3. Further discussion on the effect of soil and water conservationon water resources in the Yellow River Basin

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Abstract

The area of the Yellow River Basin is 8.3% of the area of China. Its average annual total runoff is 5.80×10^{10} m^3, or 2% of that of China. Water resources per capita in the Yellow River basin are 527 m^3, or 20% of China's per capital amount. For climate change, soil and water conservation, and water usage of agriculture and industry, the condition of water resources worsens. The water resources volume varies greatly between different years and seasons. Soil loss is severe in the Yellow River Basin with average sediment content of 37.6 kg m^{-3}. 30% of flow, or approximating 1.50×10^{10}~$2.0 \times 10^{10} m^3$ annually, is lost flushing sediment from lower riverbed to the sea. The sources of sediment and water are different and the sediment and water coming from the middle reaches of the Yellow River Basin account for 10% and 70% of that of the whole basin. A reduction of one ton of sediment erosion results in about a 3.19 to $16.15 m^3$ reduction in water Yield, but when flushing one ton of sediment; about 33 to 60 m^3 of water is needed. This shows that soil and water conservation practices can result in a relative increase in water resource. From 1970 to 1996, soil and water conservation practices reduced soil loss by an average of 1.495×10^8t annually in the section between Hekou and Longmen of the Yellow River Basin. If the water used that have to flush this sediment is considered, the water resources have increased by $4.88 \times 10^9 m^3$.

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In the last half century, because of climate change and large scale human activities, such as water resources engineering, water use of industry, agriculture, and soil and water conservation practices (SWCP), the water resource problems in the Yellow River Basin (YRB) have become more obvious. As a result of sediment erosion control, runoff has decreased in the YRB, and therefore its impact on water resources has become an issue of great concerned. Cui (2002) blamed rainfall reduction and SWCP for cutting-off of flowing to the sea. Chen (2000) considered the reason for the cutting-off of the Yellow River to be the sharp increase of water usage in the YRB, not due to the effect of drought and precipitation decreasing. SWCP can be regarded as a fundamental measure to resolve the water resources problems in the Yellow River if we consider comprehensively: reduction of sediment and flood; cutting down flood peak; and preventing flood and improving water quality (Mu, 1999). In this paper, the characteristics of water resources are shown and the effects of SWCP on sustainable utilization of water resources in the YRB are analyzed.

I. 1 Characteristics and problems of water resources in the YRB

The amount and per capita volume of water resources are both very low. The lack of water resource in the YRB in the last fifty years is not only because the water resources distribution is not temporally and spatially even, but also because of serious water pollution, climate change and industrial and agricultural use.

1.1 The total amount of water resources in the YRB is small. The difference between water supply and demand is great, and the

cutting-off of flow occurred frequently in recent years.

1.1.1 Small amount of water resources

The Yellow River is the second longest river of China with a length of 5464 km and a basin area of 7.95×10^5 km^2. Its upper and middle reaches area is semiarid, and the lower reaches area is semi-humid within temperate monsoon climate zone. Its average annual precipitation is about 445mm, and precipitation decreases gradually from southeast to northwest. The average annual evaporation from the water surface is about 1200mm, ranging from1000mm in the southeast area to 1500 mm in northwest. The average annual total runoff is 5.80×10^{10}m^3, accounting for only 2% of that in the whole country, while the watershed basin area is 8.3%.

