Final Sino-German Conference of SuMaRiO Project

Water Balance and Simulation of Eco-hydrological Processes along Tarim River

Chengyi Zhao, Han Ming, Shi Fengzhi，。。。。。。。。

National Aksu Water Balance Experimental Station, China

zcy@ms.xjb.ac.cn

Project duration: 10/2008 – 03/2016

SuMaRiO

Coordination Level (WP 1.1)

German
Leader: *Markus Disse*
Scientific Coordination
Equipment Management
Co-Leader: Bernd Cyffka
Workshop Coordination

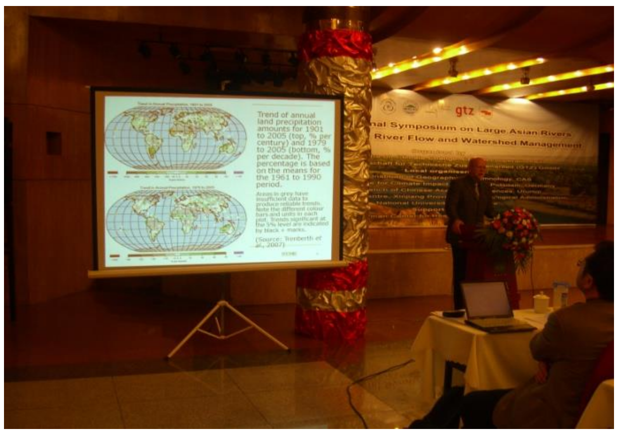
Chinese
Leader: *Zhao Chengyi*
Co-Leader: *Jiang Tong*

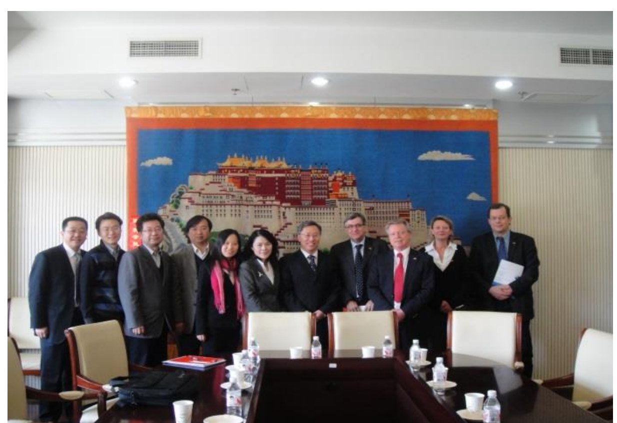
Secretary

German
Rumbaur: Scientific Coordination
Equipment Management
N.N.: Workshop Coordination

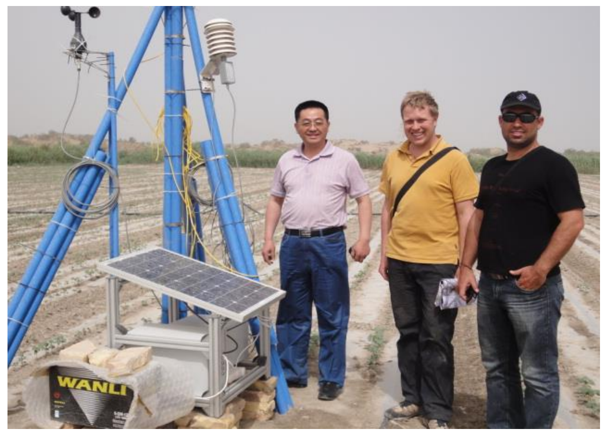
Chinese
Han Ming (Zhao Chengyi)
Li Xiucang (Jiang Tong)

SuMaRiO Project on the way





SuMaRiO Project on the way



SuMaRiO Project on the way



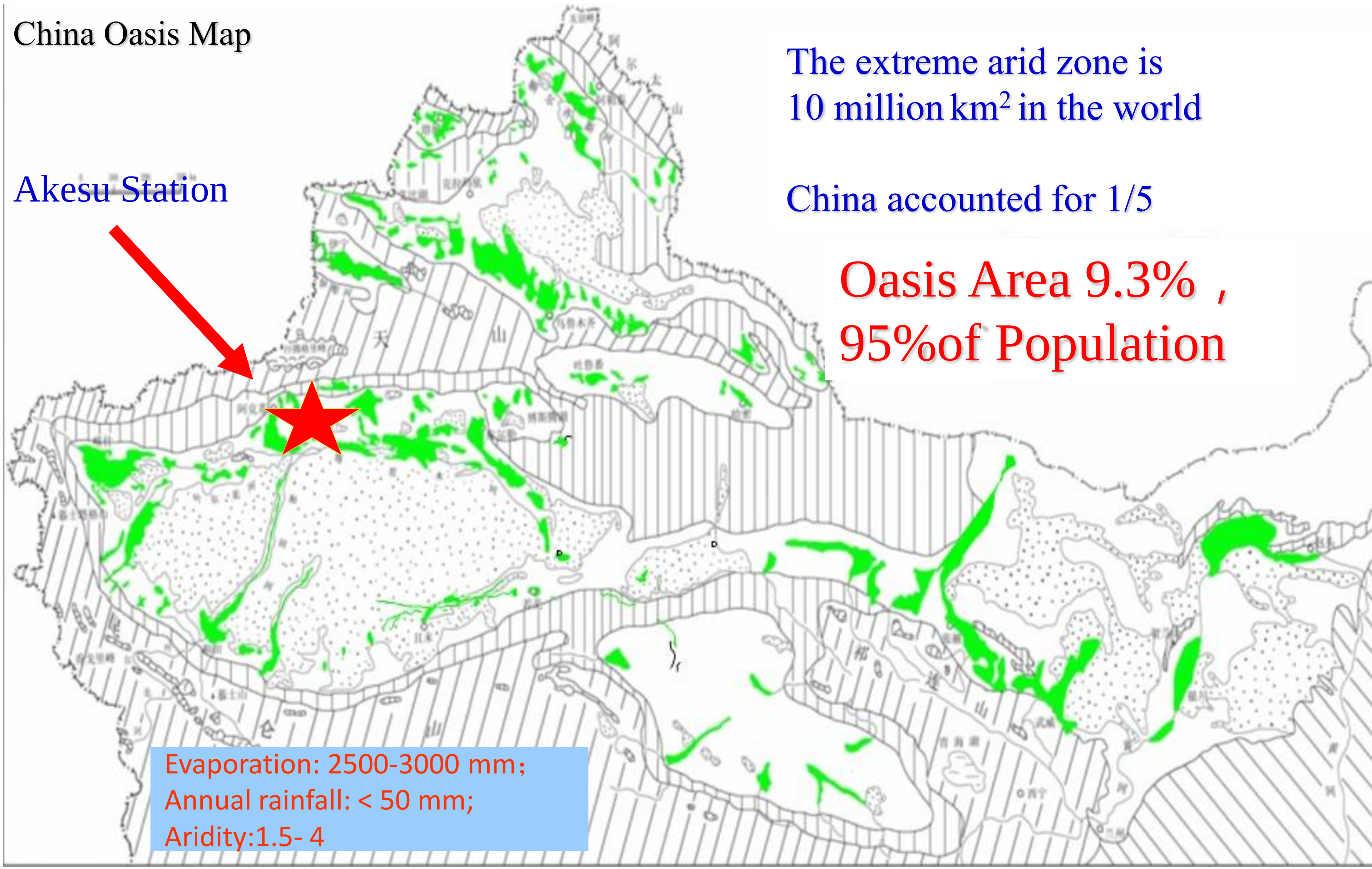






一、Challenges on Sustainable Oasis development

China Oasis Map



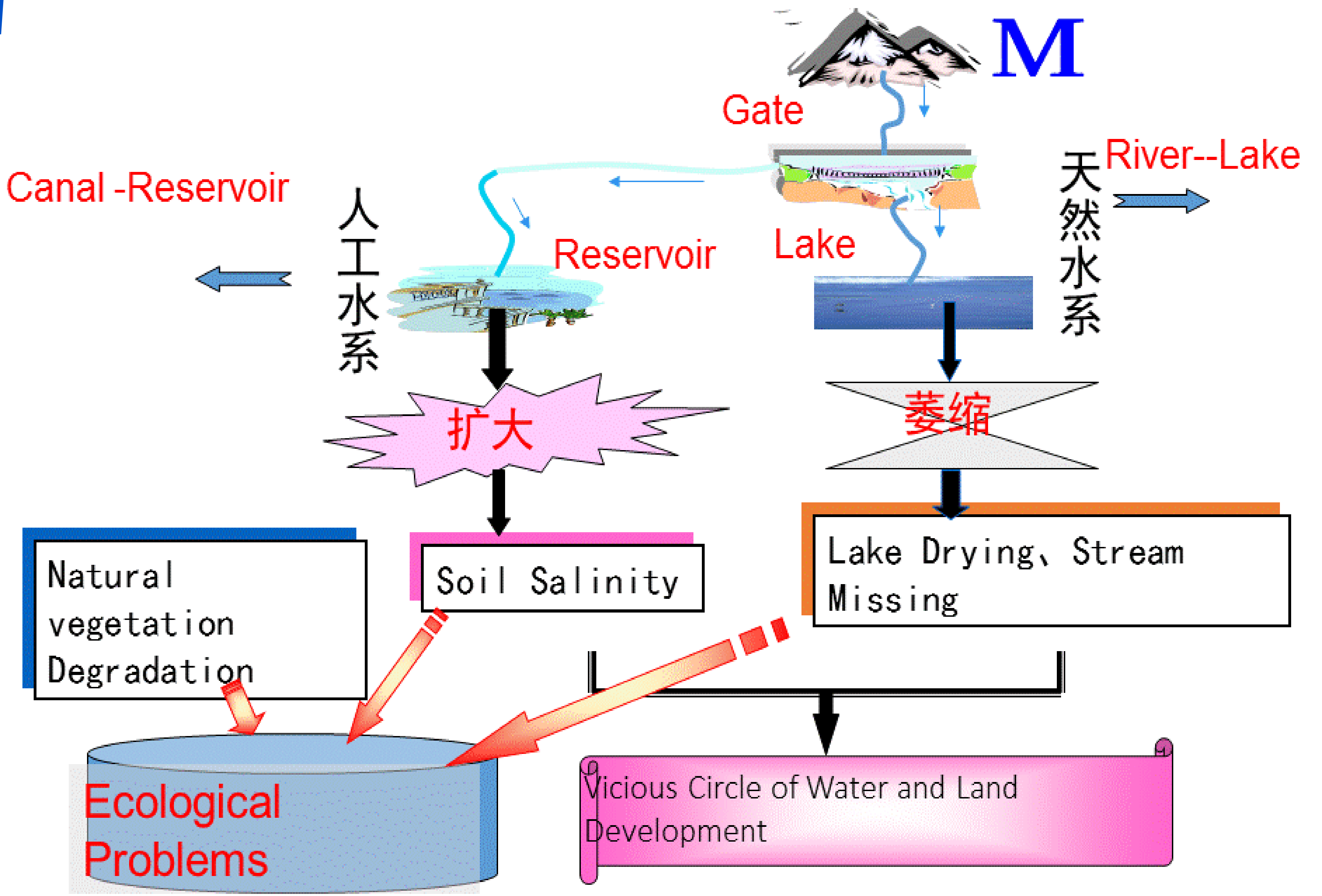
The extreme arid zone is 10 million km^2 in the world

China accounted for 1/5

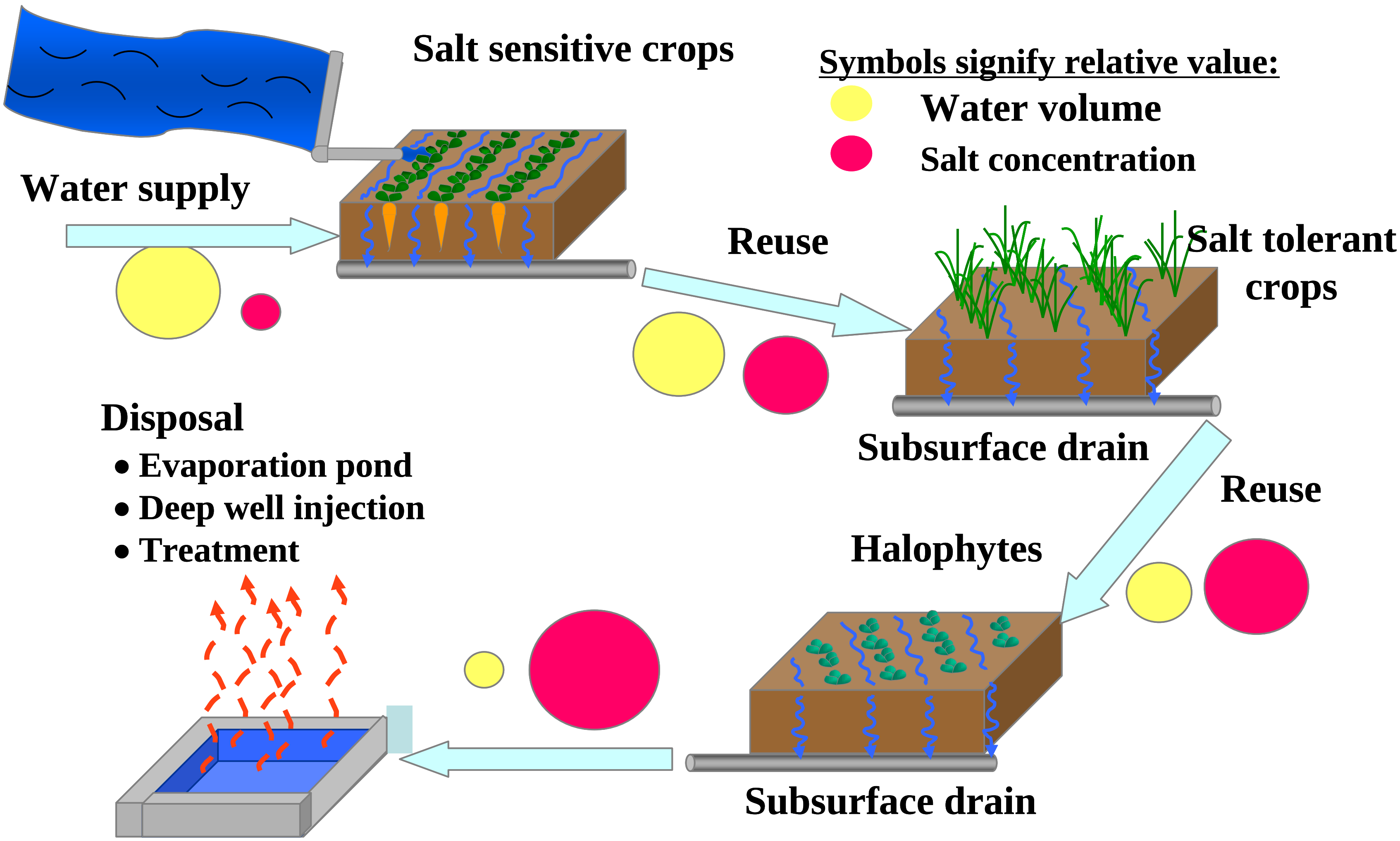
Oasis Area 9.3%，95%of Population

Evaporation: 2500-3000 mm；
Annual rainfall: < 50 mm;
Aridity:1.5- 4

一、Challenges on Sustainable Oasis development



一、Challenges on Sustainable Oasis development



（Zhao Chengyi，2002）

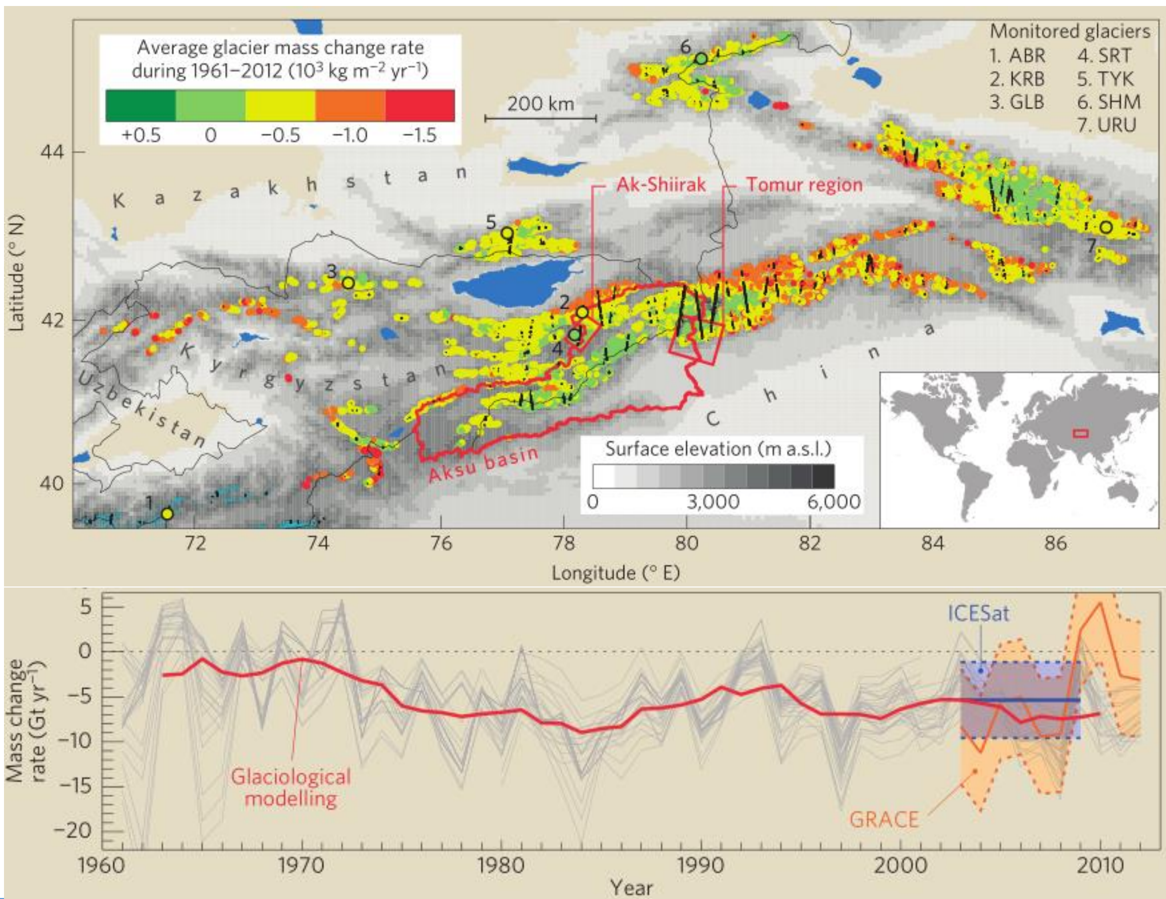
Water & salt movement from upper stream to downstream at basin scale

