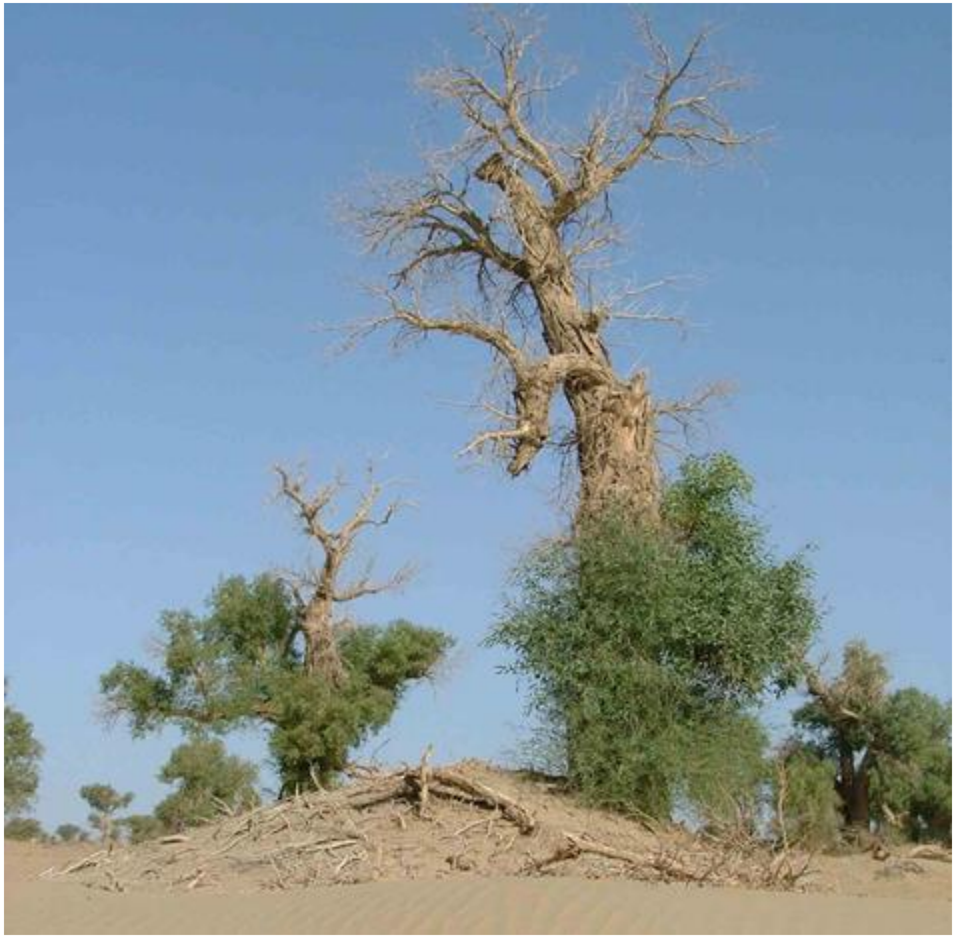
Degraded Tugai Forests under Rehabilitation in the Tarim Riparian Ecosystem, Northwest China: Monitoring, Assessment and Modelling



