



Tackling Water Security Challenges in the Beijing-Tianjin-Hebei Region

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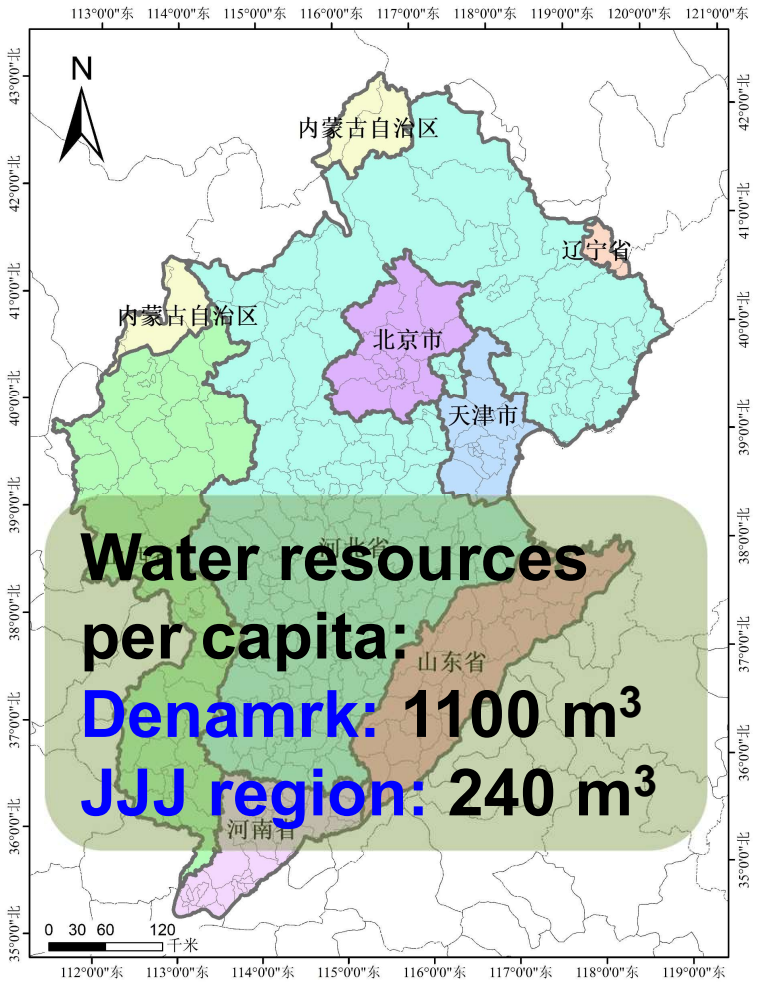
Water crisis in the JJJ region



Water resources per capita:
Denamrk: 1100 m^3
JJJ region: 240 m^3

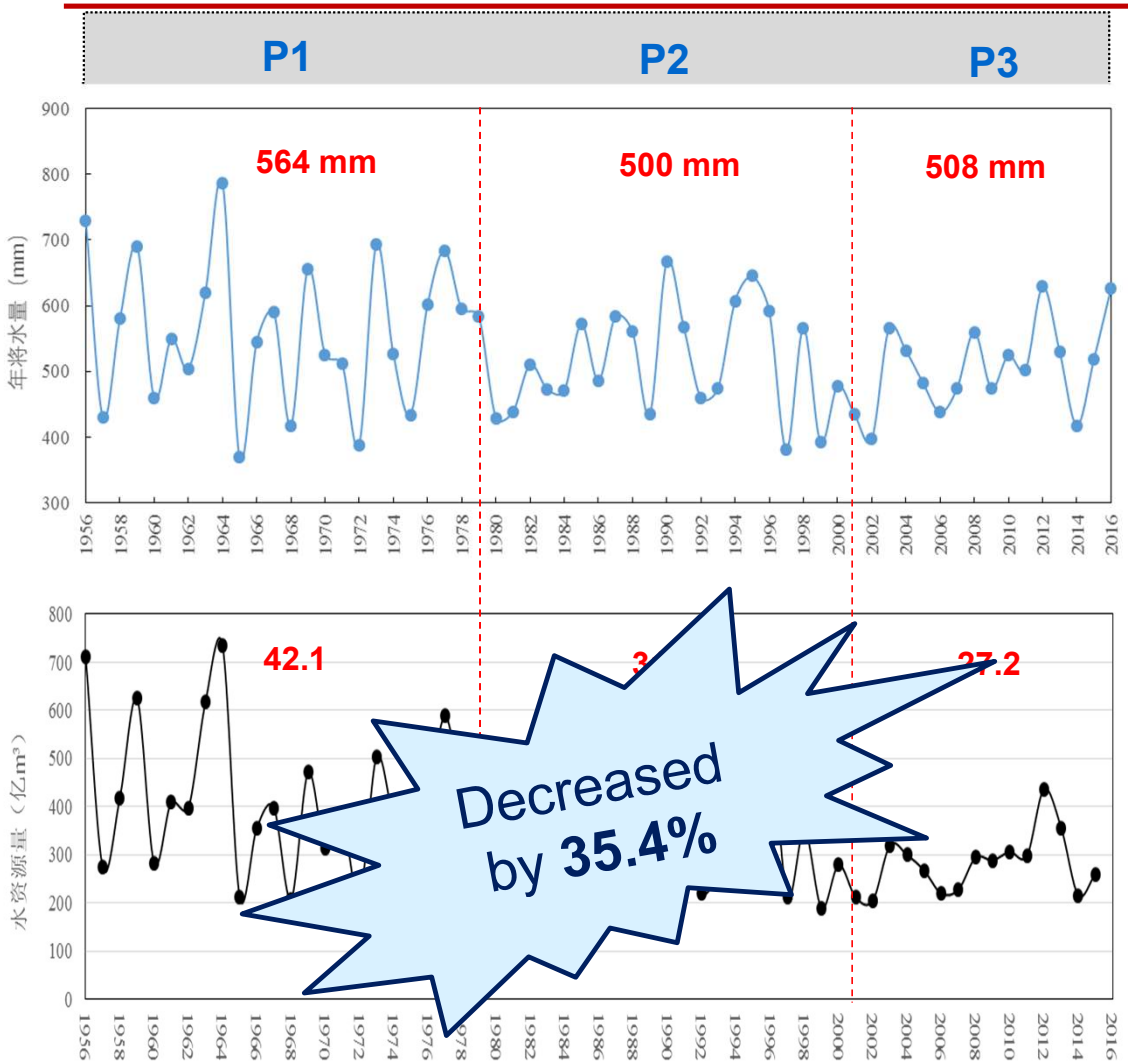
- GDP **8500 bil. CNY (8.5%)**
- Total area **217,000 km^2 (2.3%)**
- Cultivated area **52,000 km^2 (8.2%)**
- Population **85 mil. (7.8%)**
- WR availability **20.4 bil. m^3 (0.7%)**

Outline

1. Decrease of water resources availability
2. Groundwater overdraft and control
3. Water security ensurance
4. Concluding remarks

Decrease of water resources availability

National water resources assessment programs



First period （P1） : 1956 - 1979

Second period （P2） : 1980 - 2000

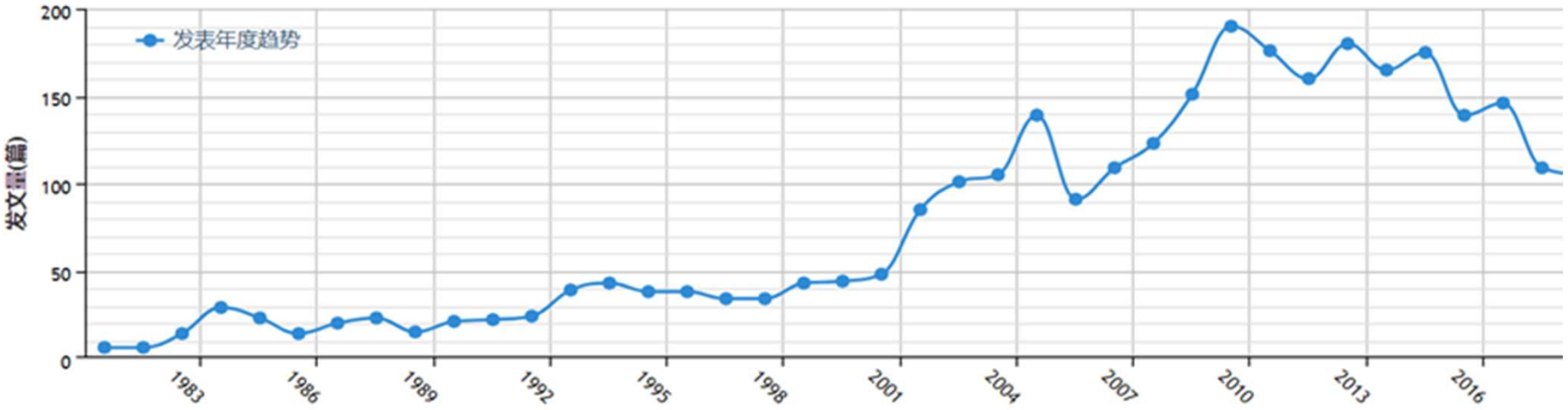
Third period (P3) : 2001 - 2016

Time	Total	SW	GW
P1	42.1	28.8	26.5
P2	31.7	17.1	21.4
P3	27.2	12.1	22.4
P2 - P1	10.4	11.7	5.1
P3 - P1	14.9	16.7	4.1

Unit: bil. m3 per year

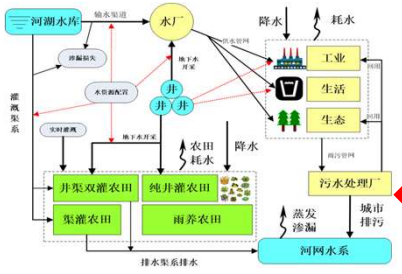
Key questions to answer

- Why this happened? Where did the water go?
- How is it going to change in the future?



