ANALYSIS ON YELLOW RIVER DELTA EVOLUTION WITH FLUXES OF RUNOFF AND SEDIMENT

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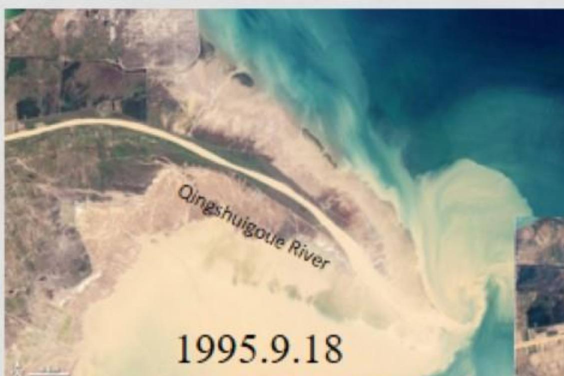
CONTENTS

INTRODUCTION

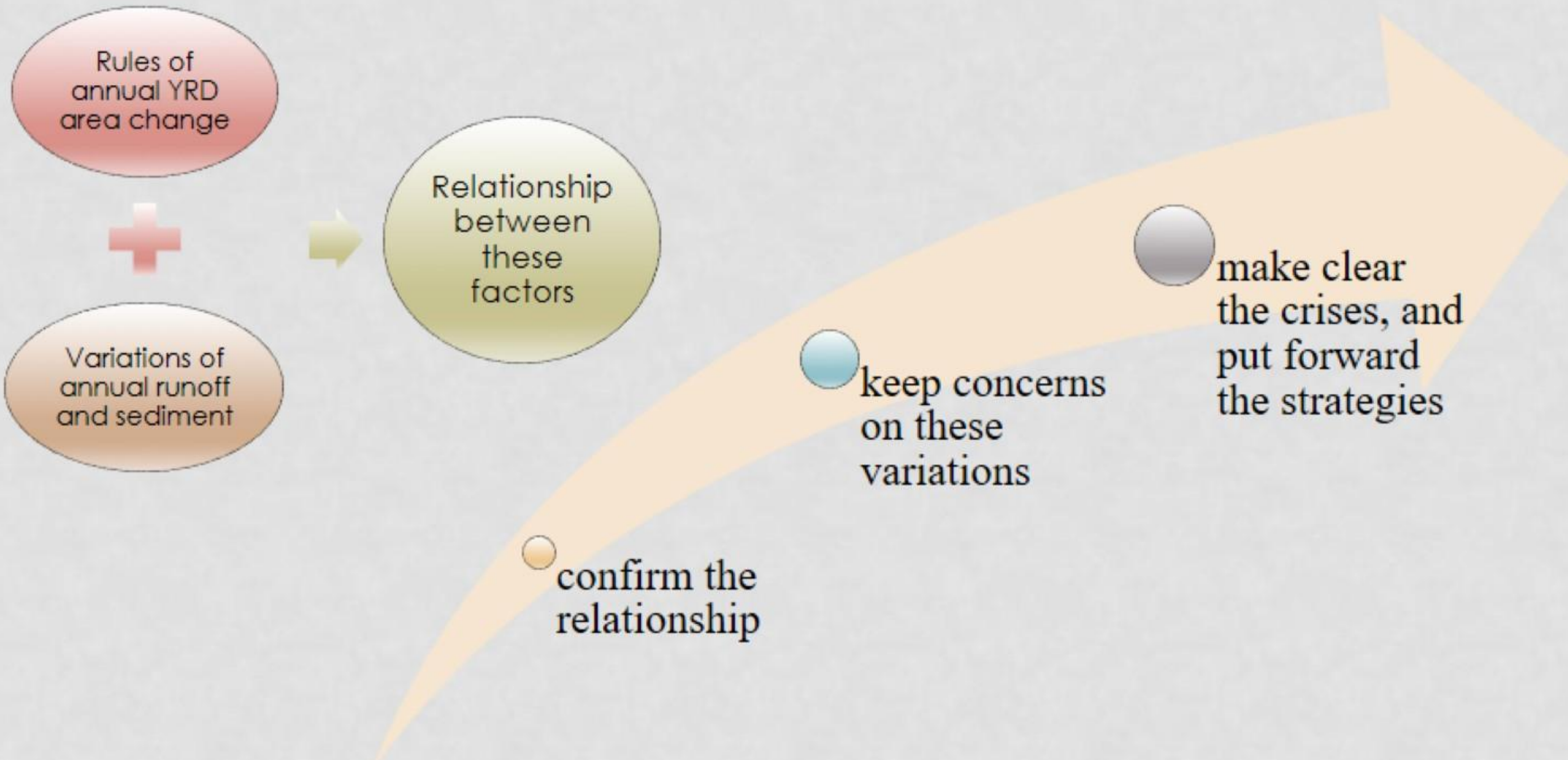
- The Yellow River is a well-known high sediment laden river on Earth. It carries lots of fine sediment flowing down to the Bohai Sea, builds new land continuously.
- The normal coastal areas are in alternations of extending by siltation of river sediment and retrograding by erosion of tidal current, so does the Yellow River Delta (YRD) .



