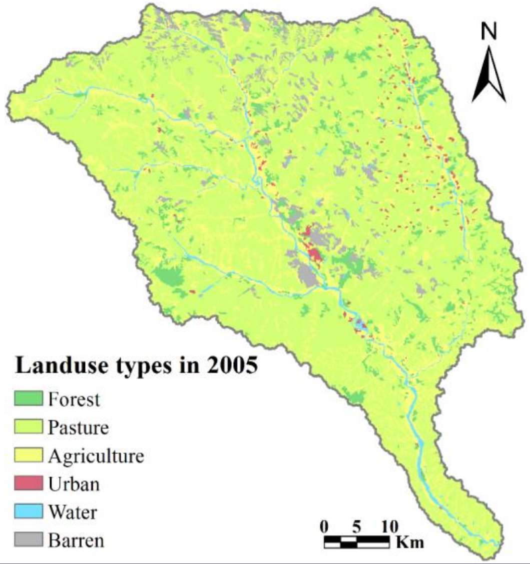
Differentiation of effects of land-use and climate changes on runoff and sediment load

S1 (C1–L1)	S2 (C1–L2)	S3 (C2–L1)	S4 (C2–L2)
Climate: 1979–1984 (C1) Land use: 1980 (L1)	Climate: 1979–1984 (C1) Land use: 2005 (L2)	Climate: 2006–2011 (C2) Land use: 1980 (L1)	Climate: 2006–2011 (C2) Land use: 2005 (L2)
Baseline Condition	**Land use change effect**	**Climate change effect**	**Combined effects**

4 Results and Discussion

Land-use types in 1980 and 2005





Land-use type	1980		2005		Change	
	Area (km^2)	Percent (%)	Area (km^2)	Percent (%)	Area (km^2)	Percent(%)
Forest	151.42	4.69	173.64	5.38	22.22	14.67
Grassland	2160.54	66.96	2142.05	66.39	-18.49	-0.86
Farmland	707.31	21.92	680.87	21.10	-26.44	-3.74
Settlement	28.10	0.87	28.26	0.88	0.16	0.57
Water body	67.31	2.09	72.47	2.25	5.16	7.67
Bare land	111.86	3.47	129.25	4.01	17.39	15.55

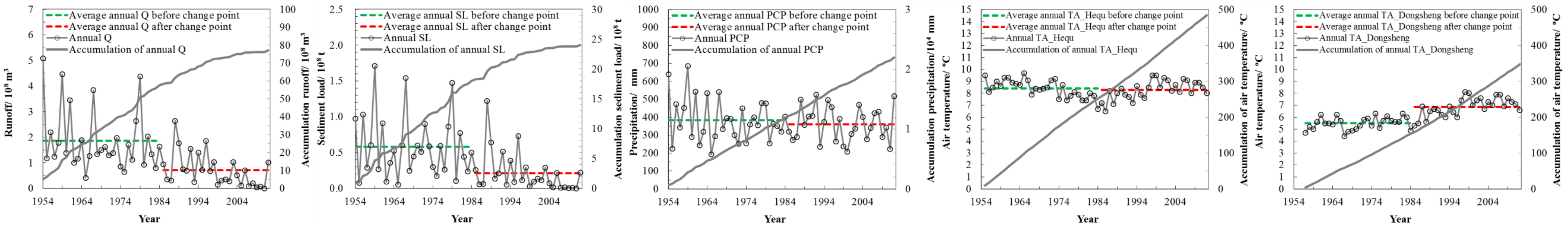
Grassland is the most common evenly distributed, showing a decreasing of ***0.86%***.
Farmland and settlements are located mainly along the riverside and in the lowland valleys, showing decreases and increases of ***3.74%*** and ***0.57%***, respectively.
Forest land is primarily found in the middle-stream area, showing an increase of ***14.67%***.
Bare land is concentrated in the middle and upper-stream area, with a growth rate of ***15.55%***.
Bodies of water increased by ***7.67%***

Transition matrix of land use changes from 1980 to 2005

2005 / 1980	Forest	Grass-land	Farm-land	Settle-Ment	Water body	Bare land	Total
Forest	**151.12**	0.3	0	0	0	0	151.42
Grassland	15.17	**2118.27**	5.46	0	0.03	21.61	2160.54
Farmland	7.29	15.13	**675.19**	0.17	5.86	3.67	707.31
Settlement	0	0.01	0	**28.09**	0	0	28.1
Water body	0.06	0.49	0.13	0	**66.57**	0.06	67.31
Bare land	0	7.85	0.09	0	0.01	**103.91**	111.86
Total	173.64	2142.05	680.87	28.26	72.47	129.25	

- 87.03% of **forest land** remained unchanged, whereas the remainder was primarily converted from **grassland** and **farmland**.
- **Farmland** and **bare land** were converted into **forest** and **grassland.**
- These conversions show significant effects of the **Grain for Green** Program.
- However, 21.61 km^2 of **grassland** and 3.67 km^2 of **farmland** were transformed into **bare land**, which indicates that this basin still undergoes **land degradation and desertification**.