WACM: Water Allocation and Circulation Model

- **In-house developed program for coupled Societal – Natural water cycle simulation**
- **Societal water cycle:** water supply, water diversion, water use, wastewater discharge
- **Natural water cycle:** surface water, soil water, groundwater



实现灌区系统、城市系统社会水循环过程精细化模拟

取供过程模拟

$$\eta_{\text{供}} = \frac{\int_1^m (\partial S'_{xi} + \partial N'_{xi})}{\int_1^m (\partial S^0_{xi} + \partial N^0_{xi})}$$

输配过程模拟

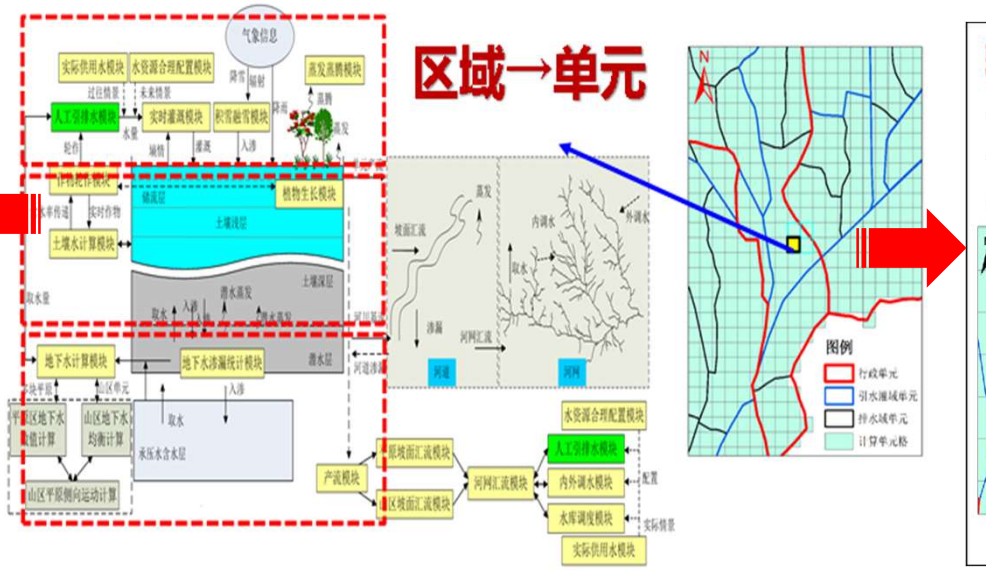
$$\eta_{\text{输配}} = g(\varphi,\omega) = 1 - (\sum_{i=1}^{M} QLS_i + \sum_{j=1}^{N} QNS_j)/QW_{zsm}$$

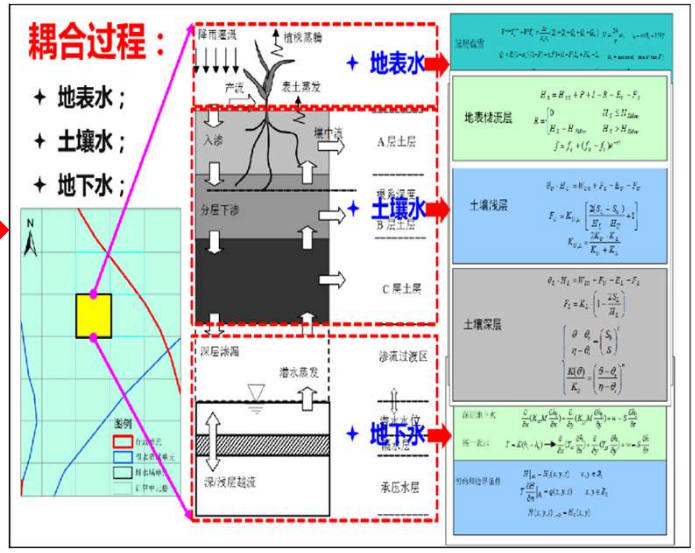
耗用过程模拟

$$\frac{dY}{dET} = (aET^2 + bET + c)' = 2aET + b$$

排水过程模拟

$$Q_{p-1} = Q_p + P + Q_{ZP} + Q_{PH} + Q_P + Q_{TP} - E_w$$



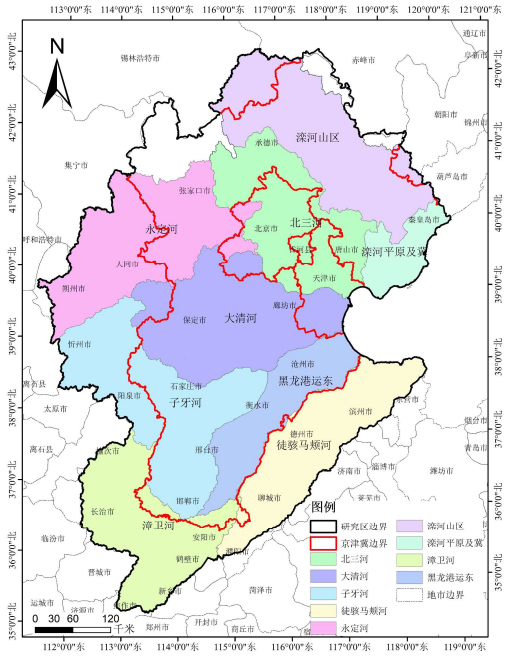


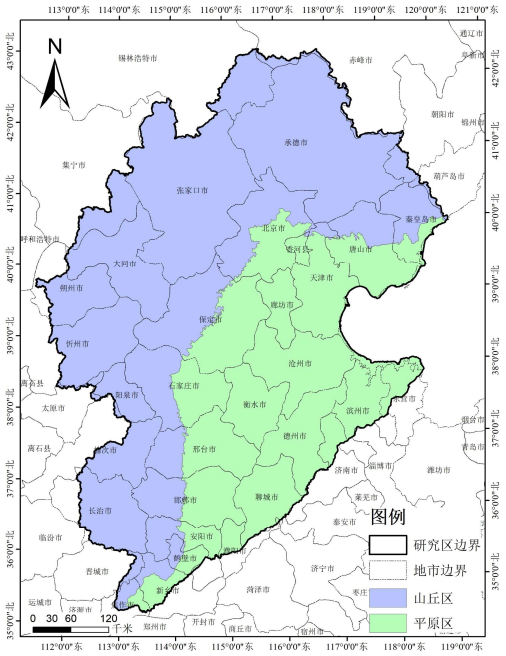
- 社会水：引用耗排过程
- 结构离散：区域-单元、耗散-汇合结构
- 自然水：地表-土壤-地下垂向一体耦合

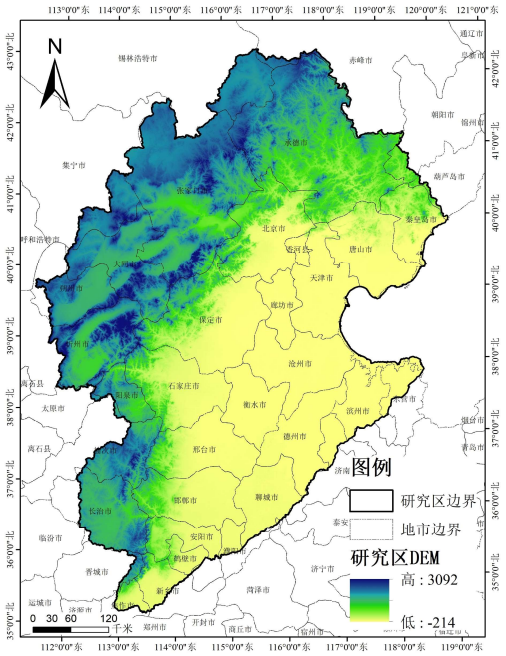
Model development (I)

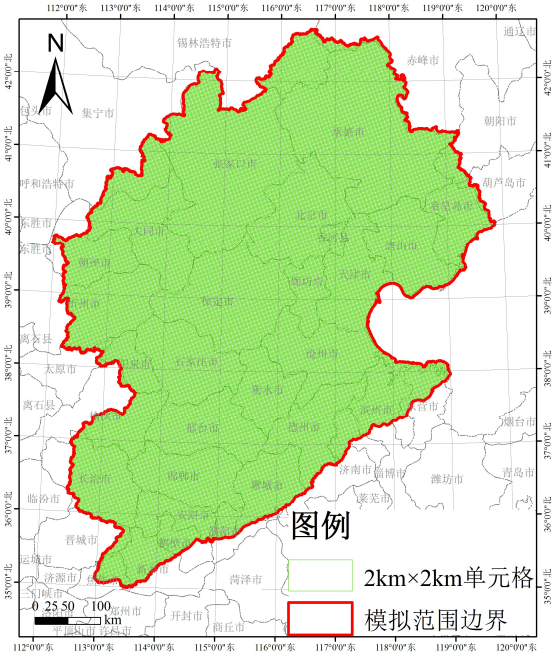
Basic setup

- **Model domain:** Haihe river basin, including the JJJ region
- **Area:** 335,600 km², mountain 204,700 km², Plain 130,900 km²
- **Resolution:** 2 × 2 km, 83923 grids in total, daily time scale





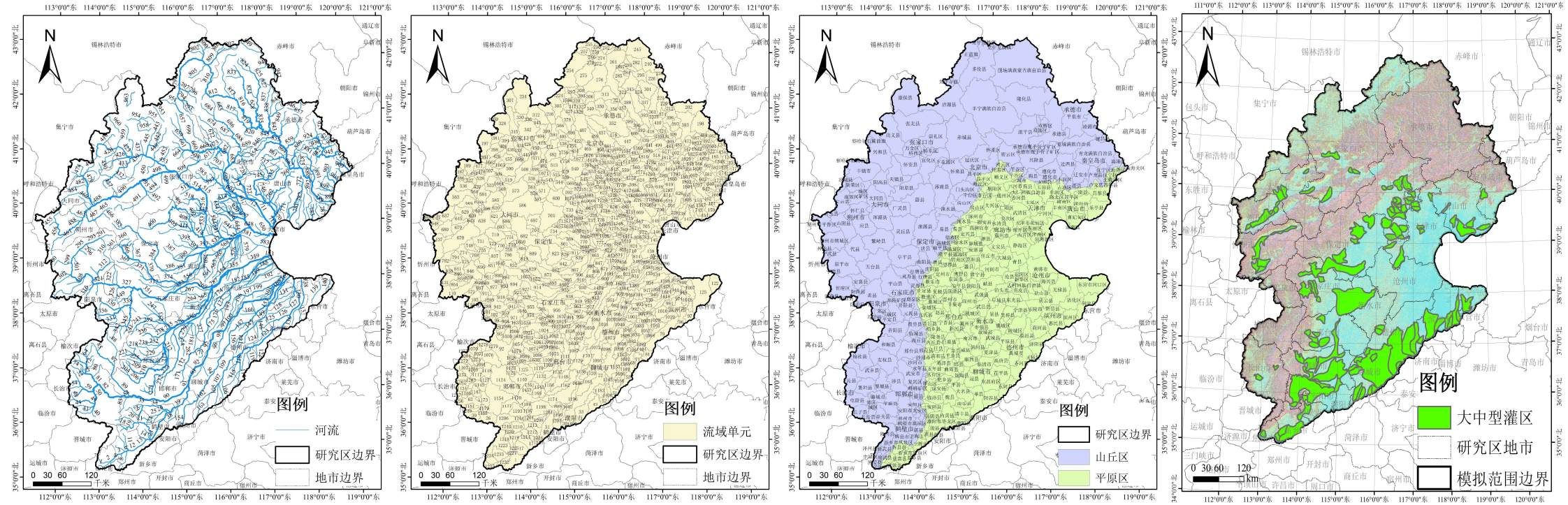




Model development (II)