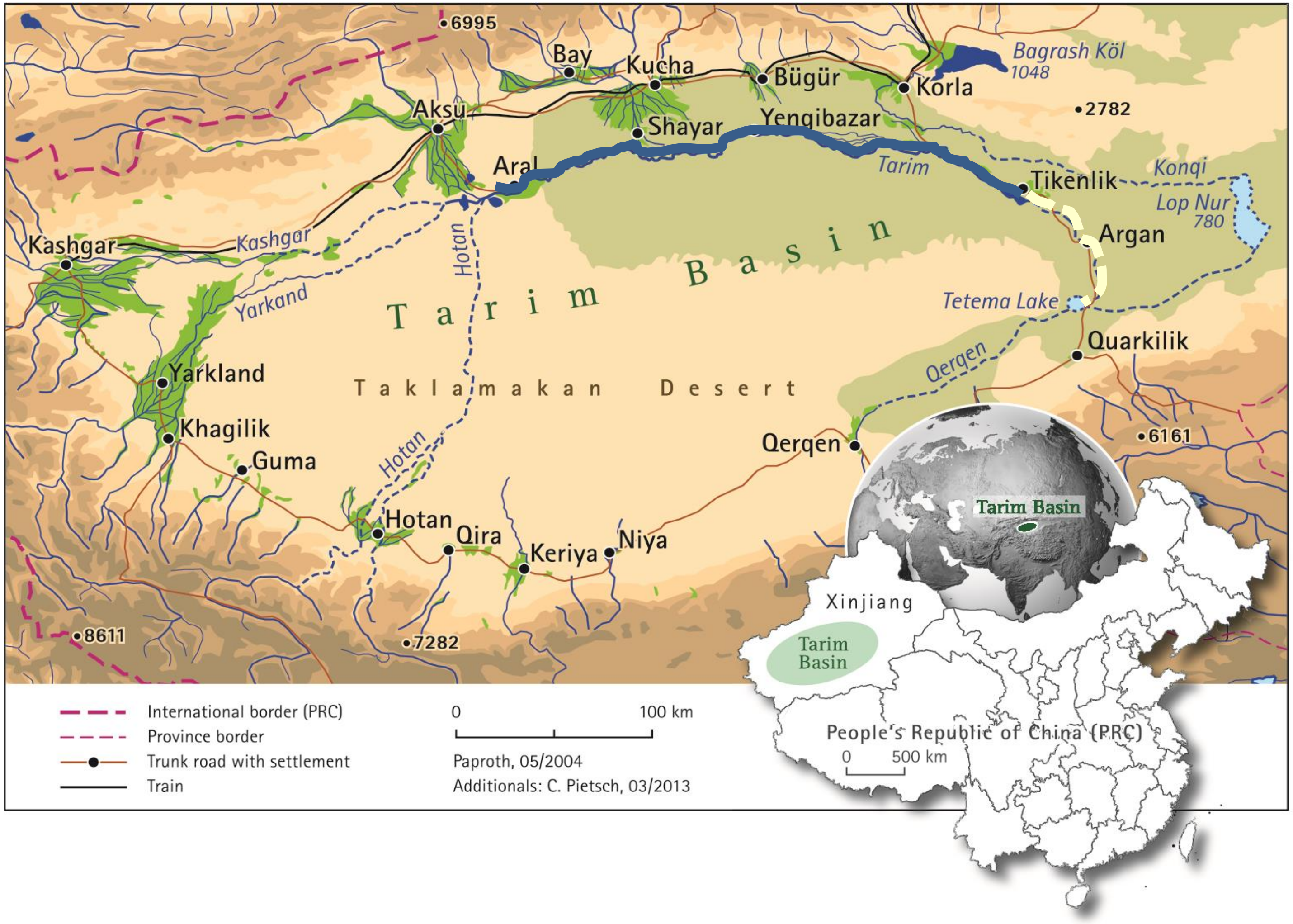
Aishan Tayierjiang

December 12, 2015

Outline

The Tarim River

- Total length of main stream is about 1300 Km
- Between the Tianshan Mountains & the Taklamakan Desert
- Typical inland river
- The River basin is home to nearly 10 million people (Uyghur, Chinese and other ethnic minorities)



The natural Tugai forests along the Tarim River

Typical Tugai forests along the river is mainly composed of trees, shrubs and herbs.

Dominant tree : ***Populus euphratica***

Dominant shrub and herb: ***Tamarix ramosissima*** **and** ***Phragmites australis***

Source: photo taken with a drone by Dr. Alishir Kurban on Sep.12, 2015 in Arghan

Distribution of *P. euphratica* in the world

Nearly 90% of existing *P. euphratica* forests in China is distributed along the Tarim River basin

Table 1-1 Distribution and area of *P. euphratica* forests in different countries in the world (ha).

Countries	China	Central Asian countries	Iraq	Iran	Syria	Turkey	Pakistan	Spain	other	total
Area (ha)	395200	200000*	20000	20000	5818	4900	2800	< 1.0	—	648719
Percentage (%)	61.0	30.8	3.1	3.1	0.9	0.8	0.4	—	—	100

*Estimated figure

Table 1-2 The distribution sites and areas of *P. euphratica* forests in China (ha)*.

Location area (ha)	Xinjiang Uyghur Autonomies Region		Inner Mongolia	Gansu	Qinghai Ningxia	total
	Tarim Basin	Junggar Basin				
Area (ha)	352200	8000	20000	5000	sparse	395200
Percentage (%)	89.1	2.0	5.1	3.8	—	100

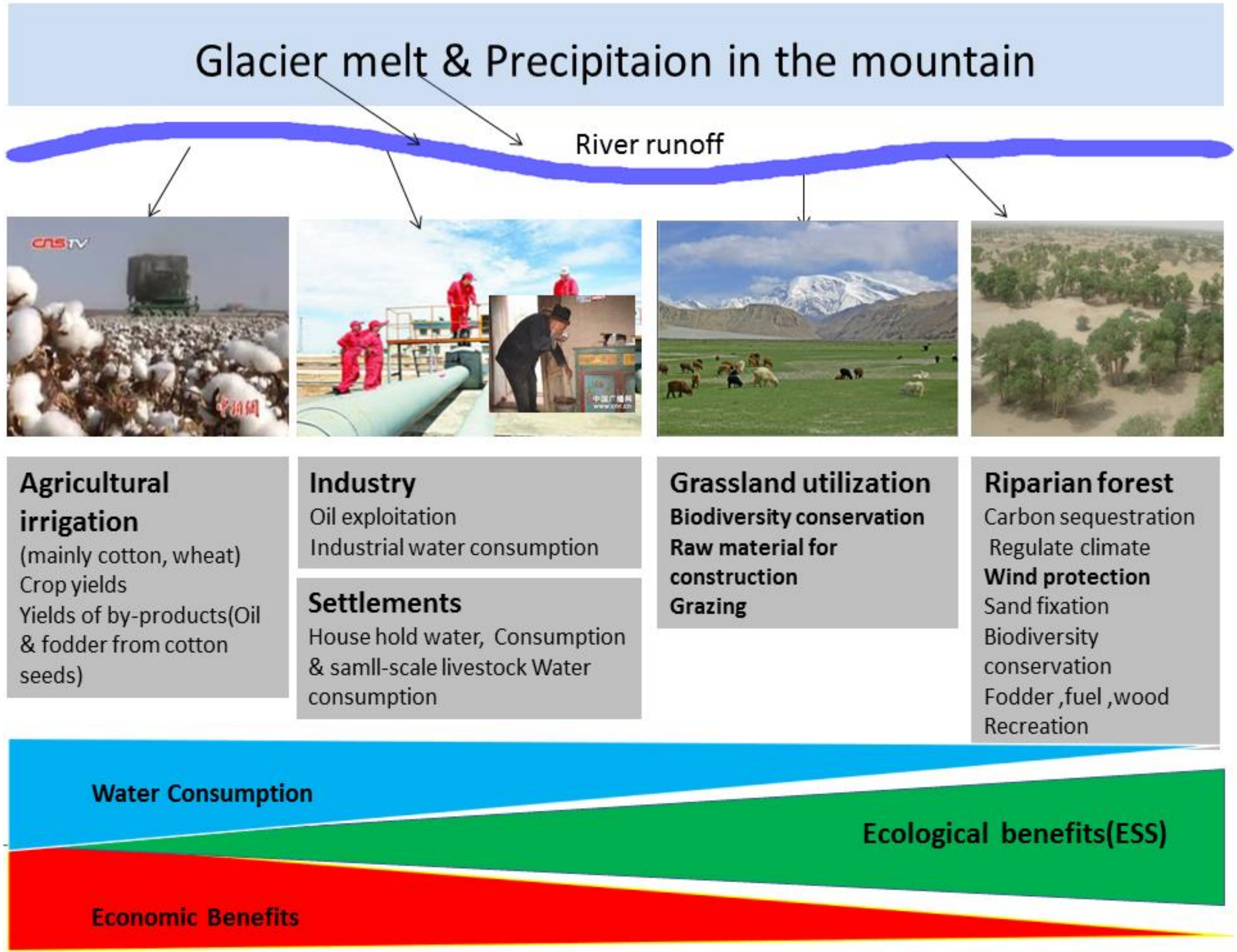
* According to the statistics provided by the Forest Bureau of Eerqina, Inner Mongolia. Presently, the total area of *P. euphratica* stands in Inner Mongolia (including sparse stands) amounts to 22700 ha.

