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YRiS Yellow River Studies

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Thanks for the completion of YRiS project

Yoshihiro FUKUSHIMA (Project Leader)

YRiS (Yellow River Studies) is an abbreviated title including two projects; the first was funded during FY2002-FY2006 by MEXT as one part of a big project called as the Research Revolution 2002. RIHN (Research Institute for Humanity and Nature) group was in charge of building a new hydrological model with collaborative relationship with Mekong River's group. We, RIHN team aimed at integrating human activities into a new hydrological model of the Yellow River which is located at rather semi-arid region.

Second was funded by RIHN itself during FY2003-FY2007 as RIHN had given us a permission on starting because of getting an evaluation which it was one of important projects to have to be promoted by the evaluation committee composed of outsiders including foreign famous scientists.

Its objectives were why severe dry-up of the Yellow River occurred in 1997 and which kinds of influences on the surrounding environment reached or not. As we have considered that an example of the Yellow River has some common issues deeply concerned with human activities in arid and semi-arid regions, a separation method between natural and human factors on hydrological modeling was new and principal key points. Furthermore, we paid attention that the Yellow River's discharge flowed down with high-concentration of sediment in which the mean concentration was the highest in the world.

Fortunately, we have succeeded to build an improved hydrological model and we could find the reason why severe dry-up started at 1970s by using a new model. It was due to decrease of river discharge from Loess Plateau area occupying almost 40% of the Yellow River basin caused by the increase of evapotranspiration. Basically, it has occurred by the success of reforestation. In the same time, sediment discharge has decreased from Loess Plateau, but lower reach of the Yellow River was still keeping risen river bed height compared to outside of river banks. It means lower reach of the Yellow River continues to be dangerous from flood disaster.

In Bohai Sea, biological circumstances have immediately changed to Phosphorus from Nitrogen regarding limiting factor due to the shortage of river water supply, and ocean current exchange between Bohai Sea and the Yellow Sea seems to be decreased. It might induce to change circumstances of oceanic organism near future.

Now we are afraid of water pollution of the Yellow River although we didn't touch it because our main task was quantitative understanding relevant to water issue of the Yellow River. We wish that our results are serviceable for the improvement of water quality in the Yellow River as our result has high reliability on including reason of the changes of river discharge quantitatively.

Mechanisms of the water shortage of the Yellow River basin

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1. Introduction

In recent years, the measured annual river flow of the Yellow River has declined significantly. Still now, the basin is confronted with frequent water shortage, and it has been great concern of the Chinese government and attracted international attention. It is well known that the drying-up of the lower reach has occurred since 1972, and the situation has become more and more serious during the 1990s. Therefore, the immediate attention and action are needed to mitigate or solve the water shortage and its related problems. In general, there are two causes for the flow drying-up in the lower Yellow River: climate change and human activity. Basically, water resources in the Yellow River basin are scarce, because the annual precipitation is much lower than the annual evaporative capacity. Furthermore, the decrease of annual precipitation may be one of the most important factors for the decrease in the river runoff. On the other hand, the impact of human activity due to intensive water use is another major reason for the drying-up. Most of the recent investigation concluded that the drying-up is due to extensive water withdrawal for agriculture irrigation. However, the contributions of these factors had not been investigated quantitatively. Thus, in the present study, we attempt to clarify the mechanisms of the drying-up of the Yellow River basin by long-term water balance analysis and several hydrological model simulations.

2. Data and Method

For the long-term analysis, we used 41 years (1960-2000) of daily observation data from 128 meteorological stations. Then, to predict the evapotranspiration loss from various land use types, a high resolution satellite remote sensing data (Matsuoka *et al*., 2005) were used . The remote sensing data includes the elevation, land surface classification map, and normalized difference vegetation index (NDVI) data sets. The hydrological model used in this study is based on the SVAT-HYCY model (Ma and Fukushima, 2002). However, this hydrological model could not predict long-term water balance of the Yellow River basin as it includes a lot of anthropogenic factors such as irrigation water intake, large reservoir operation, and human-induced land-use changes. Thus, in the present study, we considered these artificial factors in our model by applying simple sub-models. The details of model structure and parameters used in this study are summarized in Sato *et al*. (2007a,b,c).

3. Results and discussion

The performances of the hydrological model applied in this study are shown in Figure 1. These figures indicate that the annual discharges from source area to lower reach during the past 40 years (1960 to 2000) estimated by the model (red bars) and observed results (blue bars). The locations of each sub basin are shown in Figure 2a. Although, we did not consider the influence of long-term land-use change in this model simulation, the observed discharges were reasonably captured by the model except for the Middle reach-1. Therefore, the influence of land-use change on long-term water balance of the Yellow River basin will not be so severe. The disagreement in the Middle reach-1 was solved by considering the influence of land-use change (soil and water conservation) conducted in the Loess Plateau (Sato *et al.*, 2007b).

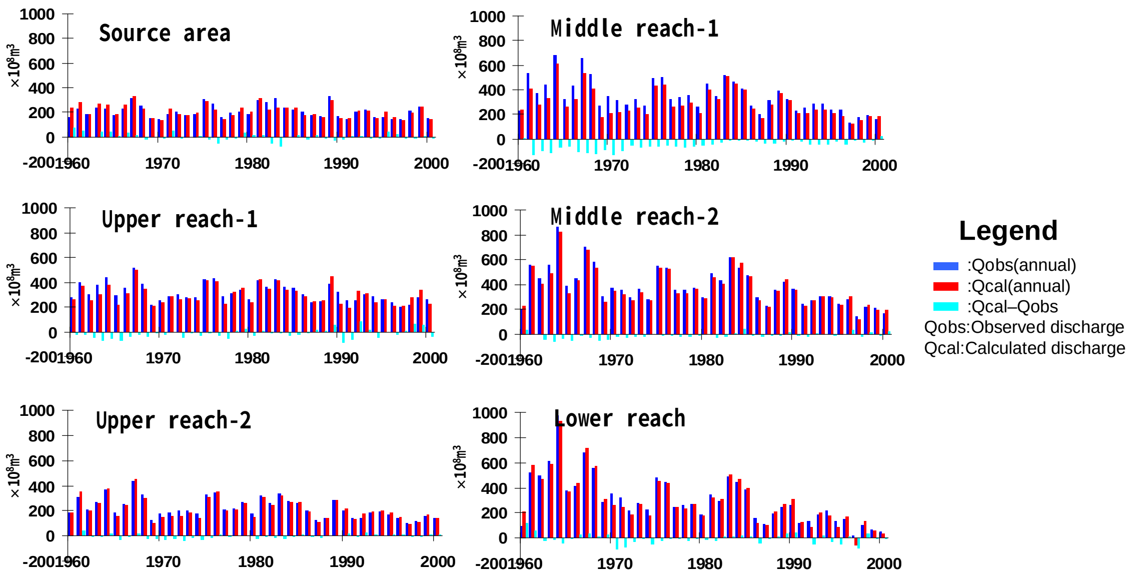

Figure 1 Performance of model simulation

Figure 2b shows that the amount of water decreased in each sub-basin between the periods from the 1960s to the 1990s. From this result, we can see that the water shortage in the lower reach of the Yellow River basin (36 billion m^3) was induced by the following two factors: (1) increase in water consumption within the lower reach (31%) and (2) decrease in water supply from upstream of lower reach (69%).