Satellite image of the Yellow River mouth in different times

INTRODUCTION

- To find the regulation of the YRD evolution



RESEARCH METHODS

➢ M-K statistic test for Trend analysis

Non-parametric statistical

➢Giving a time-series sample $(x_1, x_2, \ldots, x_n)$, constructing a rank sequence:

$$S_k = \sum_{i=2}^{k} \sum_{j=1}^{i-1} sign(x_i - x_j) \qquad (k = 2, 3, 4, \ldots, n)$$

$$sign(x_i - x_j) = \begin{cases} +1 & when x_i > x_j \\ 0 & else \end{cases} \qquad (j = 1, 2, 3, \ldots, i\text{-}1)$$

➢Assuming the time series stochastic independence, definite the statistics:

$$UF_k = \frac{[S_k - E(S_k)]}{[Var(S_k)]^{1/2}} \qquad (k = 2, 3, 4, \ldots, n)$$

$$E(S_k) = \frac{n(n\text{-}1)}{4}$$

$$Var(S_k) = \frac{n(n-1)(2n+5)}{72}$$

$|U_{0.05/2}|$>or< 1.96

➢ Rank sum test for Abrupt changes analysis

Cumulative time sequence and test

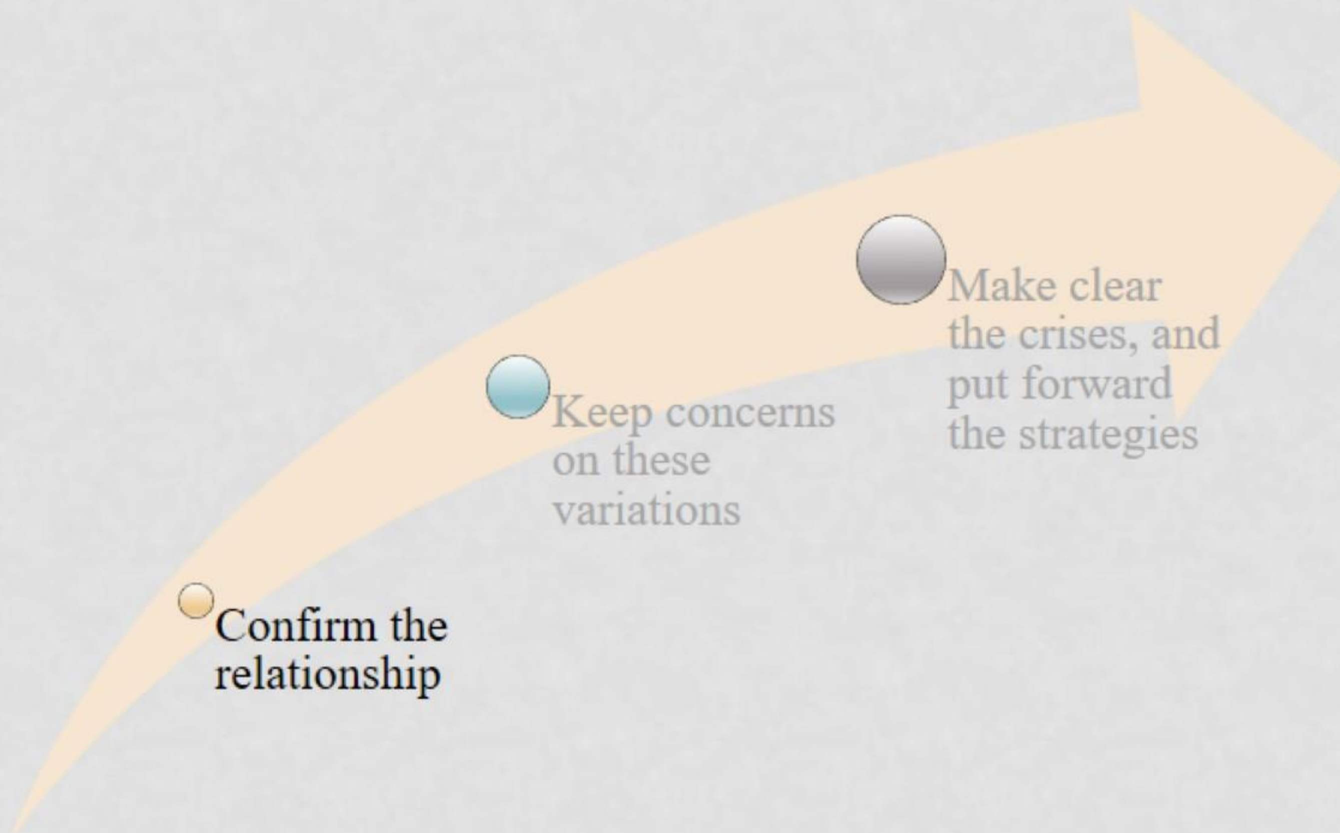
➢Research sequence $x_1, x_2, \ldots, x_n$ and reference sequence $y_1, y_2, \ldots, y_n$. Compute their cumulative time sequences respectively:

