# How could we consider environmental issues of the Yellow River?
## -Synthetic result by the YRiS Study Group-

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**Abstract**

The most severe dry-up has occurred in the downstream of the Yellow River in 1997. After that, it was legislated for the conservation of water, and was improved on the order of water use in each irrigation area. Since 2000, incidents relevant to dry-up seem to have not happened. The river water of the Yellow River at the mouth, however, continues to let low volume flow as the same as 1997. Its reasons and effect were/are studied as follows. The Yellow River project in RIHN was started to clarifying why the dry-up has occurred and what kinds of effects were to be occurred in surrounding circumstances. Now, the reason of the dry-up are considered due to the complicated factors, these are the decrease of precipitation, over-use of river water in large irrigation districts and recovery of vegetation on Loess Plateau. Though sediment production on Loess Plateau seems to decrease, the river bed in downstream of the Yellow River continues to rise up. It will enhance the danger of flood disaster in the North China Plain. On the other-hand, the environment of Bohai Sea has changed in both water and material inputs from the Yellow River. Its effects are now investigated.

**Key words**: Yellow River Basin, water resources management, dry-up, water consumption, water quality

### 1. Introduction

As shown in Figure 1, the Yellow River is the second large river basin in China. It has 752,443 $km^2$ in basin area and the length of main channel is 5,464 km. The primary production of Bohai Sea seems to change by the decrease of river flow volume, increase of chemical fertilizer from irrigated farms through river and groundwater flow. It should be examined by the model simulation in Bohai Sea. In the Yellow River, dark blue line in Figure 1 is called as upstream, normal blue is as mid-stream and light blue is as downstream.

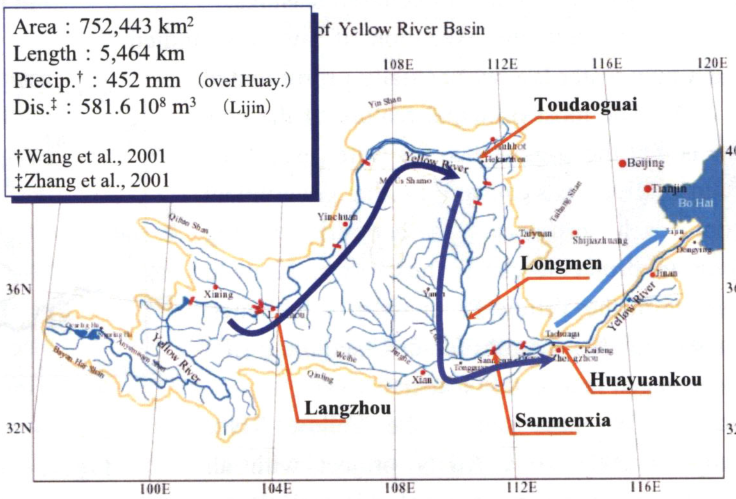


Figure 1 A map of the Yellow River domain

### 2. Situation of the North China Plain

As the whole Yellow River basin is located in rather dry climate condition in which annual precipitation amount is almost 450 mm, it seems difficult to maintain agriculture for crop production by using only water provided from vertical rainfall (1). Actually, most of farmlands are use to take groundwater for irrigated water. Therefore, groundwater level was gradually lower down shown in Figure 2. It is named as Luancheng Agricultural Station where is located at near Shijianzhang city. The drop ratio of groundwater level is 0.77 m a year. Therefore, water supply from the Yellow River was essential issues since 1970s. As a result, Figure 3 shows the days and length of dry-up in the Yellow River. It shows that the dry-up have been occurring almost every year since 1970s, but the most severe dry-up occurred in 1997.