Basic setup

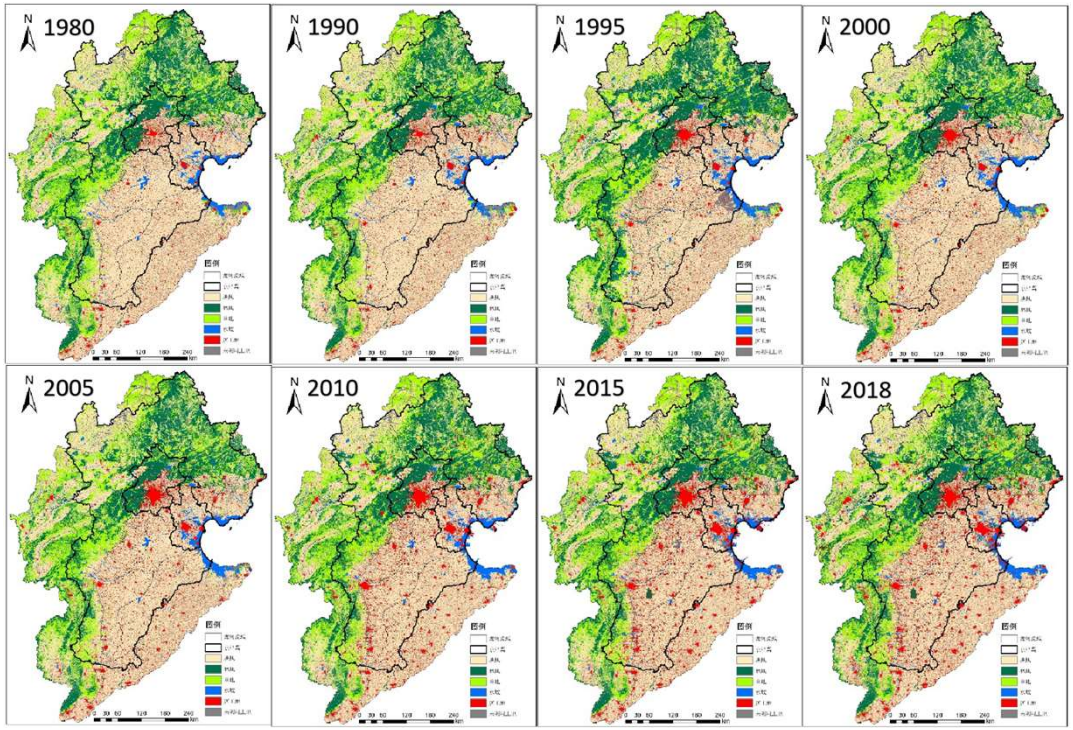
- **Rivers and subbasins:** 963 rivers in 5 levels, 963 subbasins
- **Administrative divisions:** 36 cities、326 counties
- **Irrigation districts:** 101 in total

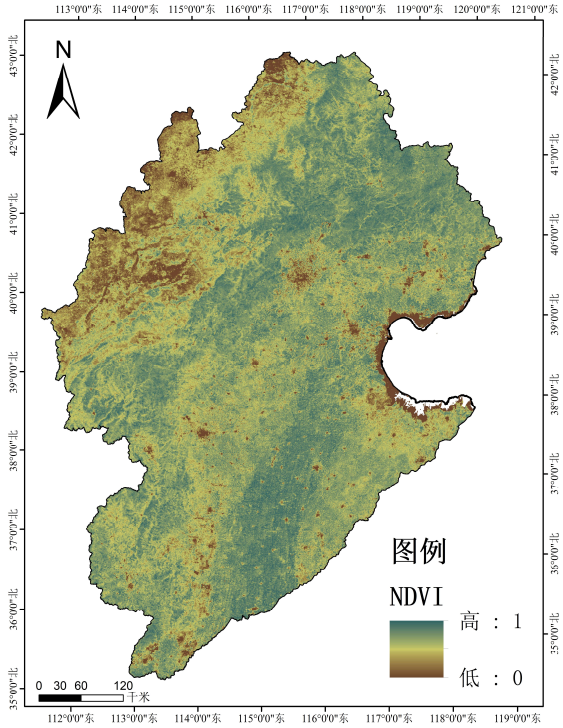


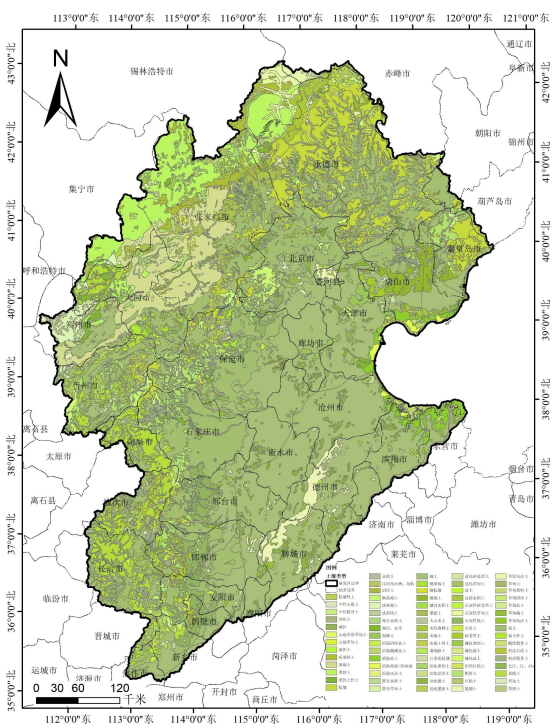
Model development (III)

Land use and soil

- ✦ **Land use:** 1980 – 2018 satellite derived, every 3-5 years
- ✦ **Vegetation:** NDVI
- ✦ **Soil types:** fluvo-aquic soil (28.1%), brown clay (21.3%), brown loam (6.9%)



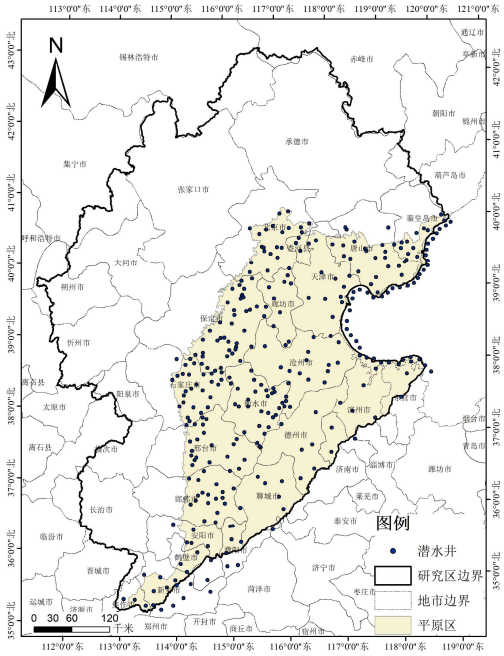


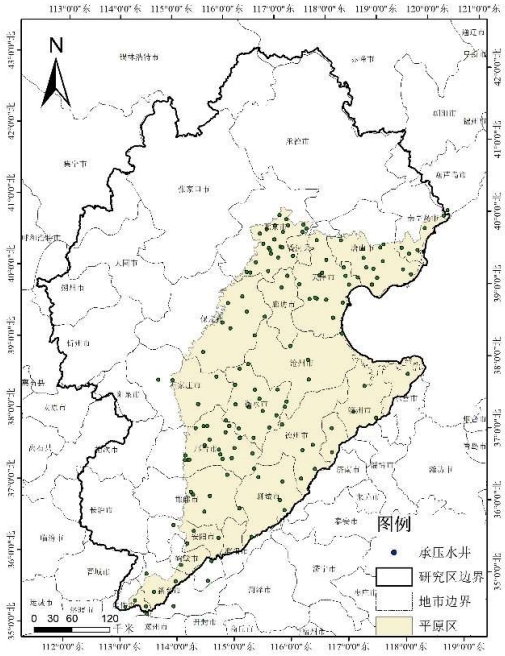


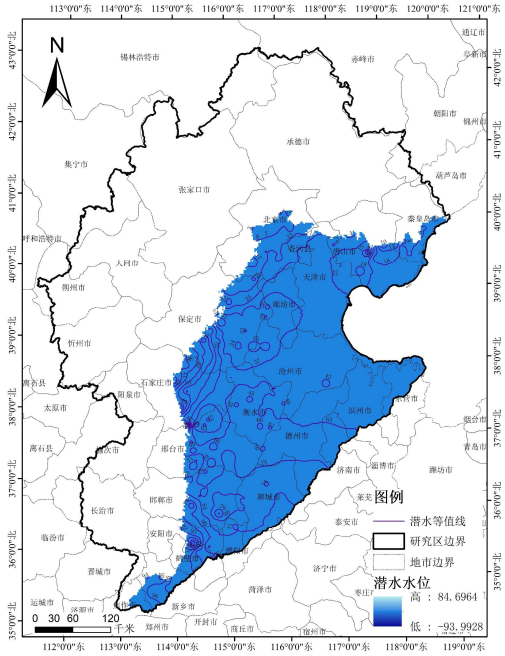
Model development (IV)