$$\left.\begin{aligned} g_j &= \sum_{i=1}^{j} x_t \\ m_j &= \sum_{i=1}^{j} y_t \end{aligned}\right\} \qquad (j = 1, 2 \ldots, n)$$

➢Assume a hydrologic sequence $x_1, x_2, \ldots, x_\tau, x_{\tau+1}, x_{\tau+2}, \ldots x_n$, Rank the sequence and number it

$$U = \frac{W - \left(\frac{n_1(n_1 + n_2 + 1)}{2}\right)}{\sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}}$$

RELATIONSHIP BETWEEN THE LAND AREA & FLUX OF RUNOFF / SEDIMENT



RELATIONSHIP BETWEEN THE LAND AREA & FLUX OF RUNOFF / SEDIMENT

> **Variation of the land area of the Yellow River mouth**

- The continent-building area was 2500 km^2 after years of 1855. In the different periods, the annual increasing rate of continent-building area are from 23.6km^2/a drop to 9.5km^2/a.
- with the annual net silting rate decreased, both the incoming annual runoff and sediment load in the different period were deduced

Continent-building area after 1855 in YRD

Peroid	IncomingRunoff $/10^9\ m^3/a$	Incoming sediment load $/10^9\ t/a$	Net silting Area $/km^2$	Net silting Rate $/km^2/a$
1855~1954			1510.0	23.6
1954~1976	44.51	1.148	548.3	24.9
1976~1980	30.66	0.866	110.0	25.9
1980~1992	26.00	0.613	183.0	15.1
1992~2001	10.90	0.306	77.3	9.5

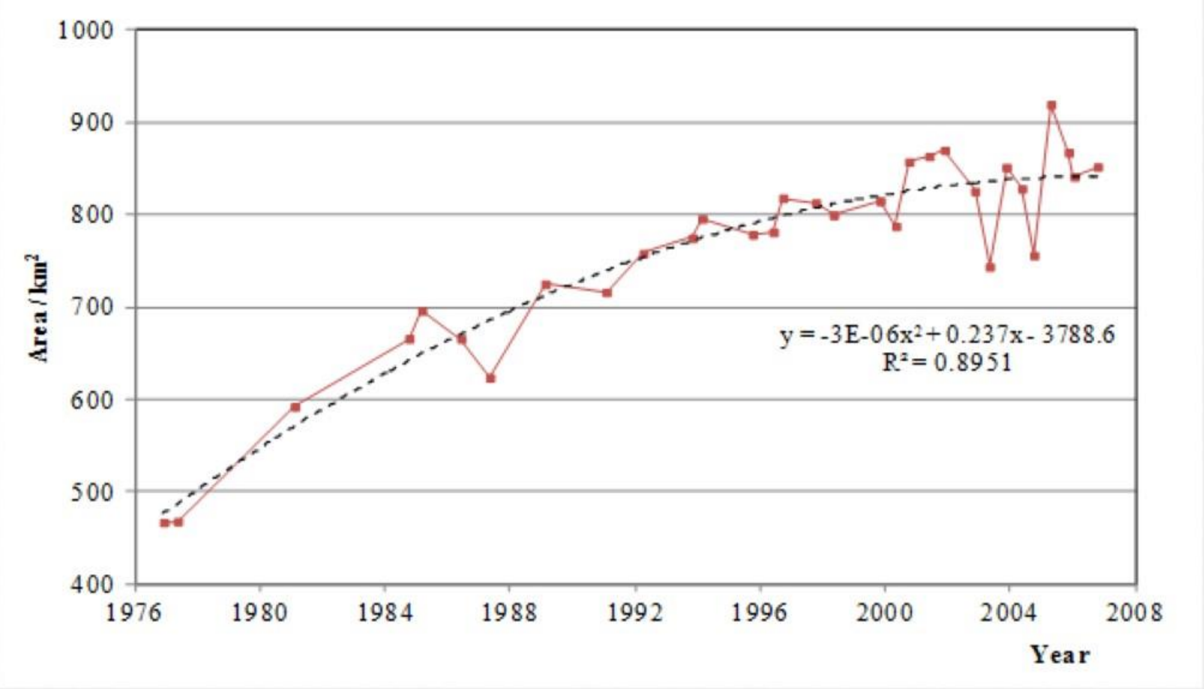
Note: the runoff and sediment load are from Lijing station field data.