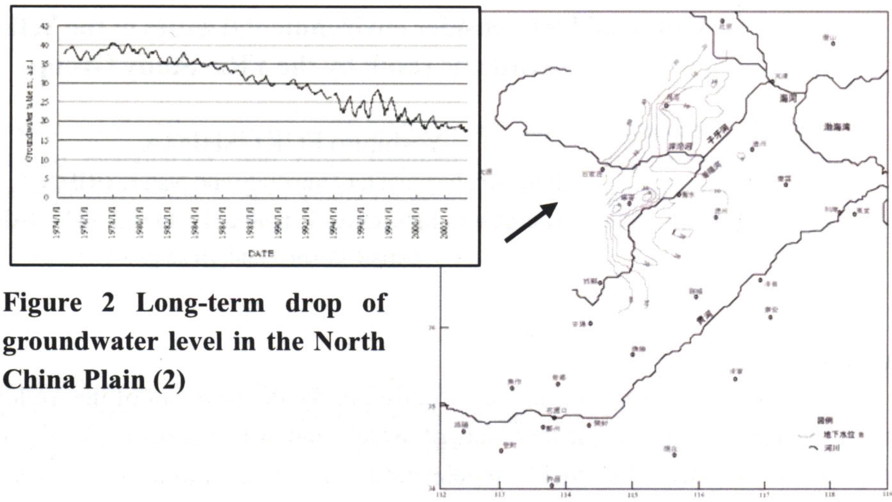


**Figure 2 Long-term drop of groundwater level in the North China Plain (2)**

The feature of the dry-up happened in 1990s was that it became extend its length to upstream. In particular, it was a year small rainfall amount in 1997. As this phenomenon surprised world peoples as related environmental problems, Chinese government had to begin the planning of countermeasures.

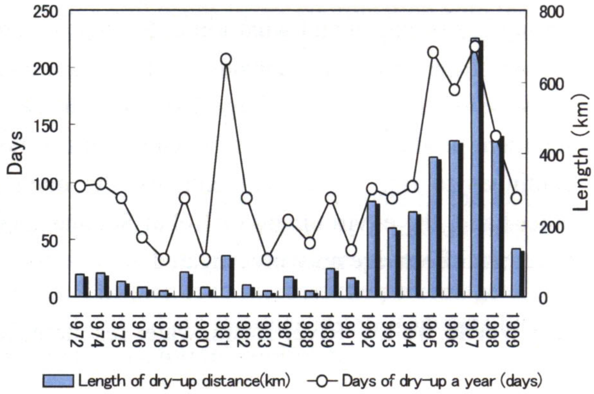


**Figure 3 Long-term Change of dry-up in the Yellow River (3)**

At first, the execution of law was studied and a new water law was actually promulgated in 2002. The most principal feature of the new law is that the competence for water use of the Yellow River has moved to the government from each province. Furthermore, a big domestic project to clarify the cause and how to manage in the Yellow River were to be better, has started after that. Professor Changming LIU has engaged in a section leader.

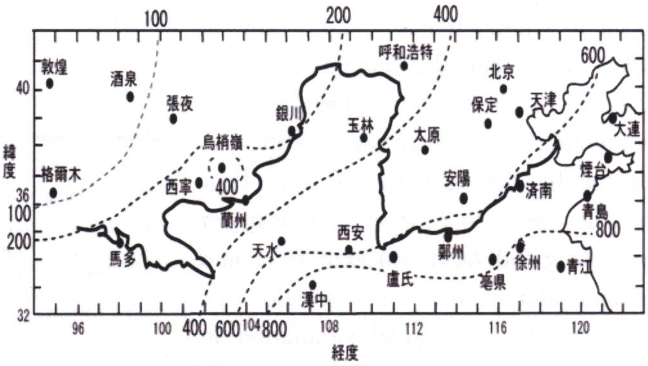


**Figure 4 Distribution map of annual precipitation in the Yellow River domain (1)**

We also started the Yellow River study in 2003 as a RIHN project with an international view point, to clarify real reason of dry-up in the Yellow River and how does affect to the surrounding circumstances such as Bohai Sea and other areas. It was thought that the world food demand is asking its increase of supply due to the expansion of human population. The objective was including analysis of water use in the Yellow River on considering food product. Therefore, agricultural development of dry region is not only Chinese particular case, but also common issue in other dry regions.