Temporal trends of hydro-meteorological variables



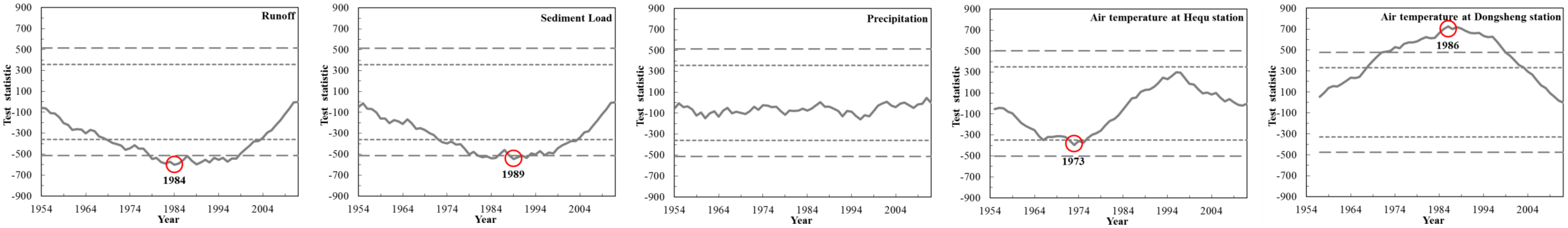
- The runoff and sediment experienced an obvious decrease, particularly after the mid-1980s.
- The precipitation showed a slightly decreasing trend.
- The temperature detected a significant increasing trend.
- The climate in the HFCRB has become warmer and drier.

Temporal trends of hydro-meteorological variables

	Test statistic Z	Sen's slope estimate Q	Significance level α
Annual runoff	-5.32	-298.778	0.001
Annual sediment load	-4.68	-94.857	0.001
Annual areal precipitation	-0.64	-0.658	>0.1
Annual air temperature at Hequ	-0.94	-0.006	>0.1
Annual air temperature at Dongsheng	6.39	0.047	0.001

The dramatic reductions in runoff and sediment have relationship with the decreased precipitation and increased air temperature. Moreover, human activity also plays an important role.

Abrupt changes in hydro-meteorological variables



- **1984** was detected as a **significant change point** for **runoff**. The **accumulation curves** also show that runoff decreased **sharply** after 1984.
- The sediment showed a similar temporal variation, in which **1989** was determined as a **significant change point**.
- **No significant change point** was detected in **precipitation**. **1986** was detected as a **significant change point** for temperature at Dongsheng.

Abrupt changes in hydro-meteorological variables

	Period I: 1954–1984	Period II: 1985–2012	Change	Change rate
Annual runoff (10^8 m^3)	1.85	0.70	-1.15	-61.97%
Annual sediment load (10^8 t)	0.58	0.21	-0.37	-63.27%
Annual areal precipitation (mm)	384.46	360.58	-23.88	-6.21%
Annual air temperature at Hequ station (°C)	8.40	8.30	-0.10	-1.23%
Annual air temperature at Dongsheng station (°C)	5.49	6.87	1.38	25.18%