RELATIONSHIP BETWEEN THE LAND AREA & FLUX OF RUNOFF / SEDIMENT

➢ Variation of the land area of the Yellow River mouth

- The land area of the Yellow River mouth from 1976 to 2006 was continuing in growth.
- The variation of land area could be divided to three stages according to the growth rate. 1976 to 1986, +19.86 km^2/a;1986 to 2000, +9.95 km^2/a; after 2000, +5.96 km^2/a.

- Based on regression test, the land area growing tendency is fit with the quadric curve very well.



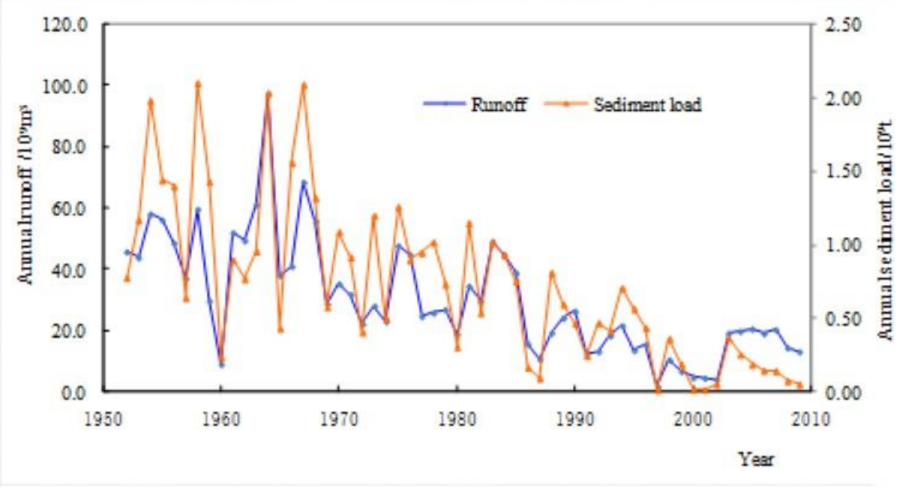
RELATIONSHIP BETWEEN THE LAND AREA & FLUX OF RUNOFF / SEDIMENT

➢ Variation of Fluxes of runoff and sediment

- The mean annual runoff of Lijin station was 30.3 billion m^3 and sediment load was 0.73 billion t.
- Both the annual runoff and annual sediment load flowing though the Yellow River Delta were in fluctuated decrease.

Variation of annual runoff and annual sediment load at Lijin station

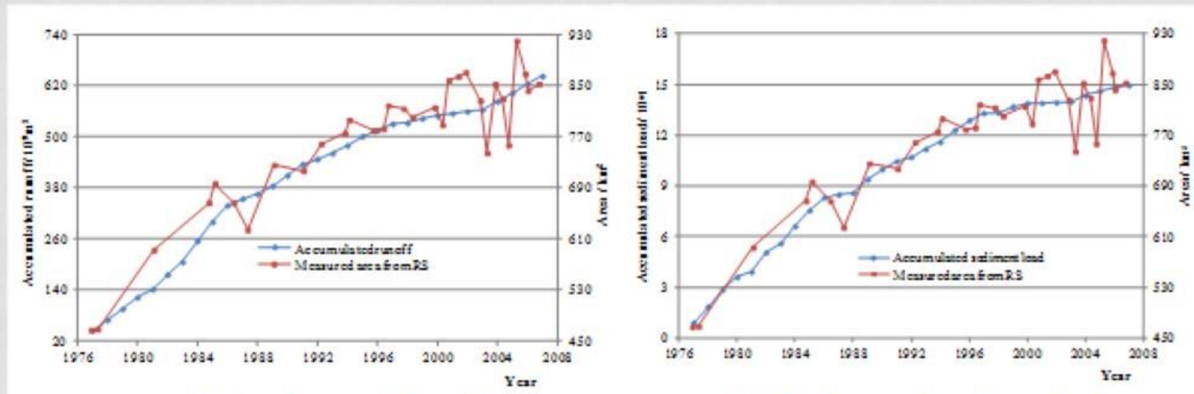
Years	Mean Annual runoff /$10^9 m^3$	Mean Annual sediment load /$10^9 t$	Mean Annual Sediment concentration /kg/m^3
1952~1959	47.4	1.37	28.86
1960~1969	50.1	1.09	21.73
1970~1979	31.1	0.90	28.86
1980~1989	28.6	0.64	22.33
1989~1999	14.1	0.39	27.71
2000~2009	14.1	0.13	9.532
1952~2009	**30.3**	**0.73**	**24.12**