Figure 4 shows precipitation mount in the whole Yellow River Basin. Its amount has a tendency of decrease since 1990s. Water loss in the irrigation areas has clarified to be rather large amount than that officially reported by our analysis over 40 years. It seems to be needed unexpected water in order to wash out saline chemicals in the irrigated field. In the middle area of the Yellow River, almost 20 billion $m^3$ a year was recently decreased compared with 40 years ago, in spite of no evidence against the increase of agricultural area. This loss is calculated as an increase of almost 58mm a year. We assumed the reason is due to cover ground surface by reforestation from the southern part to the middle part in Loess Plateau. It also might contribute to decrease of sediment yield from Loess Plateau.

Nevertheless, the altitude of river bed of the Yellow River in the North China Plain still continues to rise up by sediment deposit consisted of fine particle (4). It seems to enhance danger of flood disaster in the North China Plain. For avoiding such a disaster, it seems to construct a new river channel, though it will request tremendous expenditure. But preparation of such a safety net could help the reduction of disaster damages because it is rather easy to forecast water flow course and flooding water level could be down before being attacked by more miserable disaster with unexpected floods.

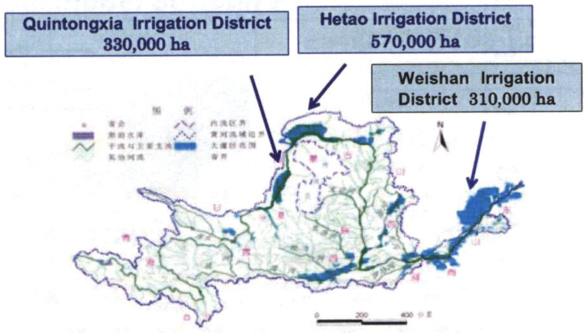


**Figure 5 Location of large irrigation districts in the Yellow River (5)**

**Table 1 Intake amount and other factors of the large irrigation districts in the Yellow River (5)**

| | Unit | Qintonxia | Hetao | Weisan |
|---|---|---|---|---|
| Total area | $10^3$ha | 624 | 1190 | 360 |
| Irrigated area | $10^3$ha | 330 | 576 | 310 |
| Intake from the Yellow River | $10^9m^3/y$ | 6.2 | 5.0 | 0.89(※) |
| | mm/y | 1880 | 868 | 274 |
| Return flow to the Yellow River | $10^9m^3/y$ | 3.53 | 0.53 | ≒ 0 |
| | mm/y | 1070 | 92 | ≒ 0 |
| Saline inflow | $10^3$t/y | 280 | 215 | - |
| Saline outflow | $10^3$t/y | 400 | 63 | - |
| Saline budget | $10^3$t/y | -120 | 168 | - |

## 3. Irrigated agriculture done in the Yellow River

Concerning a water consumption issue, the area of large irrigated agriculture districts located shown as Figure 5. Its areas are very large and cities and industrial factories are also included inside the districts. Therefore, drained water is considerably polluted because no treatment water enters to irrigation drain channels. The result officially reported, diverted and return waters are shown in Table 1 (5). Totally, three large irrigation districts uses river water almost 7.4 billion $m^3$ from the Yellow River. It is not included small scale of irrigated farmland, generally 80 % of the river water estimated roughly are used for irrigated agriculture. Finally, water used in irrigation will be estimated by newly developed water resources model.

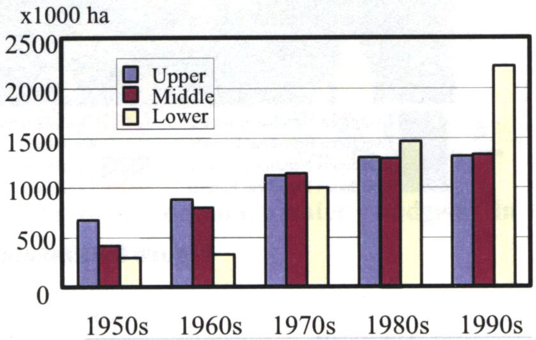


**Figure 6 Changes of irrigation area in each decade (6)**

Decadal changes of irrigated area are shown in Figure 6. It shows that upper and middle reaches of the Yellow River were mainly developed to irrigation fields by 1980s, but the lower reaches have been developing through 1990s.