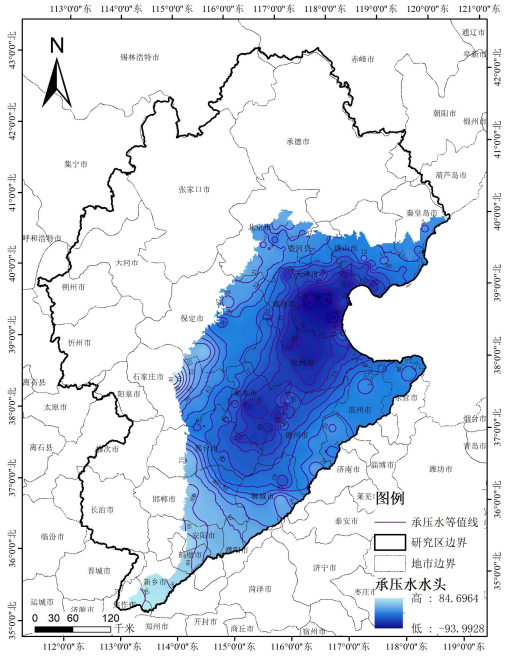
Meteo and geo data

- ✦ **Meteo. data:** 289 stations, Thiessen polygon for spatial interpolation
- ✦ **Groundwater obs. wells:** 333 shallow wells, 149 deep wells
- ✦ **Geological units:** 29 in shallow aquifer, 6 in deep aquifer





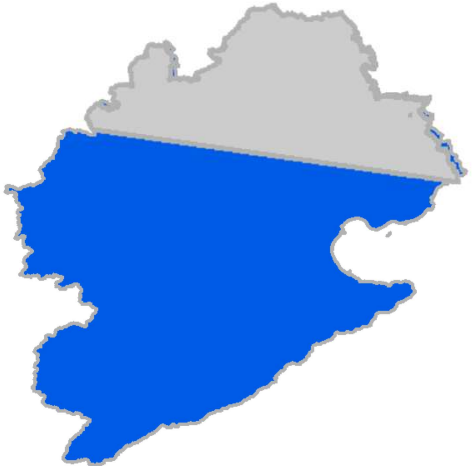




Attribution analysis

P1

P2



P3

P2 - P1

- Decrease of precip. 60%
- Mt. Vegetation 18%
- GW pumping 16%
- Change of crops 10%

P3 - P2

- Mt. vegetation 54%
- Decrease of precip. 25%
- GW pumping 12%
- Change of crops 10%

Future predictions (I)

Scenario analysis

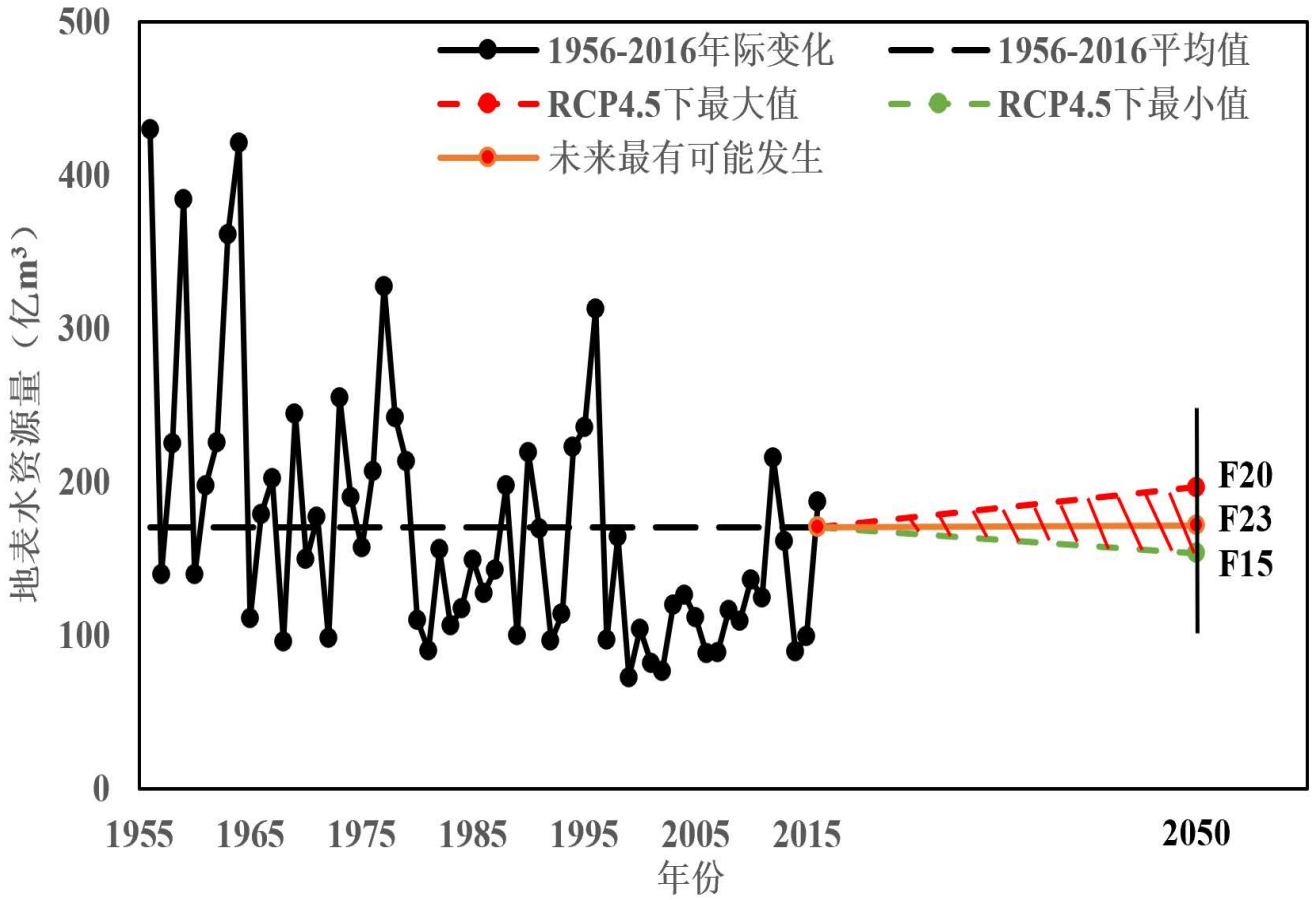
- **Climate condition:** present, RCP 4.5, RCP 8.5
- **Land use:** urbanization
- **Vegetation:** Present NDVI, NDVI increased by 10%

方案	气象			土地利用			植被质量		地下水埋深		
	现状	RCP4.5	RCP8.5	现状	低城镇	高城镇	现状	高质量	现状	6.5m	3.6m
F0	√			√			√		√		
F1	√				√		√		√		
F2	√					√	√		√		
F3	√				√			√	√		
F4	√					√		√	√		
F5	√				√		√			√	
F6	√				√		√				√
F7	√					√	√			√	
F8	√					√	√				√
F9	√				√			√		√	
F10	√				√			√			√
F11	√					√		√		√	
F12	√					√		√			√
F13		√			√		√		√		
F14		√				√	√		√		
F15		√			√			√	√		
F16		√				√		√	√		
F17		√			√		√			√	
F18		√			√		√				√

方案	气象			土地利用			植被质量		地下水埋深		
	现状	RCP4.5	RCP8.5	现状	低城镇	高城镇	现状	高质量	现状	6.5m	3.6m
F19		√				√	√			√	
F20		√				√	√				√
F21		√			√			√		√	
F22		√			√			√			√
F23		√				√		√		√	
F24		√				√		√			√
F25			√		√		√		√		
F26			√			√	√		√		
F27			√		√			√	√		
F28			√			√		√	√		
F29			√		√		√			√	
F30			√		√		√				√
F31			√			√	√			√	
F32			√			√	√				√
F33			√		√			√		√	
F34			√		√			√			√
F35			√			√		√		√	
F36			√			√		√			√

Future predictions (II)

Climate under RCP 4.5



Drastic recovery: gw depth 3.6 m (1960)

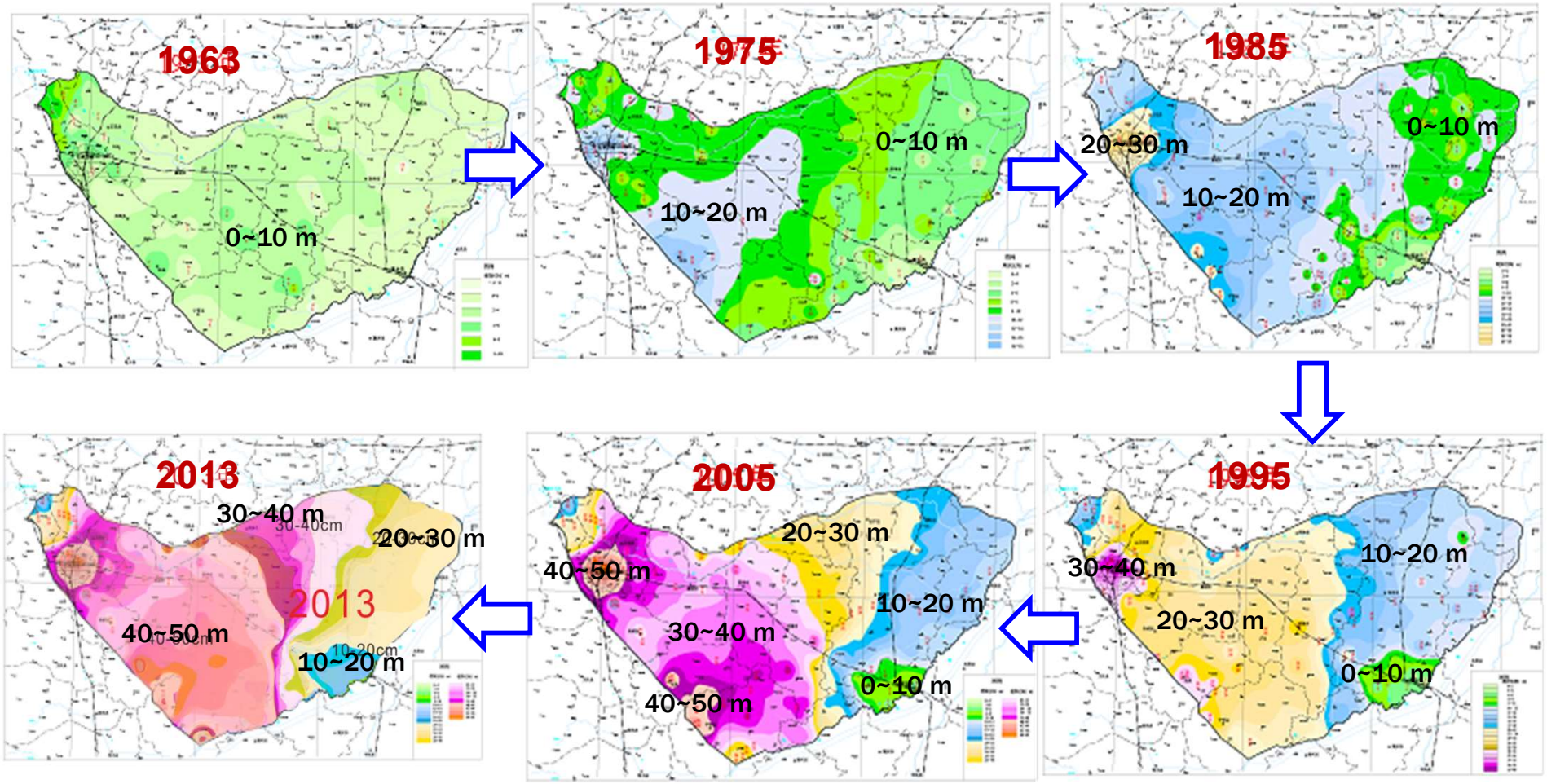
Moderate recovery: gw depth 6.5 m (1984)