RELATIONSHIP BETWEEN THE LAND AREA & FLUX OF RUNOFF / SEDIMENT

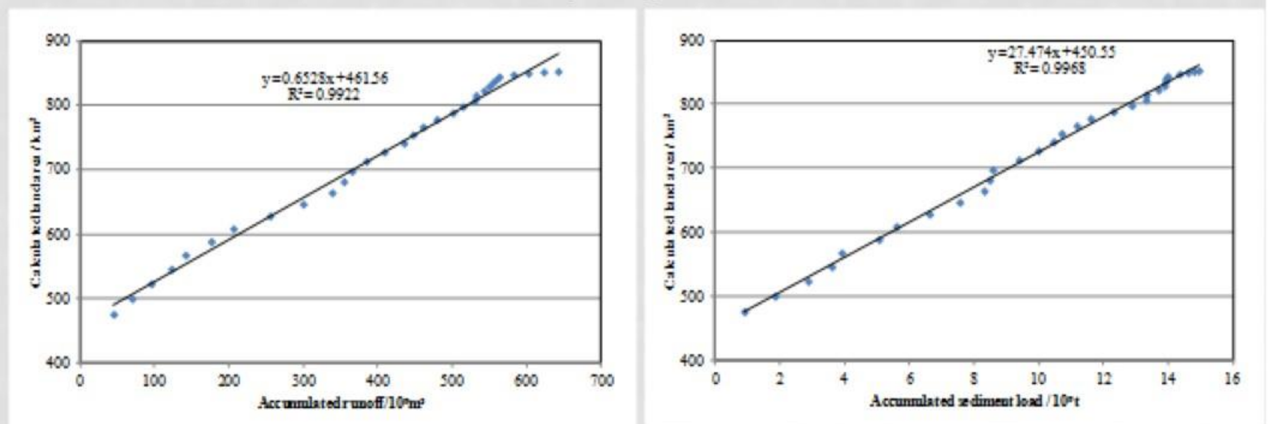
- It is not difficult to find that the yearly accumulated runoff or sediment load is well consistency with the annual land area

- The perfect linear correlation about land area & accumulated runoff/sediment load is obviously