By the statistical data relevant to crop production and usage of chemical fertilizer as shown in Figure 7(a) and 7(b), the lower reaches of the Yellow River domain were strongly increased its production and use of chemical fertilizer (7). It seems Chinese Government asked higher production of crop in the North China Plain to have to supply food for increasing human population in China.

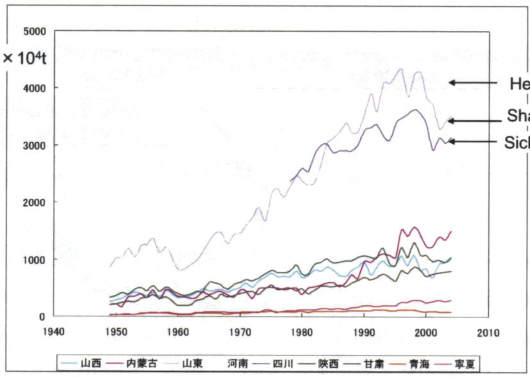


**Figure 7(a) Crop production in the Yellow River Domain (7)**

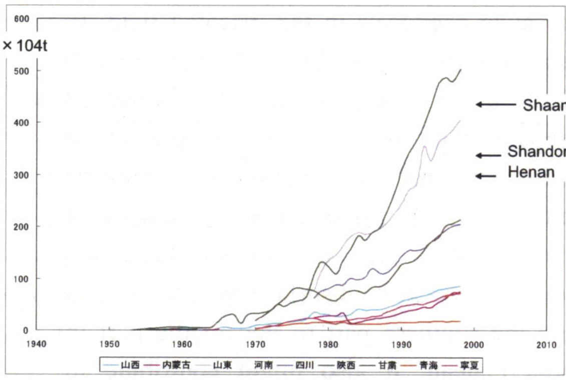


**Figure 7(b) Use of chemical fertilizer in the Yellow River Domain (7)**

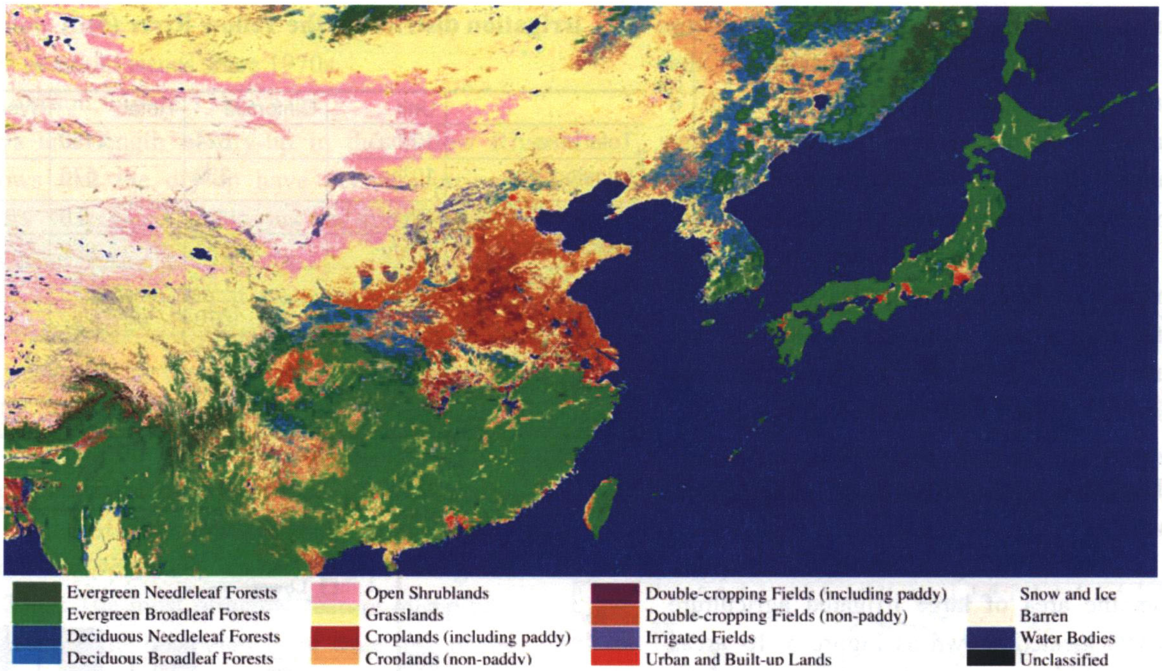


**Figure 8 Land classifications of 2000 by MODIS (8)**

## 4. Water resources model developed

In order to estimate the change of river discharge during 40 years from 1960 to 2000, including not only natural change, but also human activities like irrigated agriculture, a new water resources model was developed in this project.