Business as usual: gw depth 14.8 m

Groundwater overdraft and control

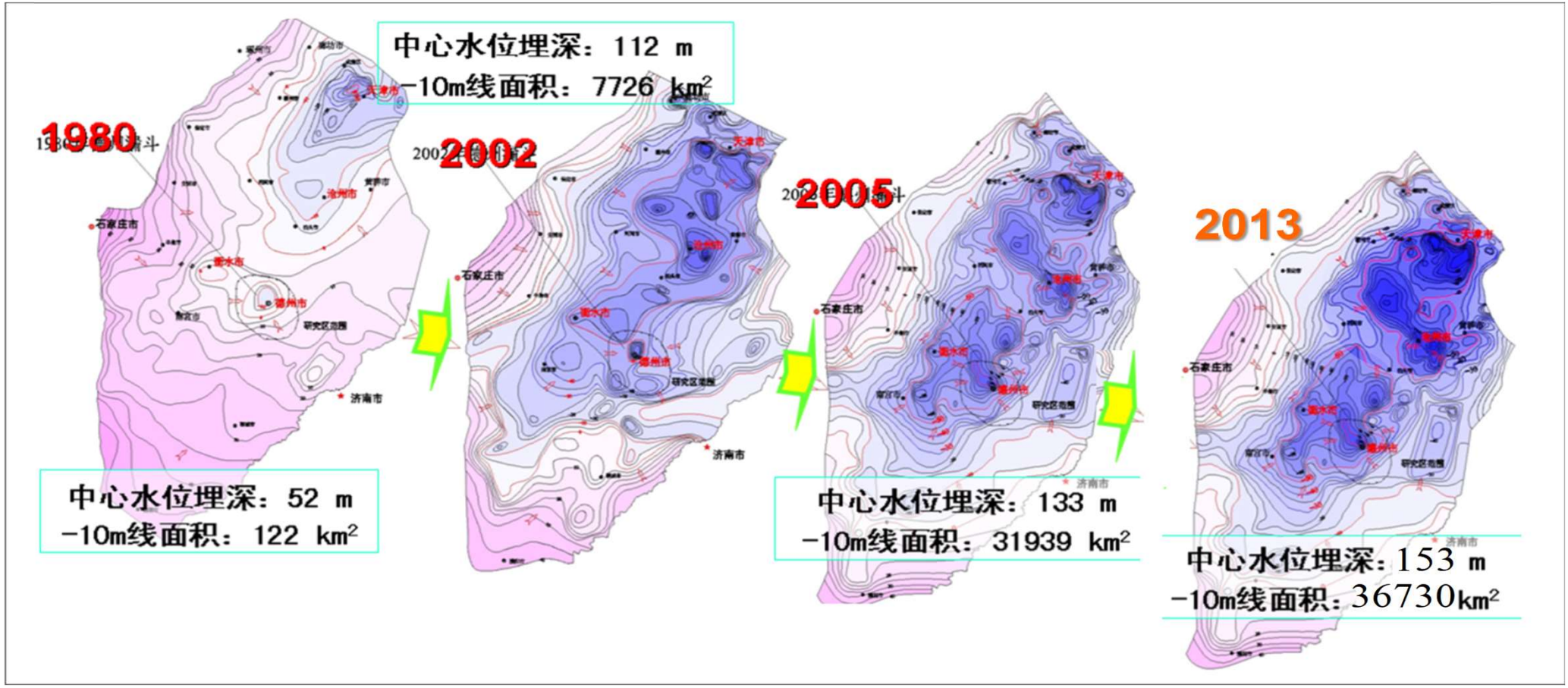
Historical change of groundwater table (I)

- Shallow aquifer in the piedmont area near Shijiazhuang



Historical change of groundwater table (II)

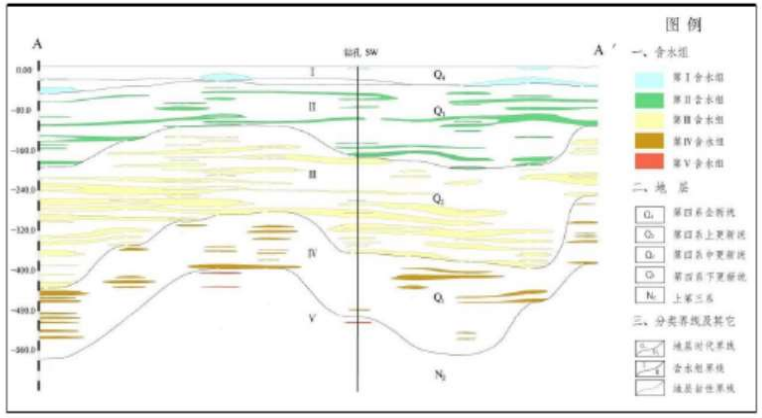
- **Deep confined aquifer in the central to coastal area**

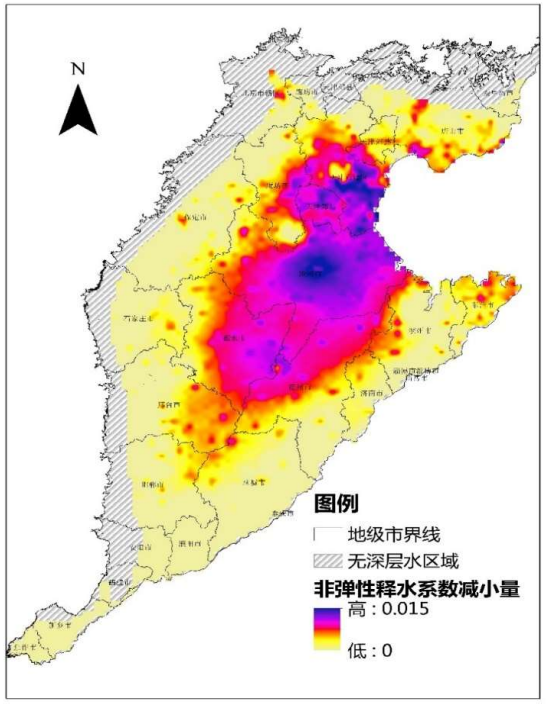


Overdraft and its impact (I)

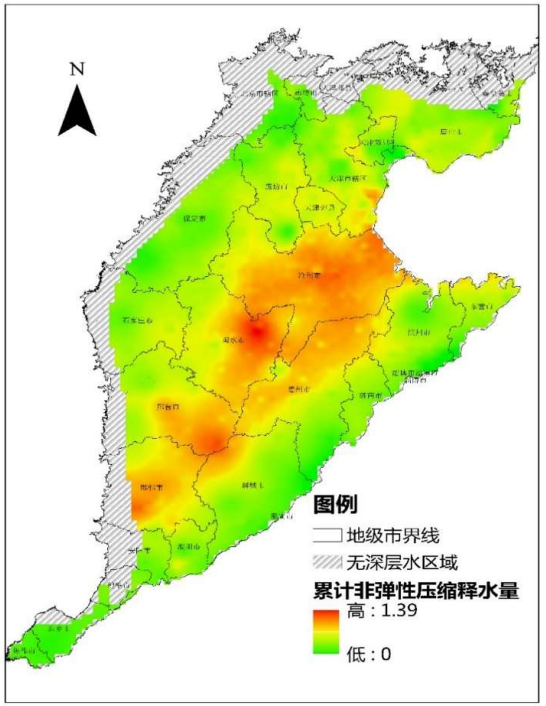
- Significant environmental consequences: land subsidence, dried up rivers and lake
- From water security's perspective, we lost 45.8 bil. m^3 storage space due to compression

Q_e	Q_v	Q_y
$\sigma' = \sigma - \mu$ $\Delta\sigma' = \gamma_w \Delta h$		
$Q_e = S_{ke} * \Delta h$	$Q_v = S_{kv} * \Delta h$	$Q_l = K\Delta t \frac{H_u - H_c}{m}$
$S_{ke} = S_{ske} * b$	$S_{kv} = S_{skv} * m$	
$S_{ske} = \frac{0.434 C_r r_w}{\sigma'(1+e_1)}$	$S_{skv} = \frac{0.434 C_c r_w}{\sigma'(1+e_2)}$	
$\Delta b = \frac{S_{ske} \times b_0}{r_w} \Delta\sigma'$	$\Delta m = \frac{S_{ske} \times m_0}{r_w} \Delta\sigma'$	
$\Delta e_1 = (1 + e_{10}) \times \frac{\Delta b}{b_0}$	$\Delta e_2 = (1 + e_{20}) \times \frac{\Delta m}{m_0}$	