一、Challenges on Sustainable Oasis development

ARTICLES
PUBLISHED ONLINE: 17 AUGUST 2015 | DOI: 10.1038/NGEO2513
nature geoscience

Substantial glacier mass loss in the Tien Shan over the past 50 years

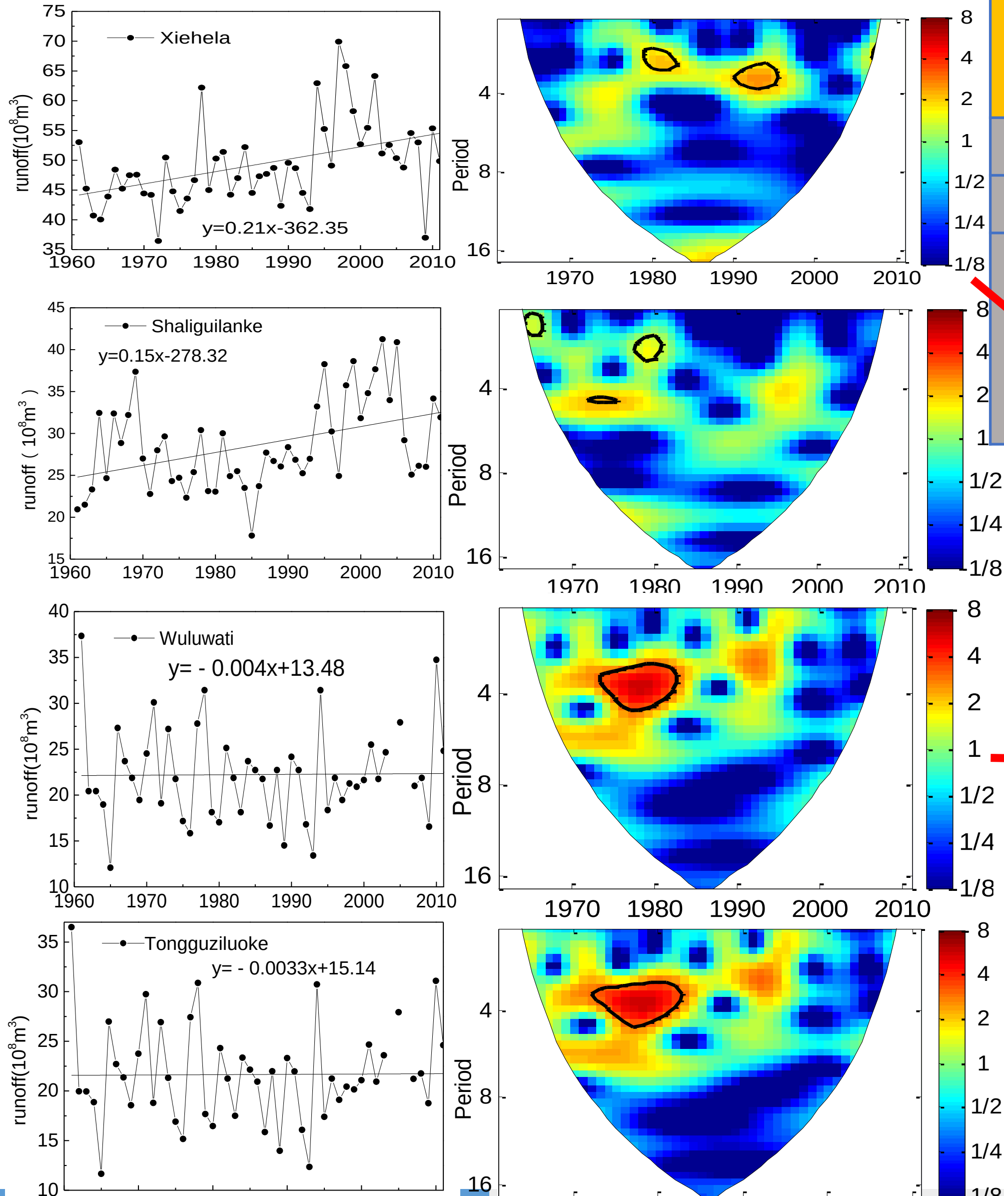
Daniel Farinotti[1,2]*, Laurent Longuevergne[3], Geir Moholdt[4], Doris Duethmann[1], Thomas Mölg[5], Tobias Bolch[6,7], Sergiy Vorogushyn[1] and Andreas Güntner[1]



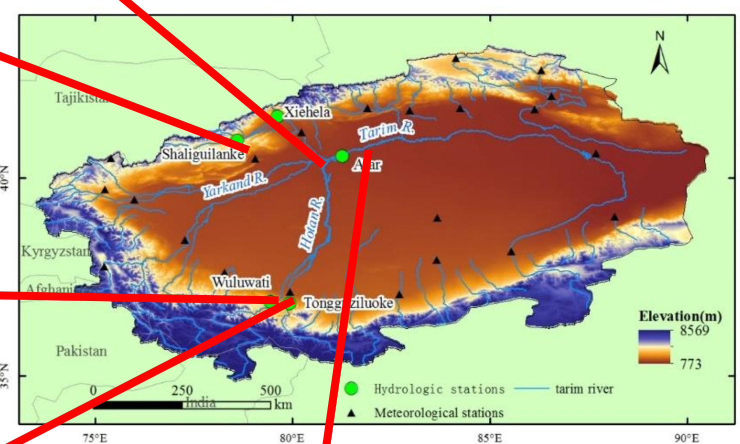
Accelerated Glacial Melting

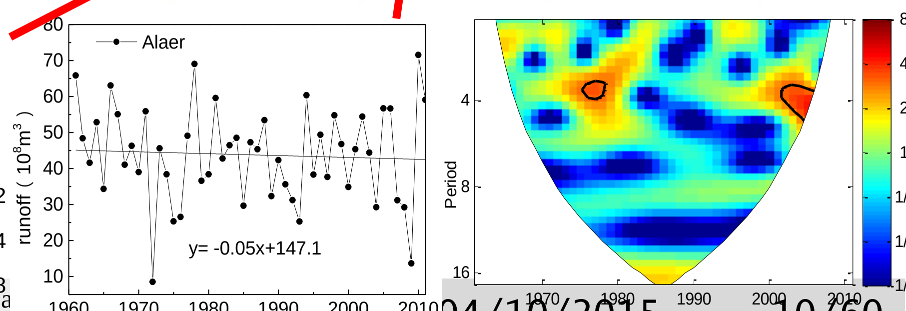
The overall decrease in total glacier area and mass from 1961 to 2012 to be 18±6% and 27±15%, respectively. These values correspond to a total area loss of 2,960±1,030km^2 , and an average glacier mass-change rate of −5.4±2.8Gtyr $^{-1}$.

Stream flows show increasing trends

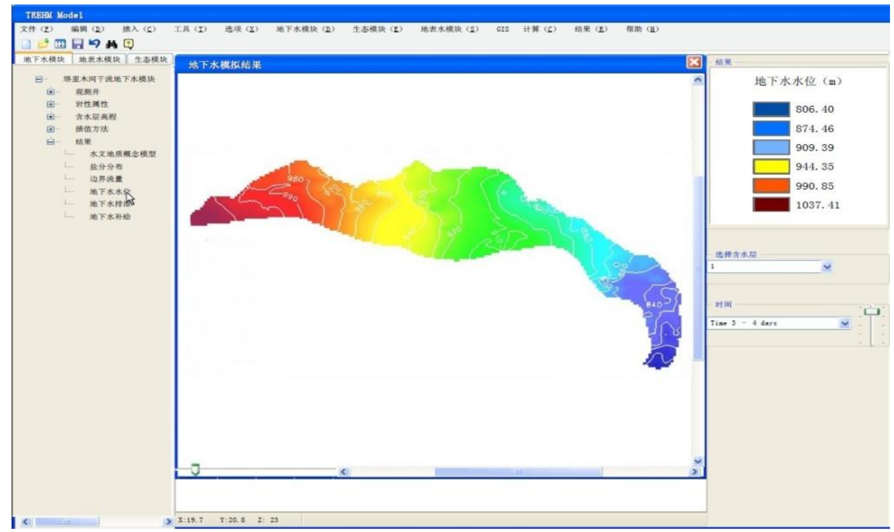


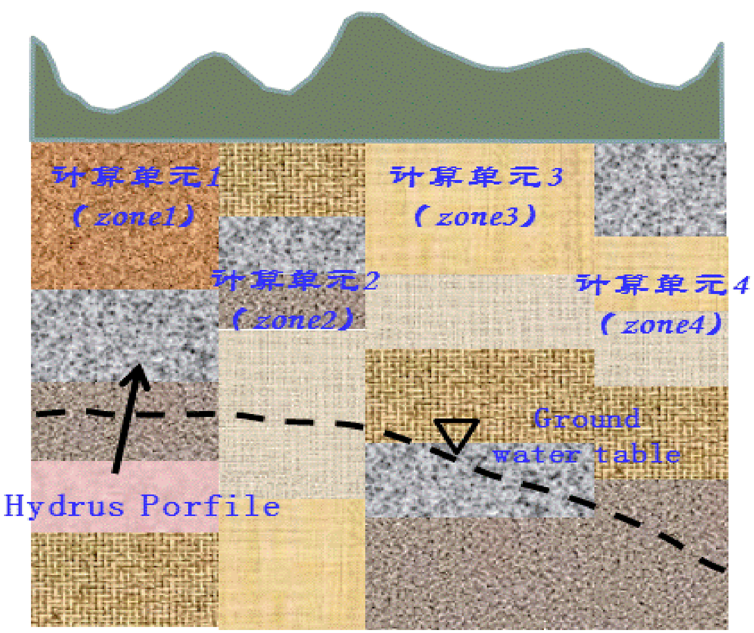
Stations Variable	Xiehe -la	Shaligu -ilanke	Wulu -wati	Tonggu -ziluoke	Alar
Trends/a	+0.21	+0.15	+0.004	+0.003	-0.05
Break year	1992	1986	2010	2009	2010
Periodicity	4years (1978-1983, 1990-1995)	4~8 years (1972-1976)	4years (1973-1983)	4years (1972-1982)	4~8 years (2002 -2007)



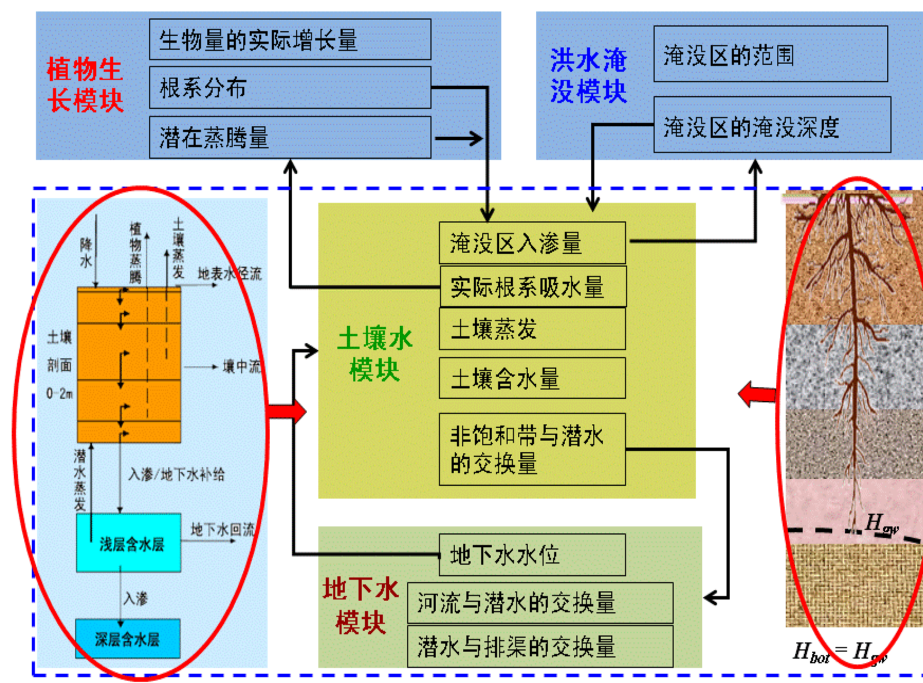


二、Methodology

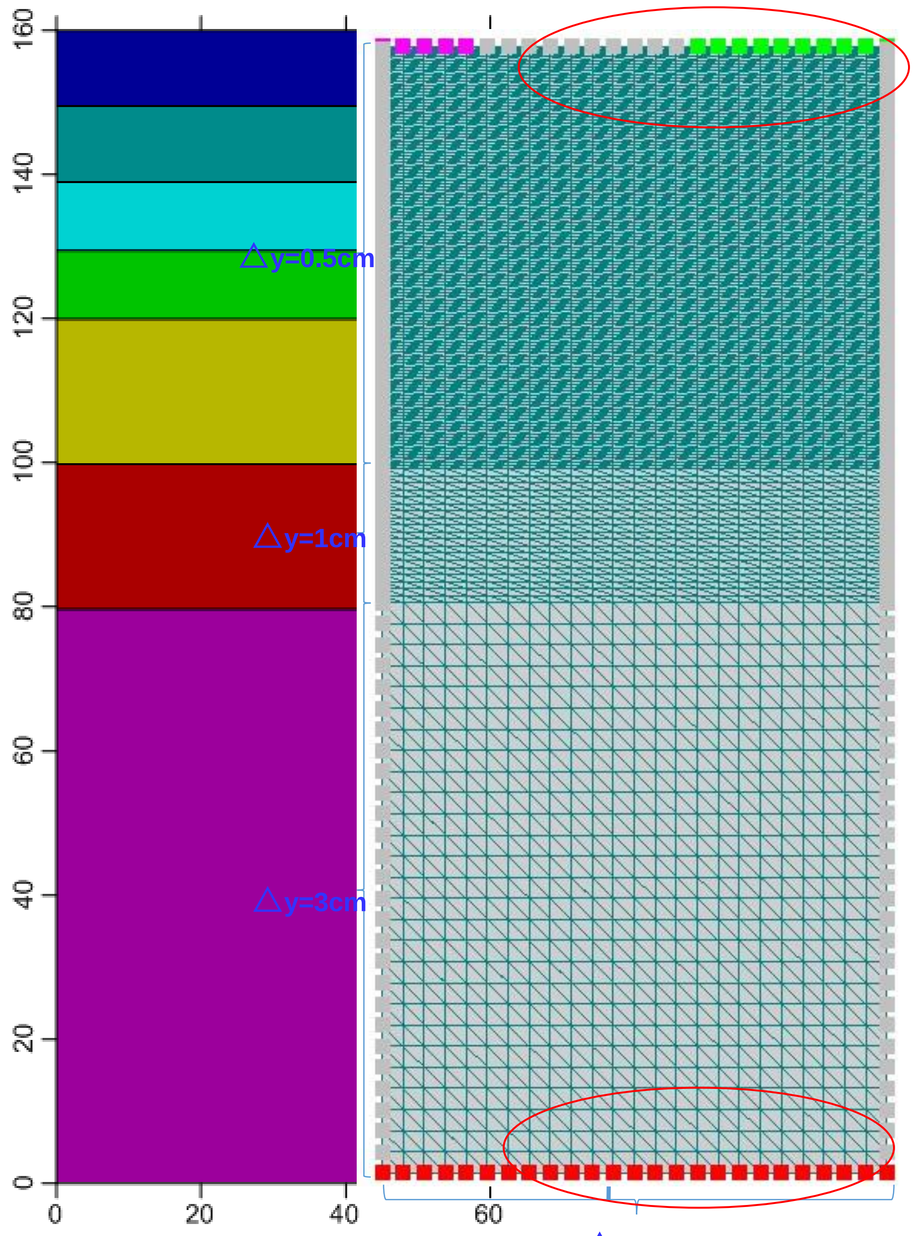




Cross section along A-B



二、Methodology



Material distribution map(left) , boundary condition and grid map

表4－1 利用PEST获得以及实测的土壤水力学参数

Tab 4－1 The van Genchten parameter got though measurement and PEST inverse solution