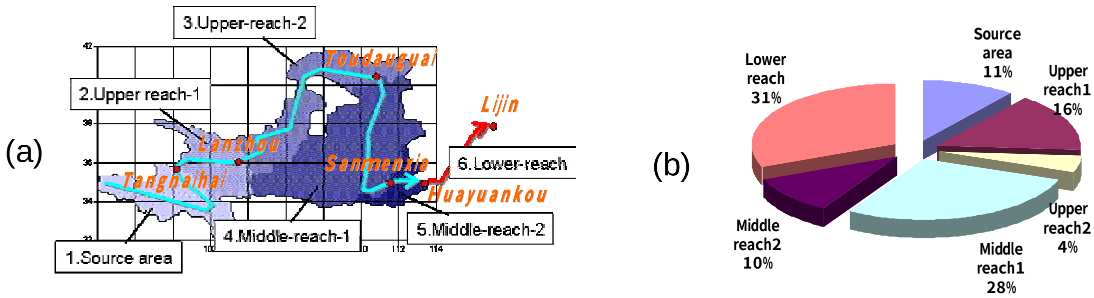

Figure 2 Analysis of long-term water balance of the Yellow River basin.
(a)Distributions of each sub-basin; (b) Amount of water decreased in each sub-basin

According to the decadal analysis of the water use within the lower reach and the water supply to the lower reach, we can find that the water use within lower reach increased between the 1960s to the 1980s and water supply to the lower reach decreased in the 1970s and the 1990s (Figure 3a). The major reason of the increase in water use within the lower reach can be due to the increase in irrigation water use with the increase of irrigation areas from the 1960s to the 1980s (Figure 3b). The decrease in water supply to the lower reach must be induced by the decrease in precipitation in the middle reach-2 in the 1970s and 1980s (Figure 3c). The influence of the increase in evapotranspiration with the increase of air temperature will not be so significant on long-term water balance of the Yellow River basin compared with the influence of the precipitation change (Figure 3d).

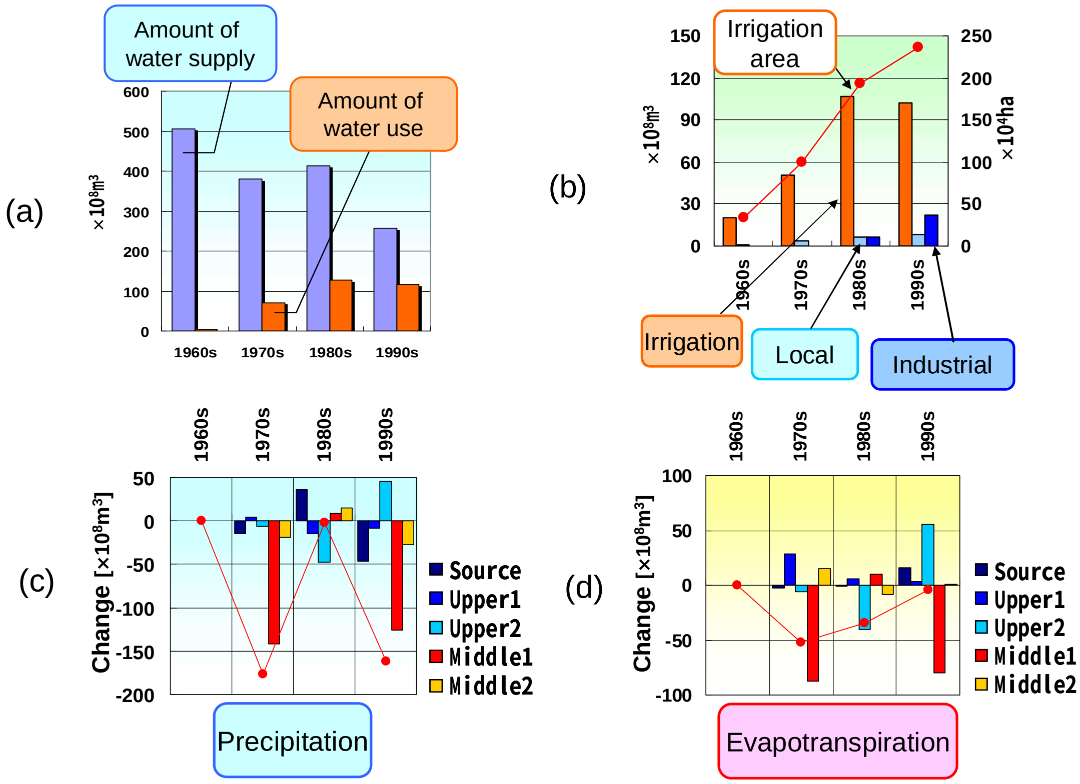

Figure 3 Mechanisms of the drying-up of the Yellow River basin.
(a) Decadal change of water supply for the lower reach and water use within the lower reach; (b) Decadal change of irrigation area, irrigation water use, local water use and industrial water use within the lower reach; (c) Decadal change of precipitation from source area to middle reach-2; (d) Decadal change of evapotranspiration from source area to middle reach-2

4. Conclusion

In the present study, we attempted to clarify the mechanisms of the drying-up of the Yellow River basin by long-term water balance analysis and hydrological model simulation. The results obtained in this study will contribute to the ongoing integrated water resources management in the Yellow River basin, such as the more adequate water allocation or soil and water conservation.

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ABL Research Activities in YRiS Project

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1. Introduction

The Loess Plateau in China is located in the middle part of the Yellow River basin, and it lies at the boundary of arid and humid regions of eastern part of Eurasia continent. The Loess Plateau significantly affects the water cycle in the Yellow River basin. Our scientific questions or motivations are listed as follows; 1) How did the synoptic condition and precipitation over the Loess Plateau change in the recent decades?, 2) How did the land surface change in the region affect for the synoptic condition and precipitation over the region?, 3) Did the land surface and atmospheric boundary layer (ABL) actively influence for the precipitation system?, 4) What are the primary differences of ABL processes between over the humid and semi-arid regions?, and 5) How does a sharp topography affect for the atmospheric turbulence within the atmospheric surface layer (ASL)?