(a) Land area and runoff (b) land area and sediment load

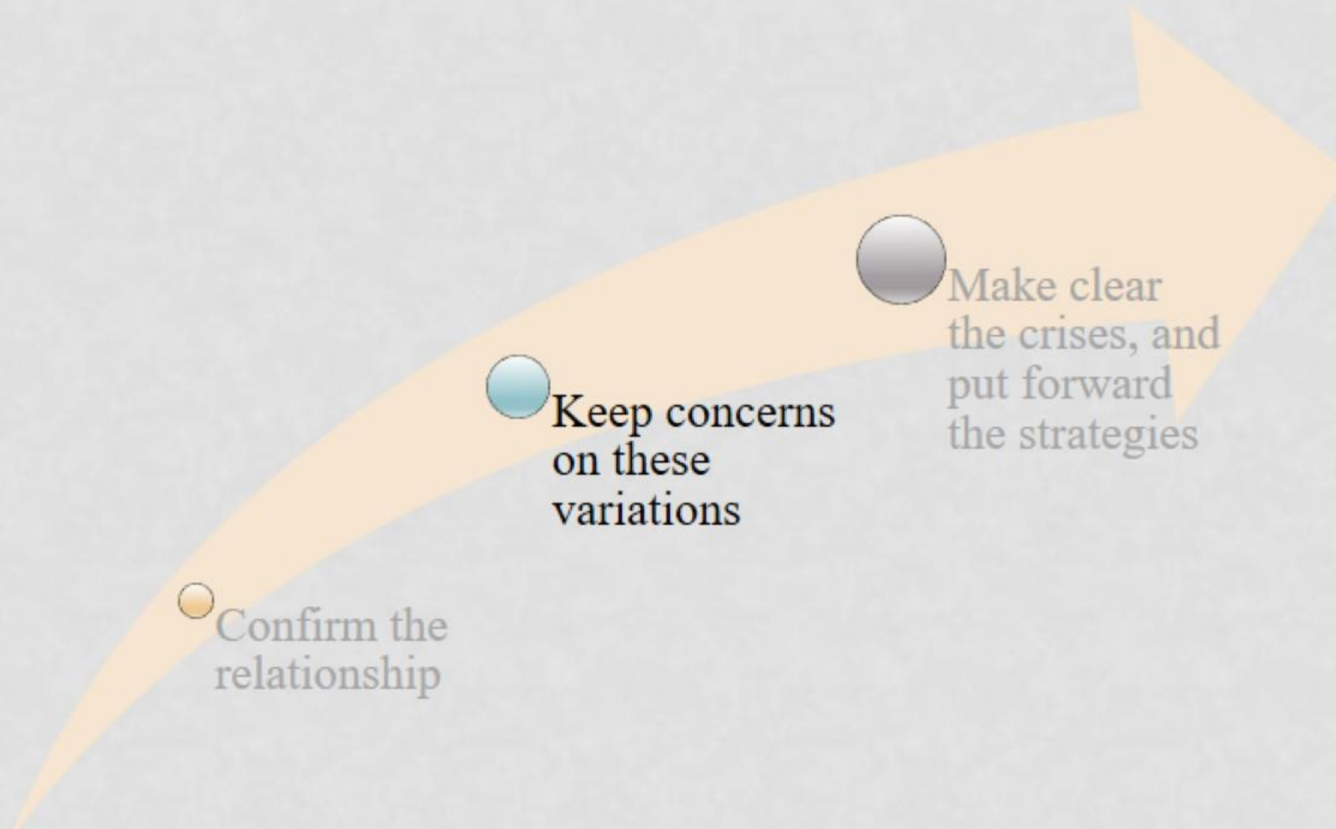
Land area coherent with the hydrological data of the Yellow River mouth



(a)Land area and runoff (b) land area and sediment load

Relationship between land area and the hydrological data of Yellow River delta

TRENDS OF FLUXES OF RUNOFF AND SEDIMENT



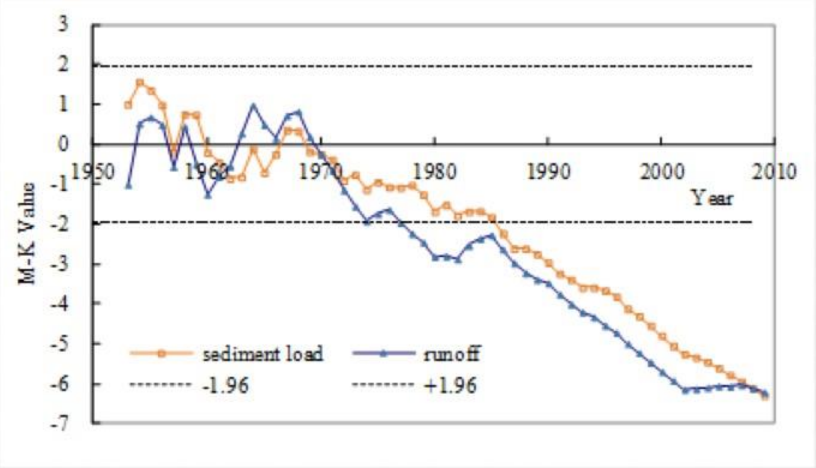
TRENDS OF FLUXES OF RUNOFF AND SEDIMENT

➢Tendency test of runoff and sediment Fluxes

- Based on M-K statistics test, the final M-K statistics from 1952 to 2009 of annual runoff and annual sediment load of Lijin station are -6.20 and -6.29.
- This manifested abnormally sharp declining trends on both the annual runoff and sediment load.