Depth	thr	ths	Alfa	n	Ks	L
10	0.04	0.453	0.012	2	27.3	0.5
20	0.04	0.483	0.011	1.7	12.5	0.5
30	0.04	0.482	0.01	1.5	8.9	0.5
40	0.0386	0.453	0.004	1.8	11.4	0.5
60	0.0386	0.482	0.009	1.37	9.3	0.5
80	0.0386	0.474	0.005	1.35	4.7	0.5
100	0.043	0.486	0.006	1.35	4.5	0.5

Colum selected with blue means all the value is measured in the field
Colum selected with means all the value is get via inverse solution using PEST

Numerical model

Pink Nodes means variable-flux boundary
Red Nodes means Free-drainage boundary
Green Nodes means Atmosphere boundary
White Nodes means No-flux boundary

Interaction among inundation model, groundwater and soil water model

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[k(\theta)\frac{\partial h}{\partial z}\right] - \frac{\partial k(\theta)}{\partial z} - S$$

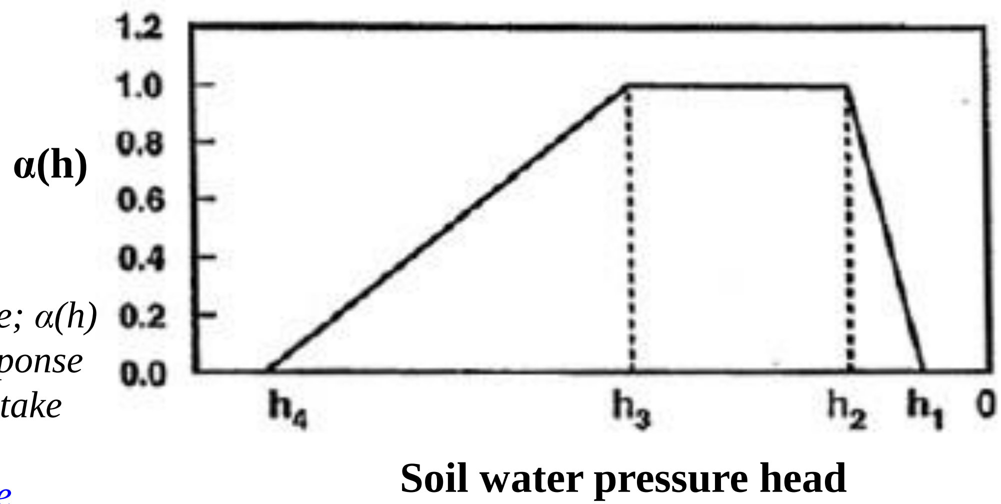
$$H_{top} = H_{flood} \quad or\ H_{top} = \mathrm{AtmosBou}$$

$$H_{bot} = H_{gw}$$

$$S(h) = \alpha(h) S_p$$

$$S_p = b(x) T_P$$

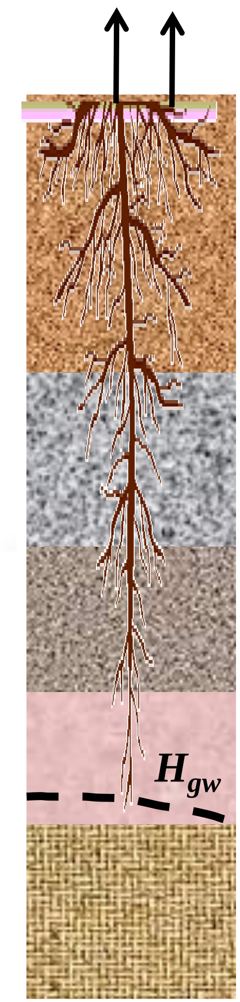
where : S(h) is the actual root uptake; α(h) is root-water uptake water stress response function , b(x) normalized water uptake distribution ,T_P is the potential transpiration from EPIC ; H_{gw} is the averaged ground water table



(Feddes,1978)

H_{top}= AtmosBoun

or H_{top} = H_{flood}



H_{bot} = H_{gw}

Interaction among river package, groundwater and soil water model

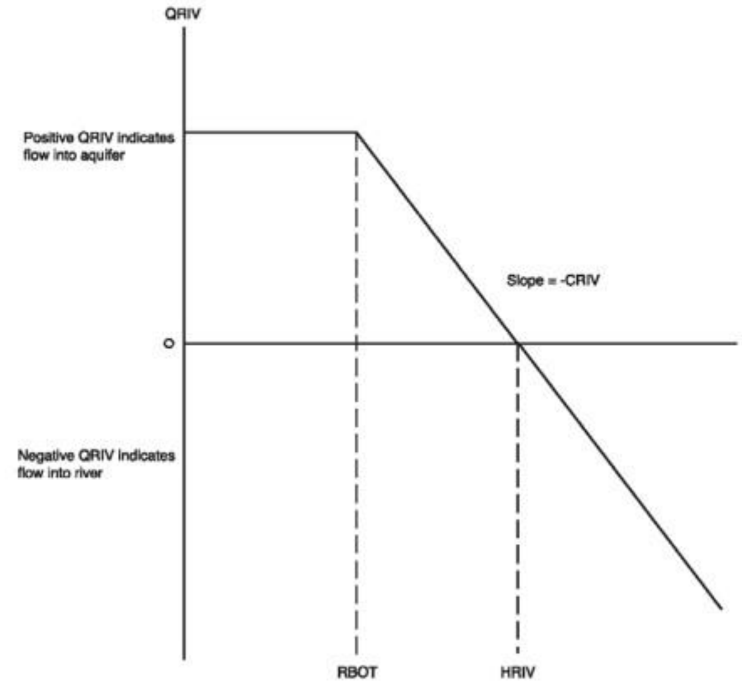
$$\frac{\partial h}{\partial t}S_S = \frac{\partial}{\partial x}[k_x \frac{\partial h}{\partial x}] + \frac{\partial}{\partial y}[k_y \frac{\partial h}{\partial y}] + \frac{\partial}{\partial z}[k_z \frac{\partial h}{\partial z}] - W$$

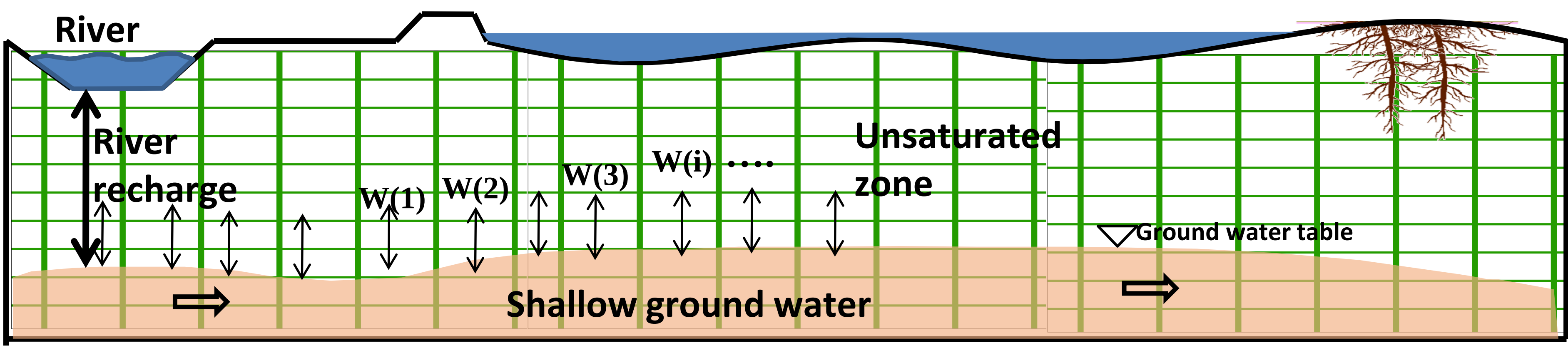
Where: *W* is the recharge include recharge estimated by soil water variation

$$QRIV_n = CRIV_n \times (HRIV_n - h_{i,j,k}) \quad h_{i,j,k} > RBOT_n$$

$$QRIV_n = CRIV_n = (HRIV_n - RBOT_n) \quad h_{i,j,k} \le RBOT_n$$

(McDonald and Harbaugh, 1988.)





二、Methodology

Interaction among vegetation growth model and soil water model

Atmosphere condition input

Optimal Vegetation growth

$$H_{phosyn} = 0.5 \cdot H_{day}(1 - \exp(-k_l \cdot LAI))$$

$$\Delta bio = RUE \cdot H_{phosyn}$$

$$\Delta LAI_i = (fr_{LAI_{mx,i}} - fr_{LAI_{mx,i-1}}) \cdot LAI_{mx} \cdot (1 - \exp(5 \cdot (LAI_{i-1} - LAI_{mx})))$$

•••••

Vegetation water stress

$$\lambda E_t = \frac{\Delta(H_{net} - G) + \gamma \cdot K_1 \cdot (0.622 \cdot \lambda \cdot \rho_{air} / P) \cdot (e_z^0 - e_z) / r_a}{\Delta + \lambda \cdot (1 + r_c / r_a)}$$

$$E_a = \sum_{i=1}^{NNodes} S(i)$$

$$REG_i = E_a / E_t$$

•••••

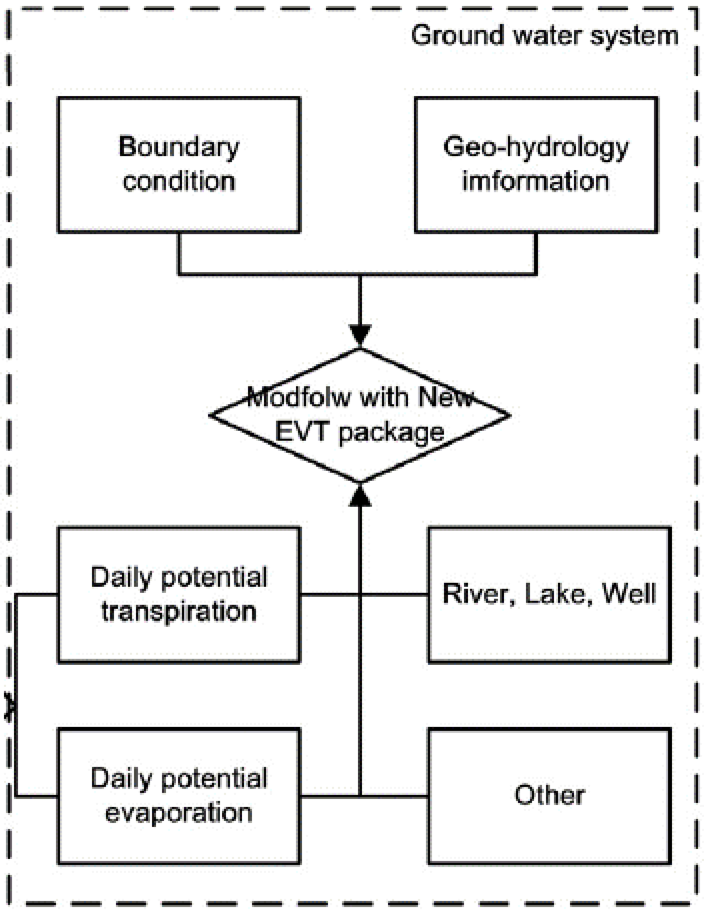
Actual Vegetation growth

$$\Delta bio_{ac} = \Delta bio \cdot REG_i$$

$$\Delta LAI_{i,ac} = \Delta LAI_i \cdot REG_i$$

•••••

where：Δbio is the optimal biomass growth, ΔLAI_i optimal LAI growth， Δbio_{ac} is actural biomass growth， $\Delta LAI_{i,ac}$ is actual LAI grwoth， REG_i为water stress ，H_{day} is incident total solar radiation，RUE is radiation use efficience，E_t is potential transpiration，E_a is actual transpiration, S(i) actual root uptake for each node in hydrus profile。



New EVT package

$$ET_{act} = \alpha(mh)_{veg,i} \times E_{t,i}$$

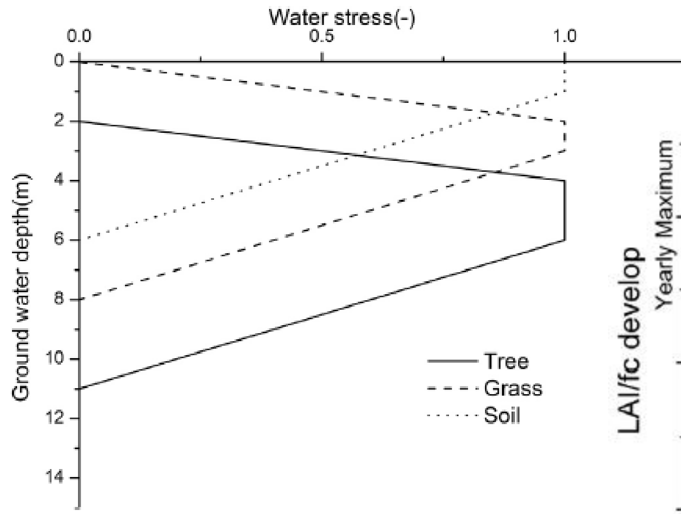
$$ES_{act} = \alpha(mh)_{soil} \times E_{s,i}$$

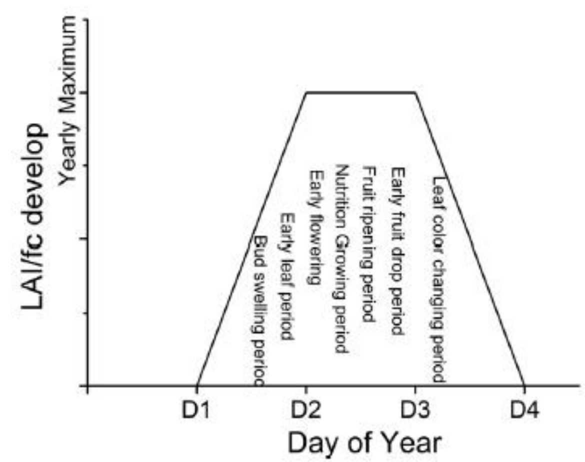
$$\alpha(mh) = \begin{cases} \dfrac{mh}{th_{a,i}} & mh \le th_{a,i} \\ 1 & th_{b,i} < mh < th_{a,i} \\ \dfrac{(mh - th_{b,i})}{(th_{d,i} - th_{b,i})} & th_{d,i} \ge mh \ge th_{b,i} \\ 0 & mh > th_{d,i} \end{cases}$$

1. Calculate soil evaporation and vegetation transpiration separately.
2. Modified the water stress function of EVT package

