# Progress of the Group Agricultural Hydrology and Water Resources

(2009-2013)

Submitted for international assessment

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# Contents

# PI's Vitae


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## 1 Education

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|---|---|
| Apr. 2001~ Mar. 2004 | PhD, Hydrology, Chiba University, Japan |
| Sep. 1995~ Jul. 1998 | M.Sc., Eco-hydrology, Graduate School of the Chinese Academy of Sciences, China. |
| Sep. 1991~ Jul. 1995 | B.Sc., Physical Geography, Hebei Normal University, China. |

## 2 Professional Experience

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|---|---|
| Mar. 2007~ | Current position |
| Jan. 2013~ Apr. 2013 | Visiting Scientist, Australian National University |
| Apr. 2004~ Mar. 2007 | Research Fellow, Institute of Industrial Science, the University of Tokyo, Japan |
| Aug. 1998~ Mar. 2001 | Research Assistant, Institute of Agricultural Modernization, Chinese Academy of Sciences, Shijiazhuang, Hebei Province, China. |

## 3 Honors and Awards (2009-2013)

(1) Best 10 papers award for young scientists, Committee of Physical Geography, China Geography Society, 2010 ($2^{nd}$ and corresponding author)

(2) Best 10 papers award for young scientists, Committee of Physical Geography, China Geography Society, 2010 ($2^{nd}$ and corresponding author, we obtain 2 of 10 awards in that year)

(3) Best 10 papers award for ecological studies, Scientific Committee of the China Ecosystem Research Network (CERN), 2011 ($2^{nd}$ and corresponding author)

(4) Wilmar Excellent teachers award, Institute of Genetics and Developmental Biology, 2012

(5) National Leading Young Scientists for Science and Technology Innovation, Ministry of Science and Technology, 2013

## 4 Editorial Duties

**Board member for**
**Chinese journals**

*Chinese Journal of Eco-Agriculture*
*South-to-North Water Transfers and Water Science & Technology*
**International journal**
*Geoenvironmental Disasters (Springer)*

**Manuscript reviewer for**
*Water Resources Research*
*Global Environmental Change*
*Journal of Hydrology*
*Hydrological Processes*
*Journal of Environmental Management*
*Agricultural Water management*
*Climatic Change*
*Landscape and Urban Planning*
*Land Use Policy*
*Acta Geographica Sinica (Chinese)*
*Chinese Journal of Hydraulics and Hydrology (Chinese)*
*Journal of Tsinghua University: Natural Sciences (Chinese)*
*Chinese Journal of Eco-Agriculture (Chinese)*

**Board membership**
Advisory Board on *the National Planning of Scientific and Technological Promotion during the 12th Five-Year Period*[①] *for Adaptation to Climate Change* (Sep 2009~ Feb 2010)
Selection Panel on *the Research Proposals in Agricultural and Rural Studies for the 12th Five-Year Period* (Sep 29~30 2010)

## 5 Conference organization

As Secretary General, Organized 2 conferences

(1) International Symposium on Environmental Changes and Efficient Use of Agricultural Resources, Shijiazhuang, China, Oct. 20~22, 2011. ~250 attendees including scientists from USA, Australia, Japan, Germany, Netherland, and Chinese academics.
(2) Forum on Water and Agriculture, Shijiazhuang, China, Sep. 17~18, 2013. ~200 attendees, including scientists from Australia, Japan, and domestic academics.

## 6 Funding and Laboratory Personnel

### *Funding*

Totally, our group has successfully competed 10 projects/subjects of funds during the period of 2009~2013, of which there are 4 from NSFC, 3 from MOST, and 3 from CAS. The total funds reached to 9.61M RMB Yuan. Around 62.2% of the funds are from national key research programme, i.e. MOST’s basic and R&D projects, 28.6% from Chinese Academy of Sciences, and 9.1% from NSFC. From the aspect of the research field, there are 9 projects focused on hydrological processes and water/energy cycle at different scales, 4 projects focused on climate change impacts assessment and adaptation strategies, from different supporting sources (Table 1).

① The 12th Five-Year Period refers to year 2011 through 2015.

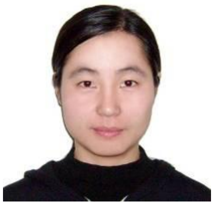
**Table 1 List of grants (2009-2013)**

| Grants name | Level | PI | Funds (RMB) | Period |
|---|---|---|---|---|
| **National Scientific Foundation of China (NSFC)** | | | | |
| Energy and water cycles in ground- and surface-water irrigated farmlands and up-scaling | Project | Y. Shen | 450K | 2009.1~2011.12 |
| Experimental study on vapor fluxes over an irrigated agricultural field based on isotopic and micrometeorological methods | Project | Y. Shen | 25K | 2010.7~2010.12 |
| Response of wheat-maize yield to continuous drying days under climate warming background in Northern China | Project | Y. Qi | 220K | 2011.1~2013.12 |
| Data assimilation by combining microwave remote sensing observations and land surface models for monitoring soil moisture in agricultural region | Project | Y. Guo | 180K | 2011.1~2013.12 |
| Sub-total | | | 875K | |
| **Ministry of Science and Technology (MOST)** | | | | |
| Assessing the biological carbon sequestration and implementation technologies in China | Subject (State R&D project) | Y. Shen | 2420K | 2009.11~2011.12 |
| Assessing impacts of climate change on water resources and its potential trend in Northwestern Arid Region of China | Subject (973 project) | Y. Shen | 2410K | 2010.6~2014.12 |
| Improving Carbon Storage and reducing GHGs emission in the field with low productivity in East Hebei Plain | Sub-theme (State R&D project) | Y. Shen | 1100K | 2013.1~2016.12 |
| Sub-total | | | 5980K | |
| **Chinese Academy of Sciences (CAS)** | | | | |
| Hydrological cycles and climate change effects in Northern China Agricultural region | Project | Y. Shen | 1150K | 2009.1~2011.12 |
| Monitoring and modeling soil moisture in agricultural region using remote sensing | Project | Y. Guo | 100K | 2009.9~2011.12 |
| Measurement and modeling agricultural water consumption in the Northern China: from field to regional scales | Project | Y. Shen | 1500K | 2010.1~2012.12 |
| Sub-total | | | 2750K | |
| Total | | | 9.61M | |

## *Laboratory Personnel*

Currently, there are 15 members in this lab, including 5 faculty members, 1 Postdoc fellow, 3 PhD students, and 6 master students. In past 5 years, 1 Postdoc fellow, 3 PhD students, and 12 Master students graduated from the lab. The postdoc researcher became a professor at Hebei University of Science and Technology in 2013, and the 3 PhD students are working in academic research institutes. The details of the current lab members are as follows,

**Table 2 Lab members' information**

| **Member** | **Role** | **Background** | **Research fields** |
|---|---|---|---|
| <br>Dr. Yanjun Shen | Group leader<br>Professor | B.Sc. in Physical Geography<br>M.Sc. in Ecology<br>PhD in Hydrology | Hydrology<br>Land surface processes<br>Climate change impact assessment<br>Water resources modeling |
| <br>Dr. Yongqing Qi | Research Associate | B.Ag. in Agronomy<br>M.Sc. in Ecology<br>PhD in Physical Geography | Agro-meteorology<br>Climatic extremes impacts on agriculture and adaptation |
| <br>Dr. Ying Guo | Research Assistant | B.Sc in GIS and Cartography<br>M.Sc. in Microwave Remote Sensing<br>PhD in Microwave RS | Soil moisture remote sensing,<br>Basin hydrology modeling, |
| <br>Dr. Yucui Zhang | Research Assistant | B.Sc. in Environmental Science<br>PhD in Agricultural hydrology | Water consumption and WUE using micro-meteorological and Isotopes |
| <br>Dr. Leilei Min | Research Assistant | B.Sc in Geography<br>M.Sc. in Physical geography<br>PhD in Hydrology | Subsurface hydrology |
| <br>Dr. Dengpan Xiao | Postdoc fellow | B.Sc. in Environmental Engineering<br>M.Sc in Ecology<br>PhD in Physical Geography | Crop modeling<br>Regional water use efficiency modeling |