In order to answer the questions, the ABL team established the following four objectives; 1) To reveal inter-annual and intra-seasonal changes in precipitation amount and related convective activities over the Loess Plateau and the North China Plain, 2) To find any convective activities and precipitation systems affected by land surface and ABL processes over the Loess Plateau, 3) To compare the diurnal and seasonal changes in the ABL developments over the humid and semi-arid regions, 4) To investigate topographical effects on the atmospheric turbulence and the local circulations appeared within the ABL over the Loess Plateau in China.

2. Observations and Data

We established an ABL observation system on a research field of the “Changwu Agro-Ecological Experimental Station over the Loess Plateau”, which is located in southern part of the Loess Plateau in China (35.24 ^{o}N and 107.68 ^{o}E). The altitude of the station is 1224 m. The observation system consists of the following device (Hiyama et al., 2005):

1) Flux and Radiation Observation System (FROS), manufactured by Climatec, Inc., Japan.
2) Wind Profiler Radar (WPR), manufactured by Sumitomo Electric Industries, Ltd., Japan.
3) Microwave Radiometer (MR), manufactured by Radiometrics Corporation, USA.

The FROS provides turbulent fluctuations of three-dimensional wind speed, air temperature and humidity at the height of 2 m, 12 m, and 32 m. From these turbulent data, we evaluated surface sensible and latent heat fluxes. We selected those fluxes at 12 m and 32 m as regional values over this area. The WPR provides vertical profiles of mean wind velocity and wind direction together with those of echo intensity and Doppler spectral width. The MR provides vertical profiles of air temperature, relative humidity, and liquid water content.

The following data were also used in this study.

1) NCEP/NCAR re-analysis data set.
2) Outgoing long-wave radiation (OLR) data set obtained from geostationary meteorological satellite (GOES 9).
3) Sounding data observed at Pingliang, which located at around 100 km northwest from Changwu station.

3. Results

<u>3.1. Time-series change in precipitation and water budget over the Loess Plateau</u>

Precipitation has slightly decreased since 1950s both over the Loess Plateau and the North China Plain, but it has no significant trend. On the other hands, the inter-annual variation in precipitation has been very large. This inter-annual variation was mainly caused by the intra-seasonal variation of precipitation during rainy season (July, August and September). Although phase of the intra-seasonal variation was similar both for wet year and dry year, amount of water vapor inflow from southern region was drastically different from each other (Fujinami, 2007).

The precipitation during rainy season is important for agricultural activities over the Loess Plateau. The available water (P – E), namely, difference in precipitation (P) and evapotranspiration (E), is positive during three months but negative in the others (Takahashi et al., 2007). The amount of the available water (P – E) during the rainy season is much affected by that of precipitation (P), because E is conserved effectively by the dry surface layer of the loess.

3.2. Effects of land surface and ABL processes on the large-scale convective activities or precipitation systems

Variations in the latent heat flux over the plateau corresponded to those in precipitation during rainy season. Those dominant frequencies were around 4 or 5 days. This means that the overpass of cyclonic (disturbance) precipitation occur around 4 or 5 days intervals in the region. On the contrary, variations in the sensible heat flux had unclear and the dominant frequency was less than 4 days (Nishikawa et al., 2007a). This might be correlated with instantaneous formation of the dry surface layer of loess, as described above.

The daily maximum height of ABL was affected by the surface sensible heat flux as well as the atmospheric stability in the middle and lower troposphere, which were the product of surface heating and intrusion of cold air mass over the region. Thus variations in the daily maximum height of ABL were affected by surface sensible heat flux and synoptic conditions.

Both in pre-rainy season and in rainy season (from April to July), land surface has occasionally enhanced cyclonic precipitation (or meso-scale convective activities). In 2005, the region has experienced 4 times in heavy rainfall at late afternoon, all of which exceeded 10 mm/hour in rainfall intensity. These heavy rainfalls have been brought by overpass of cold front. The cloud top height (i.e., brightness temperature) of the cold front, derived from a geostationary meteorological satellite (GOES 9), clearly showed diurnal variation (Nishikawa et al., 2007a).

3.3. Effects of land surface wetness and topography on regional-scale ABL development and cumulus generation

We employed a cloud resolving model (Cloud Resolving Storm Simulator; CReSS) developed in HyARC, Nagoya University, to perform sensitivity analyses of ABL and cumulus developments. In order to reveal effect of surface wetness on the ABL and cloud generation, we referred observed evapotranspiration efficiency using FROS (Li et al., 2008).

Over a virtually homogeneous flat terrain, surface wetness (or evapotranspiration efficiency) as well as relative humidity within the ABL are important for ABL and cloud generations. Lower surface wetness made mature ABL higher but generated cumulus less effective due to shortage of water vapor supply from the land surface. If the relative humidity was higher, cumulus generated more effectively. In contrast to this, over the real topography of the Loess Plateau, topographical effect is much higher than the effect of surface wetness for ABL development and cumulus generation. Topography of this region generates small-scale local circulation, in which vertical and horizontal scales are around a few kilometers (Nishikawa et al., 2007b). This scale could be correlated to the ABL height scale over the region.

3.4. Comparison of ABL processes between over a humid region and over the Loess Plateau

We compared seasonal ABL processes between over a Chinese humid region (Shouxian, Anhui province) and over the Loess Plateau (Changwu, Shaanxi province). Briefly, seasonal change in daily maximum height of ABL over the Loess Plateau was very unclear. This is mainly due to the following two reasons: 1) Land cover of the tablelands in the Loess Plateau is very heterogeneous in addition to the existence of steep gullies. These land surface features contribute to complex seasonal march in the surface fluxes of sensible heat and latent heat, and thus to daily maximum height of ABL. 2) Weak subsidence (or capping inversion) appears during summer season over the area. This cooperates with thermals developing up to ABL tops or more (Hiyama et al., 2007). If atmospheric humidity became higher due to vertical or horizontal water vapor supplies, cumulus convection effectively enhanced.

3.5. Effect of topography on turbulence structures in atmospheric surface layer (ASL)

We present the power spectra of wind velocity and the cospectra of momentum and heat fluxes observed for different wind directions over flat terrain and a large valley on the Loess Plateau. The power spectra of vertical (*w*) wind speed downwind of the valley had similar shape as previous studies. Thus topographical effect for sensible and latent heat fluxes will not be large in the region (Li et al., 2007).

The power spectra of longitudinal (*u*) and lateral (*v*) wind speeds satisfy the -5/3 power law in the inertial subrange, but do not vary as observed in previous studies within the low frequency range. The *u* spectrum measured at 32m height for flow from the valley shows a power deficit at intermediate frequencies, while the *v* spectrum at 32m downwind of the valley reaches another peak in the low frequency range at the same frequency as the *u* spectrum. The corresponding peak wavelength is consistent with the observed length scale of the convective ABL at the site. The *v* spectrum for flat terrain shows a spectral gap at mid frequencies while obeying inner layer scaling in its inertial subrange, suggesting two sources of turbulence in the surface layer.