Daily GWD

Grow season averaged GWD

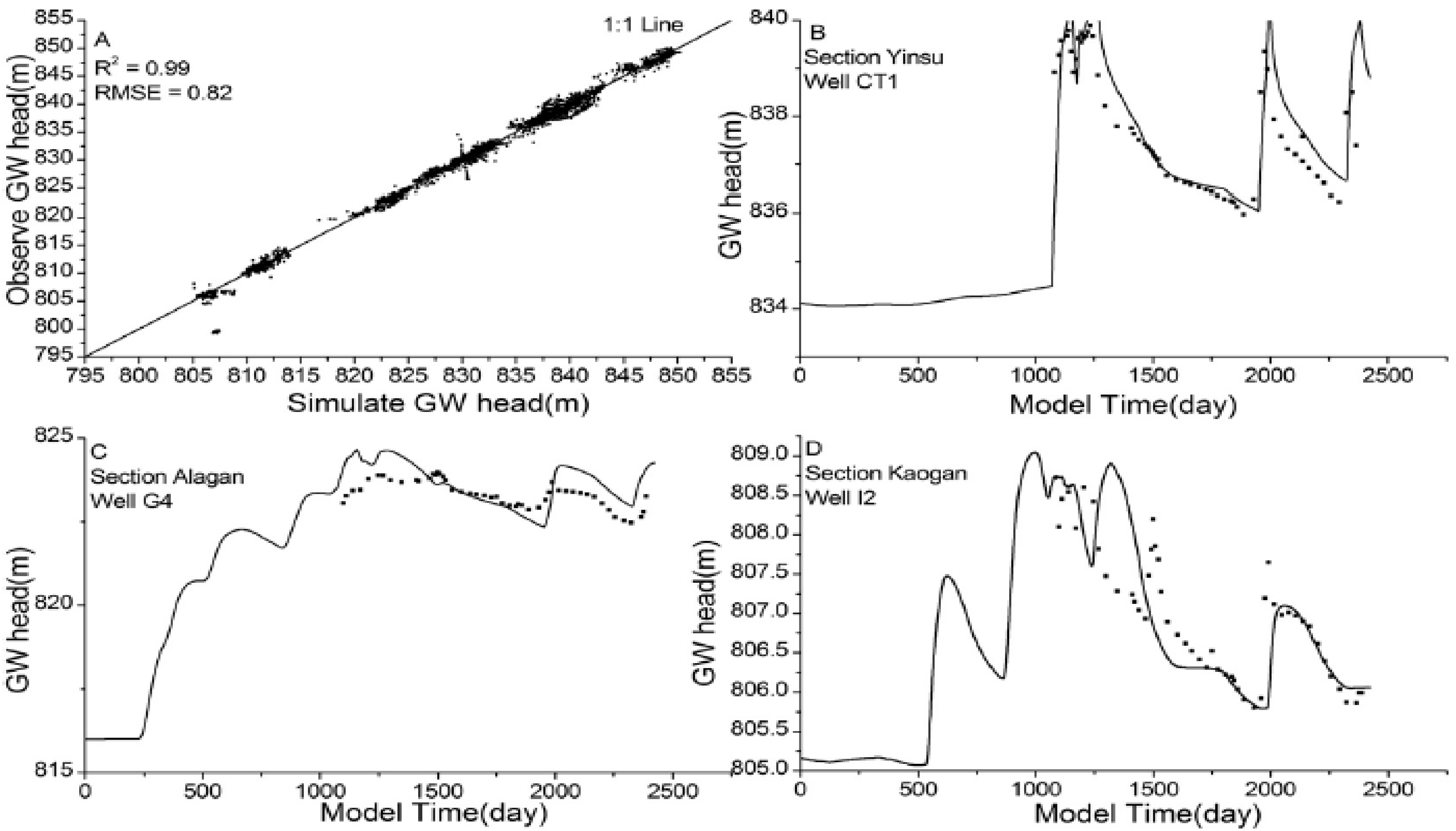




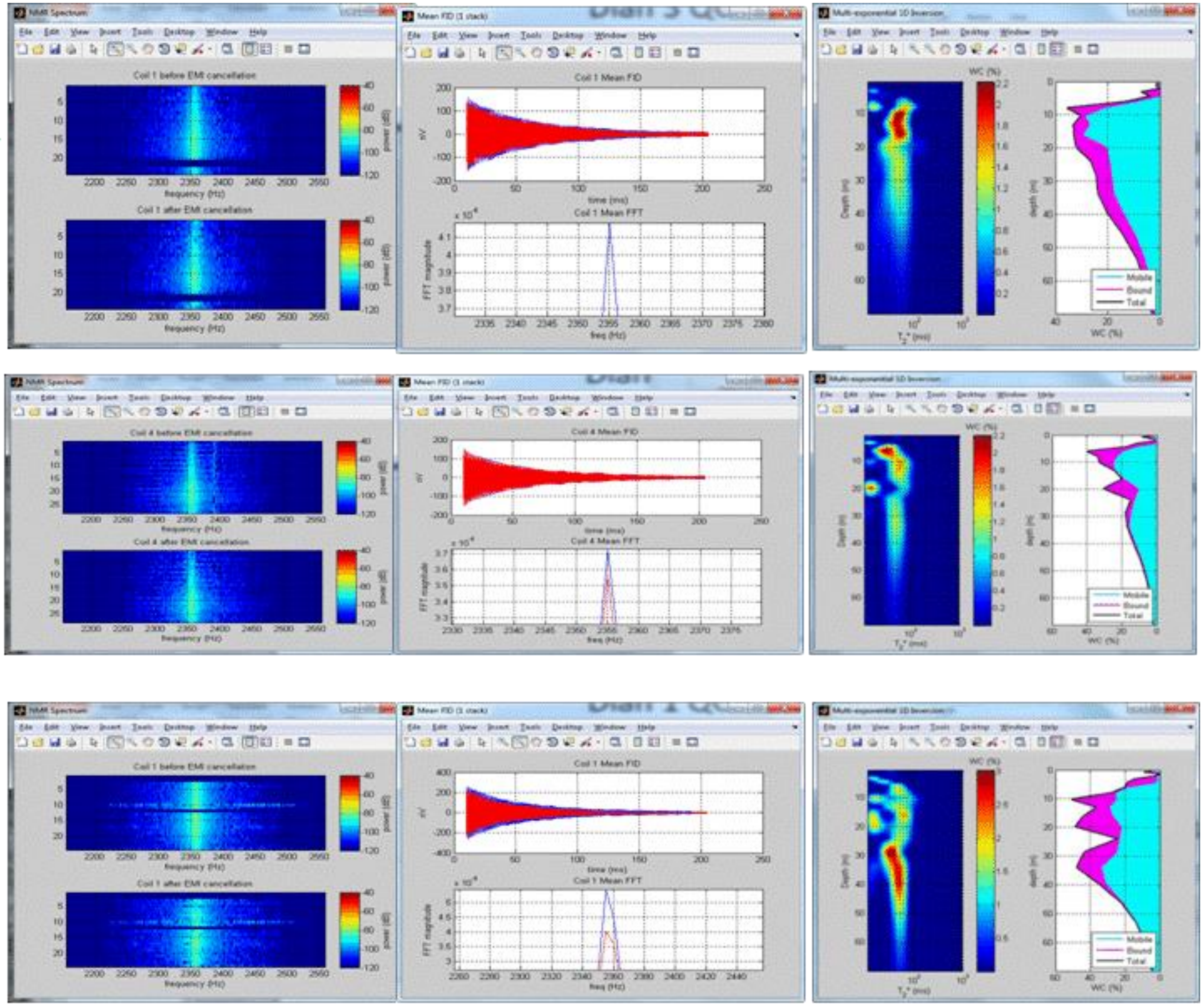
二、Methodology

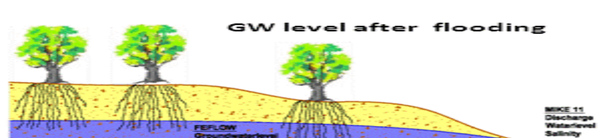
TREHM: Calibration and validation

- **Groundwater**
  - Calibrated to 12 wells in downstream



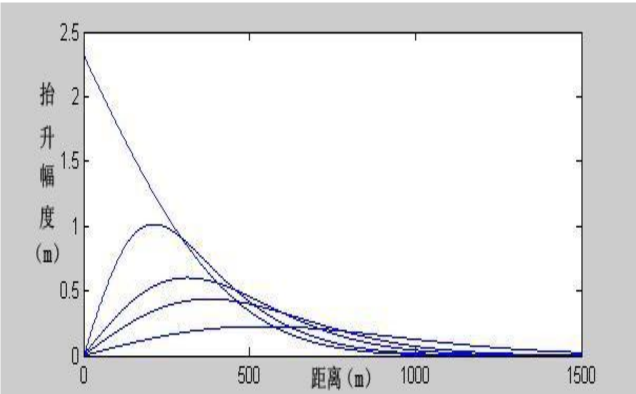
二、Methodology

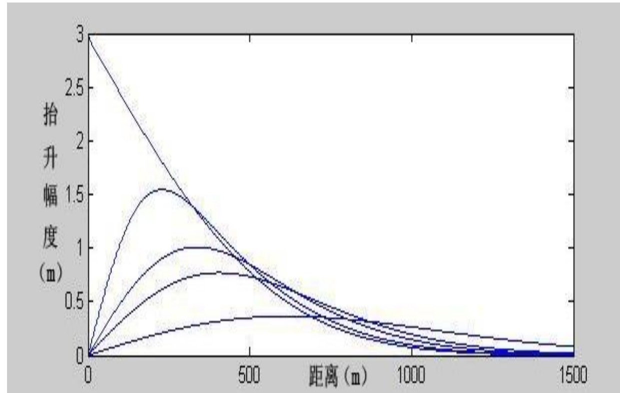


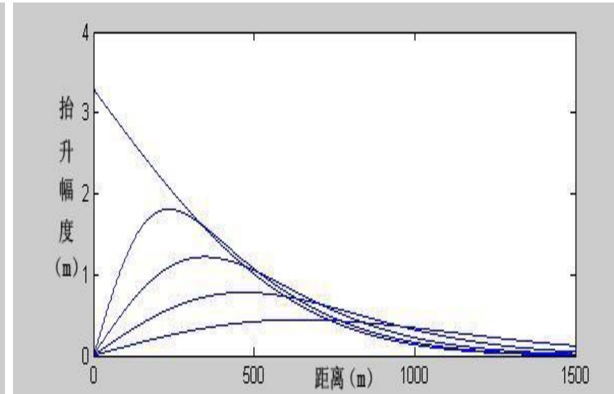


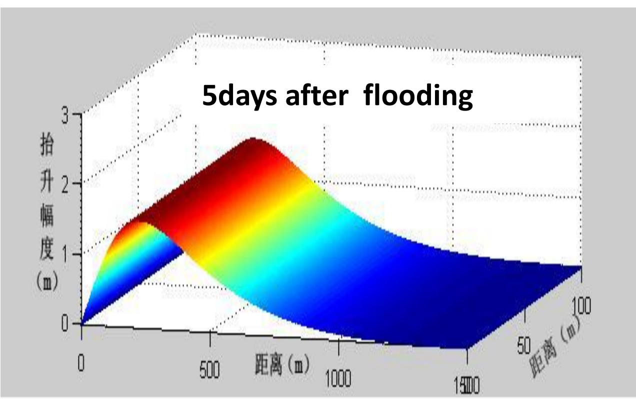
三、Simulations—(1) Simulation of river discharge to GW after flooding

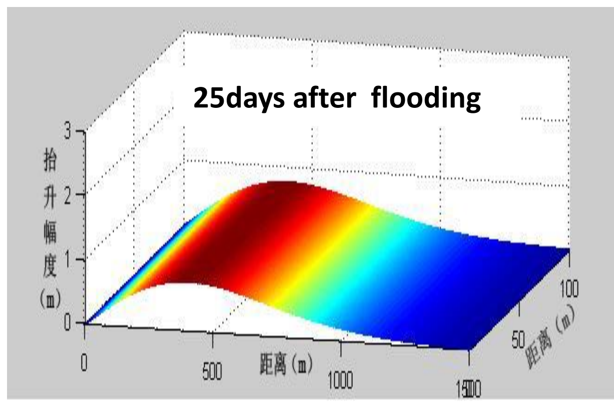
GW variation curve after flood at 5,15,25,60day, river discharge to GW from221.59m³/m， 197.06m³/m to 181.01m³/m

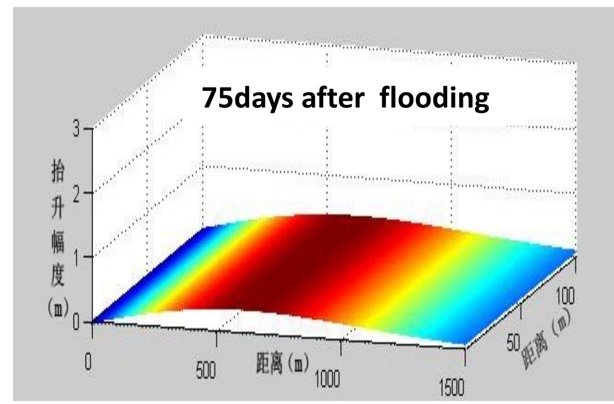




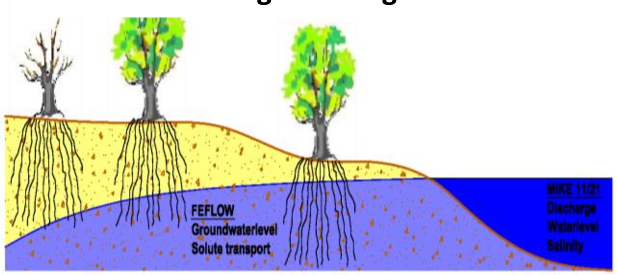




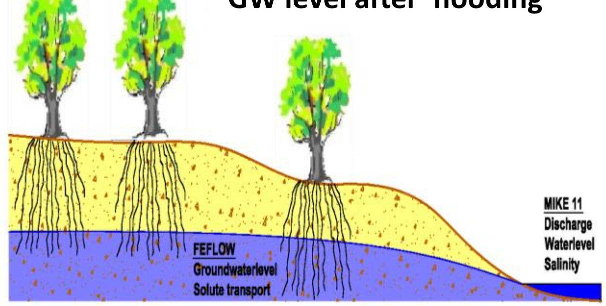




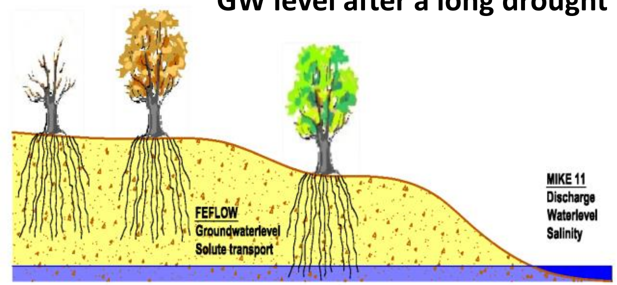
GW level during flooding



GW level after flooding

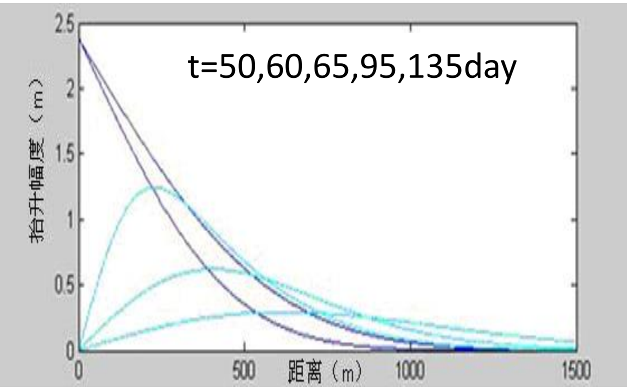


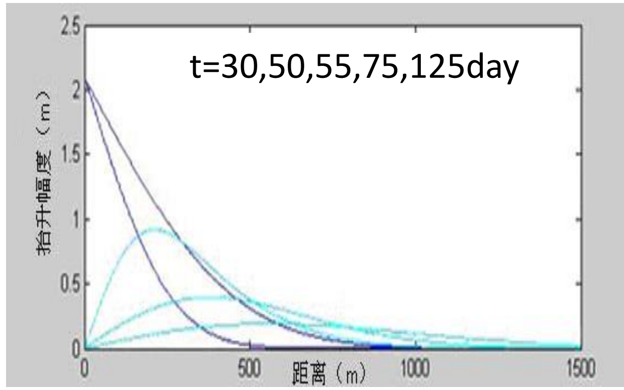
GW level after a long drought

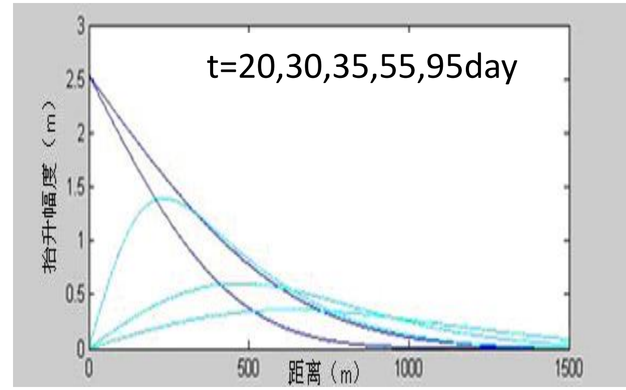


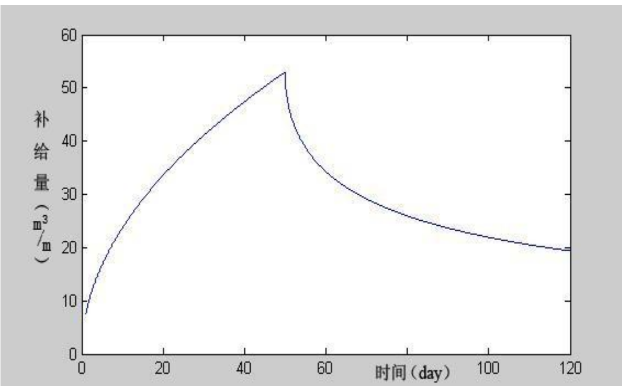
三、**Simulations**—(2) Simulation of river discharge to GW after built dam