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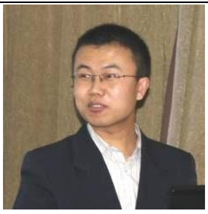
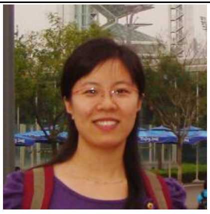
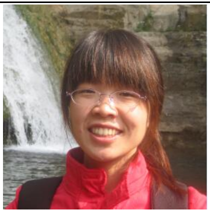
|  Hongwei Pei | PhD student | B.Sc. in Geography | Groundwater response to agricultural activities<br>Comparative study of agriculture and water in NCP and USHP |
|  Jing Zhang | PhD Student | B.Sc. in Geography<br><br>M.Sc. in Meteorology | Drought monitoring |
|  Xifang Wu | Master student | B. Sc. in Geo-information science | Spatial variation of crop water consumption and Crop water footprint |
|  Xingran Liu | Master student | B.Sc. in Geo-information science | Evapotranspiration estimation using remote sensing data |
|  Xuepeng Pan | Master student | B.Sc. in information engineering | Crop classification and agricultural land use change |
|  Bingdan Jing | Master student | B.Sc. in Hydrogeology | Soil water movement and soil water- groundwater interactions |

# 7 Selected Publications (2009~2013)

## *Patents granted*

1. A new type of soil transact scratch sampler (ZL 2010 2 0211369.4), granted on the 19th, Jan. 2011.
2. A simple water distillation device (ZL 2009 2 01021885), granted on the 1st, Nov. 2009.
3. A quantitative indicator of irrigation (ZL 2008 2 0076805.4), granted on the 28th, Jan. 2009.

## *Book's Chapters*

1. **<u>Shen, Y.J.</u> & Liu, C.Z.**, 2010. Potential impacts of climate warming to hydrology and water resources in Northern China, 37-51pp. In: Xia, J. (ed.): *Impacts of Climate Change on Water Resources and the Adaptation Strategies in Northern China* (*Blue paper of China Water Watch series*), Chinese Science Press (Beijing).
2. Liu, C.M., **<u>Shen, Y.</u>J.** & Zheng, H.X., 2013. Chapter 2, Water cycle and water balance, 21-41pp, Chapter 3, Geographical distribution of hydrological variables and hydrological zoning, In: Liu, C., Zhou, C., Yu, J., Li, L., and Zhang, Y.C. (eds): China Hydro-Geography, Chinese Science Press (Beijing).

## *Guest Editor of Journal Special Issues*

1. **<u>Shen, Y.</u>**, Chen, Y., Liu, C., Smettem, K., Special Issue on *Ecohydrology of the inland river basins in the Northwestern Arid Region of China, Ecohydrology*, 6 (6), 2013.
2. **<u>Shen, Y.</u>**, Special Issue on Sustainability of the agriculture and groundwater in the North China Plain, Chinese Journal of Eco-Agriculture, 22 (8), 2014. (In Chinese with English abstracts)
3. **<u>Shen, Y.</u>**, Special Issue on Environmental changes and Efficient Use of Agricultural Resources, Chinese Journal of Eco-Agriculture, 19 (5), 2011. (In Chinese with English abstracts)

## *Peer-reviewed papers at international journals*

1. **<u>Shen, Y.*</u>**, Zhang, Y., Scanlon, B., Lei, H., Yang, D., Yang, F., 2013. Energy/water budgets and productivity of the typical croplands irrigated with groundwater and surface water in the North China Plain, Agricultural and Forest Meteorology, 181, 133-142.
2. **<u>Shen, Y.*</u>**, Li, S., Chen, Y., Qi, Y., Zhang, S., 2013. Estimation of regional irrigation water requirement and water supply risk in the arid region of Northwestern China 1089-2010, Agricultural Water Management, 128, 55-64.
3. **<u>Shen, Y.*</u>**, Chen, Y., Liu, C., Smettem, K., 2013. Ecohydrology in the inland river basins in the Northwestern Arid Region of China, Ecohydrol., 6 (6), 905-908.
4. **<u>Shen, Y.*</u>**, Oki, T., Kanae, S., Hanasaki, N., Utsumi, N., Kiguchi, M., 2013. Projection of future world water resources under SRES scenarios: An integrated assessment, Hydrological Sciences Journal, DOI:10.1080/02626667.2013.862338
5. Zhang, Y., **<u>Shen, Y.*</u>**, Xu, X., Sun, H., Li, F., Wang, Q., 2013. Characteristics of the water–energy–carbon fluxes of irrigated pear (Pyrus bretschneideri Rehd) orchards in the North China Plain, Agricultural Water Management, 128, 140-148.
6. Yuan, Z., **<u>Shen, Y.*</u>**, 2013. Estimation of agricultural water consumption from meteorological and yield data: A case study of Hebei, North China, PLoS ONE, 8 (3), e58685.
7. Zhang, Y., **<u>Shen, Y.*</u>**, Chen, Y., Wang, Y., 2013. Spatial characteristics of surface water and groundwater using isotope method in Tarim River Basin, Northwestern China, Ecohydrol. 6 (6), 1031-1039.
8. Hu, S., **<u>Shen, Y.*</u>**, Chen, X., Gan, Y., Wang, X., 2013. Effects of saline water drip irrigation on soil salinity and cotton growth in an oasis field, Ecohydrol., 6 (6), 1021-1030.
9. Wang, Y., **<u>Shen, Y.*</u>**, Chen, Y., Guo, Y., 2013. Vegetation dynamics and their response to hydroclimatic factors in the Tarim River Basin, China, Ecohydrol. 6 (6), 927-936.
10. Ye, Z., **<u>Shen, Y.</u>**, Chen, Y., 2013. Multiple methods for calculating minimum ecological flux of the desiccated Lower Tarim River, Western China, Ecohydrol. 6 (6), 1040-1047.
11. Li, Z., Chen, Y., **<u>Shen, Y.</u>**, Liu, Y., Zhang, S., 2013. Analysis of changing pan evaporation in the arid region of Northwest China, Water Resources Research, 49 (4), 2205-2212.
12. Guo, B., Chen, Y., **<u>Shen, Y.</u>**, Li, W., Wu, C., 2012. Spatially explicit estimation of

domestic water use in the arid region of northwestern China 1985-2009, Hydrological Sciences Journal. 58 (1), 162-176.

13. Shi, Y., Xiao, J., **Shen, Y.**, Yamaguchi, Y., 2012. Quantifying the spatial differences of landscape change in the Hai River Basin, China, in the 1990s, Int. J. Remote Sens. 33 (14), 4482-4501.
14. Zhang, Y., **Shen, Y.***, Sun, H., Gates, J., 2011. Evapotranspiration and its partitioning in an irrigated winter wheat field: A combined isotopic and micrometeorologic approach, Journal of Hydrology, 408, 203-211.
15. Lei, H., Yang, D., **Shen, Y.**, Liu, Y., Zhang, Y. 2011. Evaluation of the Simple Biosphere Model in simulating evapotranspiration and carbon dioxide flux in the wheat-maize rotation croplands of the North China Plain. Hydrological Processes, 25, 3107-3120.
16. Chen, Y., Ye, Z., **Shen, Y.**, 2011. Desiccation of the Tarim River, Xinjiang, China, and mitigation strategy, Quaternary International, 244, 264-271.
17. **Shen, Y.***, Chen, Y., 2010. Global perspective on hydrology, water balance, and water resources management in arid basins, *Hydrological Processes*, 24(2), 129-135.
18. **Shen, Y.***, Liu, C., Liu, M., Zeng, Y., 2010. Change in Pan evaporation over the past 50 years in the arid region of China, *Hydrological Processes*, 24(2), 225-231.
19. Sun, H., **Shen, Y.***, Yu, Q., Flerchinger, G.N., Zhang, Y., Liu, C., Zhang, X., 2010. Effect of precipitation change on water balance and WUE of the winter wheat-summer maize rotation in the North China Plain, *Agricultural Water Management*, 97(8), 1139-1145. (Corresponding author)
20. Liu, M., **Shen, Y.***, Zeng, Y., Liu, C., 2010. Change trend of Pan evaporation and its cause analysis over the past 50 years in China, *Journal of Geophysical Sciences*, 20, 557-568. (Corresponding author)
21. Lei, H., Yang, D., Lokupitiya, E., **Shen, Y.**, 2010. Coupling land surface and crop growth models for predicting evapotranspiration and carbon exchange in wheat-maize rotation croplands, *Biogeosciences*, 7, 3363-3375.