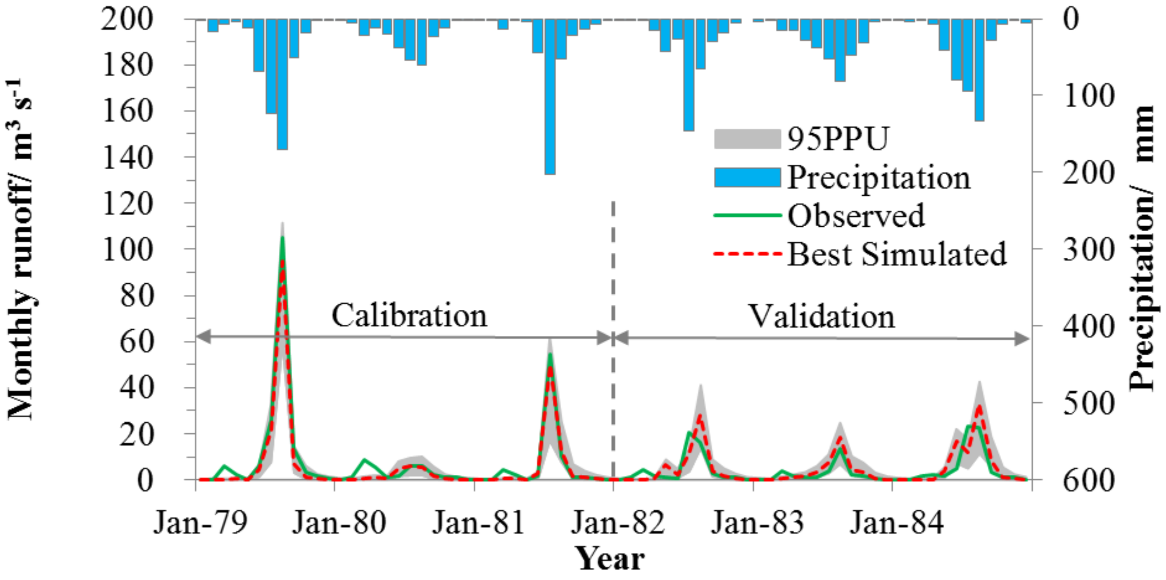
- **The changes of precipitation and air temperature don't coincide with the variations of runoff and sediment, which may results from the large scale returning farmland to forest and grassland, construction of check dams, and other soil and water conservation measures.**