Source: Wang *et al*. 1996

The importance of Tugai forest

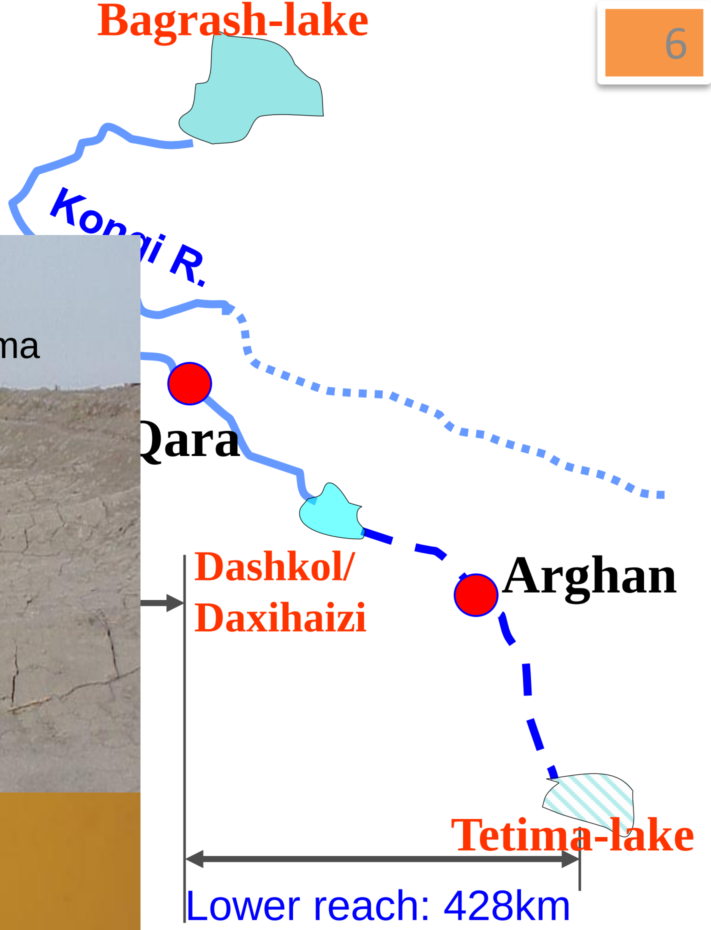
- They form the so-called “Green Corridor” to prevent the two deserts, the Taklamakan and the Kum-Tagh, from merging together.
- Effective shelter belt for the National Highway No.218 and Korla-Golmud railway

Water supply and the water use of different sectors along the river



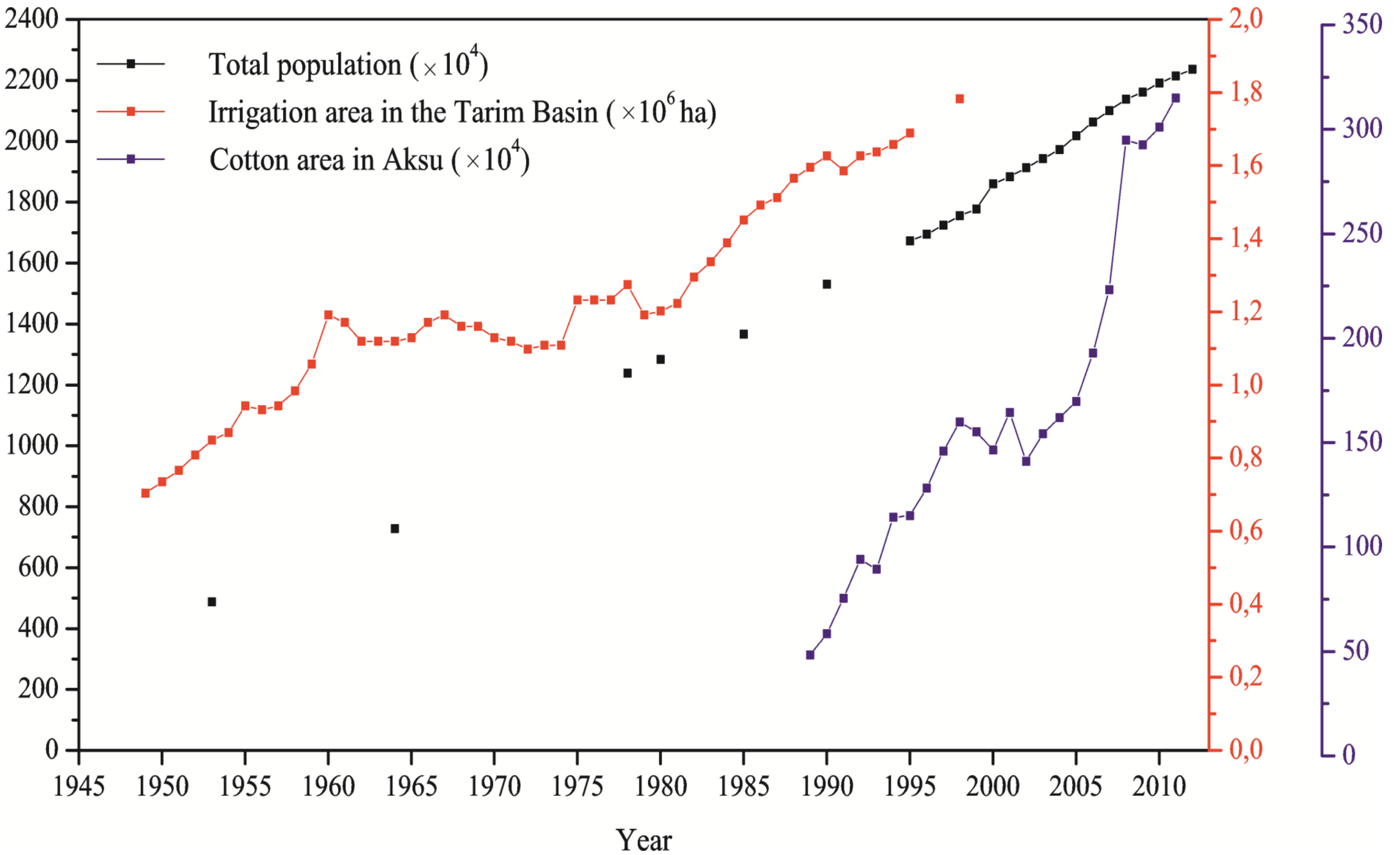
Modified by Aishan Tayierjiang, source: Niels Thves., 2011

Environmental problems……………………..