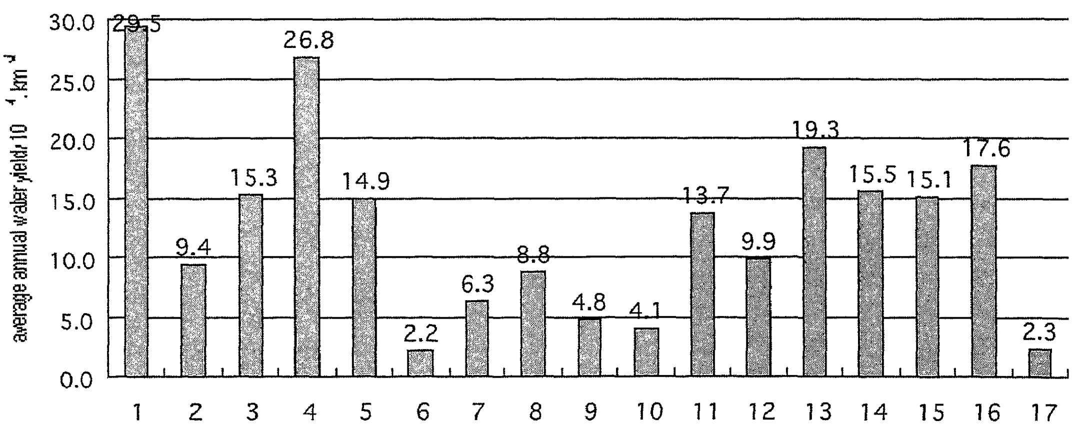
The average water yield for China is 2.95×10^5m^3. km^{-2} (Wang, 2003), but it is only 9.36×10^4m^3. km^{-2} in the YRB, about 1/3 of that of the whole country (Figure 1.). In some watershed, the water yield is low, such as Huangshui River and Weihe River (Figure 1.). In some watersheds it is worse, such as Fenhe River, Jinghe River, and the continental river area (Figure 1.).

1.1.2 Average water resources per capital and per hectare in the YRB are small

The YRB is a serious lack water region. Average water quantity of cultivated land in the YRB is just 4400m^3 per hectare, only 16% of country average level. Average water resources by population is 527m^3 per capita, which is about 22% of that of the whole country (2460m^3), and equivalent to 5.3%of that of the world (10000m^3, 1980). This value is overestimated because some of this water is supplied the areas outside of the YRB. According to the appraisal standard of per capita water resources put forward by "International population action" (those less than 1700m^3 per capita are urgent water demand countries, less than 1000m^3 per capita are lack water countries, less than 500m^3 per capita are serious lack water countries). With anticipated climate change, especially the warm and drought trends predicted for the YRB, the water supply will likely decrease further (Jia, 2001).

1.1.3 Different between supply and demand is high

With the development of the economy, water demand has increased greatly, and the contradiction of water resources demand and supply is greater. According to the distribution plan of water supply in the YRB, water resources available to be exploited and utilized is only 3.70×10^{10}m^3 annually. As social economics develop and people's standard of living rises, the amount of water use in the watershed has increased from 1.20×10m in the 1950s to 3.07×10^{10}m^3 at present (external supply is 1.06×10^{10}m^3). 2003 was the worst drought year since the 1950s, when drainage supply amount was only 1.67×10^{10}m^3. The gap of water supply and demand would be



(The Region or River Basin: 1 China, 2 Yellow River; 3 Huangshui ; 4 Taohe; 5 upstream of Lanzhou; 6 Section between Lanzhou and Hekou;7 Section between Hekou and Longmen; 8 Fenhe; 9 Jinghe; 10 Beiluohe; 11 Weihe; 12 Section between Longmen and Sanmenxia; 13 Yiluo; 14 Qinhe; 15 Section between Sanmenxia and Huayuankou; 16 Lower reaches of the Yellow River; 17 continental river area)

Figure 1. The water yield characteristic of the Yellow River and its branches

$5.0 \times 10^9 m^3$ even if the Yellow River was used up completely.

According to prediction, the total water volume of demand in the watershed in 2010 will reach 5.20×10^{10} m^3, but the most water volume of supply in the YRB is only $4.80 \times 10^9 m^3$. In other words, the water will not meet the demand and there will be $4.0 \times 10^9 m^3$ shortage in average precipitation years, and it will be more in drought years (Chen, 1991; Chinese Economy and Trade committee, 2000). According to a report by the Information Center of Ministry of Water Resources on the response and adaptation to water resources issues induced by climate change, water supply shortage of the YRB will be from $2.1 \times 10^9 m^3$ to $1.30 \times 10^{10} m^3$ annually (Wang, 2003).

1.1.4 Ecological environmental problems induced by shortage of water resources in the YRB

Cutting-off takes place frequently in the lower reaches of the Yellow River because of exploitation of water. Cutting-off happened in 21of 26 years between 1972 and 1998 due to decreased rainfall and increase amount of industry and agriculture, and domestic water demand. Cutting-off took place every year from 1990 to1998. There are 226 days of cutting-off in 1997, which is 62% of total days in the whole year, and the channel length cutting-off was 704 km. The beginning of cutting-off in that year, and its length were the maximum in the Yellow River's history.