1980-2016年海河平原非弹性释水系数减小量分布

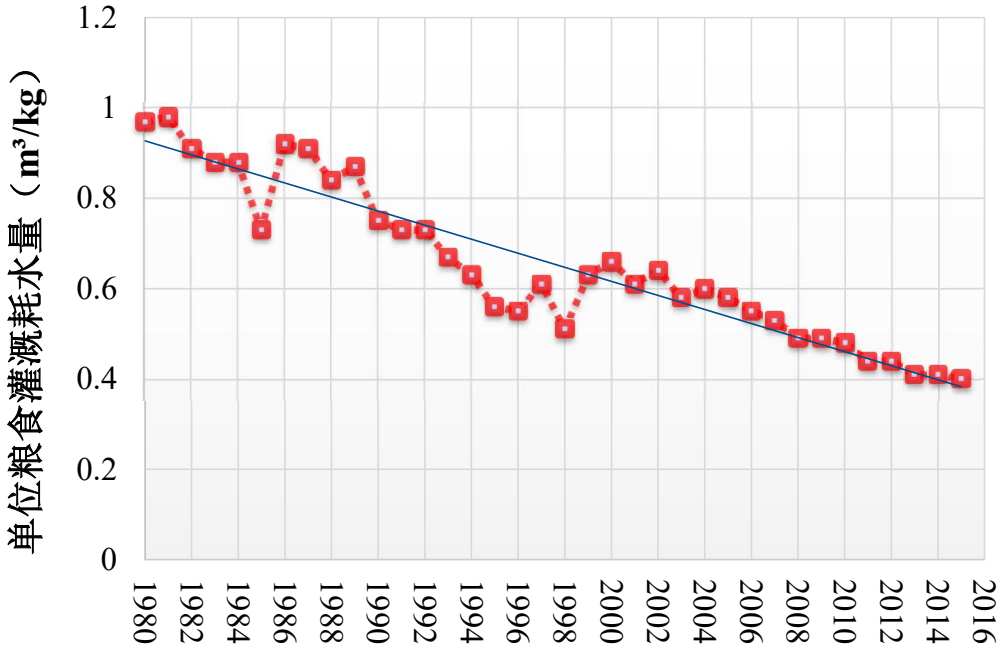


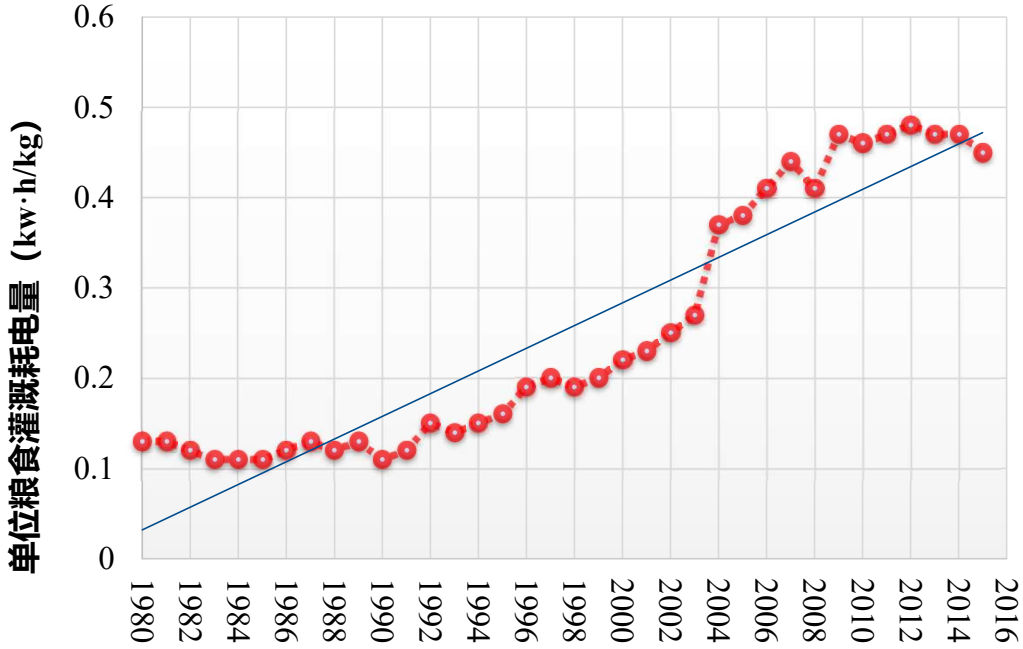
1980-2016年海河平原单位面积上累计非弹性压缩释水量分布

Overdraft and its impact (II)

To produce 1 kg of grain crop:

- **irrigation has reduced by 60% (from 1 m^3 to 0.4 m^3)**
- **energy consumption has increased over 3 times (0.12 kwh to 0.45 kwh)**





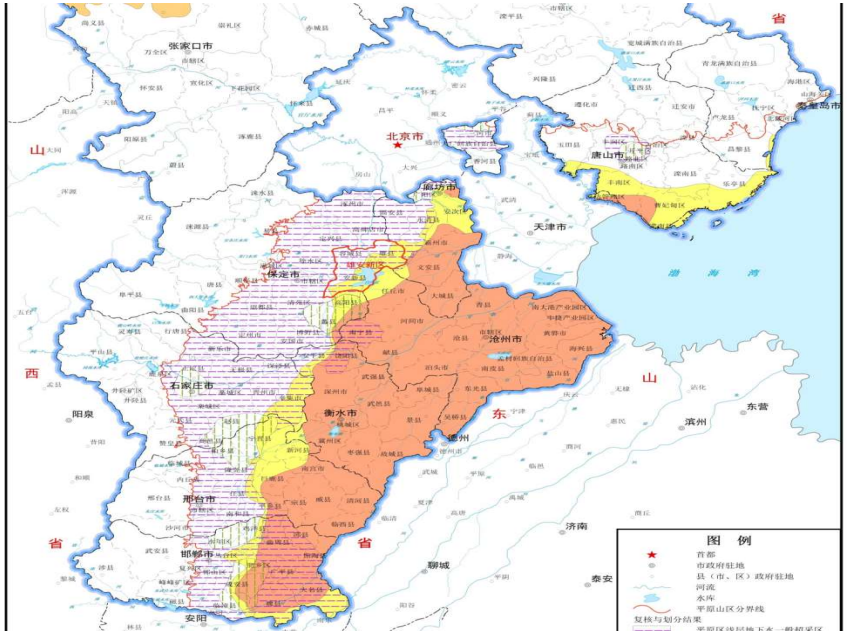
Comprehensive groundwater management (I)

National survey baseline year: 2010

省级行政区	超采区面积（万 km^2）	一般超采区（万 km^2）	严重超采区（万 km^2）
北京	0. 65	0. 31	0. 34
天津	0. 94	0. 16	0. 78
河北	7. 07	4. 20	3. 78
山西	0. 63	0. 13	0. 50
内蒙古	0. 72	0. 22	0. 50
辽宁	0. 89	0. 84	0. 07
吉林	0. 08	0. 03	0. 05
黑龙江	0. 04	0. 04	0
山东	4. 98	0. 84	4. 55
河南	3. 82	3. 70	0. 12
陕西	0. 14	0. 13	0. 02
甘肃	1. 64	1. 44	0. 20
新疆	4. 30	—	4. 30

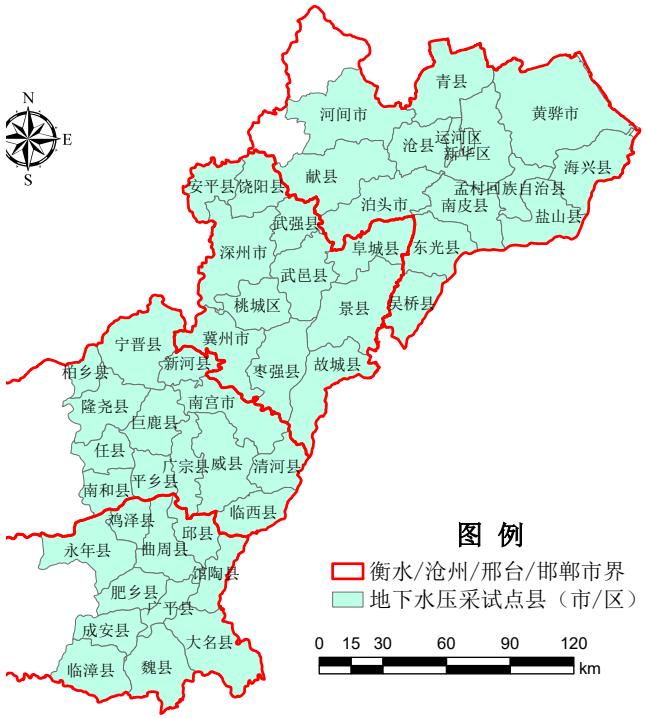
21 provinces with overdraft problem

- **Whole country**
  Overdraft area：298,000 km^2
  Overdraft amount：17 bil. m^3
- **Hebei province**
  Overdraft area：70,000 km^2
  Overdraft amount：6 bil. m^3

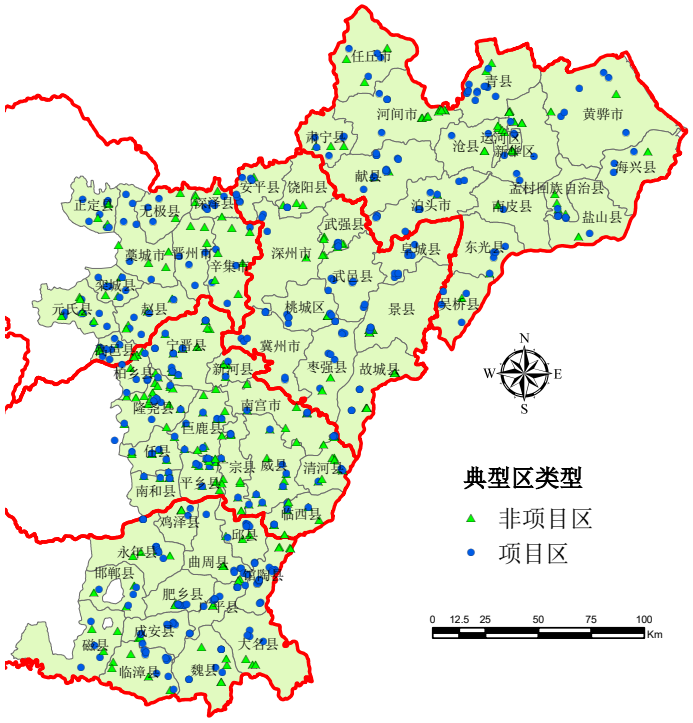


Comprehensive groundwater management (II)