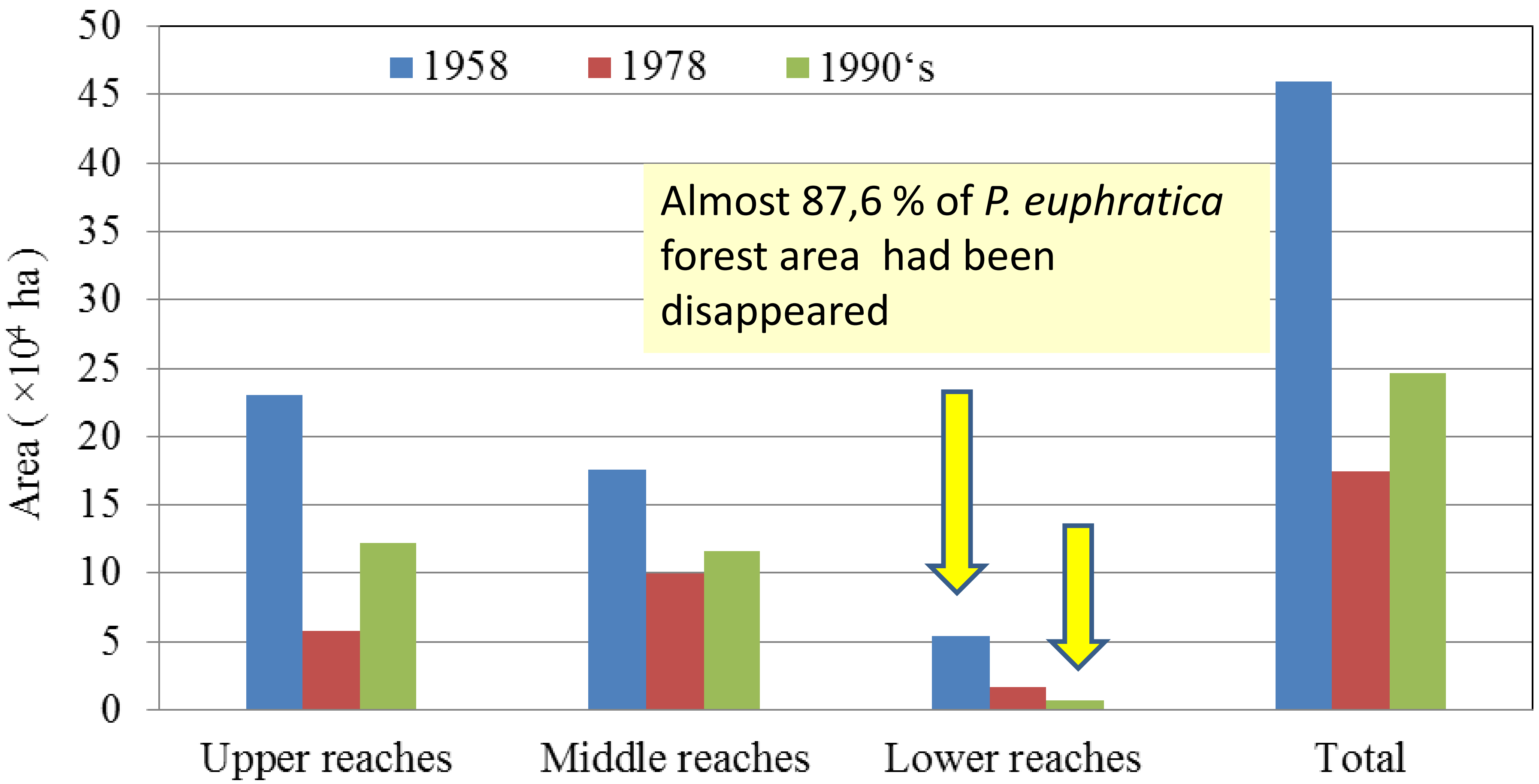


Rapid increase in population and irrigation area

By 2012, the total population in Xinjiang increased by 5 times more compared to that of 1953.
Cotton area in Aksu region expedited a large increase (7 times) over the period of 1989-2011