As surface water resources are short and the extravagant exploitation of groundwater is very serious, many groundwater funnels (area of depressed groundwater) have been formed in the YRB. According to *the Water Resources Bulletin of the Yellow River Basin in 2001*, the largest groundwater funnel is $3370.75 km^2$. Average funnel center depth is 37.8m. Area of confined groundwater funnels is 2365.4 km^2, and its average center depth is 77.6m.

1.2 Temporal and spatial distribution of water resources is not even, difference between water supply and demand increases

1.2.1 Water access is difficult because of the distribution of water resources

From *the Report of the Water Resource in the Yellow River Basin in 2000* (in Table 2), it is known that the observed runoff and the total runoff at Huayuankou Station in the Yellow River are $4.08 \times 10^{10} m^3$ and $5.568 \times 10^{10} m^3$. There are two main water sources in the YRB; one is the upstream region of Lanzhou, the other is the section between Sanmenxia and Huayuankou Station. Although their area is only 36% of the region upstream of Huayuankou, while the observed runoff (actual runoff measured at gauging station) and the total runoff (observed runoff plus water used) accounted for 86.6% and 72.4% in 2000 respectively. The two main net water consumption areas are the section between Lanzhou and Hekou and the downstream area of Huayuankou. The observed annual runoff in section between Lanzhou and Toudaoguai decrease to $2.29 \times 10^{10} m^3$. The region downstream of Huayuankou is nearly an absolute water consumption place. The average observed runoff decreases from more than $4.0 \times 10^{10} m^3$ at Huayuankou Station to about $3.3 \times 10^{10} m^3$ at Lijin Station.

Table 1. The characteristics of groundwater funnel in the YRB in 2000

Name of funnel	Funnel	Funnel	Funnel area/km^2		Center depth/m	
	Position	Quality	Area	Net	Depth	Net
Yinchuan funnel	Yingchuan Plain	Confined water	450.0	-3.2	17.7	-1.3
Fengdong funnel	Guanzhong Plain	Shallow layer	22.1	2.0	26.7	1.2
Xinghua funnel	Guanzhong Plain	Shallow layer	40.3	0.1	19.8	0.3
Luqiao funnel	Guanzhong Plain	Shallow layer	9.0	-0.4	45.4	2.0
Weibin funnel	Guanzhong Plain	Shallow layer	14.0	0.5	19.6	0.3
Songyuegu funnel	Taiyuan Basin	Confined water	134.8	3.4	63.1	-3.5
Taiyuan funnel	Taiyuan Basin	Confined water	182.6	15.6	105.4	4.4
Yuncheng funnel	Yuncheng Basin	Confined water	1598.0	31.0	96.4	-0.2
Wuzhi~Wen County~Meng county	Huabei Plain	Shallow layer	920.0	10.0	22.2	0.4

Table 2. The quantity of water resource in different stations in the YRB ($\times 10^8 m^3$)

Name of station	Lanzhou	Hekou	Longmen	Sanmenxia	Huayuankou
Area ($\times 10^4 km^2$)	22.26	36.79	49.76	68.84	73.00
Observed runoff	316.90	229.10	283.30	371.80	408.40
Total runoff	327.00	322.90	387.80	499.60	556.50

*Based on *the water Resources Report of The Yellow River Resources in 2000*

1.2.2 The water resource in the YRB changes greatly between years and seasons

The water resources change greatly in the YRB between different years. Based on *the total and Observed Runoff from 1952 to 1990 In The Yellow River*, the Cv value ($CV=S/X \times 100\%$; S is the standard errors ; X is mean) of the annual total runoff on each station is about 0.2, and the Cv value of observed runoff is from 0.21 to 0.45. The ratio between the maximum and minimum total runoff changed from 1.9 to 3.5, and that of observed runoff changed from 3.2 to 10.7 during that time.

The water resource in the YRB is distributed unevenly because of the monsoon. The runoff during July to October is 58% of the whole year. Soil and water loss can occur during rainstorms, which can cause sedimentation in the riverbed and flood in lower reaches of the YRB.