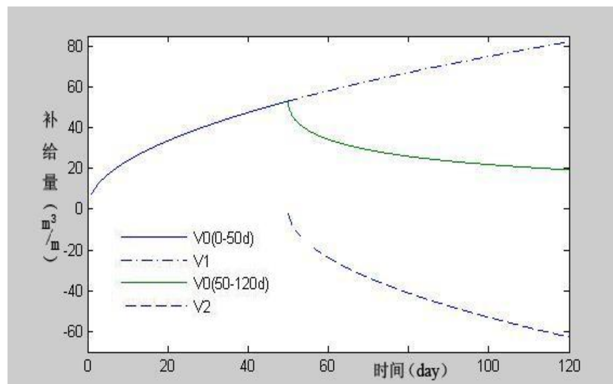
GW variation curve after built dam , river discharge to GW from 50.04m³/m， 43.06m³/m to 29.49m³/m

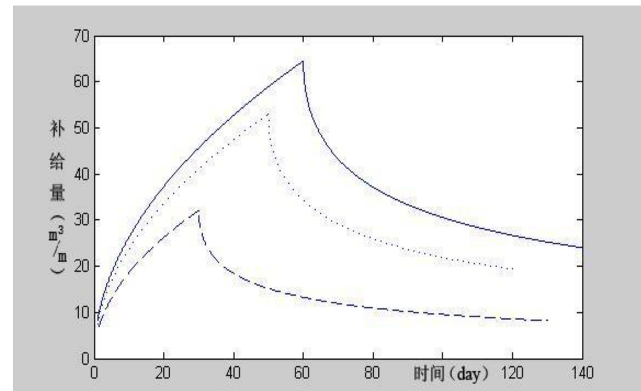




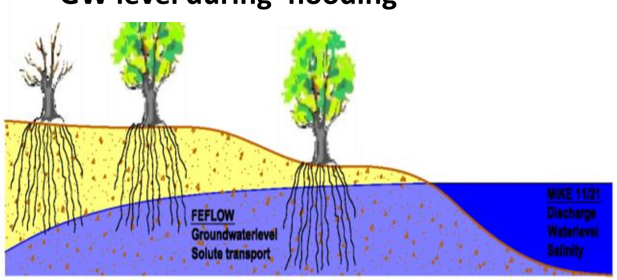




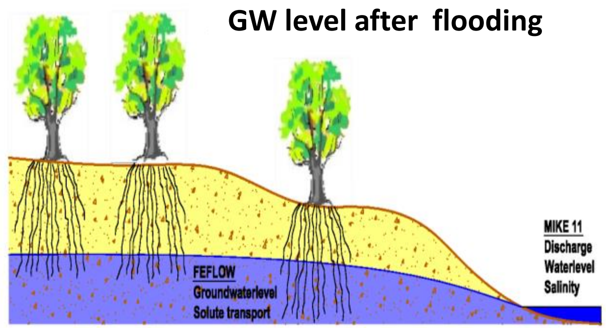




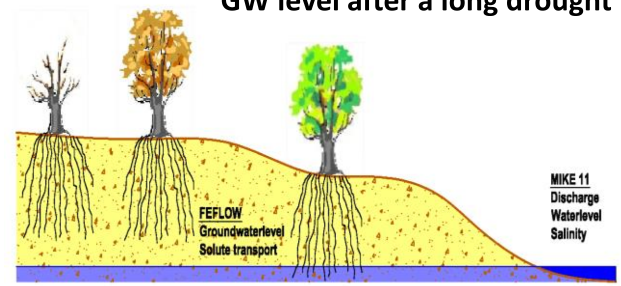
GW level during flooding



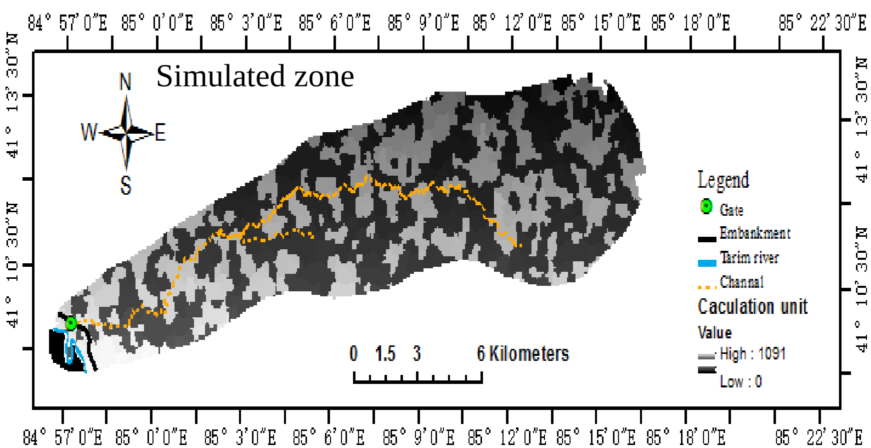
GW level after flooding

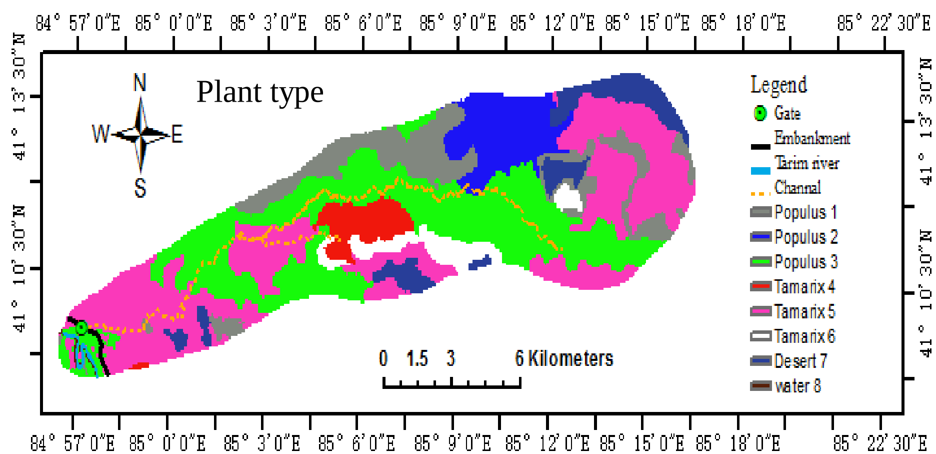


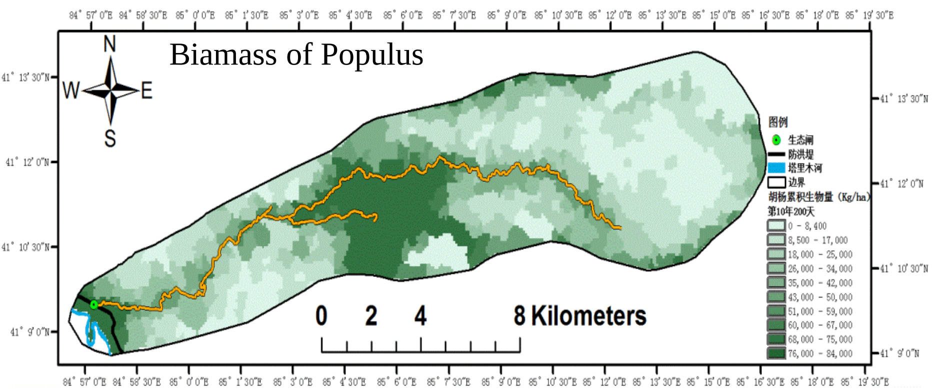
GW level after a long drought

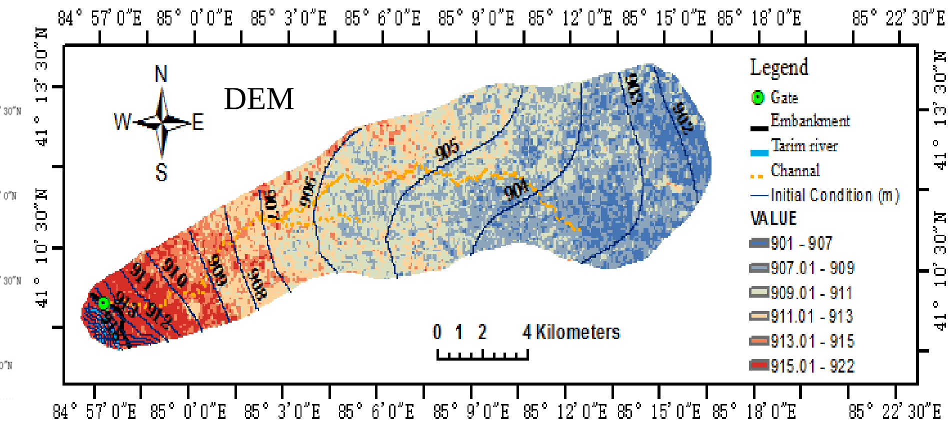


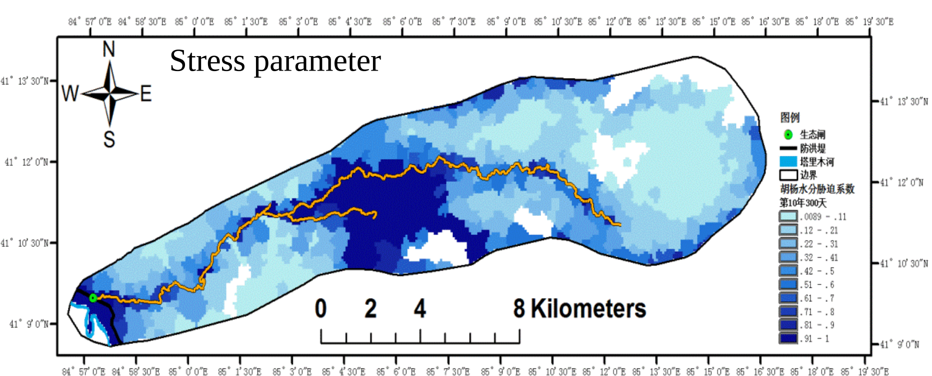
三、**Simulations**—(3) Simulation of flood gate in middle reach





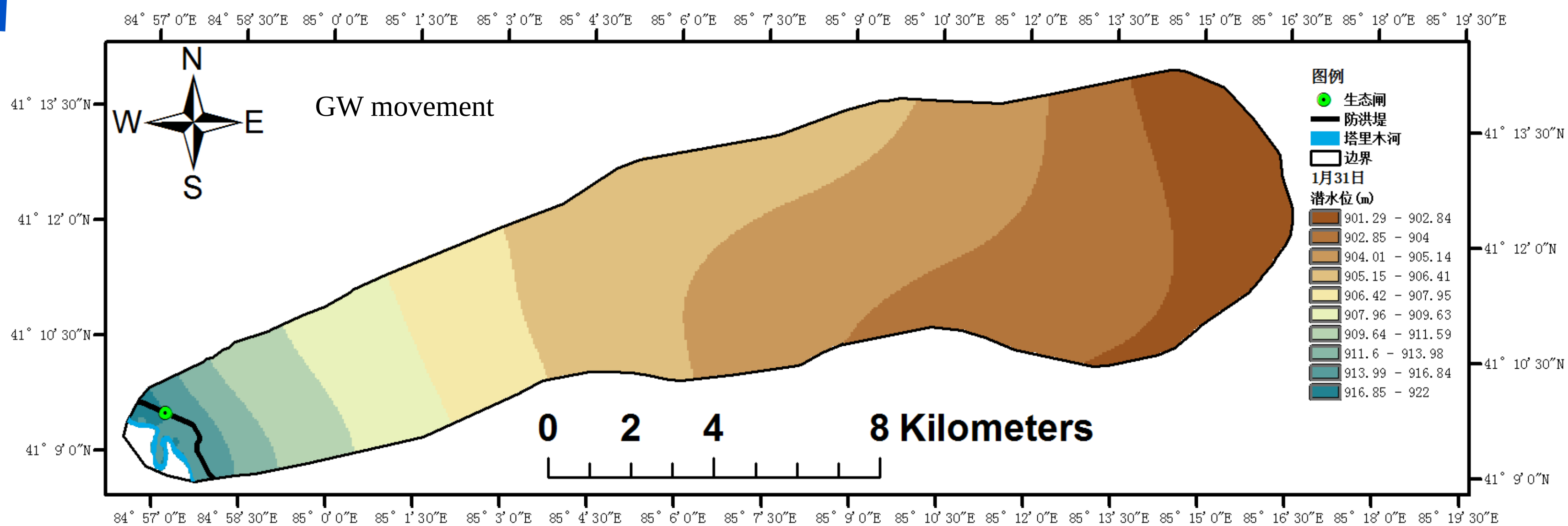




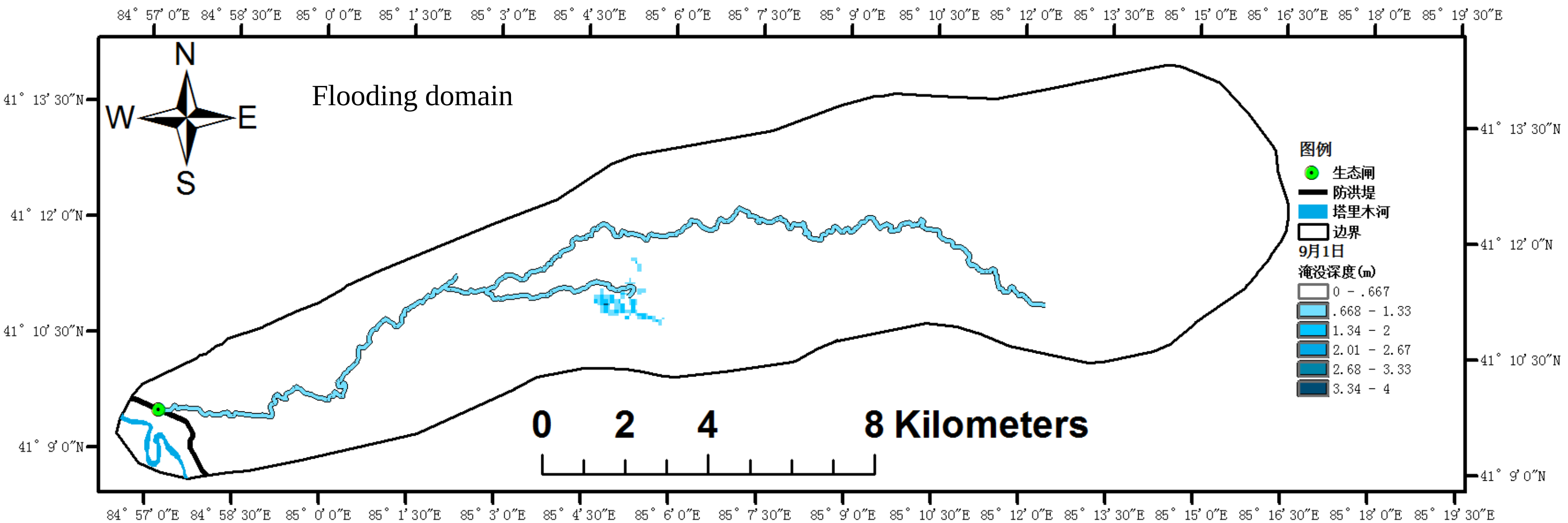


- 当胡杨水分胁迫系数>0.5，胡杨的生物量累积量大于0.7倍的柽柳生物量累积量时，该格点最终为胡杨。
- 对于不满足1条件的格点，当柽柳水分胁迫系数 大于0.5时为柽柳，小于0.5时，为荒漠。