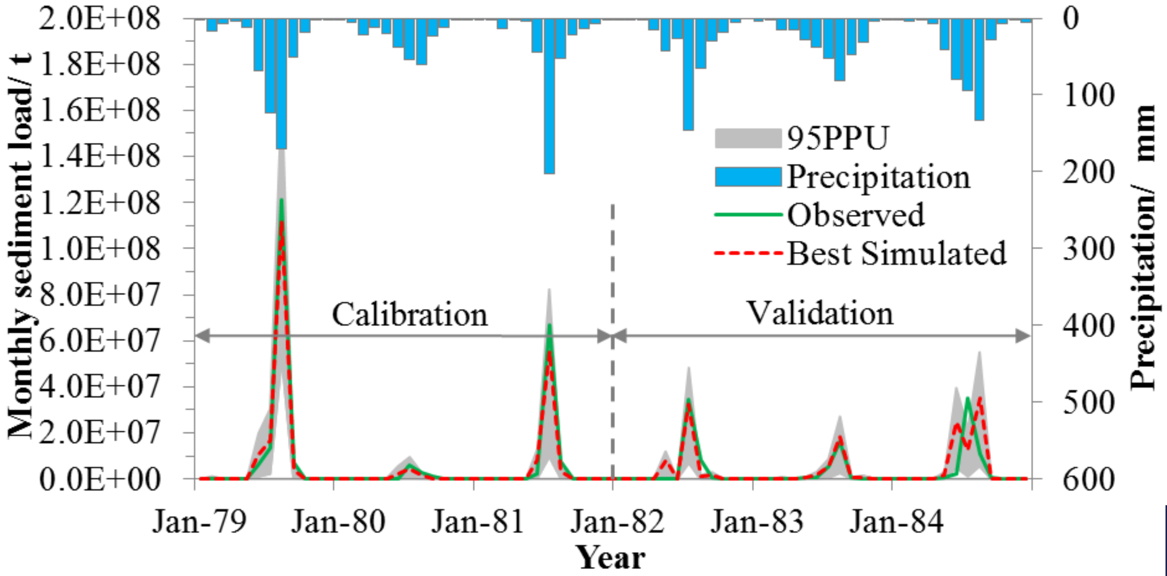
Parameter sensitivity analysis

Parameter	Runoff			Sediment		
	t-value	P-value	Rank	t-value	P-value	Rank
v__SHALLST.gw	-1.62	0.11	15	0.51	0.61	33
v__GW_DELAY.gw	-0.83	0.41	30	0.16	0.87	50
v__ALPHA_BF.gw	0.30	0.77	44	2.78	0.01	4
v__GWQMN.gw	2.85	0.01	3	0.09	0.93	54
v__GW_REVAP.gw	-2.27	0.03	6	-0.87	0.39	24
v__REVAPMN.gw	0.72	0.47	34	-0.21	0.83	49
v__RCHRG_DP.gw	-1.27	0.21	20	2.24	0.03	7
r__BIOMIX.mgt	-0.06	0.96	53	0.21	0.83	48
r__CN2.mgt	16.95	0.00	1	4.80	0.00	1
v__USLE_P.mgt	-1.18	0.24	21	3.23	0.00	3
r__SOL_Z.sol	-0.38	0.71	41	-2.05	0.05	10
r__SOL_BD.sol	-1.70	0.10	12	1.11	0.27	19
r__SOL_AWC.sol	-0.75	0.46	32	0.44	0.66	37
r__SOL_K.sol	0.69	0.49	35	-0.45	0.65	36
r__SOL_ALB.sol	-0.89	0.38	27	1.96	0.06	13
r__USLE_K.sol	1.44	0.16	17	2.63	0.01	5
v__CH_N2.rte	-1.08	0.29	24	-1.41	0.16	17
v__CH_K2.rte	-0.36	0.72	42	0.83	0.41	26
v__ALPHA_BNK.rte	2.91	0.01	2	0.77	0.44	27
v__CH_EROD.rte	-0.11	0.91	50	-1.57	0.12	15
v__CH_COV.rte	-0.36	0.72	43	2.37	0.02	6
v__SLSUBBSN.hru	-0.55	0.59	37	0.33	0.75	41
v__OV_N.hru	-0.16	0.88	49	-0.85	0.40	25
v__LAT_TTIME.hru	-1.67	0.10	13	1.31	0.20	18
v__LAT_SED.hru	1.16	0.25	22	0.28	0.78	45
v__SLSOIL.hru	-0.94	0.35	26	-0.93	0.35	22
v__CANMX.hru	-1.28	0.21	19	0.73	0.47	29

Parameter	Runoff			Sediment		
	t-value	P-value	Rank	t-value	P-value	Rank
v__ESCO.hru	-1.99	0.05	8	-1.45	0.15	16
v__EPCO.hru	0.85	0.40	29	-1.86	0.07	14
v__HRU_SLP.hru	-0.28	0.78	46	4.33	0.00	2
v__TLAPS.sub	-0.74	0.47	33	0.42	0.67	38
v__CH_K1.sub	-2.70	0.01	5	1.06	0.30	20
v__CH_N1.sub	0.29	0.77	45	0.65	0.52	31
v__SFTMP.bsn	-0.05	0.96	54	-0.33	0.74	40
v__SMTMP.bsn	0.88	0.38	28	1.01	0.32	21
v__SMFMX.bsn	0.79	0.44	31	0.54	0.59	32
v__SMFMN.bsn	-1.51	0.14	16	0.76	0.45	28
v__TIMP.bsn	-0.39	0.70	39	0.70	0.49	30
v__SNOCOVMX.bsn	1.66	0.10	14	-1.96	0.06	12
v__SNO50COV.bsn	0.57	0.57	36	1.97	0.06	11
v__SURLAG.bsn	-1.15	0.26	23	0.30	0.77	44
v__PRF.bsn	0.09	0.93	52	-2.12	0.04	9
v__SPCON.bsn	0.09	0.93	51	0.28	0.78	46
v__SPEXP.bsn	-2.20	0.03	7	-0.11	0.91	52
v__EVRCH.bsn	2.82	0.01	4	0.31	0.76	43
v__ADJ_PKR.bsn	0.19	0.85	47	2.22	0.03	8
v__BLAI{FRST}.crop.dat	-0.39	0.70	40	0.46	0.65	35
v__BLAI{PAST}.crop.dat	0.45	0.66	38	-0.36	0.72	39
v__BLAI{AGRL}.crop.dat	1.73	0.09	11	-0.32	0.75	42
v__BLAI{BARR}.crop.dat	-0.97	0.34	25	-0.50	0.62	34
v__USLE_C{FRST}.crop.dat	1.87	0.07	9	0.88	0.39	23
v__USLE_C{PAST}.crop.dat	-1.41	0.16	18	0.16	0.88	51
v__USLE_C{AGRL}.crop.dat	0.18	0.86	48	0.10	0.92	53
v__USLE_C{BARR}.crop.dat	1.79	0.08	10	0.26	0.79	47