1.3 The serious water pollution in the Yellow River makes the water deficit greater

Both ground and underground water resources are polluted because of the polluted discharge with no or unqualified measurement.

According to the Report of Chinese Environment Condition in 1996, the main and branch channel reaches in the Yellow River up to Class I and II (Class I is best, Class V is worst) of government water quality standard is 8.2% by length, which is much lower than the average value of 32.2% of the seven largest rivers in China. The length percentage of IV and V level of government water quality standard in the Yellow River is up to 65.4%, and the average value of the seven largest rivers in China is 38.9%. This shows the serious pollution status of the Yellow River. According to the *Report of Water Pollution in the Seven Main Rivers (1997)* by the National Bureau of Environment Protection, The Yellow River took in 2.0×10^9t polluted water in the 1980s, and 4.2×10^9t in the 1990s. The content of polluted water will be 6.5×10^9t by 2010. By that same time, the polluted water taken in will be increased, so the trend of pollution will increase.

Based on the data of underground water quality monitored from observation wells in five provinces in north China, including Xinjiang, Gansu, Ningxia, Qinghai, and Inner Mongolia, the underground water quality in 69 cities was estimated. The results showed that no one city reached the Class I of the government underground water quality standard, 10 cities had a standard of Class II (about 14.5% of all cities tested), 22 cities had a standard of Class III (about 31.9%), and 37cities had a standard of Class IV & V (about 53.6%). The results showed that the underground water in more than half of these cities was polluted badly.

1.4 Soil loss in the middle reaches of the Yellow River is so severe that the water consumption for flushing sediment in the lower Yellow River is great

Soil loss in the middle reaches of the YRB is severe. The area of soil loss in the loess plateau is up to 2.12×10^5 km^2. The sediment load in the Yellow River is about 1.6×10^9t, of which 90% comes from the middle loess plateau. The average in stream sediment content at Huayuankou Station is about 37.6 kg·m-3. The content of first class branches, such as Huangfuchuan River, Kuye River, Wuding River, North Luo river, and Weihe River, are 283, 139, 92.0, 195, 119, and 54.5 kg·m^{-3} respectively. The sediment content at Wenjiachuan Station in the kuye River is up to 1700 kg·m^{-3} (July 10th 1958). The average soil loss in the section between Shenmu and Wenjiachuan in the Kuye River watershed is 4.0×10^4 kg·m^{-3}·a^{-1},and it was 1.0×10^5 kg·m^{-3}·a^{-1} in 1959.

The serious soil loss in the middle YRB causes high sediment content in the stream. The limited runoff and gentle channel in the lower YRB make great sedimentation in the riverbed and reservoirs, which makes the Yellow River well known as a hanging river on the ground with a wide alluvial flat. The riverbed is nearly 22m and 13m higher than Xinxiang City and Kaifeng City. The riverbed is raising 10cm annually. To reduce the risk of flood and to lower the riverbed, about 1.5×10^{10} to 2.0×10^{10}m3 of water is used to flush the sediment into the sea (30% of the whole water resources in the YRB). This lost water is more than the irrigation volume (1.55×10^{10} m^3) of the whole basin in the 1980s. It is more than the annual 1.30-1.40×10^{10} m^3 of water from Yangtze River Basin to the YRB by the middle route of South-North Water Diversion of China (You, 2002).

2. The effect of SWCP on the water resource of the Yellow River

2.1 SWCP in the middle reaches of the YRB reduce water resource slightly

In the YRB, water and sediment comes from different areas. 50% of runoff and 9% of sediment of the Yellow River come from the upriver region of Hekou (51.3% of the whole basin area) respectively. More than 90% of the sediment comes from the middle reaches of the Yellow River, so the section between Hekou and Tongguan Station is the main sediment source area. Therefore, the section between Hekou and Longmen amounts to 15% of the whole basin, but the runoff and sediment account for 12.5% and 56% respectively.