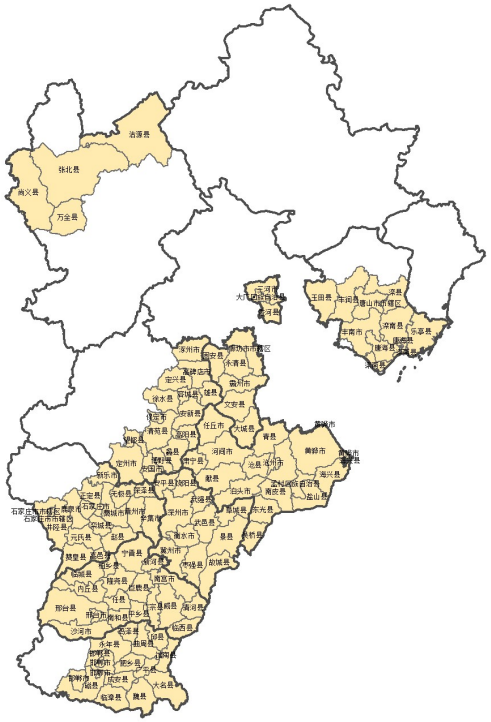
Starting from 2014, the Groundwater Overdraft Management and Control Program was launched first in Hebei Province.



2014: 49 counties

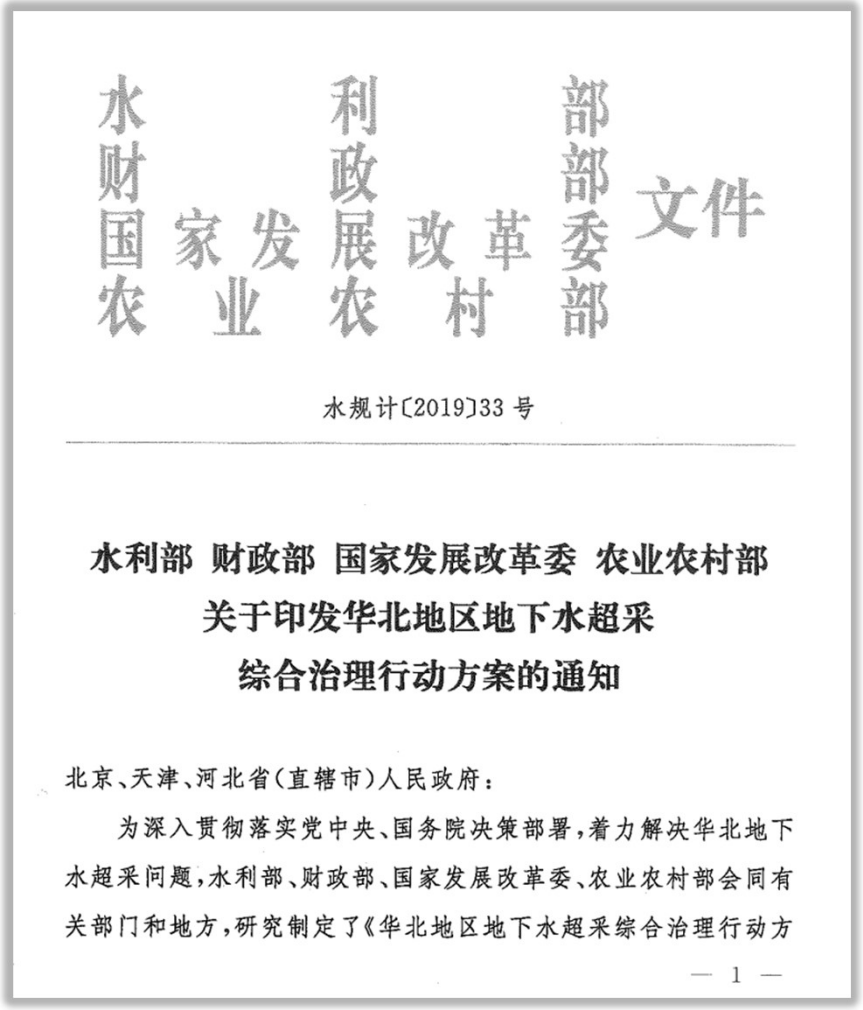


2015: 63 counties



2016: 115 counties

Comprehensive groundwater management (III)



水利部 财政部 国家发展改革委 农业农村部 文件

水规计〔2019〕33 号

水利部 财政部 国家发展改革委 农业农村部
关于印发华北地区地下水超采
综合治理行动方案的通知

北京、天津、河北省（直辖市）人民政府：

为深入贯彻落实党中央、国务院决策部署，着力解决华北地下水超采问题，水利部、财政部、国家发展改革委、农业农村部会同有关部门和地方，研究制定了《华北地区地下水超采综合治理行动方

— 1 —

- **Action Plan for Comprehensive Control of Groundwater Overdraft in the North China Plain**
- **Came into force in 2019, was by far the most powerful legislation regarding the NCP's regional groundwater crisis.**
- **Initiated by the Ministry of Water Resources and brought together a joint force with Ministry of Finance, National Development and Reform Commission, Ministry of Agriculture and Rural Affairs.**
- **The goal is to reduce the overdraft amount by 70% in 2022 and achieve zero groundwater deficit by 2035.**

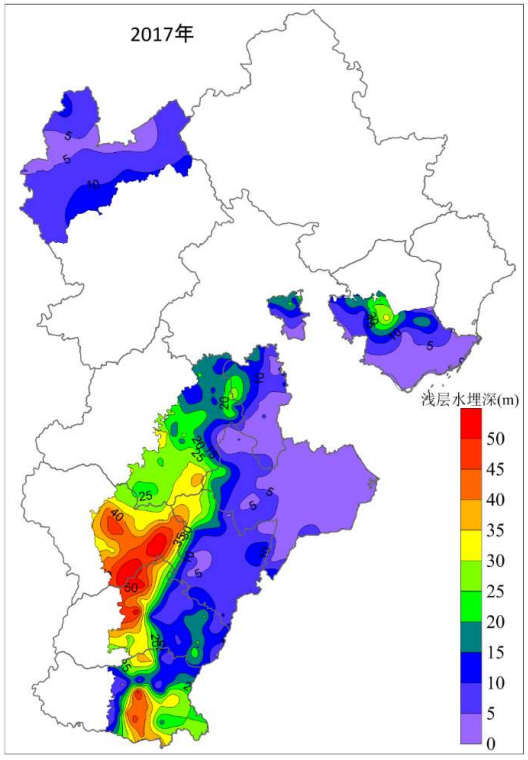
Comprehensive groundwater management (IV)

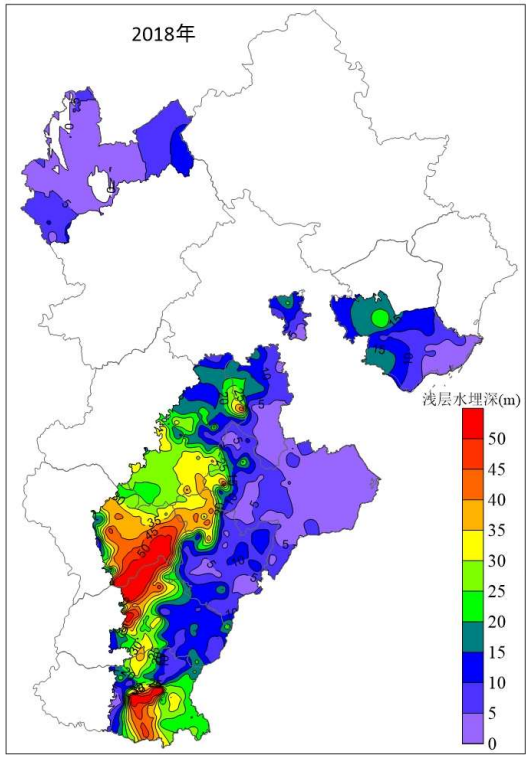
2014 to 2016, 24.4 bil. CNY was spent on dealing with overdraft problem in Hebei province

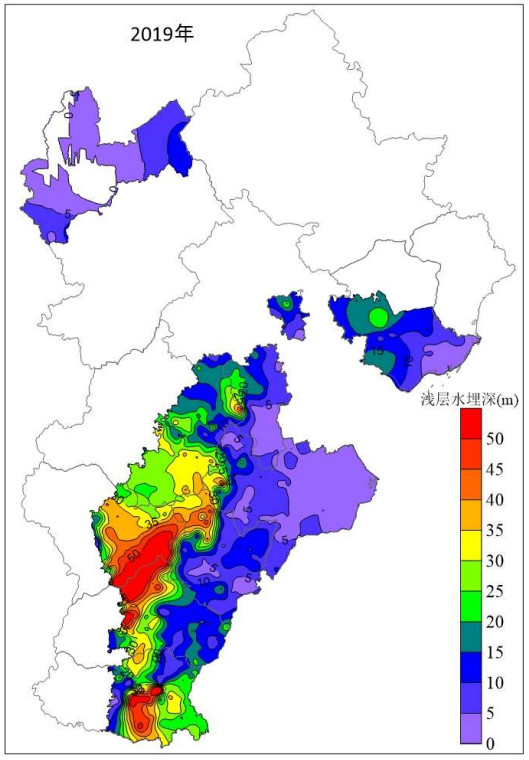
农业项目		Reduce areas for growing winter wheat		Subsidize drought resistant crops
林业项目		"Grain for Green" projects		
水利项目		Use more diverted water from the south		Promote water saving irrigation technologies

Results

From 2017 to 2019, there was still groundwater table decline in and around the largest depression cone, but the declining rate has notably slowed down compared to previous years.