三、Simulations—(3) Simulation of flood gate in middle reach



Groundwater variations

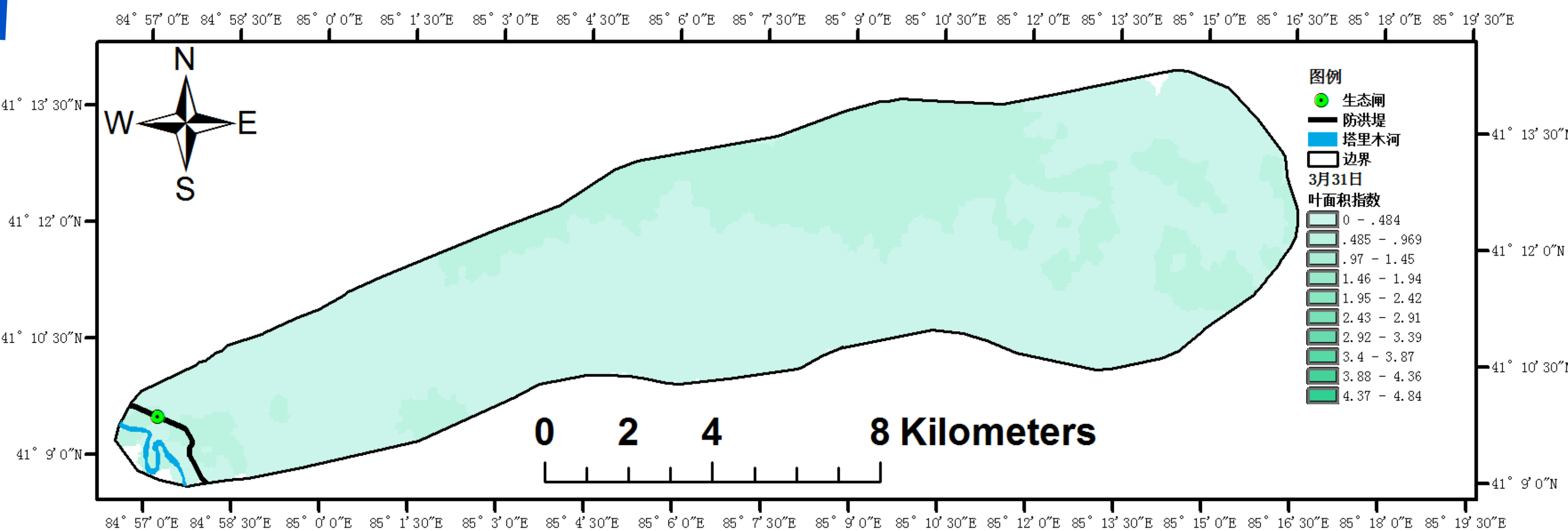


Inundation model variations

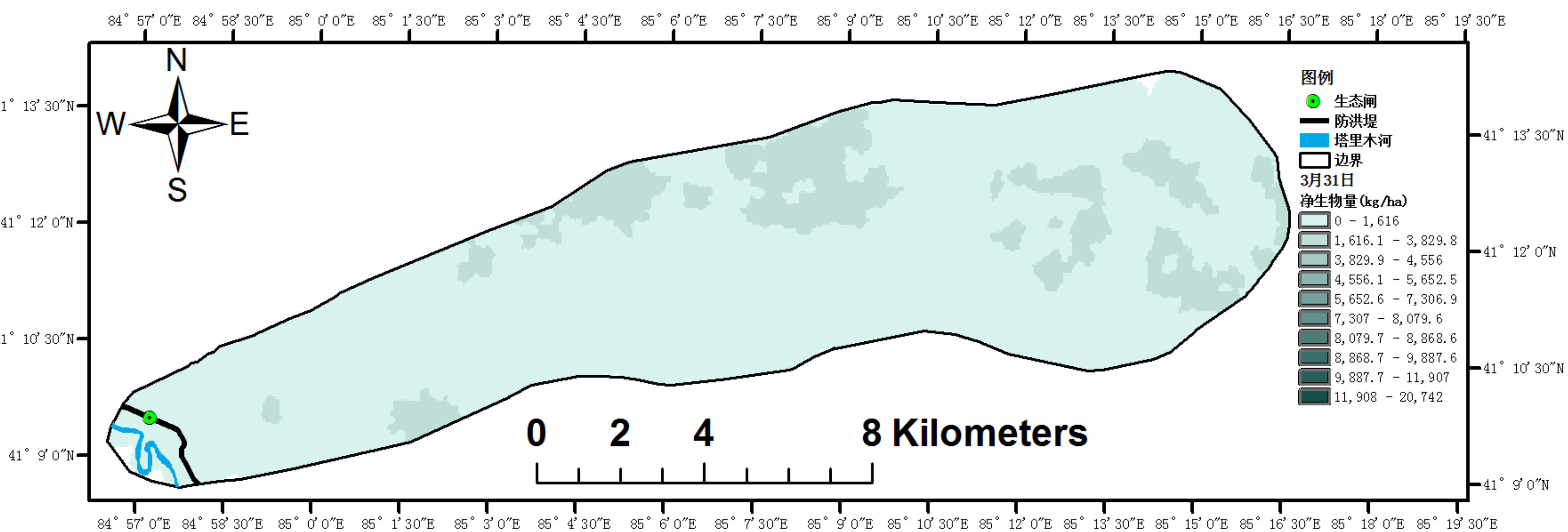
GW water balance at 10th year

GW water balance in 10 year

三、**Simulations**—(3) Simulation of flood gate in middle reach



Leaf area index variations



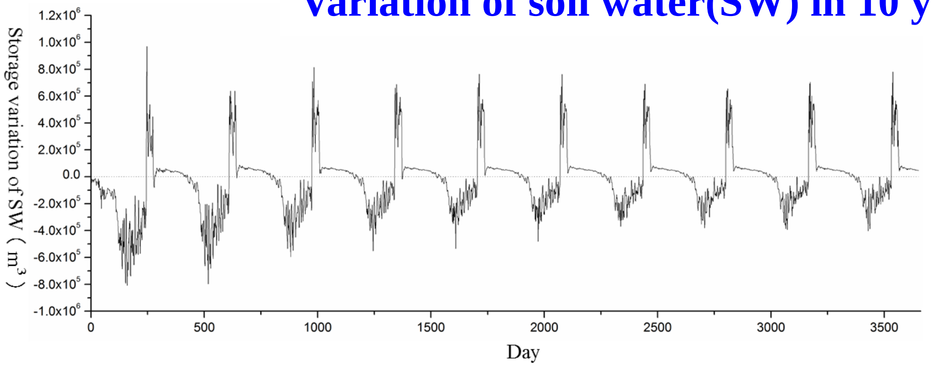
Net biomass accumulation

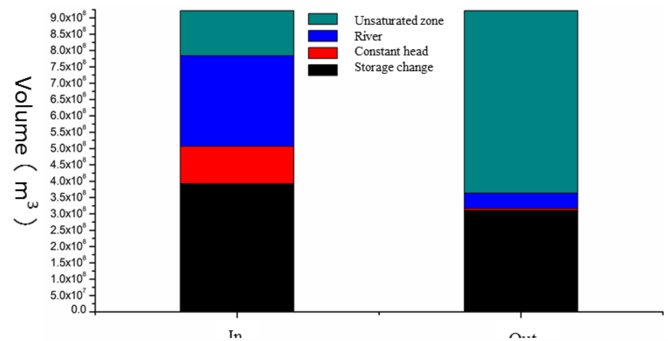
GW water balance at 10th year

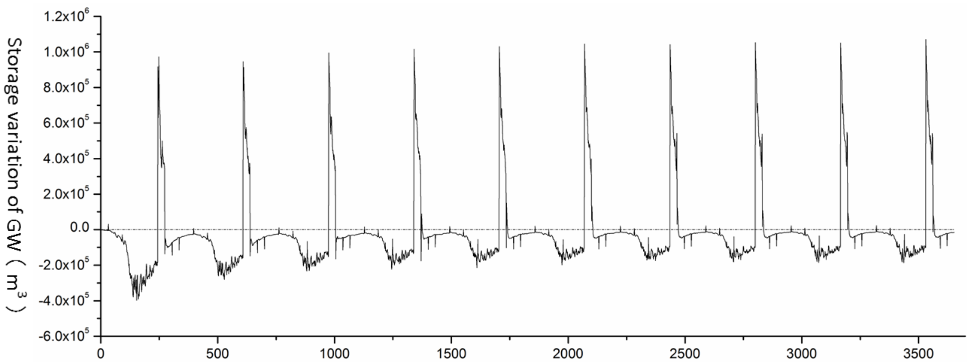
GW water balance in 10 year

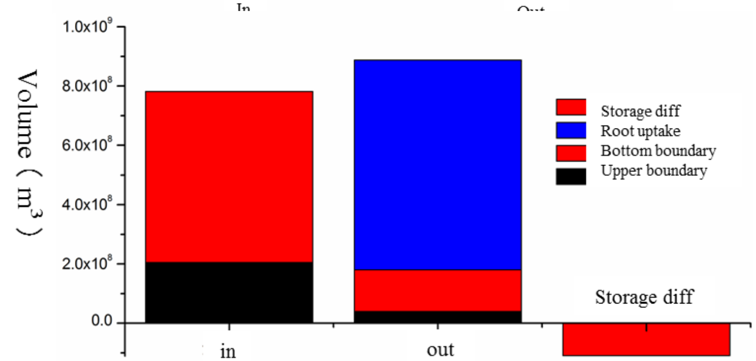
三、 **Simulations**—(3) Simulation of flood gate in middle reach

Variation of soil water(SW) in 10 years and water balance in 10th year

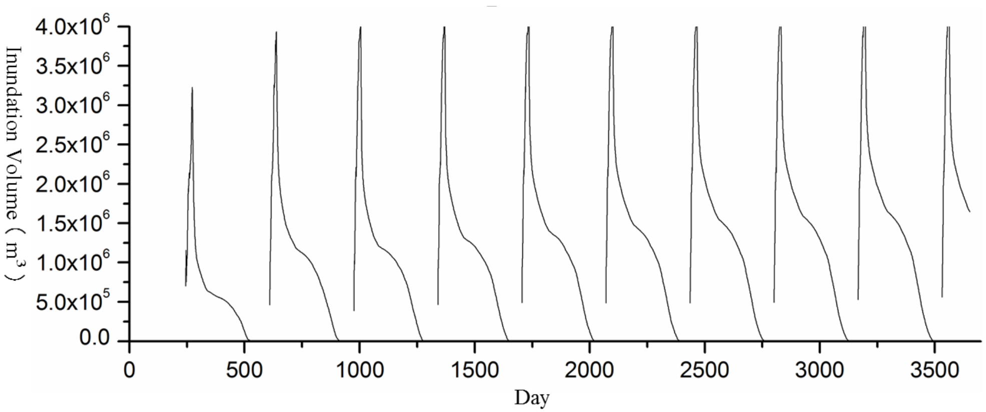


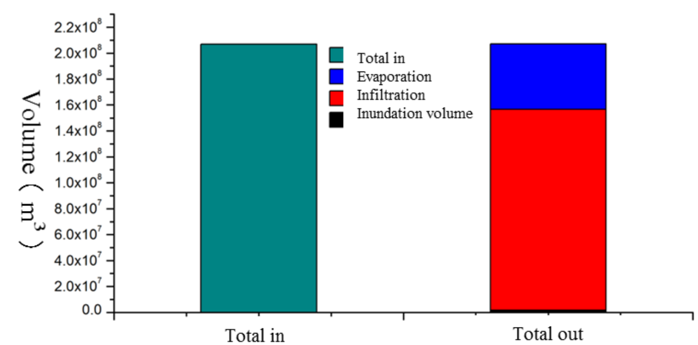






SW water balance in 10 years





Water balance for inundaton in 10 years

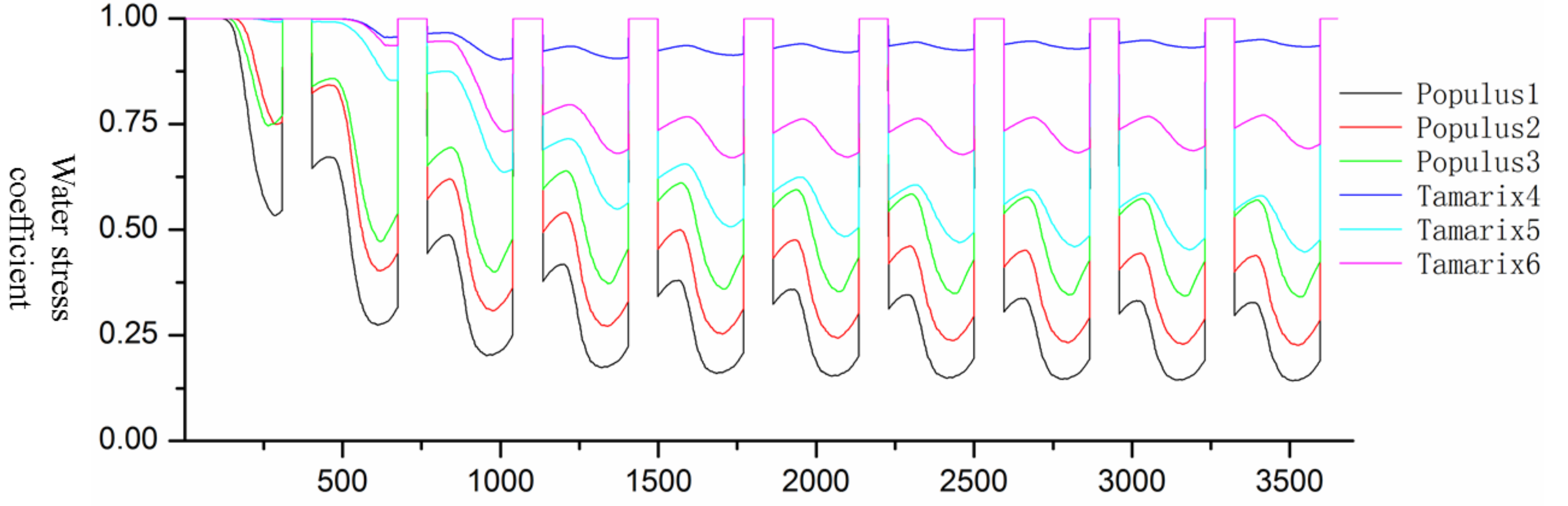
GW water balance at 10th year

GW water balance in 10 year

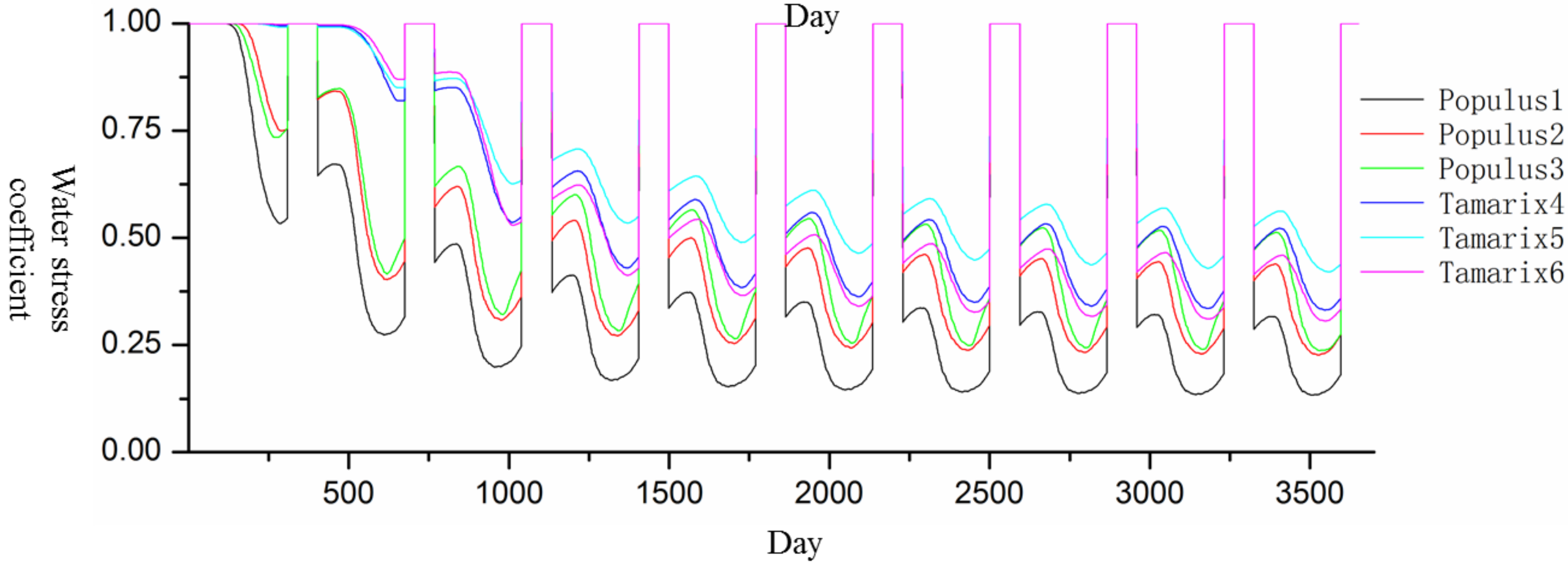
三、Simulations—(3) Simulation of flood gate in middle reach