3.6. Studies on satellite remote sensing over the Loess Plateau

Surface heterogeneity induces uncertainty in pixel-wise land surface temperature (LST). Satellite-retrieved LST may be representative of the pixel-wise LST and useful for scaling analysis, but the limited accuracy of retrieved values adds uncertainty into the scaled values. Based on the Stefan-Boltzmann law, we proposed scaling approaches for LST over the Loess Plateau including flat and relief areas to explore the combined uncertainties in scaling using satellite-retrieved data. To take advantage of simultaneous, multi-resolution observations at coincident nadirs by the Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER) and the MODerate-resolution Imaging Spectroradiometer (MODIS), LST products from these two sensors were examined for part of the Loess Plateau. 90-m ASTER LST data were scaled up to 1 km using the proposed approaches, and variation in the LST was generally reduced after scaling. Amongst the sources of uncertainties, surface heterogeneity (emissivity) and different scaling approaches resulted in very minor differences. Terrain features, taken as an areal weighting factor, had negligible effects on the upscaled value. Limited accuracy of the retrieved LST was the major uncertainty. The overall LST increased 0.6 K on average with correction for terrain-induced angular effect and 0.4 K for both angular and adjacency effects over the study area. Accounting for terrain correction in scaling is necessary for rugged areas (Liu et al., 2006).

The ratio of latent heat flux to available energy, termed the evaporative fraction (EF), and the ratio of latent heat flux to downward shortwave radiation (ES), are two useful evaporative flux ratios (EFR) for estimating daily evaporation. Both EF and ES remain relatively constant during daytime, but their value varies from day to day. It is yet unclear if long-term change signals are detectable given the uncertainty associated with the diurnal variations. Using EF and ES data obtained during the major rainy seasons on a tableland of the Loess Plateau, we showed that day-to-day variability in the EF or ES was detectable given diurnal variation. The EF and ES showed slight increasing trends from midmorning to afternoon, but the ES was superior to the EF for satellite-based monitoring of long-term evaporation trends (Liu and Hiyama, 2007).

4. Unresolved issues

The effect of land surface change on the precipitation trend over the region could not be resolved in this study. This is mainly because of difficulty on separation of land surface effect from the other meteorological factors such as synoptic-scale influences and effects of meso-scale convective activities. Use of AGCMs (Atmospheric General Circulation Models) has been employed to reveal the land surface effect on the precipitation feedbacks. However, previous AGCMs studies have ignored feedback processes of land-atmosphere interaction. Future studies will be encouraged involving such feedback processes of land-atmosphere interaction.

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Research results on groundwater-seawater interaction in Yellow River Project

Makoto Taniguchi (RIHN)

1. Introduction

The roles of "groundwater group" in the Yellow River Project (PL: Yoshihiro Fukushima) are to evaluate the interaction between groundwater - river water - sea water, and to evaluate the groundwater discharge and material transports into the Bohai sea, from the points of views of "Cutoff of the Yellow River" and the effects on Bohai sea. The studies have been made from 2003 to 2007 thorough five intensive field measurements and analyses. The groundwater monitoring in the delta, measurements of the Yellow river water, and measurements of coastal water have been done. Three of five field experiments have been made with the "Bohai group". This is the final report of the results from the groundwater group.

2. Interaction between Yellow River, groundwater, and sea water

Field experiments and analyses have been made to evaluate the groundwater flow system in the delta, hydrogeology of the aquifer, and the distribution of the saltwater and fresh water. Core sampling to evaluate hydraulic and hydrogeologic parameters, saltwater/fresh water distribution by resistivity measurements, and measurements of groundwater potential have been made. As the result, the method by use of GPS to evaluate the elevation is useful for the groundwater survey in the flat area such as Yellow River delta. The hydraulic gradient of the groundwater decreases during the low flow (similar to the condition of the "Cut-off of the Yellow River").

Three different waters, river water, groundwater and sea water, meat in the Yellow River delta. The magnitude and direction of the water have been examined to evaluate the effect of the cut-off of the Yellow river. As the results, the directions of the water were found to be from the Yellow River to groundwater and the groundwater to the Bohai sea. The replacement of the water has also been clarified from the chemical analyses of the pore water at the transect line from the Yellow river to the Bohai sea.

3. Water and dissolved material transports from the delta to the Bohai sea

Spatial and temporal variations of submarine groundwater discharge (SGD) have been evaluated by automated seepage meters from the Yellow River delta to 7 km offshore in the Bohai Sea, China. We identified three zones from the coast to offshore based on different relationships between tidal and SGD changes (Taniguchi *et al.*, 2008). Our results indicate that the point of maximum SGD shifted 2 km offshore from September 2004 to September 2006. This spatial change is thought to be caused by sediment deposition near the coast.

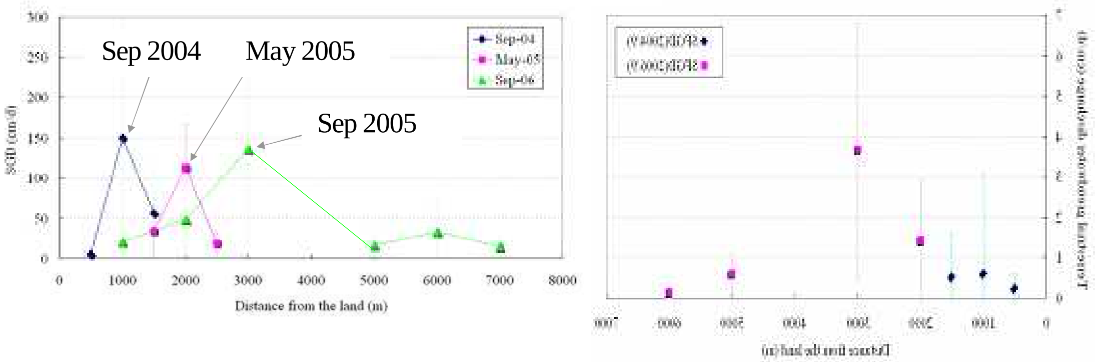

Fig.1 Changes in SGD and SFGD against the distance from the coast

Assuming the seepage face extends 7 km offshore and the shoreline length of the Yellow River delta to be 350 km, the total SGD from the entire Yellow River delta is evaluated to be 9,300, 1,200, and 12,000 m^3/s in September 2004, May 2005, and September 2006, respectively. Since the Yellow River discharge in September 2004, May 2005, and September 2006 were 676, 145, and 778 m^3/s, respectively, the total estimated SGD from the delta are found to be 13.8, 8.5 and 16.0 times the river discharge into the Bohai Sea. Note that these numbers include both SFGD and RSGD.