Since the runoff from the middle reaches of the YRB only account for about 10% of the total, SWCP there have less effect on the runoff but more effect on sediment discharge. From 1970 to 1996, SWCP decreased the average annual runoff by about 3.58×10^8 m^3, about 5.52% and 0.64% of total runoff of middle reaches and upper region of Huayuankou station respectively. At the same time, 1.495×10^8t of sediment was decreased, which is 21% of the average sediment yield of the middle reaches region (6.925×10^8t). Compared with the maximum experimental sediment yield (8.208×10^8t), the decrease in the sediment ratio is 18.2%.

2.2 SWCP can increase water resources relatively by decreasing water used for flushing sediment

2.2.1 Water yield losses associated with retaining sediment is far less than that due to water lost in sediment discharge in the lower Yellow River

The water required to flush 1 ton of sediment from the lower reaches of the Yellow River is between 33 m^3 and 60 m^3 (Liu, 2002), which equals 4.5~30 times the water required to reduce sediment erosion at the source during the flood season and 2~20 times the mean annual cost. In general, the SWCP can increase the water resources in the Yellow River comparatively.

Water erosion is the main form of erosion in the Loess Plateau. SWCP not only decrease the erosion, but also decrease the runoff. If we consider the associated runoff volume lost by retaining one ton of sediment (called the Runoff cost of Retained Sediment , RRS), the RRS between different SWCP and different regions varies greatly. The RRS in the section between Hekou and Longmen is shown in Table 3 (Wang, 2004). In the regions with severe soil loss, such as Qiushui River, Huangfuchuan River, Gushanchuan River, and Jialu River, the RRS of SWCP is lower. The RRS of practices on the slope (terrace, reforestation, and grass-planting) is about $2.2m^3$.t-1, and it

Table 3. The runoff cost of retained sediment in the section between Hekou and Longmen

Unit : $m^3 \cdot t^{-1}$

Name of branch	Shiwang, Yunyan	Hunhe	Xinshui, Wuding r, Xianchuan	Pianguan, Lanyi, Sanchuan, Tuwei, and Weifen	Zhujiachuan, Yanhe, Qingshui, Quchan, Qingjian, and Kuye	Qiushui, Huangfuchuan, Gushanchuan, Jialu
Terrace 1	7.20	6.02	3.13	3.08	2.37	2.26
Reforestation 2	7.17	6.20	3.08	3.27	2.61	2.23
Grass-planting 3	7.19	5.85	2.90	2.78	2.39	2.24
Average (1+2+3)/3	7.19	6.02	3.04	3.04	2.46	2.24
Dam	1.45	2.00	1.84	2.09	1.87	2.13
Flood period	7.34	2.46	2.34	3.01	2.08	2.04
Average annual	16.15	5.34	3.91	4.07	3.21	3.19

is very near to the RRS of check dam practices in the channel. In Shiwangchuan River, Yunyan River and Hunhe River, the soil and water losses are small, but the differences of RRS between different practices are big. This average RRS on the slope accounts for 7.19 $m^3.t^{-1}$ while only 1.45 $m^3.t^{-1}$ in the channel. The mean RRS is from 2.04 $m^3.t^{-1}$ to 7.34 $m^3.t^{-1}$ during flood season, and the mean annual RRS is from 3.19 m3.t-1 to 16.15 $m^3.t^{-1}$. That is, if the soil and water losses in mid-areas are controlled on the spot, when 1 ton of sediment is controlled, the surface runoff will be reduced by 3.19 m^3 to 16.15m^3.

2.2.2 Estimate of comparative water resource increase from SWCP in the section between Hekou and Longmen

When estimating the water resource change from SWCP in the YRB, the water reduced by SWCP must be considered. A comparative increase results because the water saving not having to flush sediment from the lower reaches is greater than the reduction in runoff decreased by SWCP. Taking the example of the section between Hekou and Longmen, the amount of water and sediment of different periods in the control areas reduced by SWCP is showed in Table 4. The amount of reduced sediment is 1.495×10^8t from 1970 to 1996. If the water lost for flushing sediment is 35 $m^3.t^{-1}$, the annual water lost for flushing sediment is 5.23×10^9 m^3. This improves exploitable water resources by 4.88×10^9m^3 which accounts for 75.1% and 8.76% of total runoff in the section between Hekou and Longmen, and the upper area of the Huayuankou Station respectively. This means that, if the balance of water and sediment in the whole basin is considered, SWCP in the section between Hekou and Longmen, can increase markedly the amount of water resources of the basin.