Response of vegetation water stress to manual irrigation

With irrigation



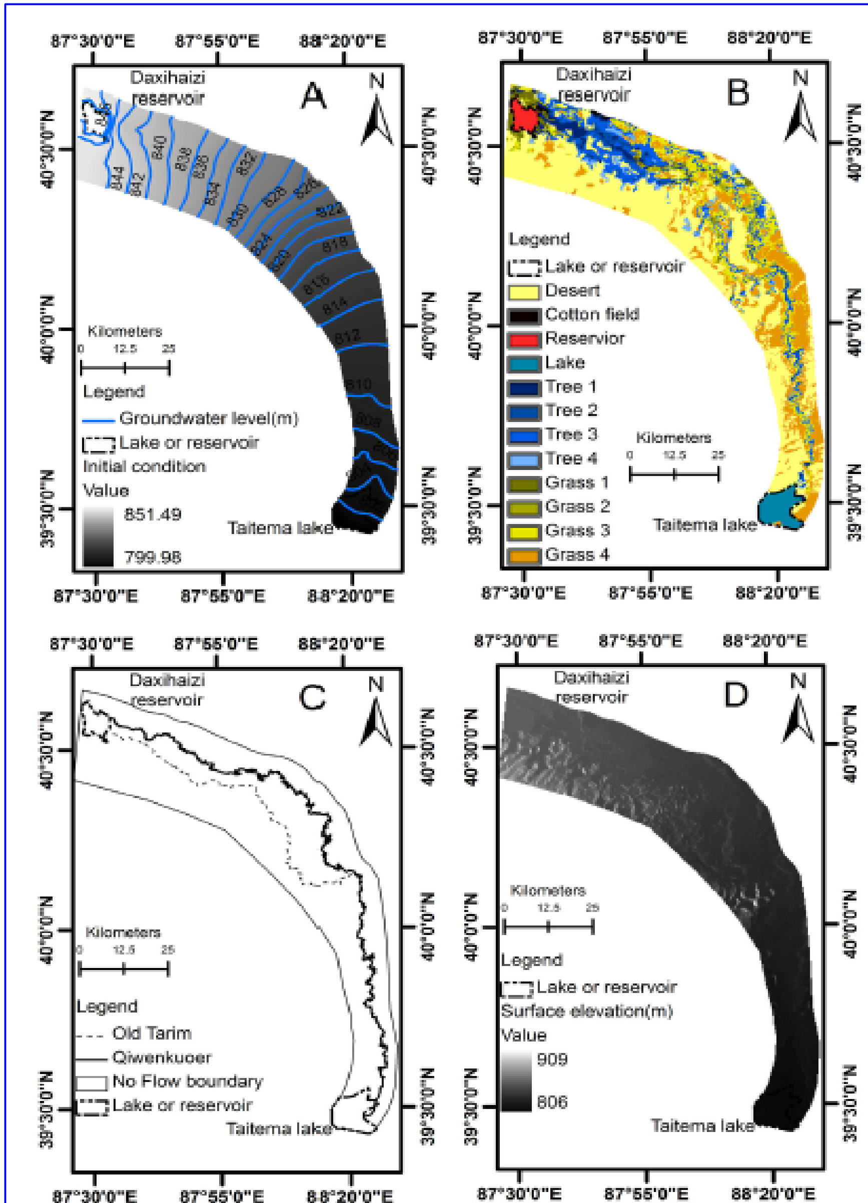
Without irrigation



GW water balance at 10th year

GW water balance in 10 year

三、Simulations—(4) Simulation of GW variation after irrigation in lower reach



Monitoring system

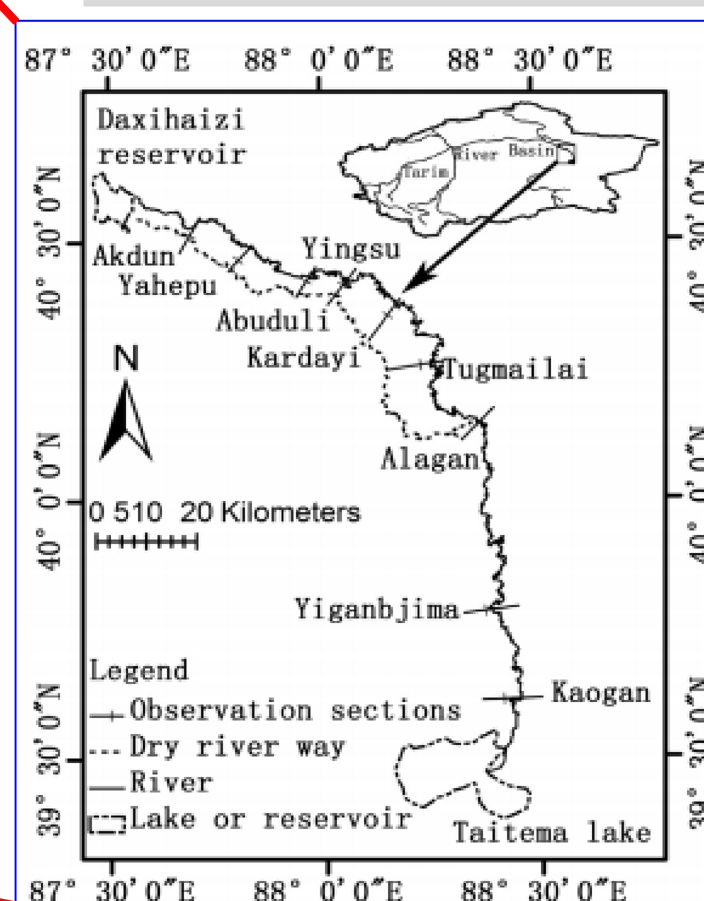
Nine observation sections includes:

1. Discharge in each section
2. 12 GW observation wells in 0- 1km
3. Vegetation monitoring such as: coverage diversity, etc.

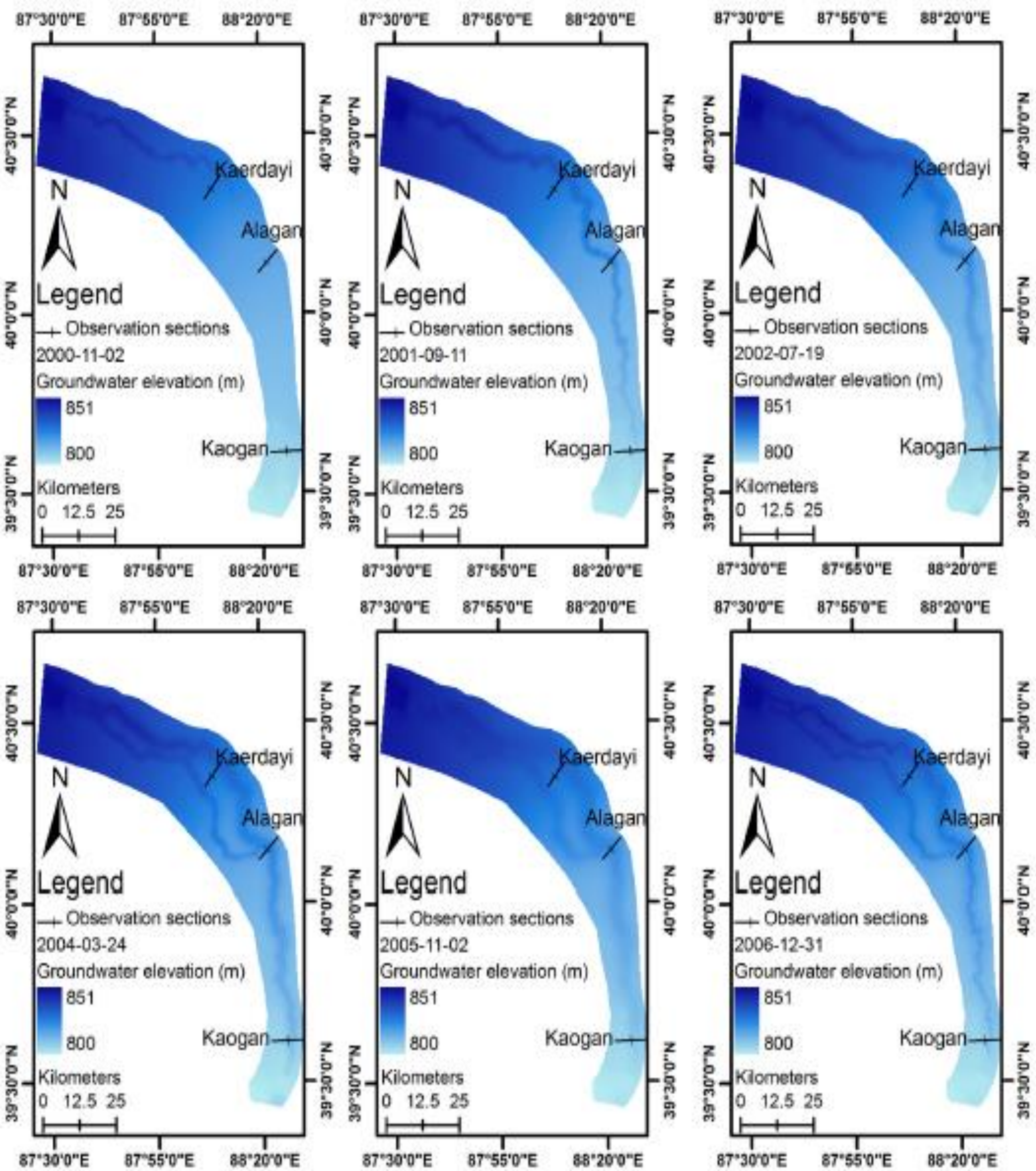
MODIS NDVI product:

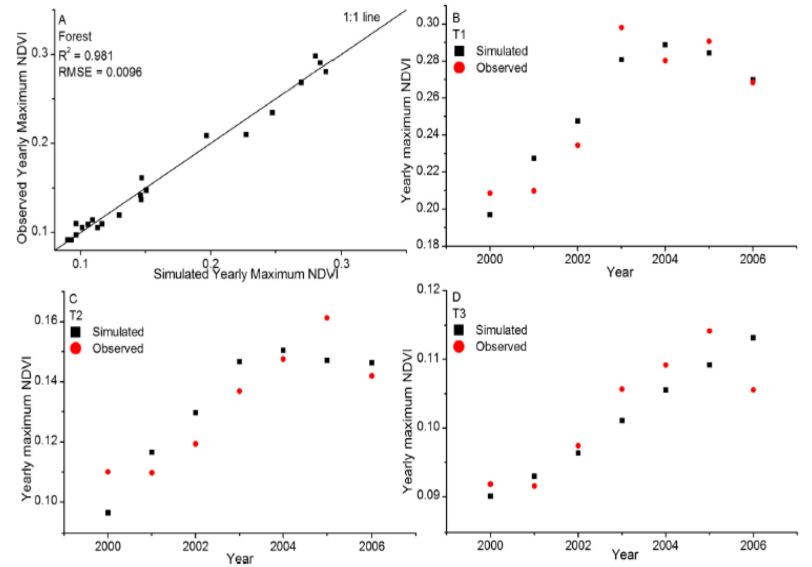
16 day interval

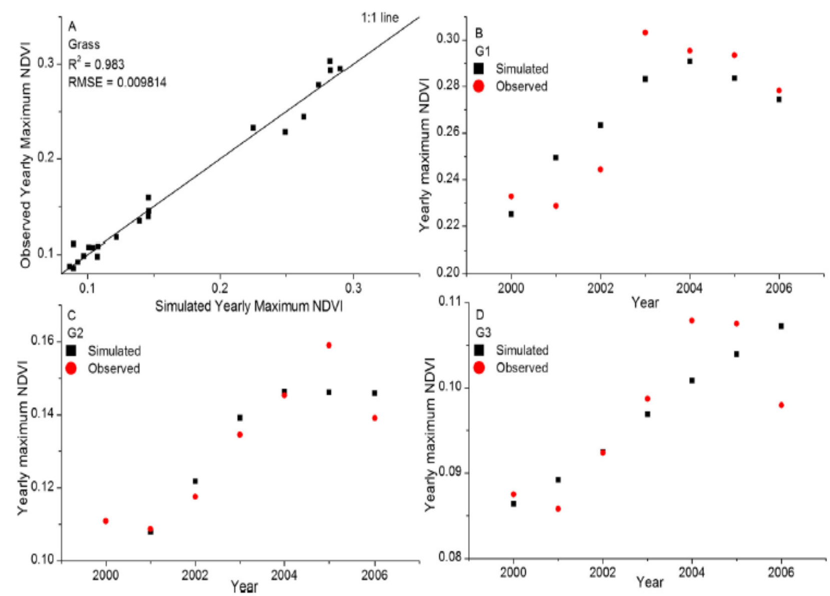
250 m resolution



三、Simulations—(4) Simulation of GW variation after irrigation in lower reach

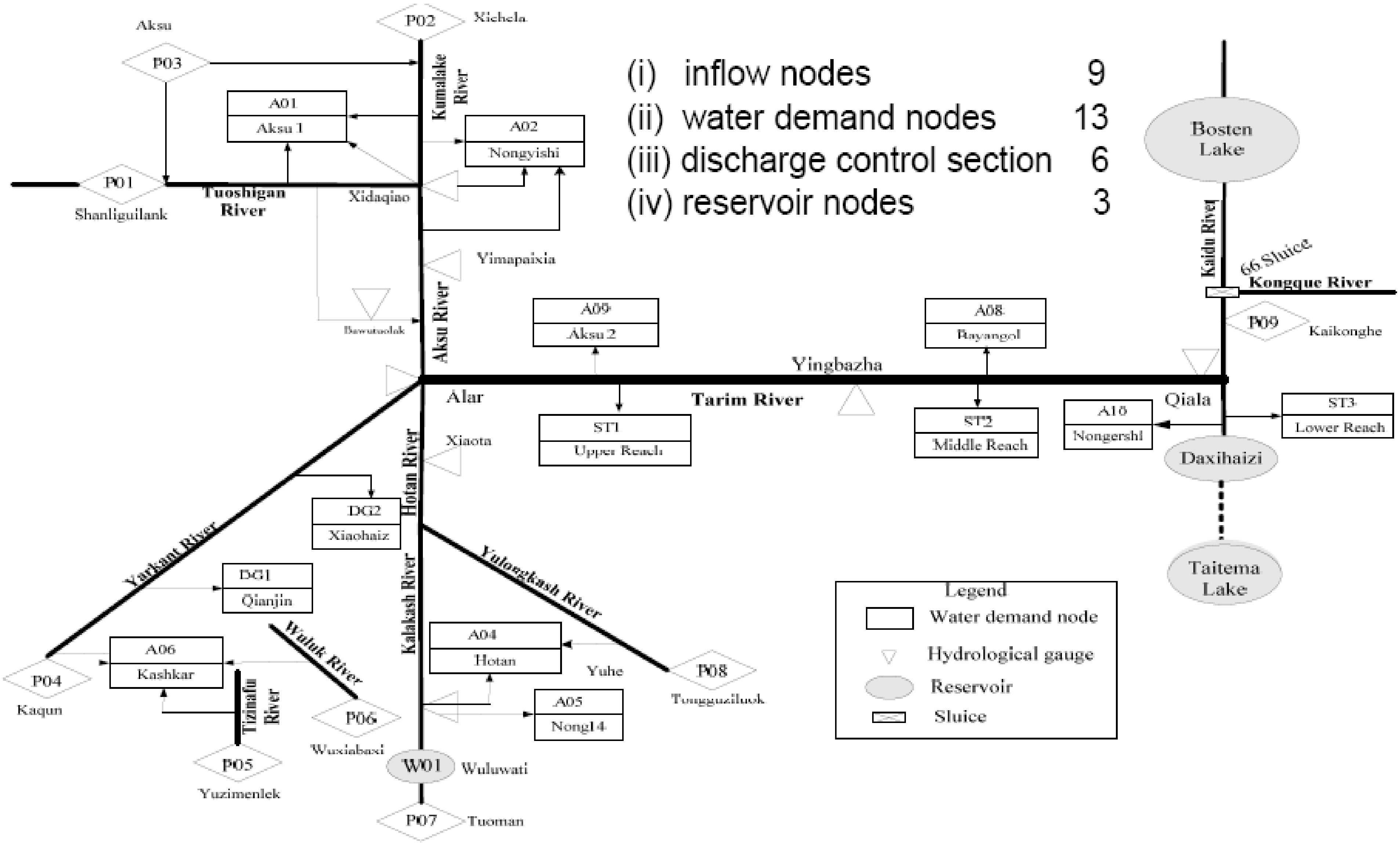






四、Water Balance in Tarim River Basin

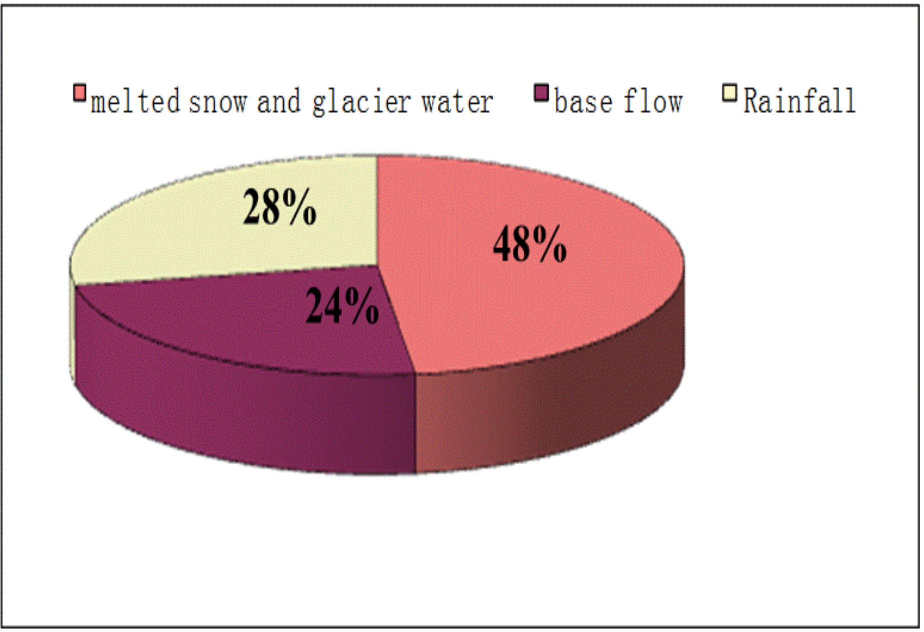
Operation nodes of water balance in the Tarim River Basin

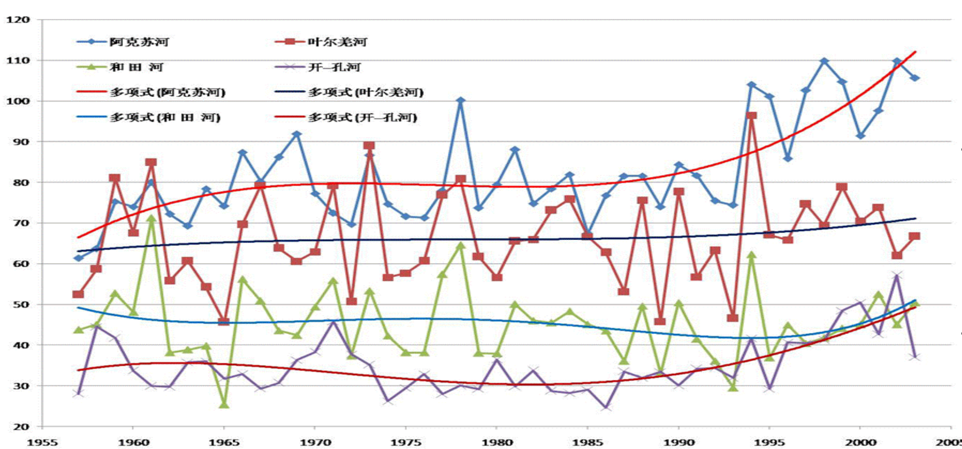


四、Water Balance in Tarim River Basin

(1) Water Balancein mountainous area

Runoff mainly origin from melted snow and glacier water, which account for 48% , the base flow and rainfall account for 24% and 28% respectively.