Change of the *P. euphratica* forest area along the Tarim River



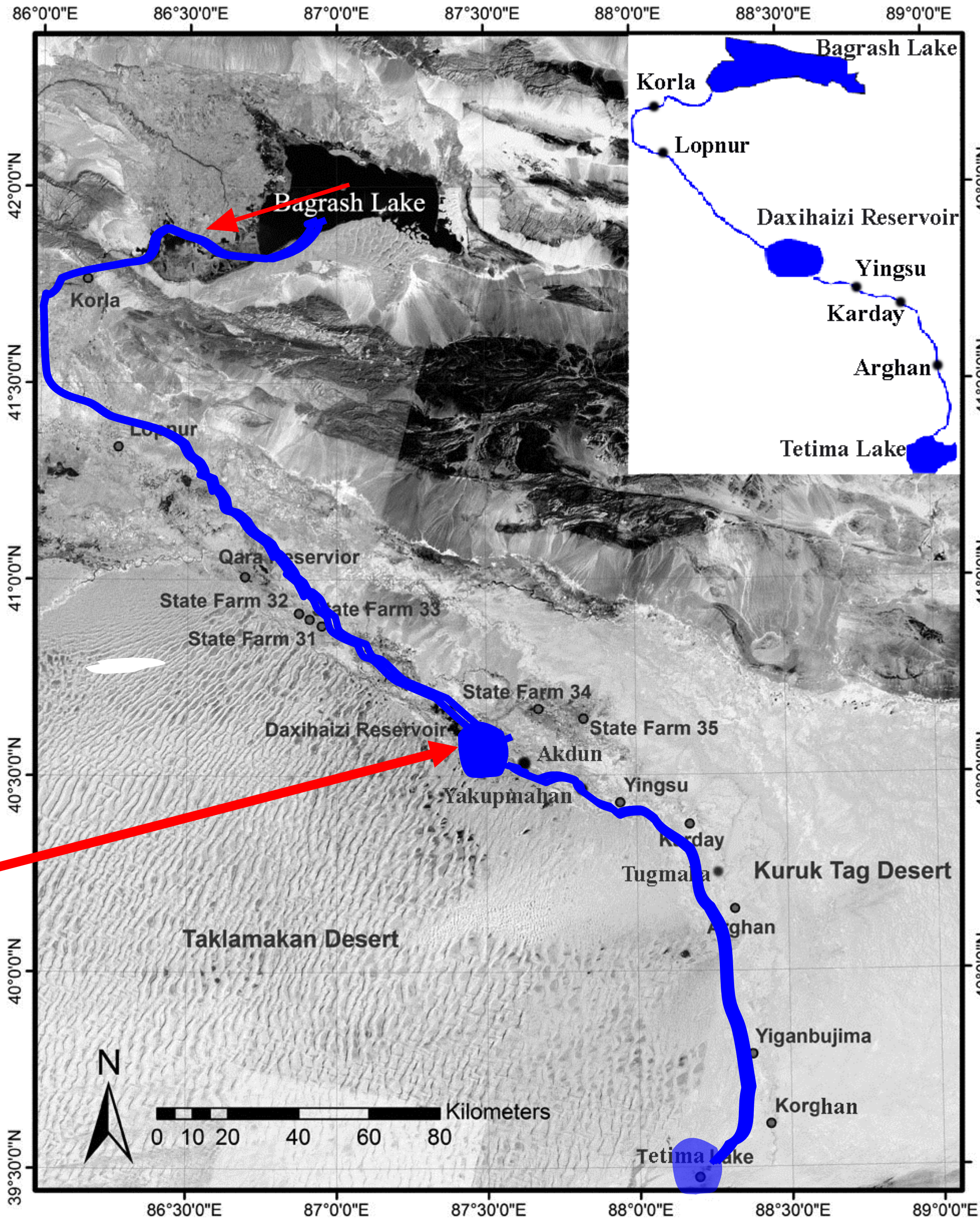
(Data source: Giese et al., 2005).

Restoration measures

-Invested over 10.7 billion yuan RMB (Approximately more than 1 billion €)

-Objective: Regeneration and Conservation of Degraded Tugai Riparian Ecosystem

Water diversion Route



Overview of water diversion project

Implemented **since 14th of May 2000**
Duration: **1280 days**
Total volume : **28.18×10^8 m^3** (till the end of the year 2011)

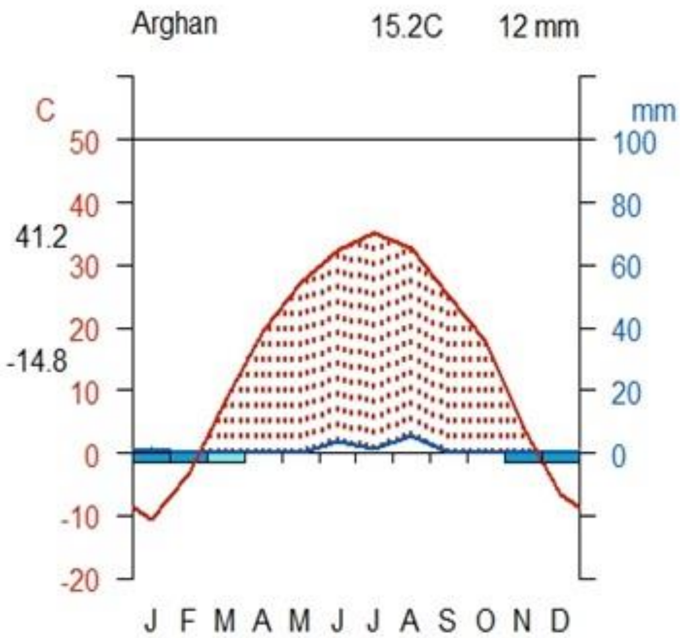
Delivery	Starting time (day/month/year)	Ending time (day/month/year)	Duration (day)	Watering distance (km)	Water volume ($\times 10^8$ m^3)	Section reached
1st	14/05/2000	13/07/2000	61	106	0.99	Karday
2nd	03/11/2000	14/02/2001	104	216	2.27	Arghan
3rd (1st period)	01/04/2001	06/07/2001	97	310	1.84	Korghan
3rd (2nd period)	12/09/2001	17/11/2001	67	357	1.98	Tetima
4th	20/07/2002	10/11/2002	114	357	3.31	Tetima
5th (1st period)	03/03/2003	11/07/2003	131	357	3.40	Tetima
5th (2nd period)	04/08/2003	03/11/2003	90	357	2.85	Tetima
6th	23/04/2004	22/06/2004	64	357	1.02	Tetima
7th (1st period)	18/04/2005	07/06/2005	32	230	0.52	Arghan
7th (2nd period)	30/08/2005	02/11/2005	65	350	2.30	Tetima
8th	25/09/2006	26/11/2006	62	227	1.96	Korghan
9th	10/10/2007	20/11/2007	41	60	0.14	Yingsu
10th	25/11/2009	31/12/2009	37	105	0.11	Karday
11th	20/06/2010	15/11/2010	145	357	3.76	Tetima
12th(1st period)	07/01/2011	25/01/2011	19	357	0.37	Tetima
12th(2nd period)	25/06/2011	23/11/2011	151	357	1.36	Tetima

Research questions and goals

- How did the groundwater, the key factor, react after water diversion?
- How are the stand structure, distribution and vitality of existing *P. euphratica* forests at different hydrological conditions?
- How the eco-morphological parameters of *P. euphratica* changed over the investigation years? to what extent? (assessment on the achievement and challenges of expensive restoration measures)
- Modelling TH-DBH relationship for predicting tree height for the long term-monitoring plans and biomass/carbon estimation.