Assuming the SFGD seepage face in September 2004 and September 2006 are 2 km offshore, the average SFGD in September 2004 and September 2006 are 18 and 28 m^3/m/day, respectively. Assuming the length of the coastline of the Yellow River delta to be 350 km and SFGD in the study area represents 3.6 times the average SFGD of the entire delta, SFGD is evaluated to be 110 and 170 m^3/s during September 2004 and September 2006, respectively. Therefore, SFGD represent about 4.5 % and 7.0 % of the Yellow River discharge during September 2004 and September 2006, respectively.

Comparison of these results with global data shows that the SFGD in the Yellow River delta is smaller than global average, but SGD is larger than the average, because of gentle slope in the coastal zone of delta.

Material transports by groundwater to by Yellow river were 100:60 for Phosphate and 100:50 for Silica, though fresh water discharge (SFGD) by groundwater to by Yellow river was 100:5. Therefore, the result shows the importance of groundwater discharge for Phosphate and Silica into the Bohai sea. On the other hands, nitrate discharge by groundwater to by Yellow river was 100:2.4. This small contribution by fresh groundwater discharge (SFGD) may be due to denitrophication. However, the nitrate discharge by recirculated seawater discharge may cause the dissolution of nitrate from the sediments transported by the Yellow river.

4. Conclusions

The conclusions of the groundwater group are as follows; (1) The usefulness of GSP measurements in the flat area such as Yellow river delta is shown, (2) The deep information on saltwater/freshwater distribution can be found remotely by uses of resistivity without borehole data., (3) The directions of water movement in the delta are evaluated to be from the Yellow river to the groundwater, and from the groundwater to the Bohai sea., (4) The hydraulic impact zone of the Yellow river was estimated to be more than 40 km by use of correlation between river discharge and groundwater level, (5) Comparisons of the results of groundwater discharge into the Bohai sea between different river discharge periods showed that the role of groundwater discharge increases during low flow (similar to the condition of the cut-off of the Yellow River), (6) The distribution of the SGD shifted 2 km offshore during two years because of the offshore shift of the coastal line due to the sedimentation, (7) The ratio of SFGD (fresh component of submarine groundwater discharge) was 5-8 % of the Yellow river discharge, which was smaller than global average, however, SGD (total submarine groundwater discharge including recirculated sea water) was 8 to 16 times of Yellow river discharge, which is much larger than the global average. This is attributed to the gentle slope of the coast in the Yellow River delta, (8) Material transports by groundwater to by Yellow river were 100:60 for Phosphate and 100:50 for Silica, though fresh water discharge (SFGD) by groundwater to by Yellow river was 100:5, (9) The nitrate discharge by recirculated seawater discharge may be caused by the dissolution of nitrate from the sediments transported by the Yellow river, (10) The 60 percentages of the water loss between Huayuankou and Lijin was used by irrigation in the lower reach of the Yellow River basin, and (11) The interdisciplinary study by groundwater hydrologists and coastal oceanographers has been made in the Yellow River delta.

The remained subjects are as follows; (1) Some hypnoses have been raised to explain the increase of nitrogen in the Bohai sea, however, no single reason was identified, (2) The process of the SGD and SFGD were clarified, however, the process of recirculated seawater, in particular the entry process of the recirculated water was remained to be unclear, and (3) Geophysical and geochemical methods were integrated, however, the effects on the ecology in the coastal zone should be evaluated in the future.

Year-to-year variation in chlorophyll-*a* concentration in the Bohai Sea

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1. Introduction

The year-to-year variation in nutrient concentration in the Bohai Sea related to that in the Yellow River discharge has been investigated (e.g.Hayashi et al., 2004) but that in chlorophyll-*a* concentration in the Bohai Sea has not been clarified yet. We reveal the year-to-year variation in chlorophyll-*a* concentration in the Bohai Sea using SeaWiFS data from 1998 to 2005 in this paper.

2. Satellite data

The horizontal and temporal resolutions of SeaWiFS data are 1.1 km x 1.1 km and 1 day, respectively. The usual algorism for estimation chlorophyll-*a* concentration from the visible band signals of SeaWiFS (for open sea water) is not available in the Bohai Sea because the water in the Bohai Sea is not Case I water (open sea water) but Case II water (turbid coastal water). Therefore we make the much-up data for obtaining the calibration curve to estimate the sea-surface chlorophyll-*a* concentration in the Bohai Sea from SeaWiFS data based on our observations in 2004 and 2005 and Gao et al. (2003) (Fig.1).

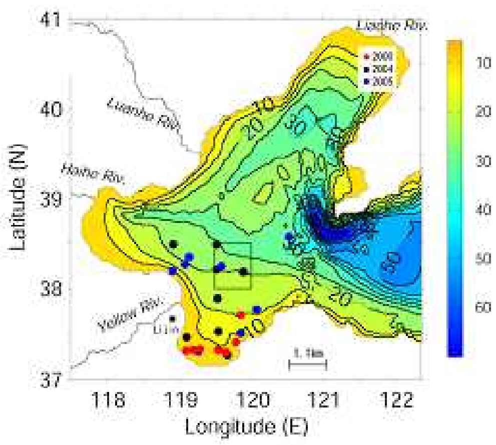

Fig.1 Observation points of sea surface chlrophyll-*a* in the Bohai Sea

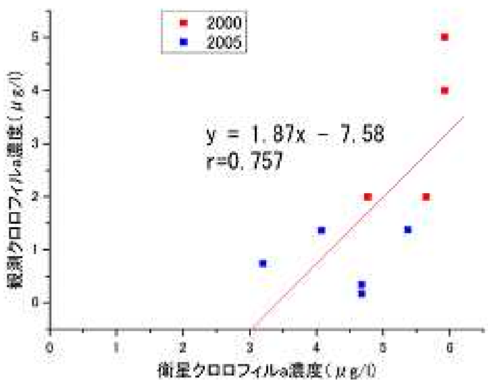

Fig.2 Correlation between in-situ observed chlorophyll-*a* (ordinate) and estimated chlorophyll-*a*.

Correlation between observed chlorophyll-*a* and estimated chlorophyll-*a* by the usual algorism of SeaWiFS before or after 4 days of field observation is shown in Fig.2.

3. Results

By using the calibration line shown in Fig.2, we estimate the sea surface chlorophyll-*a* concentration in the squared area shown in Fig.1 in the central part of the Bohai Sea from the SeaWiFS data in oder to avoid high turbid water around the Yellow River mouth.

The year-to-year variation in the estimated sea-surface chlorophyll-*a* in the central part of the Bohai Sea is shown in Fig.3 with that in Sea Surface Temperature (SST), solar radiation and

Yellow River discharge.