### *Peer-reviewed papers at Chinese journals*

22. Li, S. **Shen, Y.**, 2013. Impacts of climate warming on the changes in agricultural heat resources in Northwestern Arid Region in China, *Chinese Journal of Eco-Agriculture*, 21(2), 227-235.
23. Wang, Q., **Shen, Y.**, Pei, H., Tian ,H., Li, F., Pei, Y., 2013. Characteristics of deep soil water dynamics and the percolation estimation in irrigated cropland in the North China Plain, *South-to-North Water Transfers and Water Science & Technology*, 11 (1): 155-160. (in Chinese with English abstract)
24. Zhang, Y., Sun, H., **Shen, Y.**, Qi, Y., 2012. Application of hydrogen and oxygen stable isotopes technique in the water depletion of ecosystems, *Scientia Geographica Sinica*, 32 (3): 289-293. (in Chinese with English abstract)
25. Hu, Q., **Shen, Y.**, Chen, F., Qi, Y., Zhang, Y., 2012. Spatial-temporal change of biological productivity and carbon capture capability in the mid-south of Hebei province, *Scientia Geographica Sinica*, 32 (2): 219-224. (in Chinese with English abstract)
26. **Shen, Y.**, Liu, C., 2011. Agro-ecosystems water cycles of the typical irrigated farmland in the North China Plain, *Chinese Journal of Eco-Agriculture*, 19 (5): 1004-1010. (in Chinese with English abstract)
27. Qi, Y., Sun, H., **Shen, Y.**, 2011. Characteristics and effects of climate warming on winter wheat/summer maize cropping system in recent 50 years in the piedmont of Mount Taihang, *Chinese Journal of Eco-Agriculture*, 19 (5) : 1048-1053. (in Chinese with English abstract)
28. Zhang, Y., Cai, Y., Parkes, S., McCabe, M., Yang, F., Wang, Q., **Shen, Y.**, 2011. Preliminary research on isotopic composition of water vapor in irrigated fields, *Chinese Journal of Eco-Agriculture*, 19 (5): 1060-1066. (in Chinese with English abstract)

29. Pei, H., Sun, H., **Shen, Y.**, Liu, C., 2011. Water balance and yield-increasing efficiency of irrigation of winter wheat under different irrigation schemes, *Chinese Journal of Eco-Agriculture*, 19 (5): 1054-1059. (in Chinese with English abstract)
30. Hu, Q., Qi, Y., Hu, Y., Zhang, Y., Wu, C., Zhang, G., **Shen, Y.**, 2011. Changes and driving forces of land use/cover and landscape patterns in Beijing-Tianjin-Hebei region, *Chinese Journal of Eco-Agriculture*, 19 (5): 1182-1189. (in Chinese with English abstract)
31. Yang, F., Qi, Y., Zhang, Y., Scanlon, B., **Shen, Y.**, 2011. Comparative advantages of large aperture scintillometer and eddy covariance instrument for measuring evapotranspiration in irrigated farmlands, *Chinese Journal of Eco-Agriculture*, 19 (5): 1067-1071. (in Chinese with English abstract)
32. Yang, F., Zhang, Y., Qi, Y., Hu, W., Scanlon, B., **Shen, Y.**, 2011., Effect of high voltage wire electromagnetic field intensity on Large Aperture Scintillometer (LAS) observation, *Chinese Journal of Eco-Agriculture*, 19 (2): 436-440. (in Chinese with English abstract)
33. Yang, S., **Shen, Y.**, Guo, Y., Kondoh, A., 2011. Monitoring soil moisture by apparent thermal inertia method, *Chinese Journal of Eco-Agriculture*, 19 (5): 1157-1161. (in Chinese with English abstract)
34. Chen, F., **Shen, Y.**, Li, Q., Guo, Y., Xu, L., 2011., Spatio-temporal variation analysis of ecological systems NPP in China in past 30 years, *Scientia Geographica Sinica*, 31 (11): 1409-1414. (in Chinese with English abstract)
35. Chen, F., **Shen, Y.**, Hu, Q., Qi, Y., Zhang, Y., 2011. Responses of NDVI to climate change in the Hai Basin, *Journal of Remote Sensing*, 15 (2): 215-221. (in English and Chinese)
36. Xu, L., Guo, Y., Liu, M., Hu, Q., Chen, F., Yang, S., **Shen, Y.**, 2011. Analysis of temperature trends and change points in the Haihe river basin over the last 50 years, *Resources Science*, 33 (5): 995-1001. (in Chinese with English abstract)
37. Yuan, Z., **Shen, Y.**, Chu, Y., Qi, Y., 2010. Simulation of the energy and carbon fluxes over a typical agricultural field in North China Plain, Environmental Sciences, 31 (1): 41-48. (in Chinese with English abstract)
38. Xu, L., Liu, Y., **Shen, Y.**, 2010. Variations and change of the inflow to Huangbizhuang Reservior and its causual factors, *South-to-North Water Transfers and Water Science & Technology*, 8 (5): 46-48. (in Chinese with English abstract)
39. Zhang, Y., **Shen, Y.**, Pei, H., Yang, S., Characteristics of evapotranspiration and water use efficiency of a winter wheat field, *South-to-North Water Transfers and Water Science & Technology*, 8 (5): 39-41. (in Chinese with English abstract)
40. Liu, M., **Shen, Y.***, Zeng, Y., Liu, C., 2010. Change in pan evaporation over the past 50 year in China and its driving factors, *Acta Geographia Sinica*, 64 (3): 259-269. (in Chinese with English abstract)
41. Yuan, Z., **Shen, Y.**, Chu, Y., Qi, Y., 2009. Spatial and temporal changes in precipitation and temperature over the past 40 years in Hai River Basin, *Research on Soil and Water Conservation*, 16 (3): 24-26. (in Chinese with English abstract)

# 8 Major Research Interests and Selected Research Projects

## *8.1 Background*

The research group of Agricultural Hydrology and Water Resources was established in spring of 2007. This group mainly focus on the severely water stressed basins/regions, e.g. Hai River Basin or the North China Plain in the central north of China, and the arid basins/region in the northwestern China. In Hai River Basin (HRB), the total water use, paralleled with the rapid economic growth in China in past 3 decades, increased dramatically and even exceeded the availability of renewable annual water resources. Agriculture in this basin plays a very important role in the food security systems of China. And water withdrawal for irrigation in HRB occupies around 70% of total water use, becoming the major reason to groundwater depletion. Agriculture produces large amount of grain food, on the other hand, it also causes serious environmental problems, such as regional decline of groundwater level, drying-up of rivers, shrinking and disappearance of wetlands, etc. While, in the northwestern China, the water resources has been also overexploited for economic development, and resulted in serious ecological degradation as well. The sustainable of oasis ecosystems and society are facing to unprecedented threatens from the water shortage. Therefore, the research mission of this group is to study the agricultural aspect of hydrological cycles, such as, water processes in agro-ecosystems, the interactions between agriculture and basin hydrology, the hydrological basis for agricultural exploitation, the hydrological effects of agricultural technologies, etc.