Calibration, validation, and uncertainty analysis





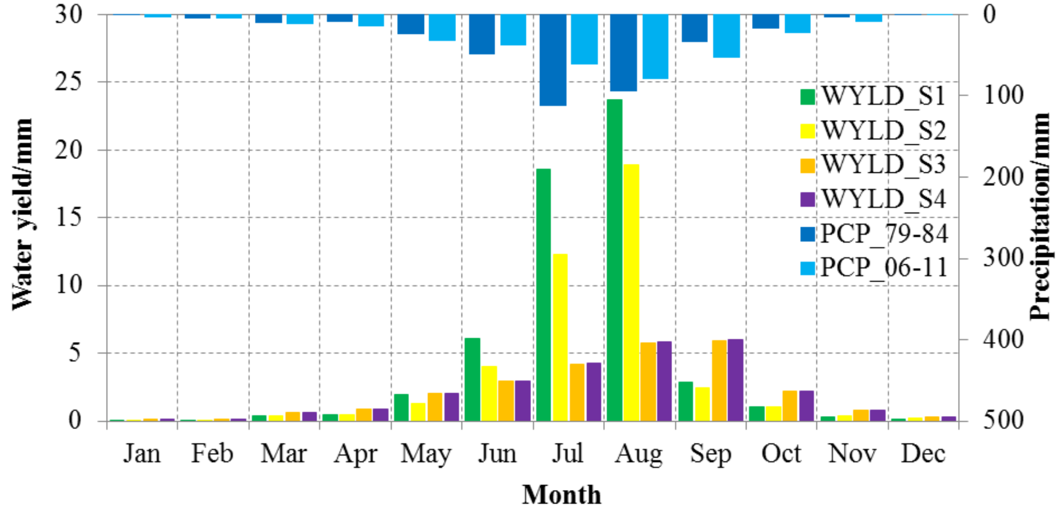
Index	Calibration (1979–1981)		Validation (1982–1984)	
	Runoff	Sediment	Runoff	Sediment
P-factor	0.69	0.50	0.53	0.67
R-factor	0.32	0.36	0.86	0.62
R^2	0.98	0.99	0.63	0.47
E_{NS}	0.98	0.99	0.61	0.43

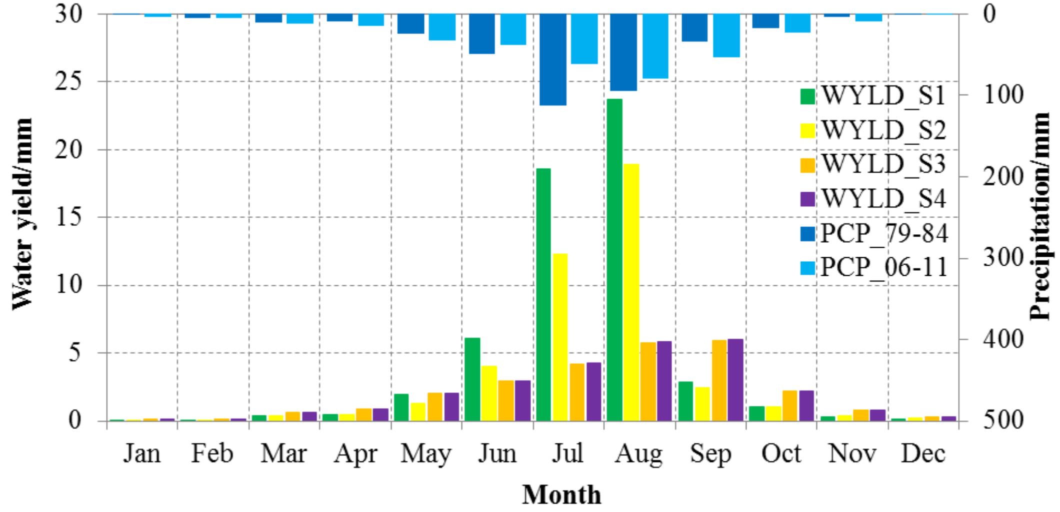
Changes in water and sediment yields at basin scale under different scenarios

Scenario	Land use	Climate	Water yield			Sediment yield		
			Average (mm)	Change (mm)	Percent (%)	Average (t/ha)	Change (t/ha)	Percent (%)
1	1980	1979–1984	55.6	–	–	196.7	–	–
2	2005	1979–1984	41.5	-14.0	-25.3%	116.8	-79.9	-40.6%
3	1980	2006–2011	25.8	-29.8	-53.7%	37.3	-159.4	-81.0%
4	2005	2006–2011	26.1	-29.5	-53.1%	39.9	-156.8	-79.7%

- Both land-use and climate changes decreased the water yield, and climate change effect was greater than land-use change effect.
- The combined effects on water yield were nearly equal to the climate change effect, likely owing to the interactions between the land use change and climate change. This phenomenon illustrates that the land-use change effect on water yield is not obvious when the climate change effect plays a dominant role.
- Both land-use and climate changes also decreased the sediment yield, which had greater impact on sediment yield than water yield.