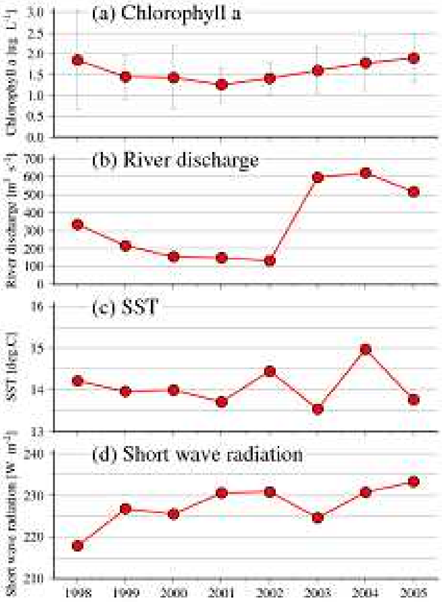

Fig.3 Year-to-year variations in sea-surface chlorophyll-*a* in the Bohai Sea, Yellow River discharge, SST and solar radiation in the Bohais Sea.

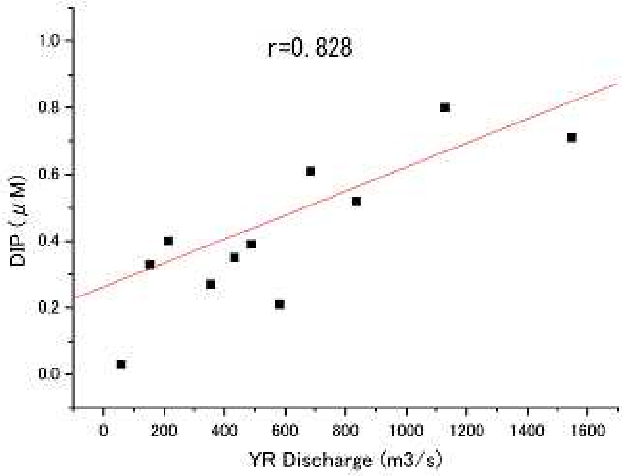

Fig.4 Correlation between DIP in the Bohai Sea and the Yellow River discharge.

The year-to-year variation in the sea-surface chlorophyll-*a* does not have good correlation between those of SST and solar radiation but it has a good correlation to that of the yellow River discharge from Fig.3. This is due to that the Yellow River discharge controls the nutrient (Dissolved Inorganic Phosphorus; DIP) concentration in the Bohai Sea as shown in Fig.4 and DIP is the limiting factor of primary production in the Bohai Sea (Hayashi et al., 2006), that is, large (small) river discharge results in high (low) DIP and high (low) chlorophyll-*a* concentrations in the Bohai Sea.

4 Conclusion

When the Yellow River discharge is large (small), DIP concentration becomes high (low) in the Bohai Sea and it results in high (low) sea-surface chlorophyll-*a* concentration in the Bohai Sea.

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Cognitive Background to Flood Control Work

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The greatest opposition in the cognitive background to water control of the Yellow River was the opposition to both the proposal for a water control policy and the main motivation for its implementation; in other words, opposition between the civil government's viewpoint and the military and national security viewpoint.

The water control work by Wang Jing during the Hou Han Dynasty was primarily to create the infrastructure for facilities that would be indispensable in stabilizing and improving the lives of the local people and the shipping and irrigation waterways of the Canal Bian, the provision of a water source for its irrigation system (namely, facilities taking water from the Yellow River), and construction to assure a stable waterway to prevent against flood damage, which threatened the entire plains region. The civil government's ideas of a primary motivation for stabilizing and improving the lives of the local people drove the planning and implementation of this construction work.

On the other hand, during the North Song Dynasty, the attempt to return the flow eastwards by changing the natural northwards flow of the river by force and thereby assaulting the residents along the riverbanks with massively profligate costs, ultimately exhausting and devastating the local economic society, arose from the central government's desire for a policy whose primary motivation was national defence and a military strategy against invasion by the Khitai people. From this viewpoint, considerations for the local people were eliminated.

Further, the start and maintenance of a southwards-flowing waterway during the South Song and Jin Dynasties was also born from measures and policies taken from the national defence and military viewpoint. The south-flowing waterway was unnatural from the start when viewed from the properties of the sinking on the geology of the North China Plain. Consequently, in the year Xianfeng 5 of the Qing Dynasty (1855), the south-flowing waterway was unstable right up until its diversion along the north banks of the Shandong mountain mass, and despite the attempts to shore it up using embankments, its destruction, flooding, and diversification of tributaries were never-ending, indicating a striking contrast with the stability that lasted 800 years of the waterways built by Wang Jing.

After the opening of the Jing-Hang Canal during the Yuan Dynasty, scrutiny fell on the maintenance of these canals from a desire for national sovereignty, which strove to maintain the capital, which was located where Beijing is today, through the bales of rice transported from the south, and river control policy was promulgated from that viewpoint. Locating the capital on the northern tip of the North China Plain, very far from the economic hub, was probably because in the midst of a geopolitical understanding that broadly divided into the North China Plain southwards and the northern plains, which could be seen from the Great Wall of China dating from the Ming Dynasty, the land was considered from the perspective of bases from which to mobilise armies and bases of political power from which both regions could be viewed. To protect the main food supply routes to the capital, Beijing, or to protect them as far as possible, work to control the rivers was promulgated as an antidote.

The river control work of Pan Jixun during the end of the Ming Dynasty, and Jin Fu and Chen Huang at the start of the Qing Dynasty, was unable to stray greatly from this framework. This is because in all cases, they were working to the basic wishes of the central government to maintain the south-flowing waterway at all costs. As understood from historical records the plans for river control that Pan ji-xun, Jin Fu, and Chen Huang had, however, it is possible to point to the influence of passionate Neo-Confucian ideas of encouraging work by the civil government with all its might in the execution of human wisdom and consideration for the local people in attempting to achieve some sort of hard labour.

Neo-Confucianism was a type of local social revolutionary movement in which appeared the inherited idea of a “civil government state” reborn by the people, as typified by Fan zhong-yan and others; a renaissance during the North Song Dynasty of the ideas of civil government that had been crystallized by the Emperor Xuan during the Qian Han Dynasty and the Emperor Guangwu during the Hou Han Dynasty. These passions and ideas were adopted by Pan Jixun, Jin Fu, and Chen Huang, and can be said to have been brought to life through them.