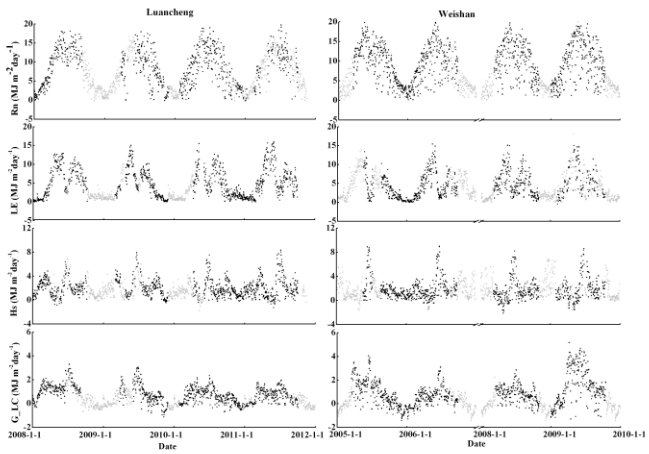
## 8.2 Major research achievements

During the past 5 years, we made some research progress in interpretation of the crop evapotranspiration, water consumption structures, and groundwater depletion at field and regional scales in the North China Plain. In the northwestern arid region, we investigated the impacts of climatic change on vegetation and crop phenology, agricultural water demand and the potential trend of water supply and demand in future under RCP scenarios.

### 8.2.1 Highlights of studies in agricultural water consumption in NCP

- **Updated water budgets in different crop seasons and proposed cropping pattern adjustment (Shen et al., AgrForMet, 2013)**

Through continuous 4 years of energy and water fluxes observation, the water balance of wheat-maize crop land was updated and determined. Different from the measurement by weighing lysimeter, which measured the annual ET from wheat-maize field can reach to 800 - 900 mm, the updated water balance showed ET is only 675mm/year, with about 420mm in wheat season and 255mm in maize season. The water deficit in wheat season (with a precipitation of 150 mm) is about 270mm, relies on pumping groundwater to irrigate; while, the water surplus in maize season is observed for 70 mm because of the relatively abundant precipitation of 325 mm. As a result, the annual water deficit is about 200 mm in the wheat-maize cropping system in this region. This deficit caused the continuous groundwater depletion at a rate of around 0.85 m/year. According to these results, we proposed to change the wheat-maize double cropping system to single maize in the NCP to conserve the groundwater. Through adapting the new maize varieties and cultivation technology, the single maize has potential to obtain almost the same productions.




**Water budgets for typical cropland（mm）**

| | ET | P | P-ET |
|---|---|---|---|
| Annual | 675 | 475 | -200 |
| Wheat | 420 | 150 | -270 |
| Maize | 255 | 325 | + 70 |

**Fig. 1 Multi-year observation of energy fluxes in irrigated field (left) and the synthesized water budgets for different crop seasons (right).**

- **<u>Determination of ET partitioning and root water uptake depth using combined micrometeorologic and isotopic method</u> (Zhang et al., J Hydrol., 2011)**

By a combination of eddy covariance flux observation and a mini-lysimeter, which is used to determine the soil evaporation, we divided the evaporation (E) water loss through soil surface occupies around 30% of the total water consumption, i.e. evapotranspiration (ET), over wheat growing season. And the amount of E can reach about 160 mm (Fig. 2a) in whole wheat season, equivalent to 2 irrigation applications. Through a Keeling plot model, we successfully separated the E and T using stable isotope method. The separation results at two different days were compared with mini-lysimeter and showed very good consistence (Fig. 2b).

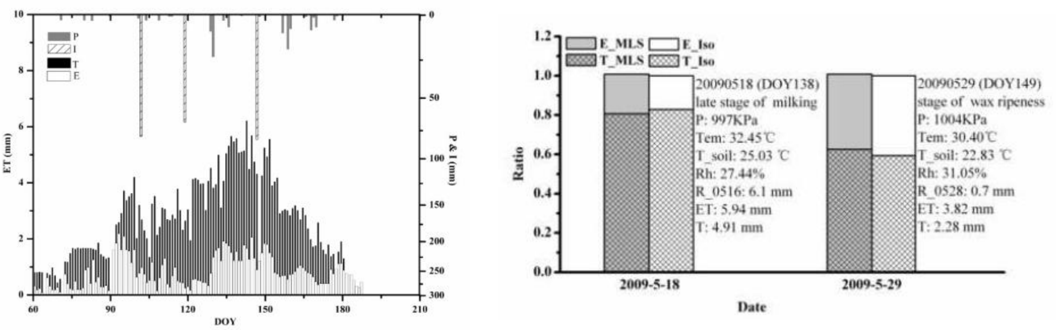



**Fig. 2 Daily evaporation (E), Transpiration (T), precipitation (P) and irrigation (I) during winter wheat season in 2009 measured by EC and mini-lysimeter (left) and comparison of ET separations using isotope and mini-lysimeter methods (right).**

Major root water uptake depth is important for irrigation water management, such as determine the planned wetting depth. We analyzed the isotopic composition of wheat stem water and soil water at different layers and used a mixing model to determine the major water uptake depth. The results shows that wheat mainly uptake the soil water in 0-40 cm layer. And the soil evaporation depth is about 20 cm (Fig. 3). So, we suggested that the planned irrigation wetting depth can be reduced at least to 40 cm, rather than the traditional 100 cm, as a means of water conservation. Measures for decreasing evaporation are also proposed. Widespread implementation of these practices could amount to a water savings of almost 100 million $m^3$/yr across Hebei Province.

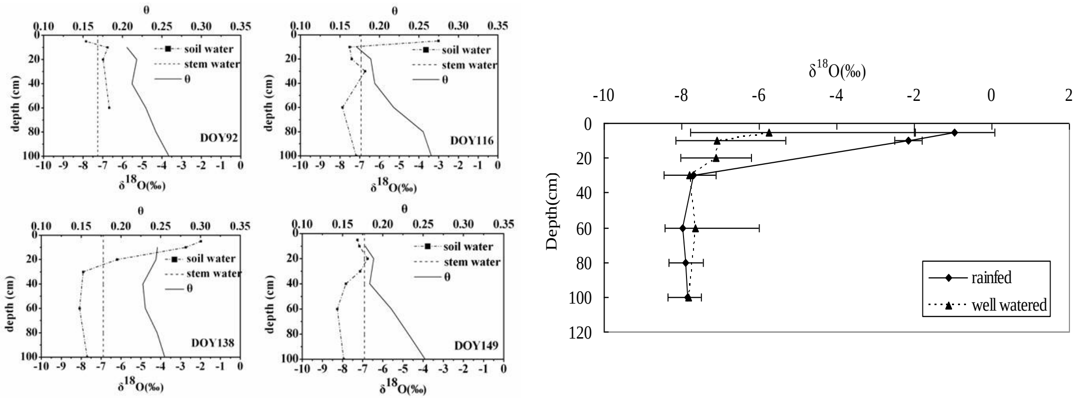



**Fig. 3 Determination of major root water uptake depth (left) and evaporation depth (right).**

- **<u>Deep soil water dynamics and percolation estimation using tracer balance method</u> (Wang et al., SNWT & WST, 2013)**

Quantifying the deep drainage in an irrigated region is extremely important to close the water balance and has great implications to water management. Through monitoring a large-depth soil moisture profile, we analyzed the soil moisture dynamics and its controlling factors. Soil moisture varies seasonally as responses to the precipitation and irrigation, but the absolute water content in different depth is controlled by the soil texture.