Study area


LOWER REACHES OF TARIM RIVER
Project Area
Tarim River Basin
Xinjiang
Tarim River Basin
Project Area
People's Republic of China (PRC)
0 500 km
87°30'
88°00'
41°40'
41°20'
41°00'
39°40'
88°30'
Tikenlik
218
851
866
847
Yingsu
Karday
Old Yingsu
Daxihaizi Reservoir
966
Chiwinkol River
Old Tarim River
Arghan
Kuruk
Tagh
Desert
1024
Taklamakan Desert
Iganbujima
1041
Korghan
Tetema Lake
LEGEND
Transect
River
Barrage
Oasis/Irrigation Land
0 20 km
966 Elevation in meter (above sea level)
218 National Road
1000 – 2000
500 – 1000
Elevation in meter (above sea level)
N


Arghan
15.2C
12 mm
C
mm
50
40
30
20
10
0
-10
-20
100
80
60
40
20
0
41.2
-14.8
J F M A M J J A S O N D


阿拉干村

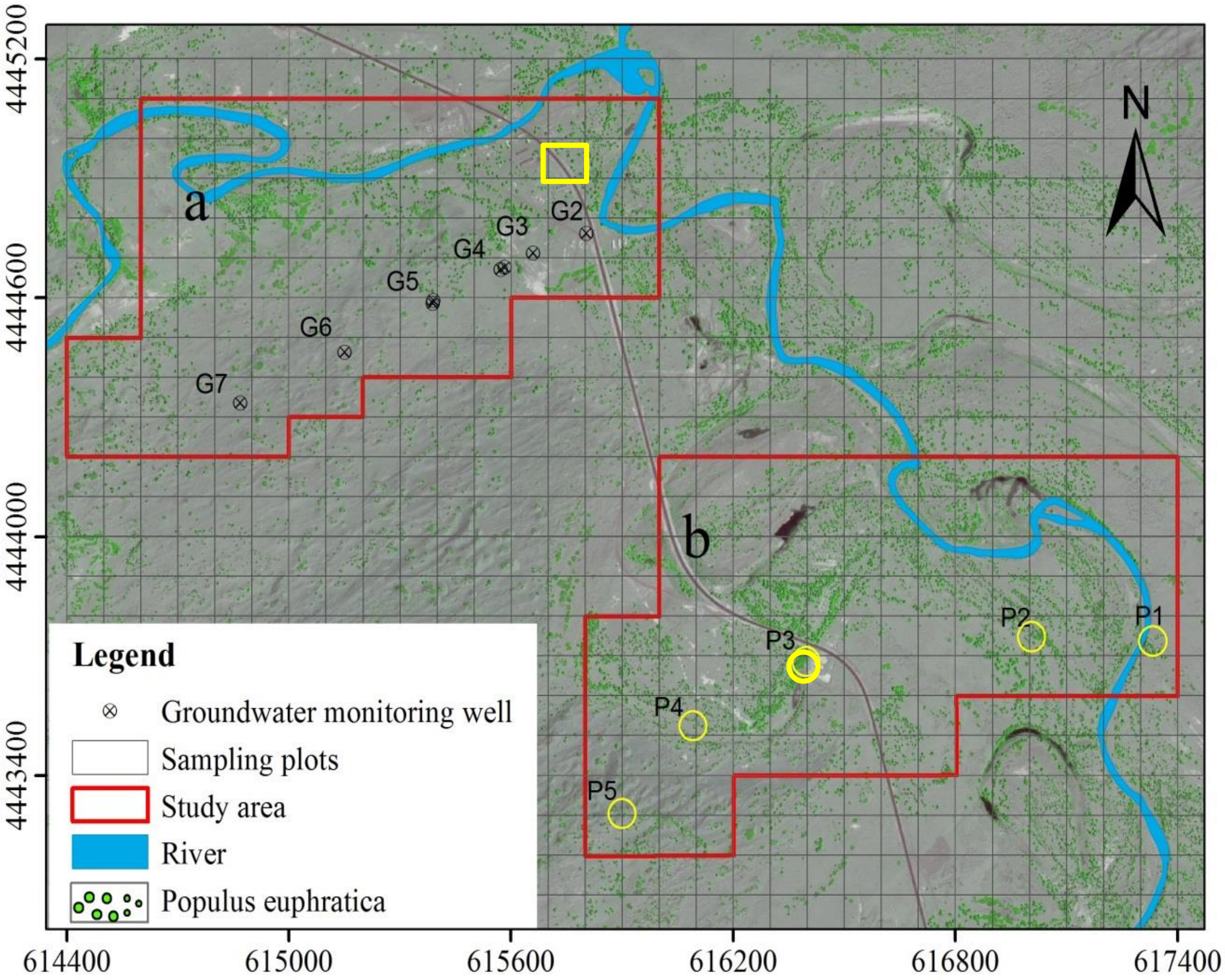
Design of Long term investigation plots in Arghan

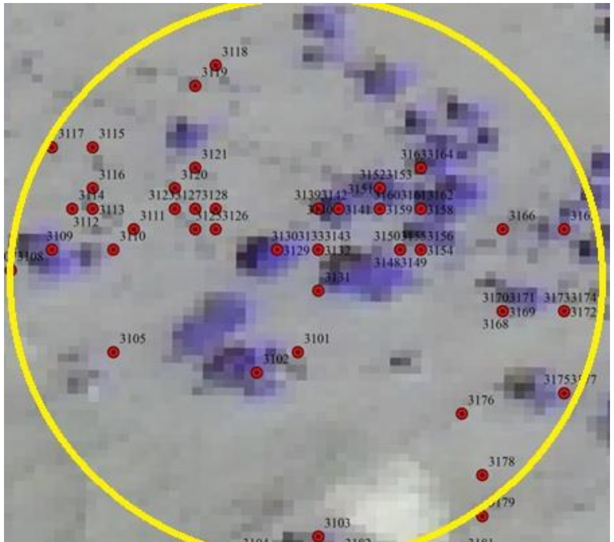
Plot size : plot(a)=permanent sampling plot/ plot(b)=random sampling plot

total area of plot(a) = **100 hectare** (100 square subplots with 100 m * 100 m size)