Basically, we need the land-use category related to hydrological model. A new map based upon MODIS image data of 2000 is shown in Figure 8 (7). In the same time, we developed water resources model and validated model applicability using river discharge data at six stations in the Yellow River shown in Figure 9.

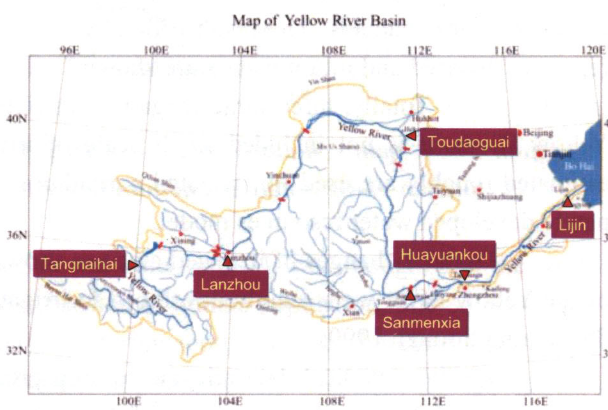


**Figure 9 Six stations observing river discharge in the Yellow River**

In each section, water budget is written as follows;

$L=P+Qin-Qout \pm \Delta S$--------(1)

L□E--------------------------------(2)

where, L; water loss, P: precipitation, Qin; inflow to the section, Qout; outflow from the section, E; evaporation.
If the period is taken as one year interval, ΔS□0.

Ep is used as potential evaporation estimated by Kondo & Xu's way based upon the bulk method, and Ea is defined as a actual evaporation written as Figure 10 which is a function of Ep, f(LAI) and β(θ). Here, LAI is leaf area index and θ is soil moisture index. This model shown as Figure 10 is developed by Sato *et al.* (9).