The Yellow River forms a great fan and the North China Plain while changing its flow within a broad framework of sinking on the North China Plain due to neotectonic movement. Where should this natural change and humans compromise? The river control work of Wang Jing, which considered a local government that elevated consideration for local people to the highest, is one such response. On the other hand, the south-flowing waterway, which is a route maintained since its start artificially and which from the first began as ideas born of national defence and national sovereignty, did not compromise by distancing itself from nature, but instead maintained ideas of artifice and control that attempted to wrestle nature into submission. The economy and society of the people living on the North China Plain was pressured and ultimately ruined by exorbitant demands for manpower, materials, and funds for this reckless construction work against the Yellow River.

Study on the relationship between economic development and water demand structure in the Yellow River basin

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We studied on the theme of 'Analysis of the relationship between economic development and water demand structure' for the project. In particular, we examined following three sub-studies.
(1) Water resource management policies and programs in the Yellow River basin
(2) Water resource supply and demand structure in the Yellow River basin and issues relating to improvements in water resource utilization
(3) Current situation and issues for water rights trading
The main findings of each sub-study are summarized in next chapters.

1. Water resource management policies and programs

We reviewed trends in water resource management in the Yellow River basin, and examined the current situation and issues for water resource management. Further information of the water resource management in the basin is documented by Shi *et al.* (2007) in the report of proceedings of YRiS joint meeting.

We found that water resource management issues that led to water shortages included the following: (1) There is an absence of punitive provisions in cases where a party draws more water from the river than its regulated allocation. (2) Water conservation measures have not been adequate to respond to increases in water demand. (3) Water usage fees were set too low, resulting in a lack of water conservation incentives for water users. (4) There was a "Prisoners' Dilemma" in connection with regional conflicts of interest relating to water resource conservation.

An effort is being made today to introduce resource management methods such as punitive provisions for excessive water withdrawals, market mechanisms, and so on. However, no information has been released about discussions leading up to the establishment of the systems and regulations, and no data has been released that would permit analysis and evaluation of the rationality of water resource allocation. It will be important to create an environment for more transparent and rational debate by the various stakeholders with different interests, coupled with a good understanding of the situation in the entire river basin.

2. Assessing the water resource supply and demand structure and improving water resource utilization

We constructed a water resource supply and demand model based on (1) a macro-level population and economy framework, (2) a water demand module, and (3) a water resource module (**Fig.1**). It then estimated the monthly water resource supply and demand balance for each county and city. This work indicated that the severe water shortages downstream since the mid-1990s were mainly caused by increases in water demand in the upstream and downstream irrigation districts, and by a drop in available water resources in the upstream area (**Fig. 2**). Further information is documented in Imura *et al*. (2005) and Onishi *et al*. (2007).

In addition, a comparison of agricultural water use efficiency between regions showed that the upstream region is less efficient that the downstream region. In particular, it became clear that efficiency in the irrigation districts of Inner Mongolia Autonomous Region and Ningxia Autonomous Region were significantly lower than in other regions (**Fig. 3**). As a result, in the future, the improvement of agricultural water use efficiency in these irrigation districts will be an important challenge if the there is any hope to improve the water resource supply and demand balance in the river basin.

3. Current situation and issues for water rights trading

As China shifts to a market economy, there is also a growing debate about introducing market mechanisms in the area of water resource management in order to make water resource utilization

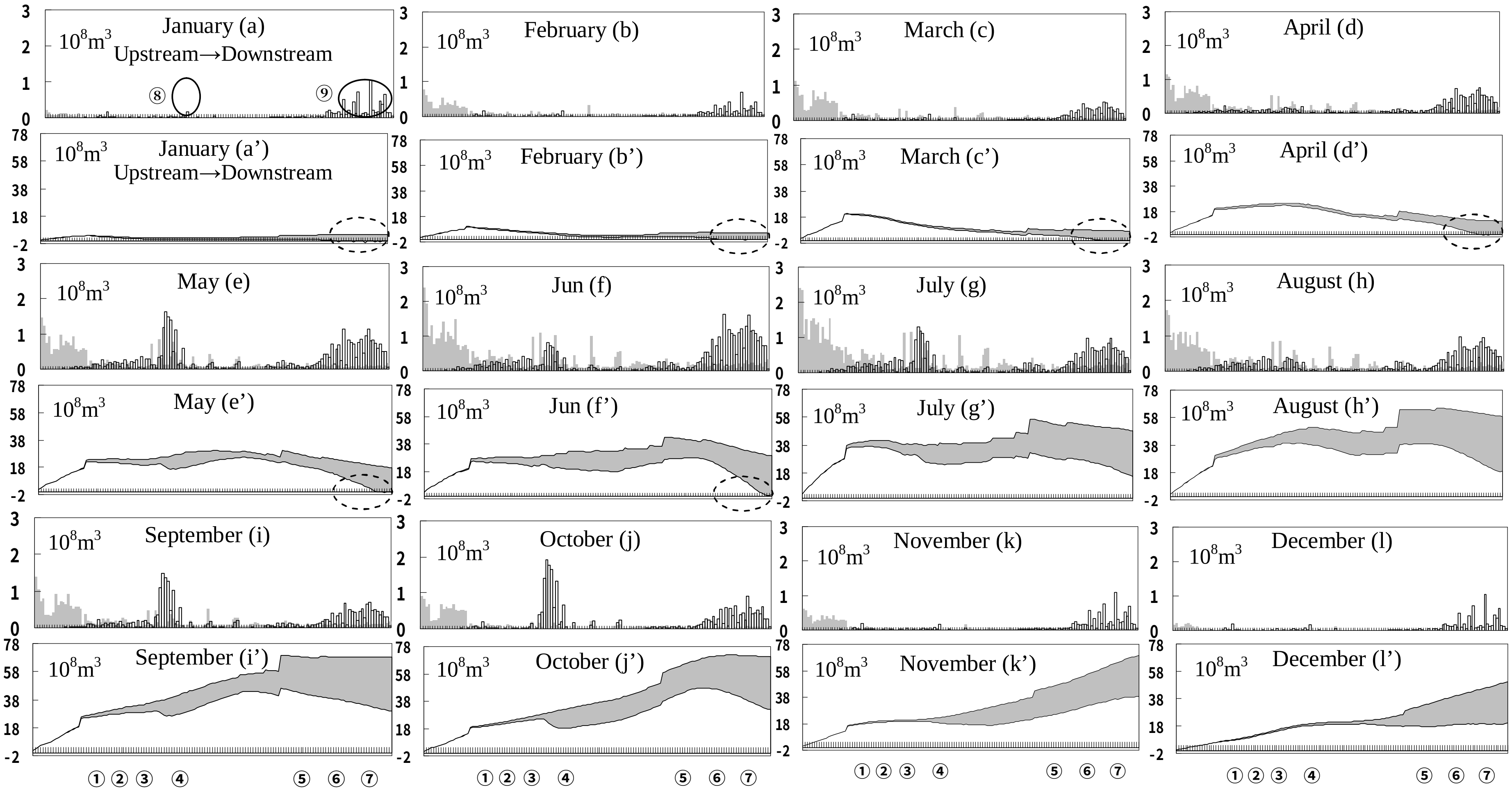
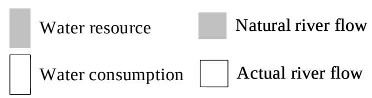