within plot (a), 6 groundwater monitoring wells

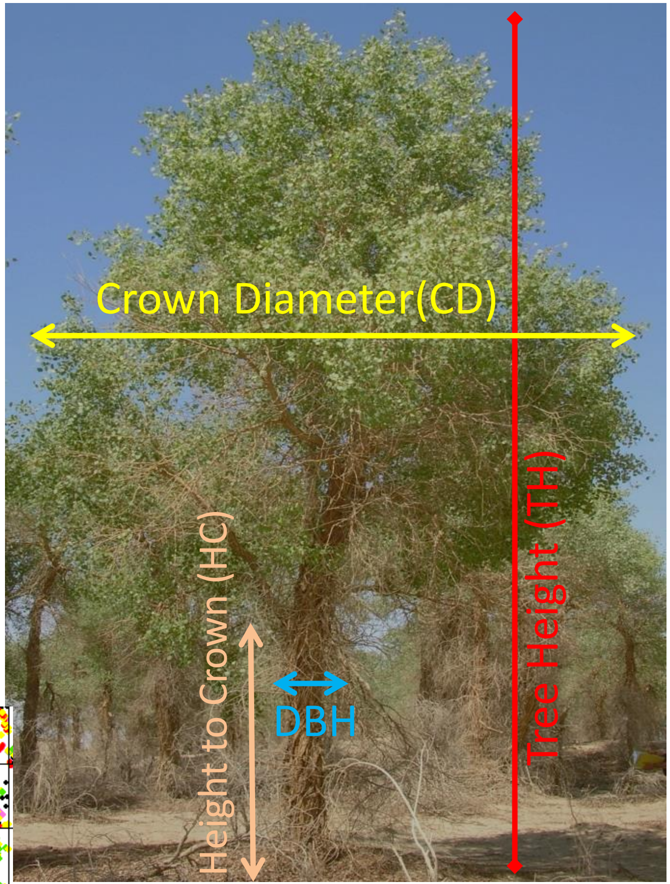
plot (b) = 5 circle subplots with 50 m radius



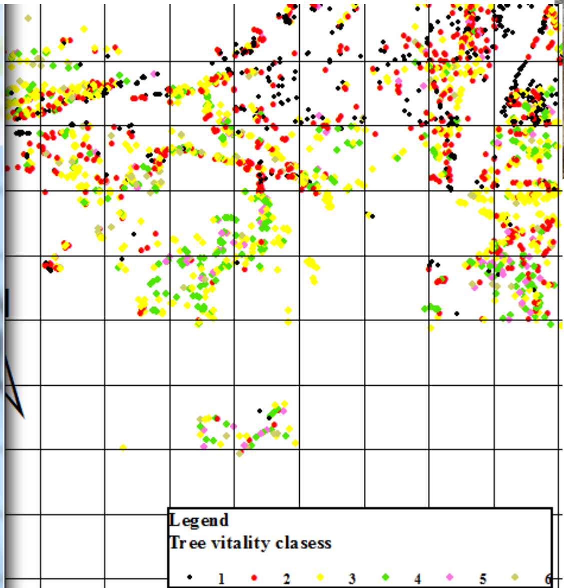


Measurement of Eco-morphological parameters of *P.euphratica*

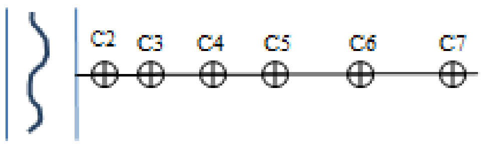
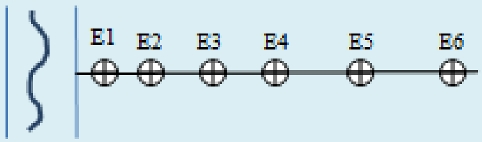
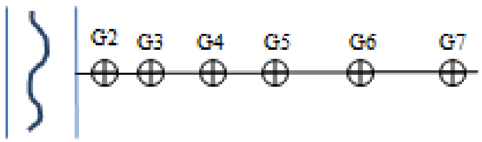
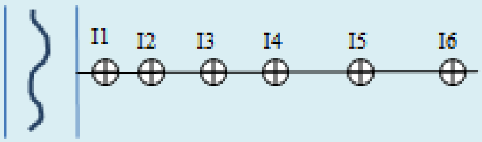
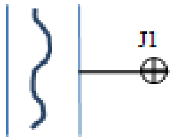
Tree Parameter	Remarks	Inventories of forest attributes
Tree height Diameter at breast height Stem inclination Crown Diameter Primary & Secondary crown Leaf loss , Top thinning Crown shape Stem sprouting (Shoots) Picture-Nr. Topography Vitality Level	Crown rest Young stands Dead tree Insect infection Fructification	Permanent sampling plot(a): Years 2004, 2011 Number of trees: 4640 Random sampling plot (b): Years 2004,2007,2011 Number of trees: 457



NEAR DIST	T NO	AGE	T H1	T H2	BHD1	BHD2	BHD3	BHD4	TR DIAM	TR NUM	TR INCL	Z
153	4	2	7	7	22	0,00	0,00	0,00	0	1	0	9
160	5	2	7	7	35	0,00	0,00	0,00	0	1	0	9
161	6	2	6	6	38	0,00	0,00	0,00	0	1	0	9
152	7	2	6	6	45	0,00	0,00	0,00	0	1	0	9
155	8	2	8	8	23	0,00	0,00	0,00	0	1	0	9
149	9	2	10	10	37	0,00	0,00	0,00	0	888	0	8
152	10	2	6	6	24	16,20	0,00	0,00	0	2	0	8
148	11	2	7	7	19	17,16	0,00	0,00	0	2	0	8
147	13	2	6	6	26	0,00	0,00	0,00	0	1	0	9
143	14	2	8	8	29	0,00	0,00	0,00	0	1	0	9
141	16	2	6	6	20	0,00	0,00	0,00	0	1	0	9
137	17	2	6	6	36	0,00	0,00	0,00	0	1	0	9
137	18	2	8	8	30	0,00	0,00	0,00	0	1	0	9
134	19	2	5	5	22	0,00	0,00	0,00	0	1	0	9
134	20	2	5	5	27	0,00	0,00	0,00	0	1	0	9
135	21	2	7	7	26	0,00	0,00	0,00	0	1	0	9
129	22	2	8	8	40	0,00	0,00	0,00	0	1	0	9
127	23	2	7	7	24	22,50	0,00	0,00	0	2	0	8
126	24	2	4	4	34	20,60	0,00	0,00	0	2	0	8
123	25	2	5	5	35	0,00	0,00	0,00	0	1	0	9
112	26	2	6	6	35	19,00	0,00	0,00	0	2	0	8
116	27	1	3	3	2	0,00	0,00	0,00	0	1	0	9
115	28	2	7	7	29	0,00	0,00	0,00	0	888	0	8
126	29	2	6	6	20	17,00	0,00	0,00	0	2	0	8
128	30	2	6	6	26	0,00	0,00	0,00	0	1	0	9
117	31	2	4	4	28	0,00	0,00	0,00	0	1	0	9
118	32	2	5	5	31	0,00	0,00	0,00	0	1	0	9
113	33	2	5	5	25	0,00	0,00	0,00	0	1	0	9
110	34	2	9	9	30	0,00	0,00	0,00	0	1	0	9
113	35	2	11	11	34	0,00	0,00	0,00	0	1	0	9
105	36	2	8	8	28	0,00	0,00	0,00	0	1	0	9
98	37	2	7	7	54	0,00	0,00	0,00	0	888	0	8
86	38	2	7	7	27	0,00	0,00	0,00	0	1	0	9
80	39	2	10	10	38	0,00	0,00	0,00	0	1	0	9