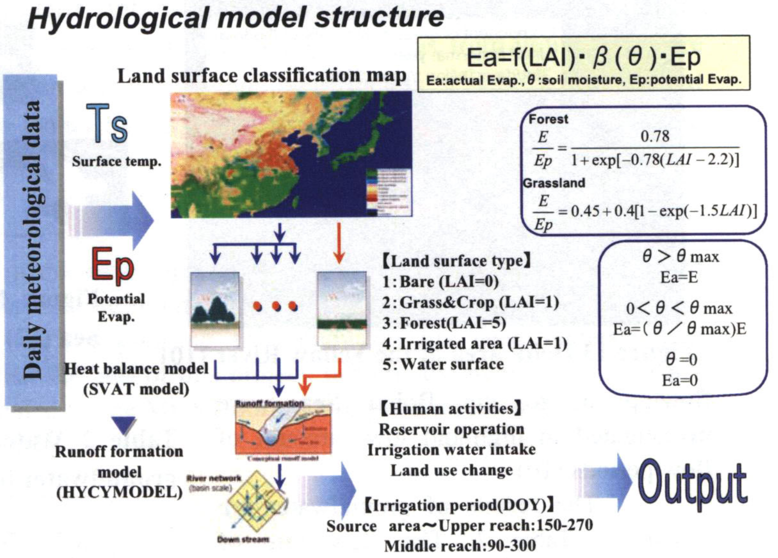


**Figure 10 Developed Model structure of Hydrology and water resources**

After vegetation covers were fixed at 2000, decadal loss and evaporation were compared in each section. Water budgets of three sections in upstream agreed with the calculated value almost. But, in the midstream which flows down and carves Loess Plateau with many tributaries, water loss in previous decade shows small amount compared with the calculated value (Figure 12). It seems to be grown vegetation planted as soil and water conservation works started from 1950s, at first. And recent decrease of precipitation is also influenced for the evaporation drop as soil moisture deficit. But, large irrigation districts upstream have used river water constantly. It's estimated almost 10 Billion $m^3$ in these 40 years. Therefore, main reason for dry-up happened at 1997 was due to the decrease of precipitation at midstream and the gradual increase of evaporation by the success of the soil and water conservation works, mainly. Therefore, river discharge at Huayuankou station dropped down, but we don't forget the amount of sediment discharge has surely decreased. It must contribute the stability of river bed at downstream.

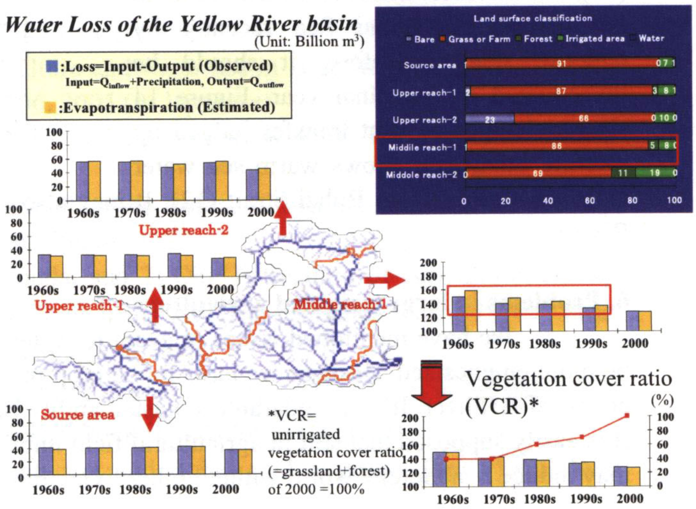


**Figure 11 Long-term decadal water budgets in upstream and midstream**

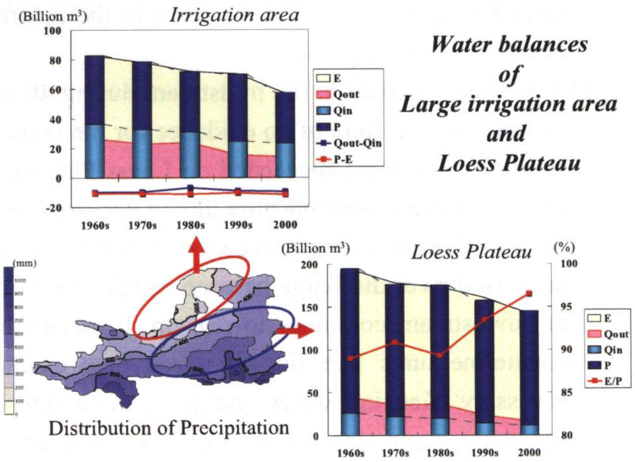


**Figure 12 Comparison between upstream with large irrigation Districts and midstream**

## 5. Effects to Groundwater in delta area and Bohai Sea

In the delta area of the Yellow River shown as Figure 13, how much of groundwater and chemical materials

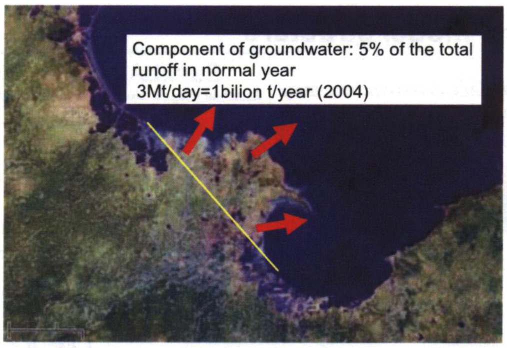


Figure 13 Delta area of the Yellow River (10)