We also used a mass balance method to determining the deep drainage of the soil water. During the period of Mar. 26 ~ Sep. 27, 2012, the effective precipitation is of 408 mm, irrigation water input to the field is about 340 mm, we calculated the deep drainage is about 91 mm through the mass balance of chloride in the 0-550 cm soil profile. The evapotranspiration estimated through soil water balance is 557 mm in the same period, which agree greatly with the measurement from eddy covariance system, i.e. 542 mm.

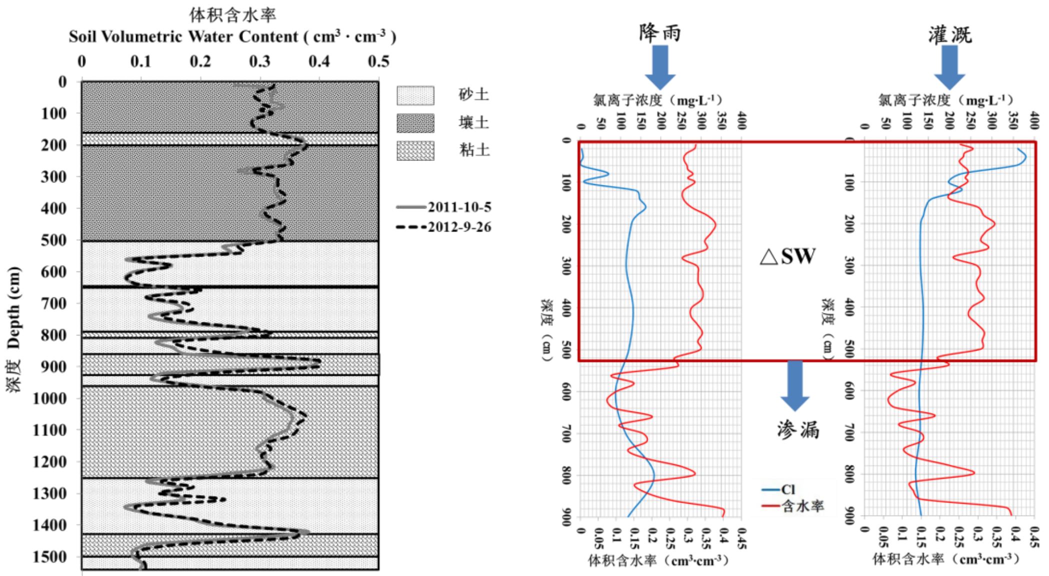



**Fig. 4 Soil moisture as controlled by soil texture in a large depth profile (left) and the chloride content change at the beginning and end of the study period (right).**

- **<u>Quantifying agricultural water consumption and accounting groundwater usage</u> (Yuan & Shen, PLoS ONE, 2013; Wu et al., Chinese J Eco-Agr, 2014)**

In a sense the high yield of crop cultivation in NCP is a trade-off of groundwater, therefore, accurately estimate agricultural water consumption and net groundwater irrigation is important to account the groundwater footprint of the grain productions in this region, and will help improve water management over the plain. We established a simple model to calculate evapotranspiration using the meteorological observations and statistical yield data. The model was validated using remote sensing ET data at county scale and showed good performance in ET estimation. Furthermore, groundwater extractions in the past decades were estimated using the ET estimated and the effective rainfall. The results revealed that the total groundwater consumed for grain production in the period of 1984 to 2008 is accounted for 140 $km^3$, which obtained a grain production gain of about 190 million tons caused averagely 7.4 m groundwater table drop over the NCP.

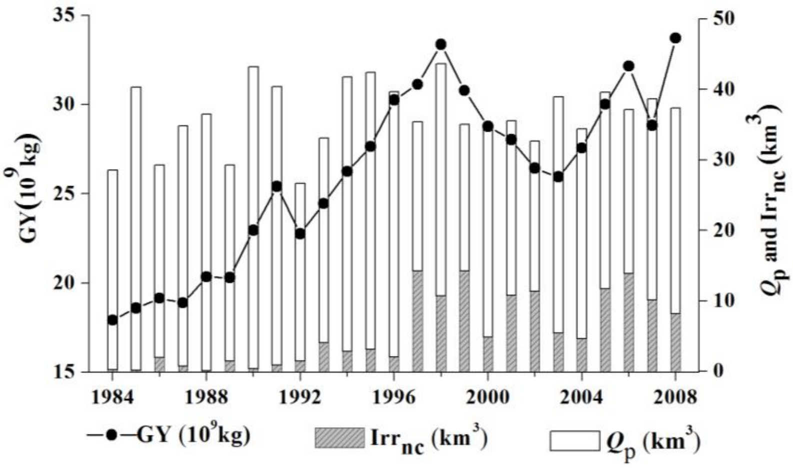



**Fig. 5 Estimated net irrigation (groundwater) consumption, grain yield, and effective precipitation in Hebei Plain during 1984-2008.**

In order to investigate the spatial details of different crop and the planting change, we used MODIS/NDVI data to extract wheat, maize, cotton, fruit trees changes over the NCP and calculated the evapotranspiration from those different agricultural land uses through an approach of combined FAO Penman equation and satellite observed vegetation greenness. There are obvious decrease of wheat planting area in the north part of the plain observed, the groundwater pumping was calculated decreased significantly as well.

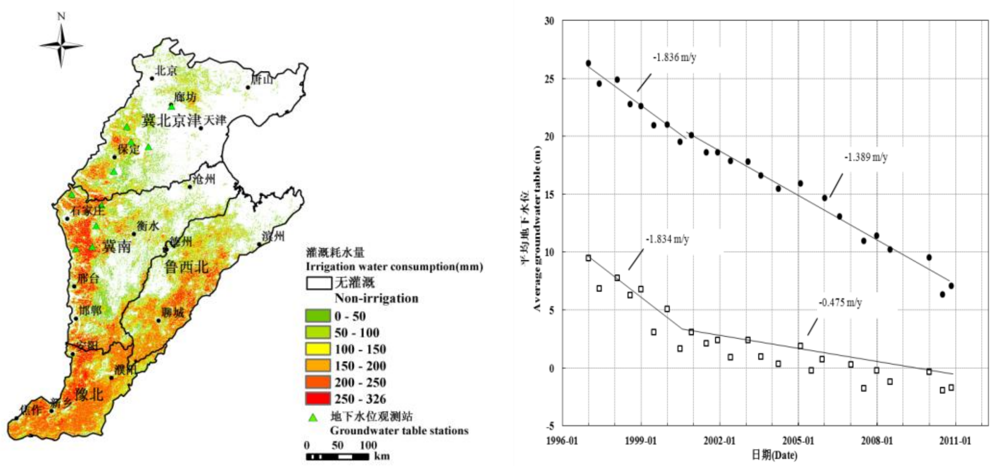



**Fig. 6 Estimated groundwater pumpage in 2000-2013 (left) and the changes in groundwater level in the**

**north (blank squares) and the south (filled dots) of the NCP (right)**

- **<u>Modeling water and energy balance and changes over HRB</u> (Guo et al., J Hydrol., submitted)**

In order to clarify the changes in water and energy balances over Hai River Basin (HRB) over the past decades and investigate the effect of human activities and climate change on land surface water and energy process and implications to hydrological cycle and water resources, a water and heat flux model was established based on water balance, energy balance and P-M equation. The net radiation, evapotranspiration, and sensible heat flux from 1981 to 2008 in HRB were simulated using the model.

Fig. 8 shows the Change rate of net radiation, evapotranspiration, aridity index, and Bowen Ratio from 1981 to 2008 in HRB, respectively. In the western, the net radiation mainly decreased in the HRB mountain area and increased in the cities and cropland where is more affected by human activity. It is shown a decreasing trend in the mid-south part of the basin where is the irrigated farming plain (Fig. 8a). The evapotranspiration increased in the mountain area especially in the Taihang Mountain where the greening project was carried out since 1980s. ET decreased in the urban regions, and increased in the irrigated farming plain and coastal lower plain such as the Heilonggang region where the croplands productivity was increase several times owing mainly to increase of irrigation areas (Fig. 8b).