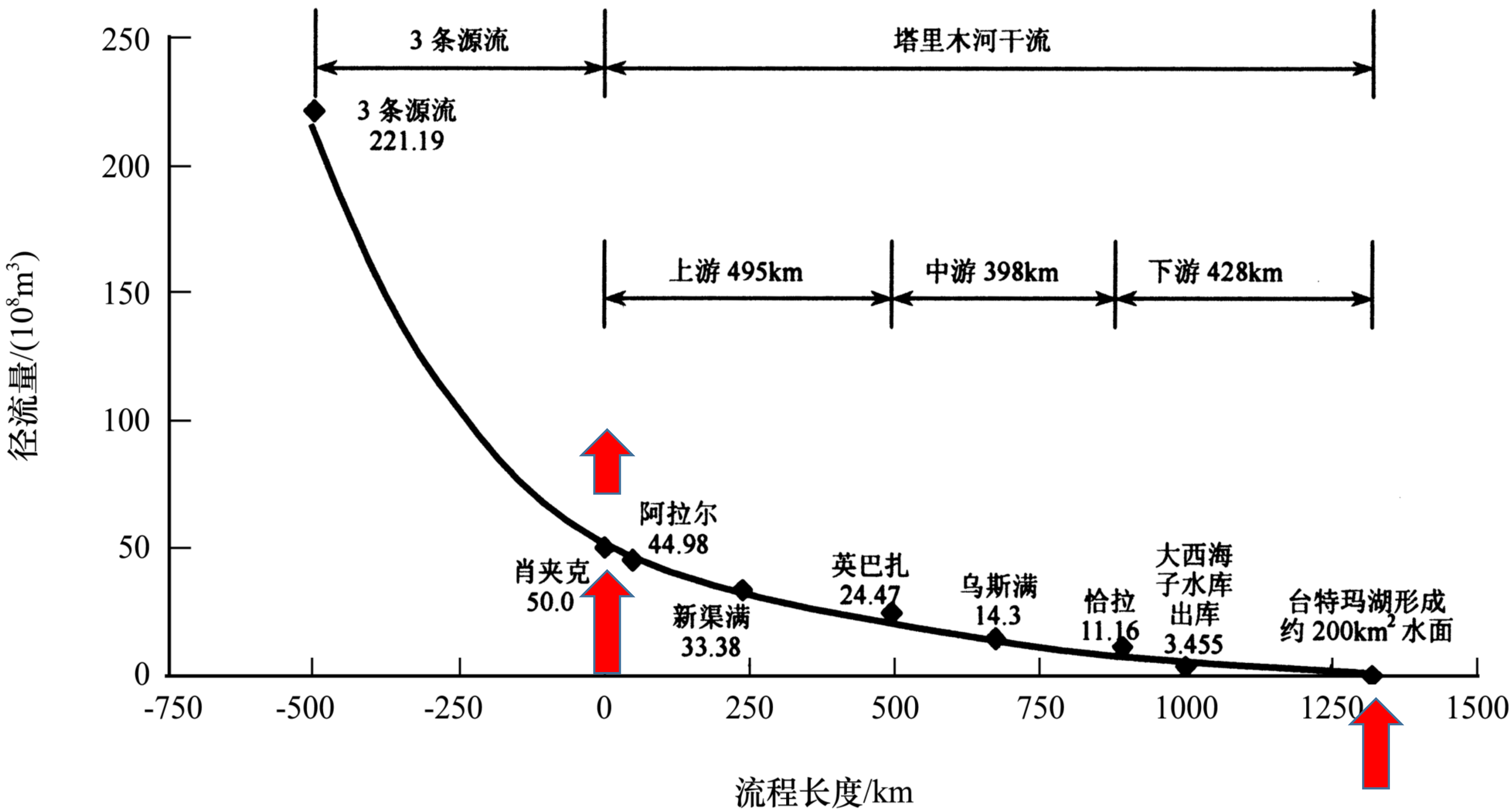


塔河气候变化引起的耗水增加量　单位:亿m³

项目	0.5℃	1℃	2℃
农业耗水增加	3.5579	7.7214	16.6536
生态耗水增加	1.456	2.9547	5.9093
水库蒸发耗水增加	0.37	0.7528	1.5056
合计	5.3839	11.4289	24.0686

气候情景	塔河干流	基本生存	适宜	最佳
0.5℃	上游	23.63	27.07	29.87
	中游	22.53	27.22	31.65
	下游	5.50	5.50	5.50
	合计	51.67	59.79	67.02
1℃	上游	23.90	27.42	30.29
	中游	22.86	27.66	32.19
	下游	5.58	5.58	5.58
	合计	52.34	60.66	68.06
2℃	上游	24.43	28.12	31.13
	中游	23.50	28.54	33.28
	下游	5.73	5.73	5.73
	合计	53.67	62.39	70.15

(2) Water Balance in main Tarim River Basin



(3) Water Balance in farm land

Irrigation norm and suitability evaluation of cotton drip irrigation under mulching

Degree of salinity	S_1 (g/kg)	S_2 (g/kg)	I (m³/hm)	I_1 (m³/hm) demand	I_1 (m³/hm) LR	I_2 (m³/hm)	Suitability
Light	0.3-0.6	1.0	5432	3465	0	2909	Y
Middle	0.6-1.0	1.0	5432	3465	0	2909	Y
Heavy	1.0-1.5	1.0	5432	3465	1158	2909	M
	1.5-1.7	1.0	5432	3465	2010	2909	M
	1.7-2.0	1.0	5432	3465	3300	4728	N
Solonchak	>2.0	Cotton dead					N

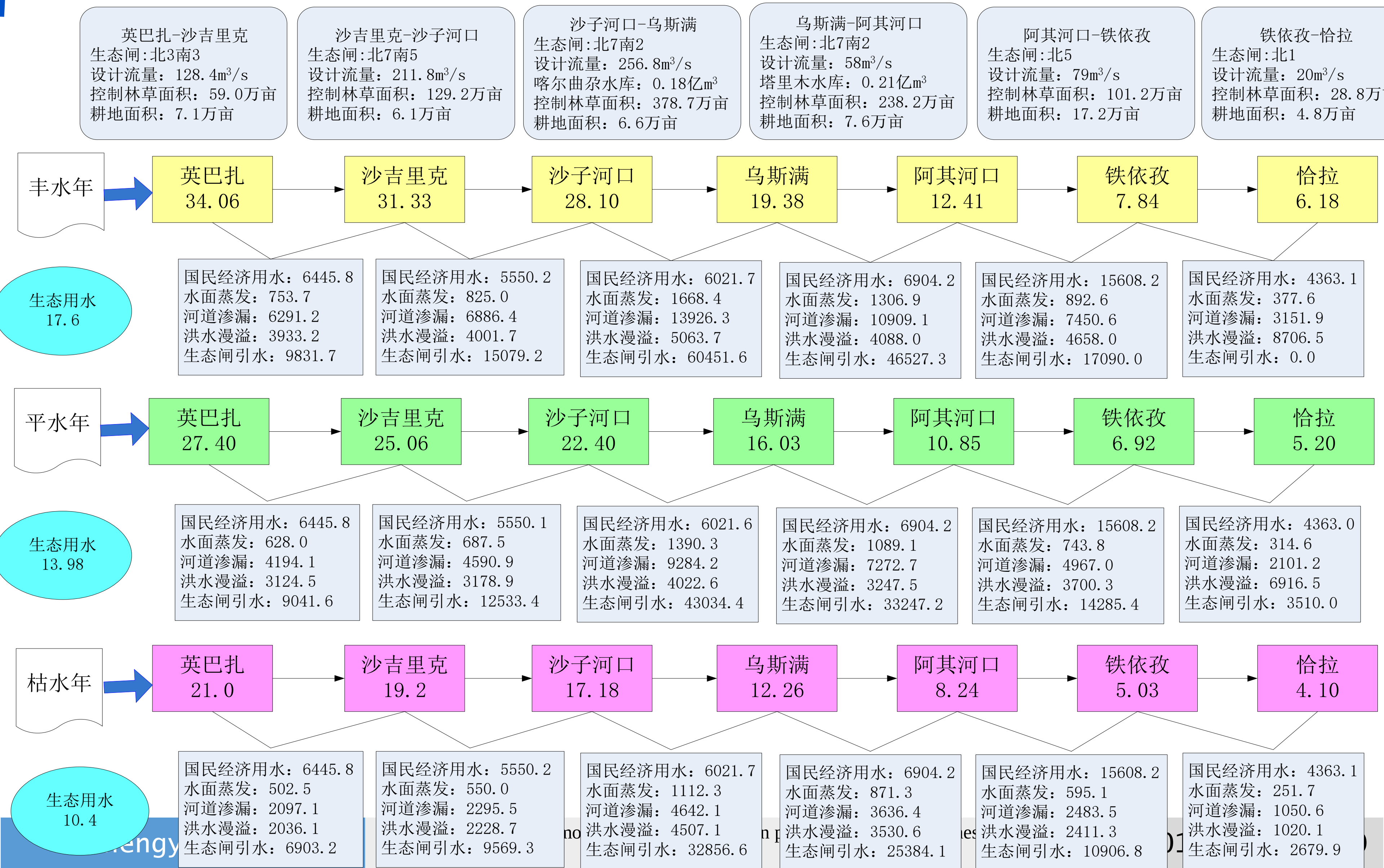
I_1--irrigation norm in cotton growing season, it include cotton water demand and LR;
I_2---added irrigation in winter or spring

(3) Water Balance in farm land

四源一干			现状年	温度升高 1℃	温度升高 2℃	适应成本（亿元）	产生效益（亿元）
水资源总量		亿m^3	274.88	302.368	327.1072		
总需水量	现状年	亿m^3	291.2661	316.3895	340.6128	0	
	节水660万亩	亿m^3	278.3961	303.5195	327.7428	16.41	12.83
	节水1000万亩	亿m^3	272.4076	297.531	321.7543	248.65	209.54
余缺水量	现状年	亿m^3	-16.3861	-14.0215	-13.5056		
	节水660万亩	亿m^3	-3.5161	-1.1515	-0.6356		
	节水1000万亩	亿m^3	2.4724	4.837	5.3529		

四、Water Balance in Tarim River Basin

(4) Water Balance in middle reach



四、Water Balance in Tarim River Basin

(5) Water Balance in lower reach

Water balance after 12 times irrigation in lower reach

Start Date	End Date	Total water convergence	To Taitema lake	River leakage	Reseriver leakage	Lake leakage	Evapotras ipiration	GW storage Change
2000-5-14	2000-11-2	0.99	0.00	0.96	0.07	0.00	-0.26	0.76
2000-11-3	2001-3-31	2.27	0.00	2.16	0.06	0.00	-0.14	2.08
2001-3-32	2001-9-11	1.84	0.00	1.79	0.06	0.00	-1.08	0.78
2001-9-12	2002-7-19	1.98	0.00	1.75	0.12	0.06	-0.86	1.07
2002-7-20	2003-3-2	3.31	0.08	2.53	0.08	0.07	-0.75	1.93
2003-3-3	2004-3-24	6.20	0.37	4.96	0.14	0.10	-3.02	2.19
2004-3-25	2005-5-6	1.12	0.00	1.01	0.15	0.00	-1.93	-0.77
2005-5-7	2006-9-24	2.82	0.12	2.56	0.19	0.03	-2.17	0.61
2006-9-25	2006-12-31	2.01	0.00	1.99	0.04	0.00	-0.18	1.85
2000-5-14	2006-12-31	22.55	0.57	19.71	0.91	0.28	-10.39	10.50

1. ET not only influenced by water convergence amount, but also groundwater depth and vegetation recovery status.
2. Via scenario study, vegetation recovery during 6 year totally increasing 3.8% of total evapotranspiration.

SUMMARY

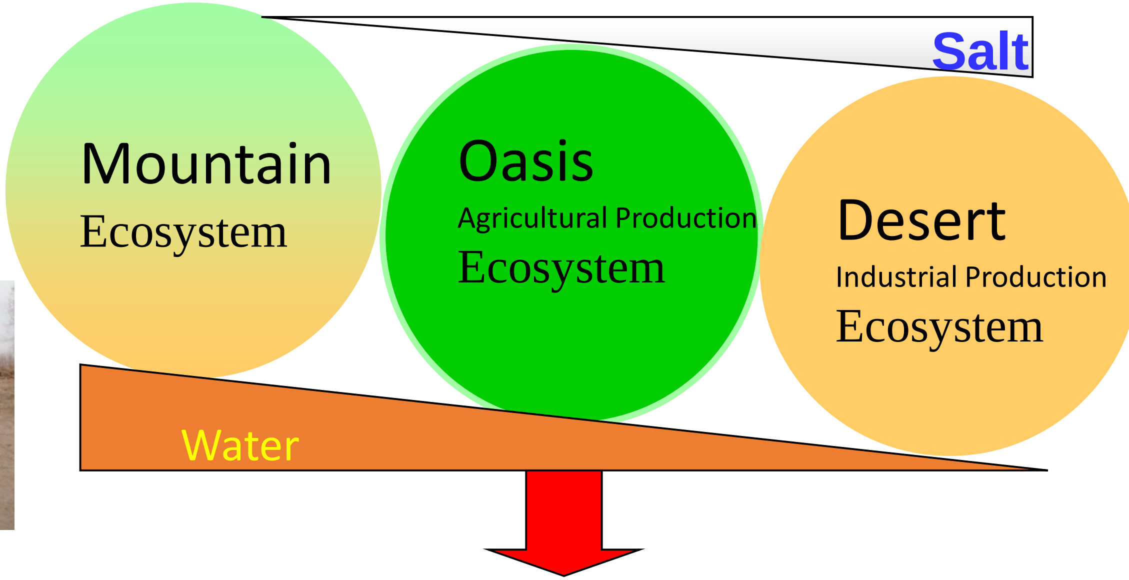
- TREHM model can simulate ecological and hydrological process in river system. Simulated results are helpful to understand riparian system and management water resources

- The probability woody species(*Populus* and *Tamarix*) distribution patterns is predicted.Using TerraSAR-X data allows the detection of flooded areas in regions with dense vegetation

- Floodplains have a high influence on groundwater recharge. The protection of the natural Tugai-forests requires enough water running into the floodplains

- Integrating the natural forests into the present agricultural land could create a win-win-situation for agriculture (drainage) and the natural vegetation (water supply)

Strategy on Sustainable development 0f Oasis under Climate Change in Xinjiang



Cropping Structure and Land Use Pattern in Oases

Farming, Animal Husbandry and Forestry Production

?

VOLUNTARY REDUCTION POTENTIAL OF *TAMARISK*

肉苁蓉(*Cistanche deserticola Ma)*
Desert living Cistanche

Output: 3000-5250 kg/hm^{-2}，
Market price: 80～100 yuan/kg

Thanks for your attention!