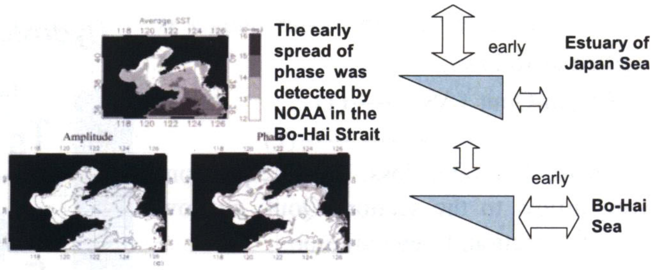


**Figure 14 Heat flow change occurred in Bohai Sea (12)**

flowing in to the Bohai Sea were investigated in high-and low -amount of flow periods (10).

The results of groundwater are shown in Table 2. The flow rate of groundwater has only 5 % for surface water, but Si and P are rather high concentration (11). On the other-hand, Nitrogen seems to be increase in Bohai Sea recently by Chinese side. Therefore, it should be investigated in our final year. Figure 14 shows changes of heat transfer judged by satellite images. It shows warm sea water entering by SST from Bohai Strait (12). It may also affect the decrease of flow amount from the Yellow River.

**Table 2 Water and nutrients material flow through groundwater in delta area of the Yellow River (11)**

| | Surface | Groundwater |
|---|---|---|
| Flow | **100** | **5** |
| Si conc. | 100 | 1190 |
| Discharge | **100** | **60** |
| TP conc. | 100 | 1000 |
| Discharge | **100** | **50** |
| DTN conc | 100 | 50 |
| Discharge | 100 | 2.4 |

## 6. Problems in large irrigated agriculture

We have mentioned issues relevant to water use in semi-dry area, but water quality issue should be more emphasized. Because we have found crop production in China is supported by the usage of lots of chemical fertilizer. It is not guaranteed sustainability because chemical world never permit animate nature. It is easily supposed that soil in agricultural field implied organism is to turn to inorganic circumstances. It may induce a monotone world without other living thing by the overuse of agrochemical.

## 7. Conclusions

1) The remarkable changes on both annual precipitation and annual mean air temperature are not so changed in the Yellow River basin except 1990s generally.
2) Annual evaporation during 40 years in the upstream seems to be not changed although there are two large irrigation districts.
3) Evaporation amount in the midstream during 40 years has almost decreased 10 billion m3 y-1 less than that in 1960s in spite of no evidence for the reduction of agricultural field. If the reforestation and gully control works were succeeded on Loess Plateau, evaporation might increase. But actually evaporation decreased due to soil moisture deficit occurred by decrease of annual precipitation recently.
4) Nevertheless, the 70~80 percent of water resources of the Yellow River basin are used for irrigation. As decreased river discharge became usually weak in energy for sediment transport, the river-bed altitude in downstream continues to rise up. It means the danger for flood disaster is to be enhanced. As a countermeasures like flood control, new channels in both outsides of the existing channel seem necessary. Keeping water quality is more important for everywhere of the Yellow River basin. In particular, some scenic place like Lake Ulansuhai, Inner Mongolia, should be kept as safe and healthy area for fishes and birds. Because it has symbolic meaning that Chinese is making effort to maintain people's environment.

5) In the delta area of the Yellow River, material inflow from surface water and groundwater were investigated in different methods. Finally, it was found silica and phosphorus from groundwater are high concentration, but nitrogen concentration was not so high. Nevertheless, it is to be investigated further because nitrogen concentration in Bohai Sea is told as high by the information of Chinese scientists.

## 8. Acknowledgements

This project study was composed of not only Japanese, but also Chinese scientists concerned with the Chinese national key project team for the resolution of the Yellow River problems. In particular, Academician, Professor Changming LIU was/is supporting this study on his deep understanding international meaning. And we have to say that the part of this project, namely, the hydrology and water resources modeling of the Yellow River, is funded by the MEXT during five years research from 2002 as a part of the subject 5 of the Research Project 2002.

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