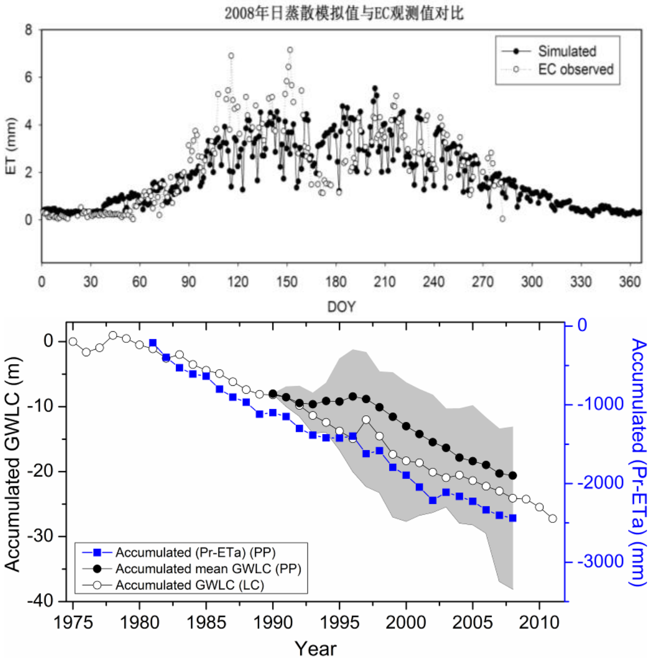



**Fig. 7 Model validation using eddy covariance observation (upper) and groundwater table (lower) in HRB.**

The water and heat environment change can be represented by the change rate of aridity index (i.e. the ratio of annual potential ET to precipitation) and Bowen ratio (i.e. the ratio of sensible to latent heat). During the past 28 years, the aridity index showed an increasing trend in large part of the basin except the southwestern part (Fig. 8c) indicating the environments becoming more arid. This is coincident with the M-K detection using only meteorological records (Liu et al., 2010). The increasing trend is most apparent along the Jing-Guang Railway, especially around the municipal regions, which indicates that the fast urbanization along the transportation line converts large portion of agricultural or natural vegetation covered lands to imperious surface. The Bowen Ratio also indicates the obvious increasing trend in these areas

(Fig. 8d). The increasing trend is most significant around the cities; it is shown a decreasing trend in the mountain area and Heilonggang region.

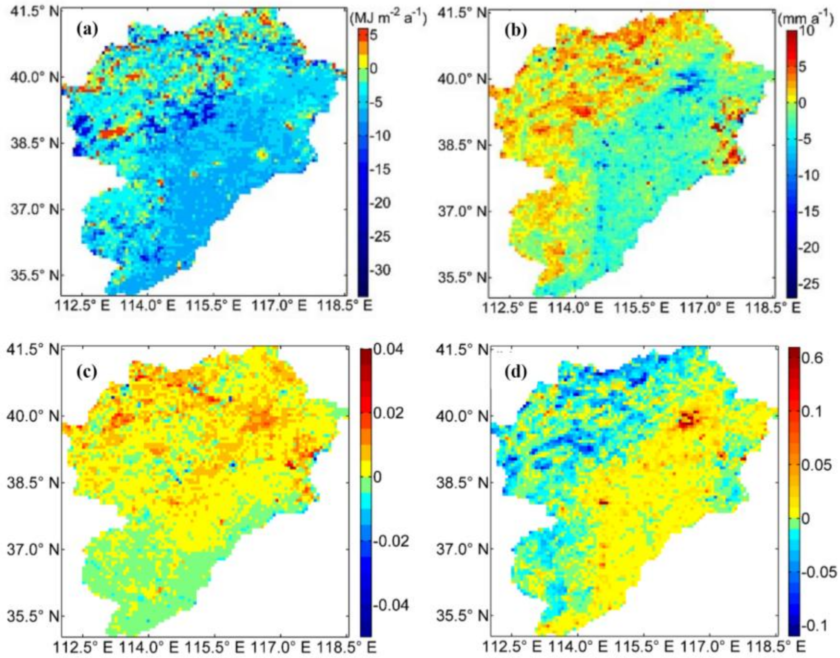



**Fig.8 Change rate of net radiation (a), evapotranspiration (b), aridity index (c) and Bowen Ratio (d) from 1981 to 2008 in HRB.**

Based on the simulation results and analysis, we can conclude that the energy balance composition has changed over the past 28 years. The Bowen Ratio and aridity index increased in cities apparently, which indicates that the human living environment becomes drier and hotter, the heat island effect enhanced, and the ecological environment deteriorated. The decreasing of Bowen Ratio and increasing of evapotranspiration in mountains reflects a positive ecological effect, but from the view of water resources generation, increase of evapotranspiration in mountain areas will definitely reduce the water yield capacity and lead to a negative effect on the water resources in this basin.

### 8.2.2 Highlights of studies in the northwestern arid region of China (NWARC)

- **Agricultural water demand and water supply risk in NWARC (Shen et al., Agricultural Water Management, 2013)**

Agricultural water use occupies more than 95% of the total water consumption in the arid region. It is crucial to manage the agricultural water use efficiently and effectively for maintaining a harmonized ecosystems and society in this hyper arid region. In the past 4 decades, the ecosystem was greatly degraded due to fast and mass exploitation of land and water. We estimated the irrigation demand for 5 main crops in the NWARC, wheat, maize, cotton, canola, sugar beets, including the planting structure change and the water demand change. It is accounted that more than 42 km$^3$ of water was irrigated in the year of 2010 and in some typical basins, the water supply faces great shortage risk in critical month, i.e. May, to meet the irrigation demand.

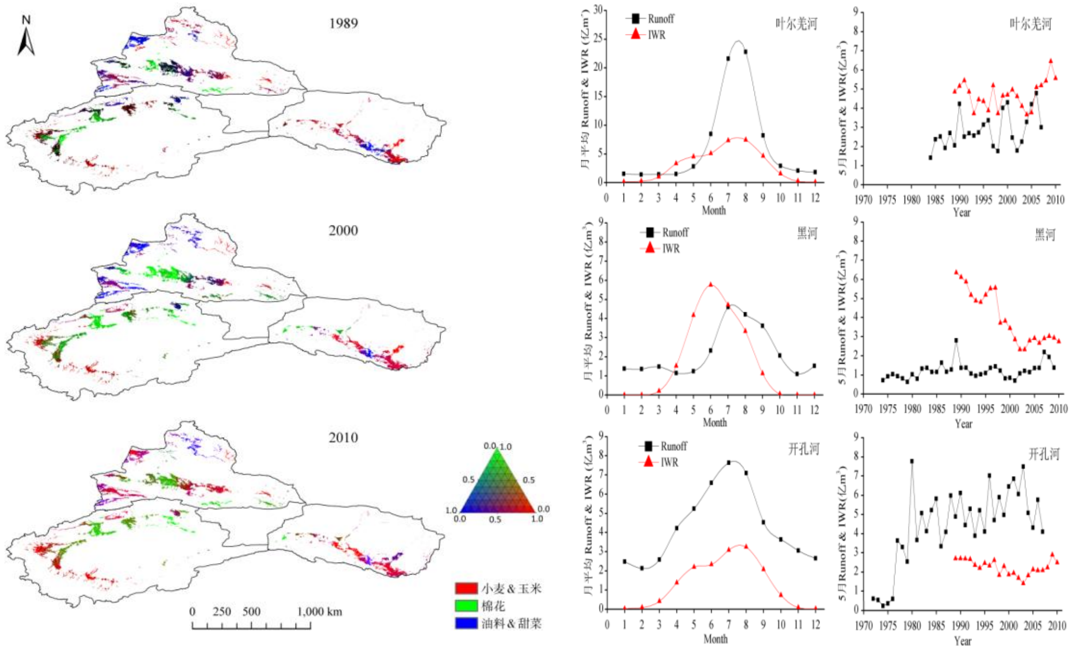



**Fig. 9 Cropping area changes in the different periods (left) and the comparison of irrigation water requirement and river discharge in typical river basins (right).**

- **Domestic water use and integrated water demand/supply assessment in NWARC (Guo et al., Hydrological Sciences Journal, 2013; Liu et al., Hydrological Sciences Journal, submitted)**

We established a model to estimate the domestic and industrial water use in the NWARC, and assessed the total water demand and supply. This can provide an integrated view of water resources and its allocation status in the different economic sectors, agriculture, industry, and domestic use. The domestic water use can be estimated through a log-log relationship between per capita daily water demand and GDP per capita, and the industrial water use be estimated using an exponential function between water use of per unit industrial added value and the GDP per capita.