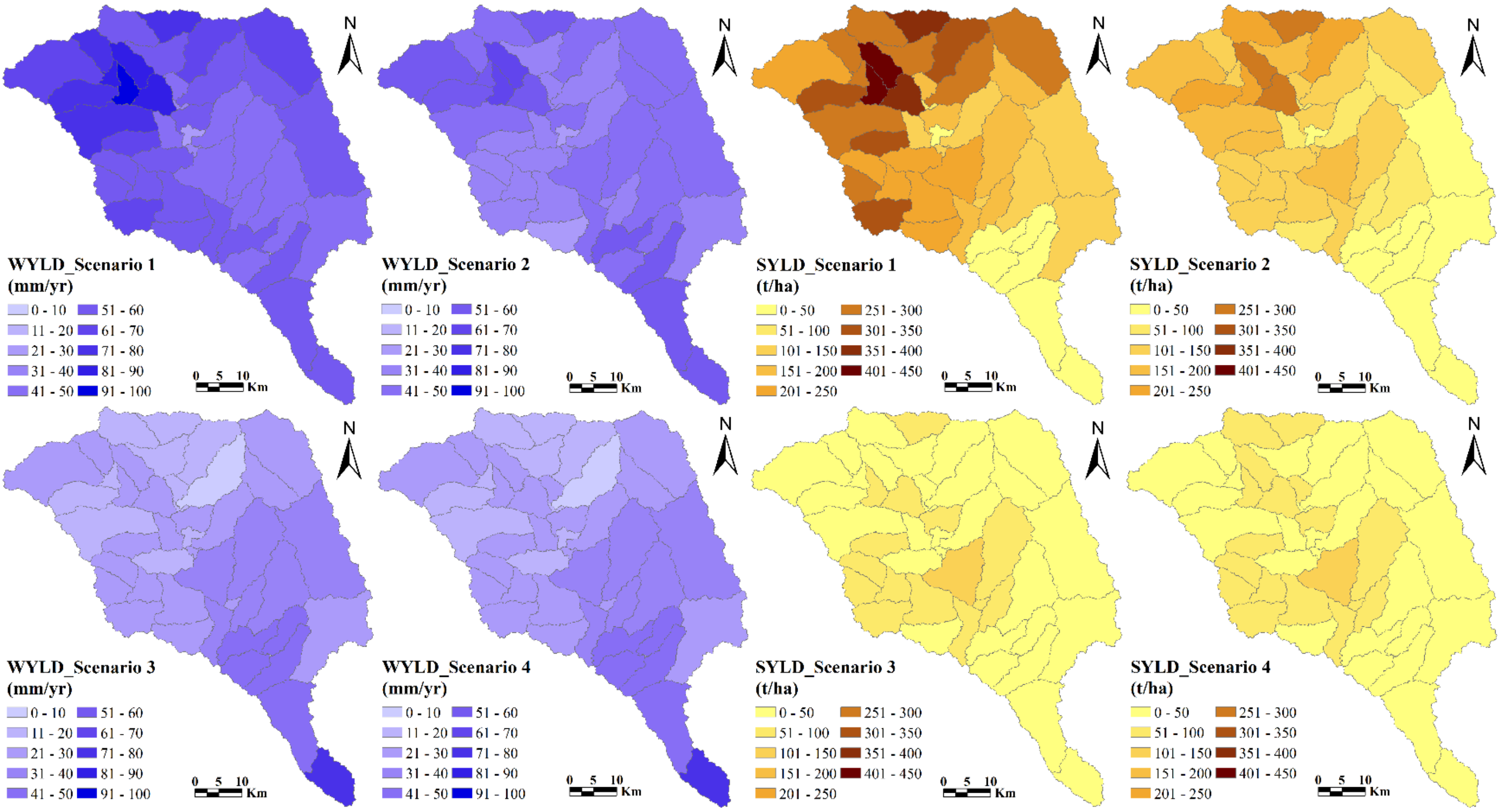
Changes in water and sediment yields at basin scale under different scenarios