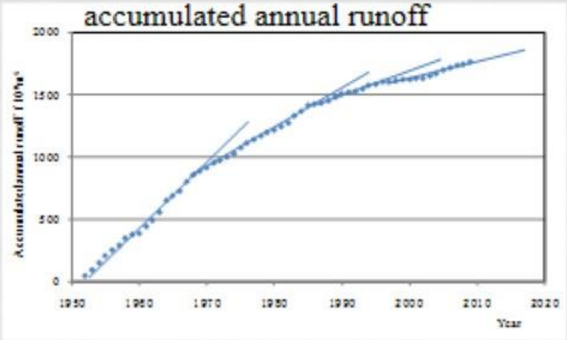
M-K tests for annual runoff and annual sediment load of Lijin station

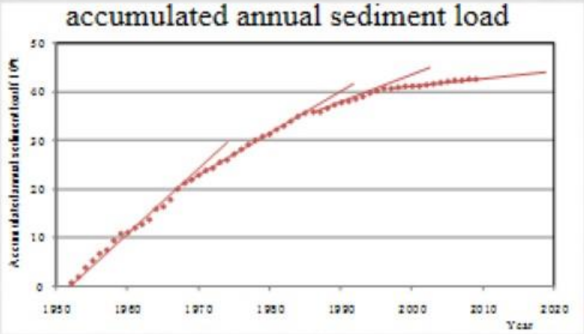
M-K test	Test for runoff	Test for sediment load
Values	-6.20	-6.29
Manifest for Tendency	Sharp drop	Sharp drop



TRENDS OF FLUXES OF RUNOFF AND SEDIMENT

➢Leap test of runoff and sediment Fluxes





Identification of abrupt change points at Lijin station

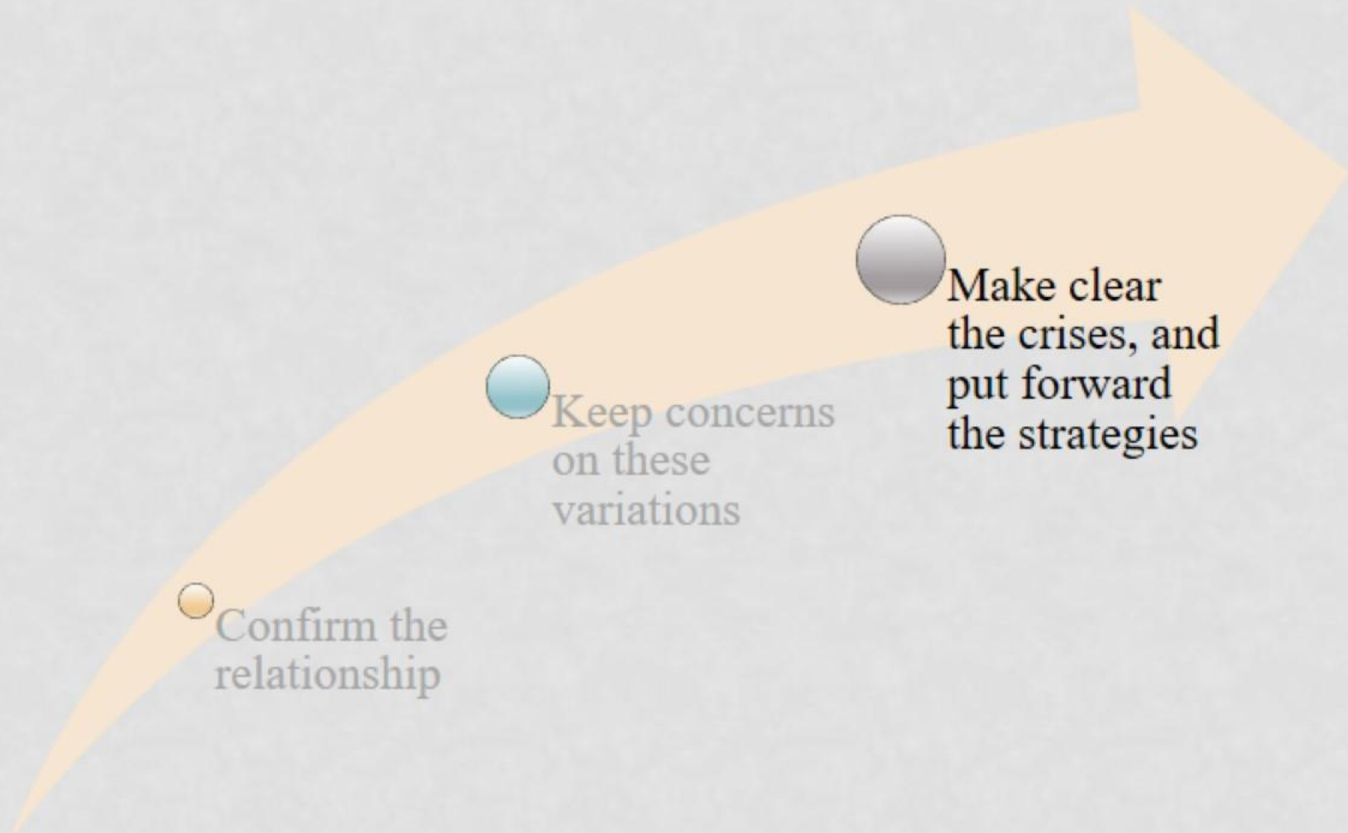
Based on the curve of cumulative time sequence, it can be seen that both the annual runoff and sediment load changed abruptly with an obvious turning point in the year of1968, 1986 and the year of 1997