Fig.2 Monthly water supply and demand structure by county/city in 1997: (a)..(l) show spatial distribution of water resources and consumption; (a')..(l') show natural river flows and actual river flows; ①Lanzhou, ②Qingtongxia, ③Yinchuan, ④Baotou, ⑤Sanmenxia, ⑥Puyang, ⑦Jinan, ⑧ HetaoID, ⑨downstream ID; the inflow from tributaries to the main channel, they join the Yellow River at the county/city where they pour into the main course of the river. The figure is referred from Onishi *et. al* (2007)



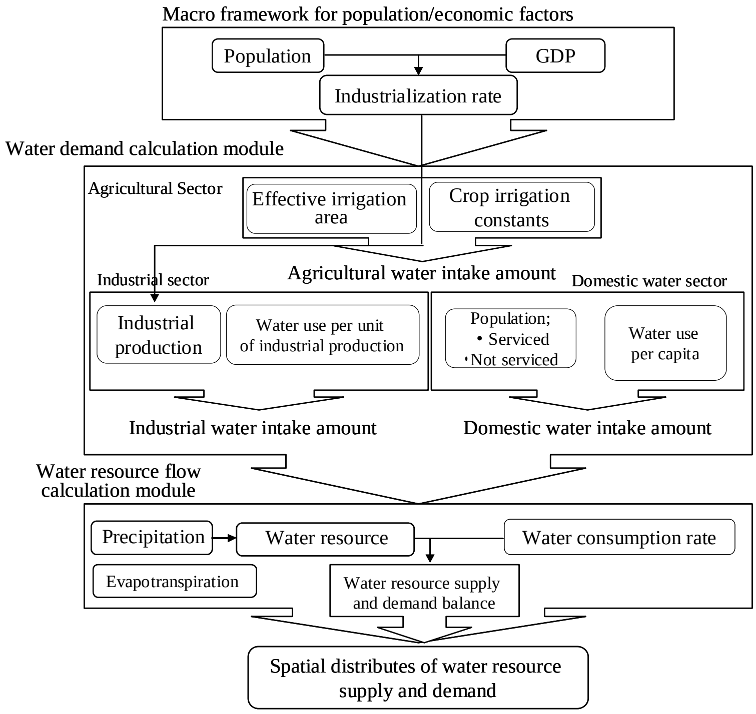


Fig. 1 Framework of water resource supply and demand model: The figure is created by Onishi.

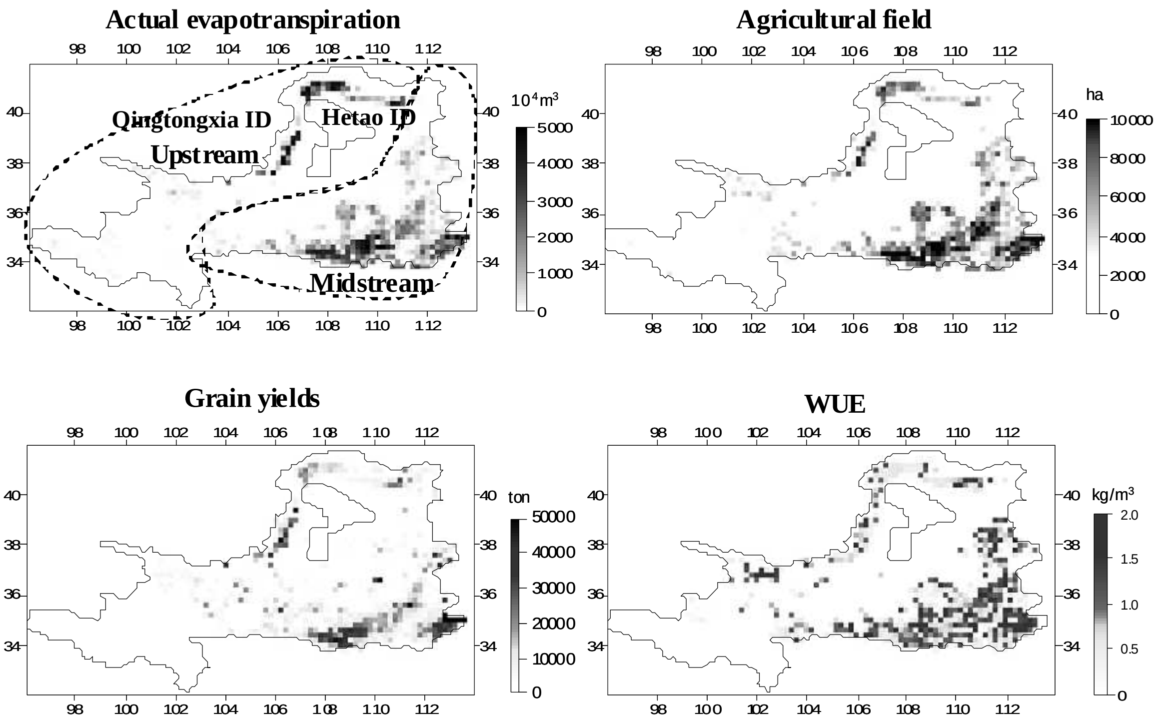


Fig. 3 Agricultural water use efficiency of 2000 in the Yellow River basin: The figure is created by Onishi.

more efficient. Of particular note, it is being suggested that the agricultural sector should sell its water-drawing permits to the industrial sector, because not enough water resources are currently being allocated to meet new demand from industrial uses. We therefore examined the current situation and issues for water rights trading in the Yellow River basin. Our findings are as follows: (1) Emissions trading is not actually being conducted under free market conditions, as the government is involved in the negotiation of transactions. (2) As a result, water rights trading are strongly nuanced in favor of economic compensation for vested interests. (3) The costs of water conservation measures should normally be the basis for the valuation of water rights, but because the methods to calculate those costs are not adequately established, their actual use is less than what is stipulated by legislation. Water rights trading can contribute to water conservation in the agricultural sector, and at the same time can increase production in the industrial sector without resorting to additional water withdrawals from other rivers. Thus, water rights trading can contribute to more efficient use of water resources. However, if water rights are not priced at the appropriate level, greater disparities are likely to arise between regions. It is therefore important to examine the socio-economic impacts of changes in water resources distribution, and to establish methods to calculate water rights pricing.

4. Conclusion

We studied on the relationship between economic development and water demand structure in the Yellow River basin. By summarizing above sub-studies, our research objective was to contribute to discussions about water resource management of the Yellow River basin.

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