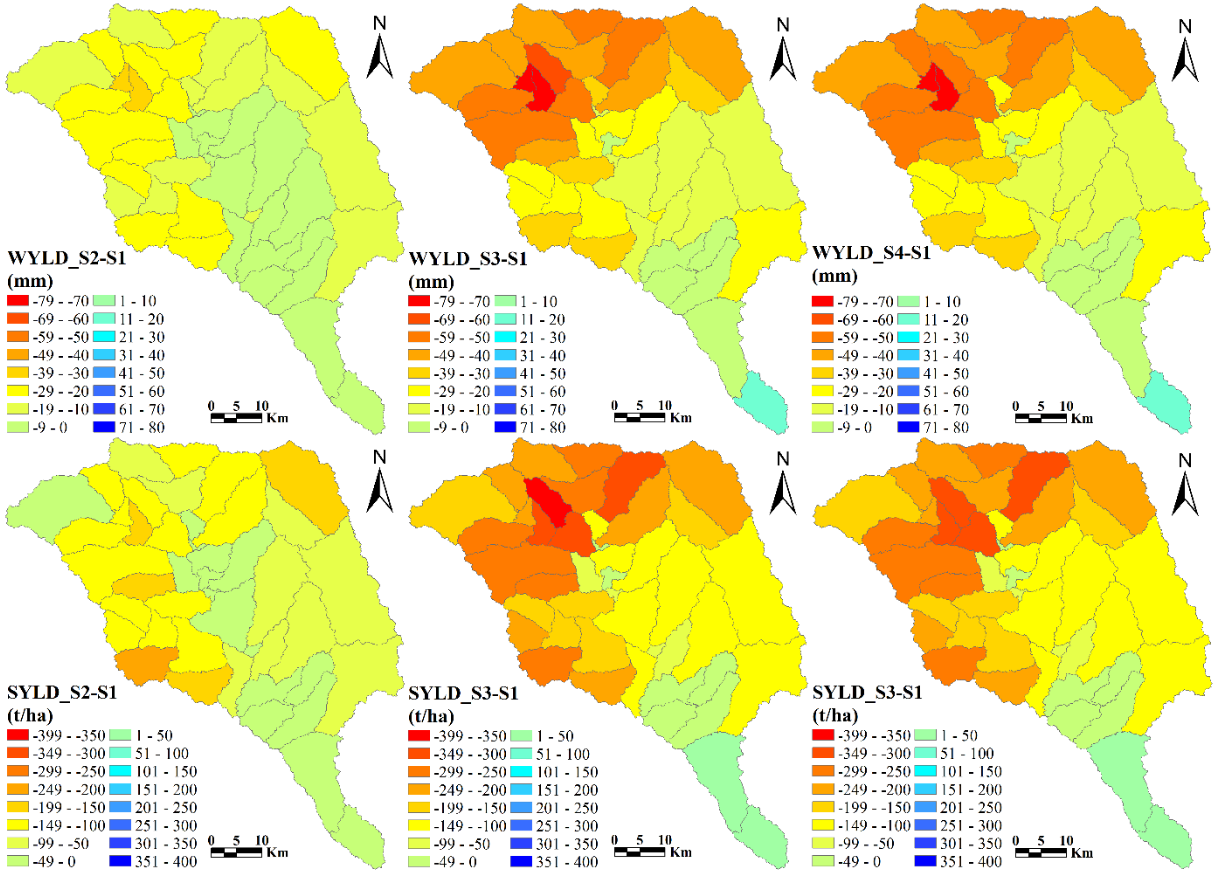
- More than 90% of the water yield was concentrated in the rainy season under scenarios 1 and 2. For scenarios 3 and 4, the percentage of water yield contributed by the rainy season decreased to approximately 70%
- The month of the peak value changed from August to September, which demonstrates that climate change during recent years resulted in lagging and attenuating flood peaks.
- The phenomenon might have been caused by changes in the seasonal pattern of precipitation.