Ensuring water security in the JJJ region

Goals for healthy water balance

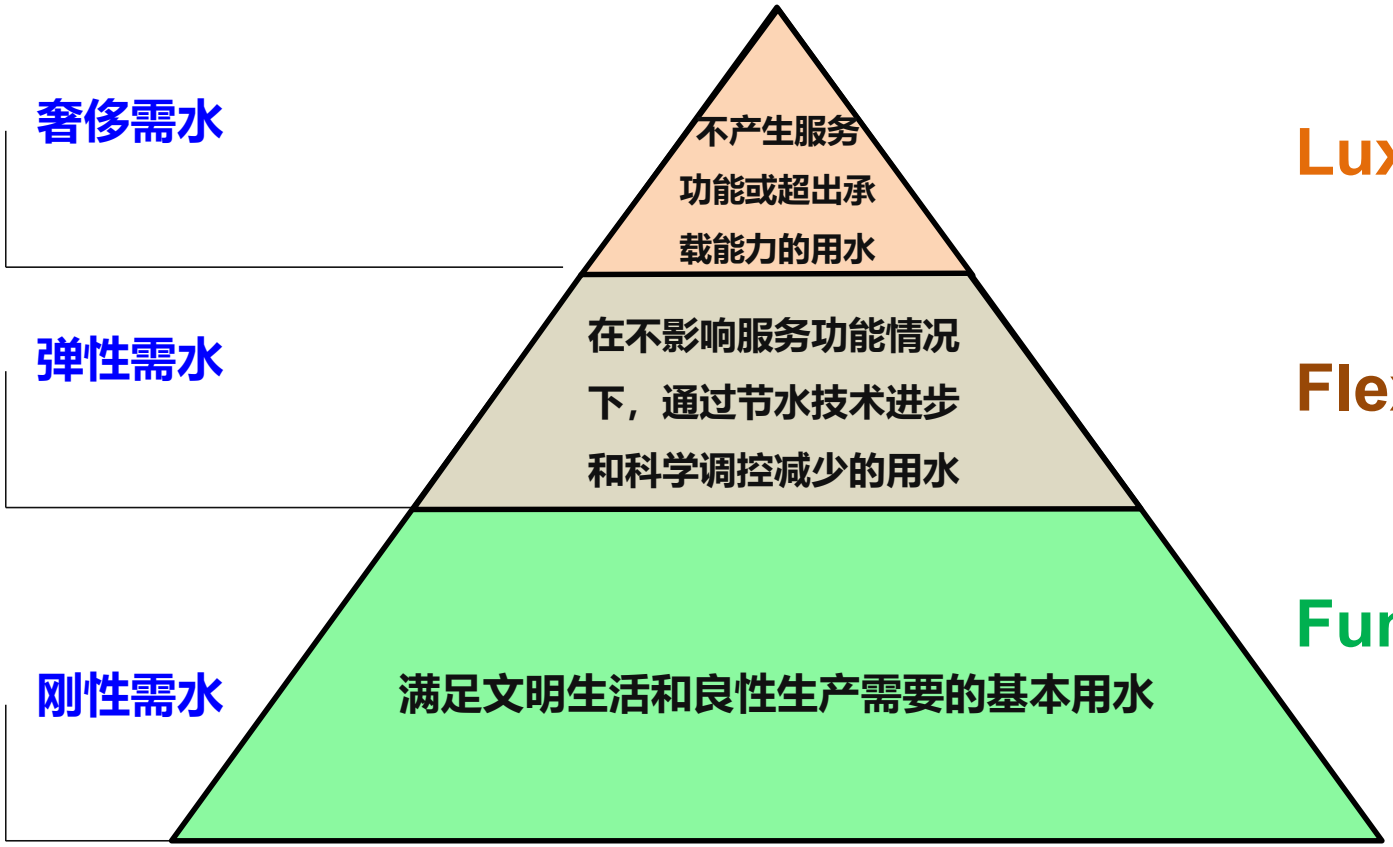
➢ **To ensure healthy balance in both the natural and societal water cycle:**

- **natural hydrological flows need to be protected and**
- **increasing water demand for economic growth has to be satisfied**

Criteria for evaluating healthy water balance

1. **Reasonable water demand**
2. **Sufficient ecological flow**
3. **Differentiated groundwater regulations**

1. Reasonable water demand



Luxurious demand

Flexible demand

Fundamental demand

2. Sufficient ecological flow


京津冀41条主要河道生态需水量


京津冀63块主要湿地生态需水量


京津冀11处入海口生态需水量


河道、湿地、入海水量交换关系

类别	水面面积 (km^2)	最小生态需水 (亿m^3)	适宜生态需水 (亿m^3)	理想生态需水 (亿m^3)
河道	599	35.8	68.8	87.4
湿地	1066	9.3	37.9	101.0
湿地重复	332	0.0	18.3	28.5
入海口	342	20.4	39.2	49.8
总计	1333	43.5	55.2	66.3
	开发利用率	60%	50%	40%

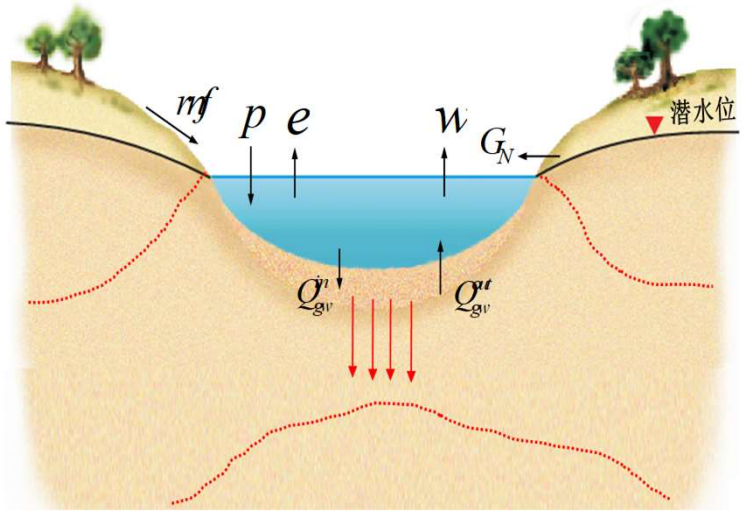
Minimal ecological flow

Suitable ecological flow

Optimal ecological flow

3. Differentiated groundwater management

Regulations have to be made based on the geological, hydrological and ecological conditions of the individual region.



Piedmont region: **continuous baseflow**

Central region: **constant gw recharge**

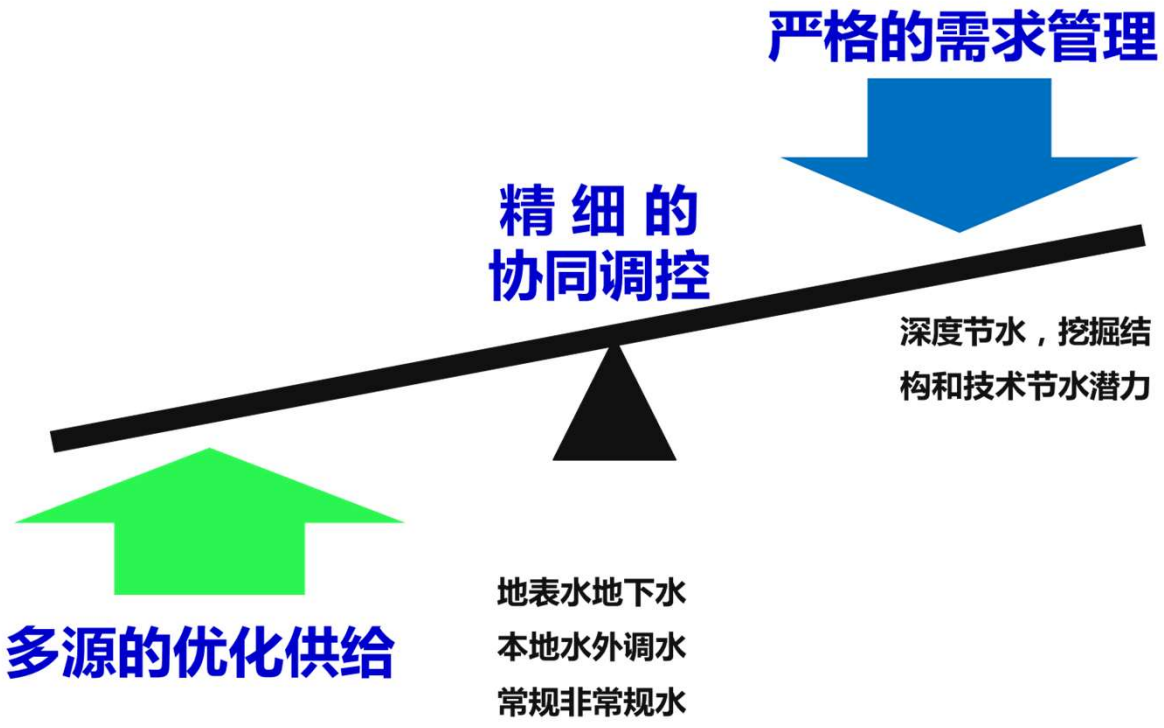
Coastal region: **reducing land subsidence and sea water intrusion**

在山前平原，导致山区地下水难以出漏，河道基流萎缩甚至消失，河道渗漏严重

在中部平原，导致降水难以补给地下水，地表水地下水几乎割裂，河湖渗漏严重

What to do?

节水优先，空间均衡，系统治理，两手发力



- **Control demand** (Water saving technologies)
- **Balance supply and demand** (Coordinated water allocation)
- **Multi-source water supply** (diverted water and reclaimed water)

水资源保障的三大举措

Concluding remarks

- **JJJ region is facing severe water security problems.**
- **There has been significant decrease of water resources availability in the region, which was mainly caused by change in climate and vegetation (afforestation and farm crops).**
- **Groundwater abstraction in the past was unsustainable, which has resulted in various environmental consequences. New local and national regulations will help alleviate the problem.**
- **Goals and evaluation criteria for healthy water balance in the region has been setup. Road map for achieving such goals are clear. However, new technologies and social awareness are still needed.**

Thank you for your attention!

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