2.3 Other effects of SWCP on water resources

2.3.1 Increasing the soil water capability and reducing the water lost as flood

It is shown that, in the gully loess area, compared with natural basins, the ability to capture rainstorm water is 45~98% (the average is 77%). When the average intensity of the rain is less than 4mm.h^{-1}, runoff will be cut by 40~50%(Mu, 1999), while it will be reduced by 45~55% when the average intensity of the rain is 4~10mm.h^{-1}. SWCP can improve infiltration, make rainstorm water change into available soil water resources and decrease the water loss due to sheet flow.

2.3.2 Improving water quality

In addition to soil degradation resulting from surface soil and soil nutrient losses, soil and water losses also induce water pollution through adding organic matter, mineral and sediment into water. Although this kind of pollution has no serious negative effects on field irrigation, it can cause or worsen eutrophication of the water body. The organic carbon, nitrogen and phosphorous of cultivated soil are 5.73 $g.kg^{-1}$, 0.56 $g.kg^{-1}$ and 0.66$g.kg^{-1}$ in the sloping land of the loess plateau respectively (Guo, 2003). If the average sediment content of flow is 40$kg.m^{-3}$, the concentration of phosphorous will reach as high as 0.026$mg.l^{-1}$,which is worse than Class 1 of the government water quality standard. In cropland with vegetation and fertilization, soil nutrient content is even worse, and the pollution caused by soil and water losses is more serious because chemicals such as pesticide, and herbicide and so on, are applied widely to agricultural production. If SWCP are

Table 4. The water resource increase estimation of different stage

Stage	Runoff detained			Sediment retained	Water reduction for sediment flush*	Water increase relatively**		
	Volume	Percentage 1***	Percentage 2****			Volume	Percentage 1***	Percentage 2****
	10^8 m^3	%	%	10^8t	10^8 m^3	10^8 m^3	%	%
1970-1979	3.352	5.17	0.60	1.458	51.034	47.682	73.47	8.57
1980-1989	3.521	5.42	0.63	1.398	48.918	45.397	69.95	8.16
1990-1996	3.993	6.15	0.72	1.688	59.073	55.080	84.87	9.90
1970-1996	3.580	5.52	0.64	1.495	52.331	48.750	75.12	8.76

Note: *The average annual water for flushing sediment is 35 $m^3 \cdot t^{-1}$; **The water increased relatively is the difference between the water saving from for sediment flushing and the runoff detained. ***Percentage of the section between Hekou and Longmen; ****Percentage of upper Huayuankou area carried out, contamination will decrease and the water will improve.

2.3.3 SWCP can reduce the sedimentation of reservoirs, and spatial and temporal distribution and use of water resources

Soil erosion is the main reason for reservoir sedimentation. The average annual sedimentation rate in China is 2.3%, which is higher than that of Algeria (1.8%), Japan (1.02%) and USA (0.24%) (Qian, 1991). 601 of the large and middle reservoirs have been built since 1950 with a total capacity of 5.23×10^{10} m^3. About 20.8% of this capacity was lost by the end of 1989 (Floods and Drought Disasters Committee of the Yellow River basin and northwest part China, 1996). SWCP can prevent the sedimentation of reservoirs thus resolving the problem of water resources shortage.

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CHINA: DISCUSSION

Question: Is there any problem with the construction of the 3 major water reservoirs? Are there any effects on the environment and the ecosystem in China?

Answer: The 3 major dams in this slide could be called "trapping silt dam" considered soil and water conservation measures. It is considered to be very effective in improving the ecosystem especially the degraded part of the Loess plateau in China.

Question: What is the crop water requirement in China?

Answer: It is a good question for understanding the regional agricultural water management. I should give some data but I cannot remember them for the different crops and we never discussed that in this slide.

Question: Does soil and water conservation practices reduce run-off and sediment transportation/ soil erosion?

Answer: Yes, SWCP could effectively reduce soil erosion.

Question: How can soil and water conservation practice be related with bio-production?

Answer: SWCP should cover the different vegetation forest, pasture and so on; it is very much related to bio-production.