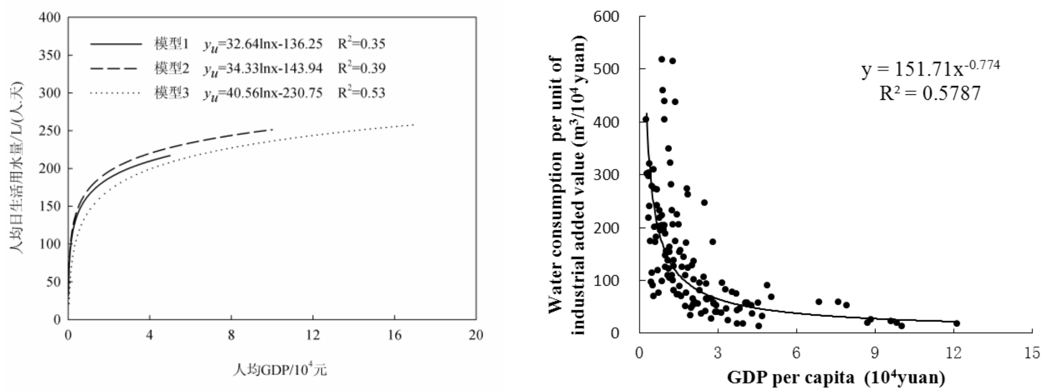



**Fig. 10 Models for domestic water use (left) and the industrial water use (right).**

The water stress level of different basins was evaluated by using a demand to availability index. The total water use increased from 32.0 $km^3$ in 1989 to 38.9 $km^3$ in 2000, and even 48.2 $km^3$ in 2010. The severe water stressed basins are also increased, both in the number of highly water stressed basins and the extent of the water stress. The water supply situation in the NWARC will facing more challenges in future years, especially under the climate change background, which leads to large uncertainty in water supplies.

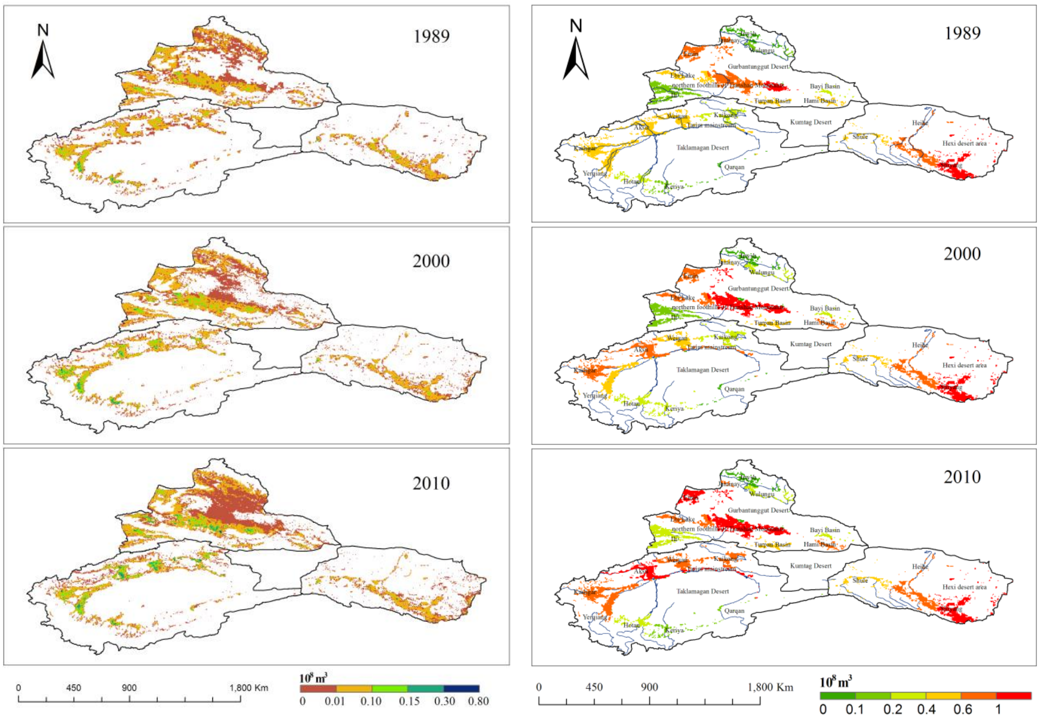



**Fig. 11 Distributions of total water use (left) and the water stress index (right) for different years.**

- **<u>Determining the vegetation dynamics and responses to hydro-climatic factors</u> (Wang et al., Ecohydrology, 2013; Wang et al., Theor. Appl. Climatology)**

Using GIMMS NDVI data investigated the vegetation dynamics and its responses to precipitation and temperature in Tarim river basin. The results showed that in the mountain area vegetation is largely relies on precipitation and snow melt but in oases the vegetation is mostly controlled by agricultural activities. Due to the enlargement of cropland in oases the riparian vegetation at the lower reaches of Tarim was observed significant degradation. Further investigations illustrated that the growing seasons of different part of the NWARC are prolonged at different extents.