The above mentioned years for both runoff and sediment are pass the rank sum test and show an obvious leap.

Leap test for Lijin station

	Period	1952-1967	1968-1985	1986-1996	1997-2009
Sample number		16	42		
Statistical test value	runoff	4.54			
	sediment load	3.90			
Sample number		24		34	
Statistical test value	runoff	-5.90			
	sediment load	-5.59			
Sample number		45			13
Statistical test value	runoff	-4.39			
	sediment load	-5.08			

CRISIS AND DEALING MEASURES TO SHORTAGE OF WATER AND SEDIMENT



CRISIS AND DEALING MEASURES TO SHORTAGE OF WATER AND SEDIMENT

- **Sources of the water in YRD**

The local YRD yields little water resources:

- The direct surface runoff by precipitation is $450 \times 10^6 m^3$;
- except brine, salt water or brackish water which are more than 90% of the total, the underground water useful for agriculture or domestic consumption is only $58 \times 10^6 m^3$.

The Yellow River flows through the Delta, and supplies lot of foreign water, $30.3 \times 10^9 m^3$

The runoff coming from the Yellow River as the main fresh water resources of the Delta, will keep the balance of local eco-system.

CRISIS AND DEALING MEASURES TO SHORTAGE OF WATER AND SEDIMENT

➢ Sources of the sediment in YRD

- Among the sediment load transported by the Yellow River, 22% of the incoming sediment load deposited in the river channel, 47% in the estuary, and the rest 32% carried by tidal waves to the sea area deeper than 15m.

Water way	Period	Incoming form YR /bill t	Deposition in river mouth		Deposition in littoral		Transport to sea	
			volume /bill t	Account to incoming/%	volume /bill t	Account to incoming/%	Volume /bill t	Account to Incoming/%
Shenxiangou	1953-1964	13.03	3.4	26	4.7	36	4.93	38
Diaokouhe	1964-1976	14.28	2.86	20	6.12	43	5.3	37
Qingshuigou	1976-1980	3.33	1.03	31	1.57	47	0.73	22
	1980-1992	7.38	1.19	16	4.82	65	1.37	19
	1992-2000	2.74	0.36	13	1.82	66	0.56	20
	1976-2000	13.45	2.58	19	8.21	61	2.66	20
Summary	1953-2000	40.76	8.84	**22**	19.03	**47**	12.89	**32**

- Sediment as resources mainly uses to continent-building.

CRISIS AND DEALING MEASURES TO SHORTAGE OF WATER AND SEDIMENT

- **Crisis brought by less runoff**
  - Less runoff will decrease the replenishment of fresh water for wetlands, destroy the balance of fresh and salinity, and bring a lot of ecological problems.

- **Crisis brought by less sediment**
  - With the less incoming sediment of the Yellow River, in addition to the rising sea level, the coast would be eroded quickly, even the net erosion would take place.

CRISIS AND DEALING MEASURES TO SHORTAGE OF WATER AND SEDIMENT

➢ Rational allocation of the water and sediment resources

- The rational allocation of the water resources and sediment resources of the whole River basin should be put forward and carried out.
- Firstly, by legislation, the reservation measures of water source region should be strengthened; the schemes of water allocation and diversion in each district of the Yellow River basin should be sound planned.
- Secondly, the water-saving society should be educated and implemented both in ordinary life of citizens and agriculture irrigation.
- Thirdly, the structure of infrastructure should be modified. Such as some large water consumption projects should be strictly limited.

CONCLUSIONS

- There are close relationship between the YRD area and fluxes of runoff and sediment. The more fluxes, the faster the land area grows. The less fluxes, the slower the area builds;

- The annual runoff and sediment fluxes of the Yellow River estuary have obvious decreasing trends, which are great challenges to keep the balance of the YRD;

- To deal with the shortage of incoming water and sediment of the YRD, the rational allocation of the water and sediment resources is one of the principle measures.

THANKS
FOR YOUR ATTENTION!