Spatial variability of water and sediment yield under different scenarios



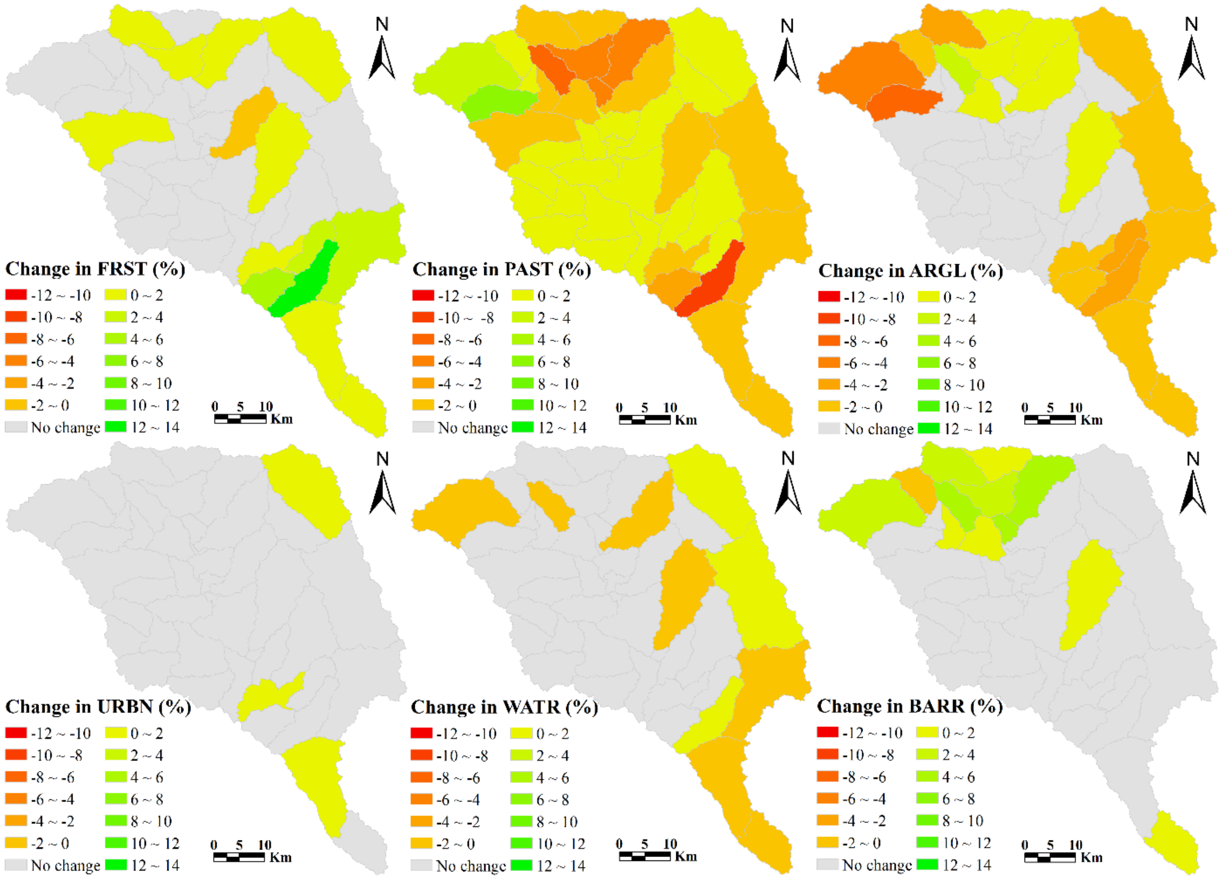
- Baseline condition, the highest water yield occurred in the upstream region, whereas the lowest values occurred in the midstream region.
- The spatial pattern of the water yield under scenario 2 was generally consistent with that under scenario 1; however, the maximum value contributed by the upstream region decreased.
- The spatial distributions of water yield under scenarios 3 and 4 were similar, showing an increase from the upstream to downstream regions.

Spatial variability of water and sediment yield under different scenarios



- The decrease in water yield caused by land-use change was less significant than that caused by climate change. The combined effects were generally consistent with climate change effect, more significant decrease in the upstream region than that in the downstream region.
- Similar to that of water yield, the sediment yield in the upstream region decreased more significantly than that in the downstream region under different effects.

Spatial variability of water and sediment yield under different scenarios



- The obvious increase in grassland and decrease in farmland in the upstream region are important factors for the reductions in water and sediment yield.
- The decrease in farmland and increase in forest in the downstream region and the eastern part of the HFCRB might have also contributed to the reductions in runoff and sediment load.
- The main cause of soil erosion in the Loess Plateau is deforestation for farmland reclamation and cultivation on steep slopes.
- The soil and water conservation measures implemented in the 1980s, and the Green for Grain Project of the 1990s have been effective, which confirms the rationality of the results obtained in this study.
- In addition, more attention should be paid to the expansion of bare land in the upstream region, which increases the risk of soil erosion in the HFCRB.

5 Conclusions

Conclusions

1	2	3
Significant decreasing trends in both annual runoff and sediment loads, whereas slightly decreasing and significantly increasing trends are detected for annual precipitation and air temperature, respectively. 1984 is identified as the dividing year of the study period.	The land-use changes between 1980 and 2005 show that grassland and farmland decreased, while forest and bare land increased, which indicates the significant effects of the Grain for Green Program in China that began at the end of the 20th century.	Both land-use change and climate change have greater impact on the reduction of sediment yield than that of water. Water and sediment yields in the upstream region show more significant decreases than those in the downstream region under different effects.

The results obtained in this study can provide useful information for water resource planning and management as well as soil and water conservation in the Loess Plateau region.

THANK YOU FOR LISTENING