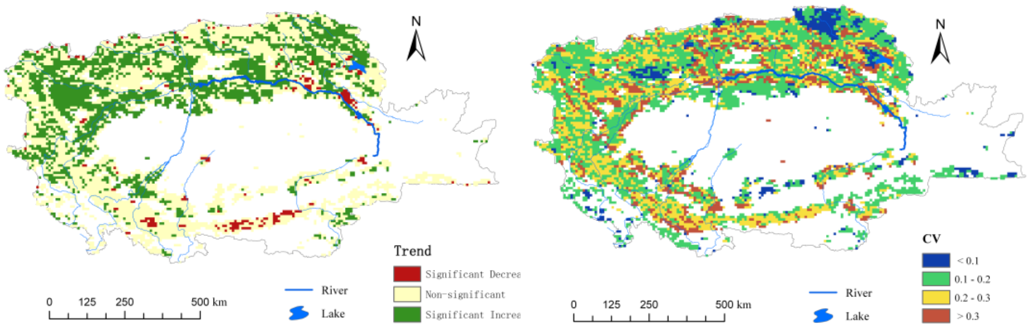



**Fig. 12 NDVI trend (left) and interannual variance (right) in Tarim river basin in 1982-2006.**

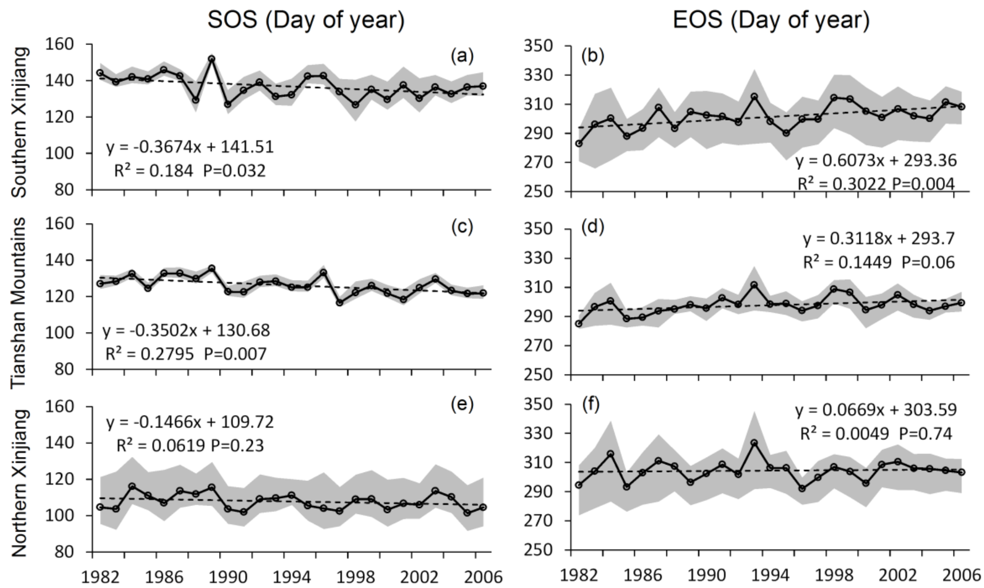



**Fig. 13 The start (SOS) and end (EOS) of growing seasons in Tarim (a), Tianshan (b), and Northern Xinjiang (c) respectively in 1982-2006.**

- **<u>Quantifying the contributions of climate and human activities to regional vegetation changes in the arid region</u> (Wang et al., HESS, 2014)**

The areal averaged vegetation index is usually used for evaluating the vegetation changes. However, in arid region, due to large area of sparse vegetation in the natural lands and small area of intense, high cover vegetation in the oases, the areal average of NDVI could not help understand whether the natural vegetation change or the human managed agricultural vegetation contributes more to the regional vegetation. In most cases, the natural land are undergoing a degradation, but the averaged NDVI show increase trend due to enlarged cropland where the irrigation make sure high cover vegetation appears. In this study, we proposed a numerical method to separate the contributions from climate variables, such as rainfall and temperature change, and the human activities, i.e. irrigation, in the lower reaches of Heihe river basin. The results shows about 51% of water supply from precipitation and runoff can interpret 51% of the interannual variation of regional vegetation cover, and at least 68% of vegetation increase, in which the contribution from precipitation can account for 18% and runoff for 50%.

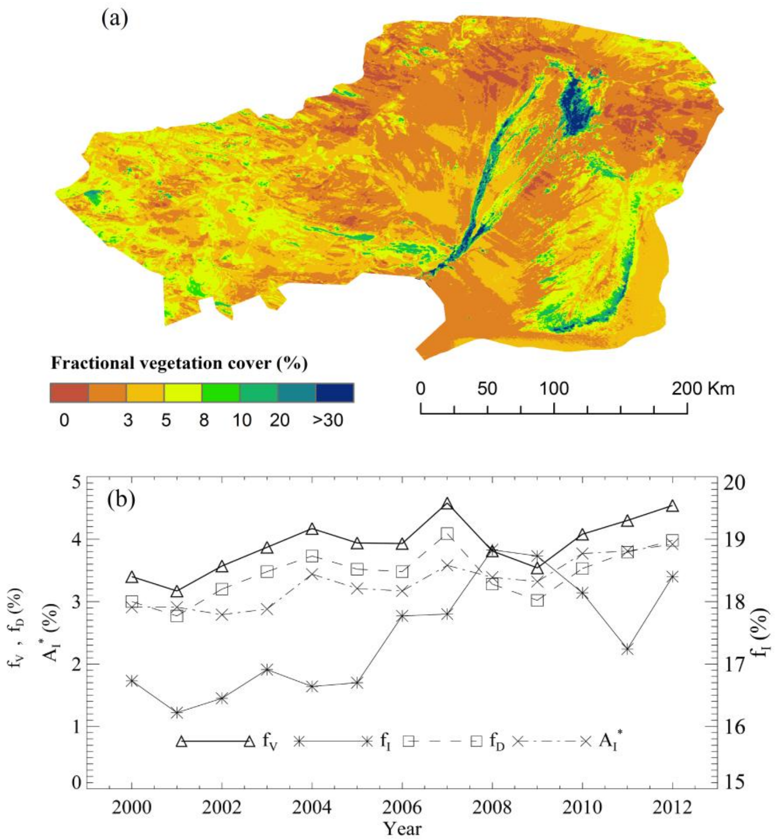



**Fig. 14 Spatial-temporal change of the growing season mean annual fractional vegetation cover (2000-2012). (a) Spatial pattern and (b) Trends in the regional annual fractional vegetation ($f_V$), desert ($f_D$), irrigated ($f_I$), and the fractional area of irrigation ($A_I^*$)**

### *8.2.3 International collaborations*

In the past 5 years, we established good collaborative relations with some international partners, especially, focusing on the agriculture and water resources sustainability, we are carrying out comparative studies among the North China Plain, US High Plains, and Murry-Darling basin in Australia with the University of Texas at Austin, and University of New South Wales, respectively. Table 3 lists the detailed information on our international collaborations and related research activities.

In the summer of 2010, we have conducted a joint field campaign on real time measurement of vapor isotopic fluxes over irrigated maize field in North China Plain with University of New South Wales (UNSW) and Australian Nuclear Science and Technology Organisation (ANSTO). We also have good collaboration with Australian National University, Prof. Graham Farquhar was invited through CAS Einstein Professorship project and gave lectures in CAS institute.

**Table 3 International collaborations**

| International partners | Collaboration fields | Periods | Counterpart person |
|---|---|---|---|
| The Australian National University | Climate change and food security, physiological ecology | 2012~ | Prof. Graham Farquhar<br>Graham.farquhar@anu.edu.au<br>Prof. Michael Roderick<br>Michael.roderick@anu.edu.au |
| The University of Texas at Austin | Sustainability of groundwater and agriculture | 2008~ | Dr. Bridget Scanlon<br>bridget.scanlon@beg.utexas.edu |

| | | | |
|---|---|---|---|
| The University of Nebraska-Lincoln | Groundwater budget and recharge systems | 2009~ | Dr. John B. Gates jgates2@unlnotes.unl.edu |
| The University of New South Wales | Modeling basin hydrology and agriculture | 2008~ | Dr. Matthew McCabe mmccabe@unsw.edu.au |
| CSIRO/Land and Water | Climate change and hydrology | 2007~ | Dr. Lu Zhang lu.zhang@csiro.au |
| Chiba University | Agriculture and its effects on basin ecological services | 2007~ | Prof. Akihiko Kondoh kondoh@faculty.chiba-u.ac.jp |
| The University of Tokyo | Climate change and global water resources | 2007~ | Prof. Taikan Oki taikan@iis.u-tokyo.ac.jp |

## 8.3 Future works

During past 5 years, most of our efforts are put to building the research capacity, such as the field experimental facilities, human resource construction, and international collaborations. There are some initial/preliminary results obtained and published in international journals. It is, however, still far away from the missions and goals of our group, exploring the mechanism of agriculture and hydrology interactions. Therefore, lots of research tasks still remain for the next several years. They are,

- To quantify accurately the relationship between agricultural water use and groundwater budget and seek the best way for keeping high grain productions and groundwater conservation, i.e. change the planting and cropping systems
- To modeling the basin hydrological changes during past 40 years in HRB using multi models
- To continue the analysis of nation-wide hydro-climatic changes as well as the extremes and study their implications to agriculture and water resources
- To enhance the research ability of the group and make it to be the special one in China

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