Hydrological data collection

From Daxihaizi (km)	Transect	Code of the monitoring wells	Distance to the river (m)	Layout of the monitoring wells	218 National Highway distance (km)
60	Yingsu (C)	C2 C3 C4 C5 C6 C7	50 150 300 500 750 1050		929
110	Karday (E)	E1 E2 E3 E4 E5 E6	50 150 300 500 750 1050		951
190	Arghan (G)	G2 G3 G4 G5 G6 G7	50 150 300 500 750 1050		984
328	Korghan (I)	I1 I2 I3 I4 I5 I6	50 150 300 500 750 1050		1048
346	Tetema (J)	J1	100		

Distances of 6 wells from the river in Arghan:

Well G2 → 50 m

Well G3 → 150 m

Well G4 → 300 m

Well G5 → 500 m

Well G6 → 750 m

Well G7 → 1050 m

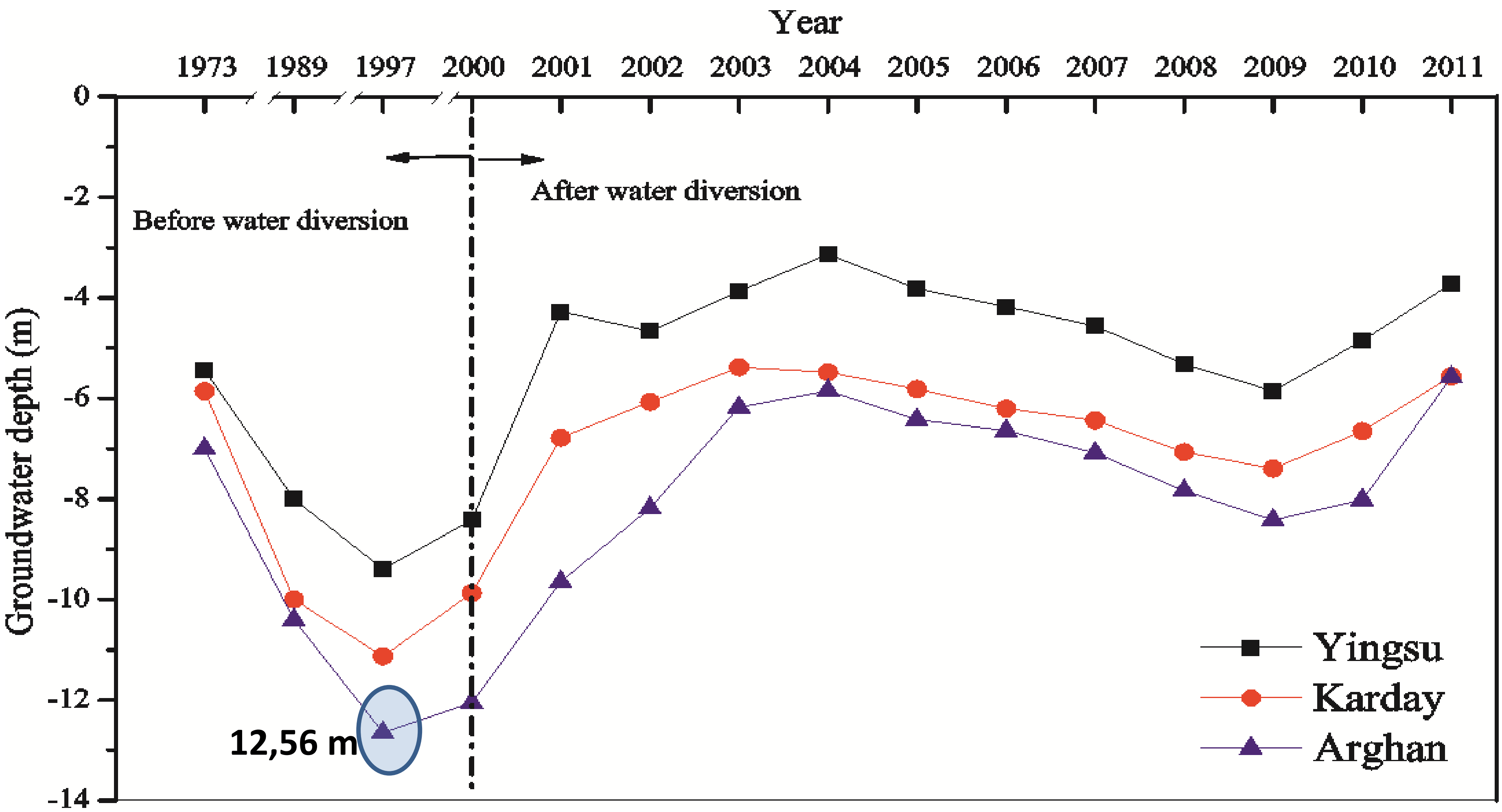
Years for data collection:

from 2003 to 2011

Data source:

Tarim River Basin Administration Bureau (TRAB)

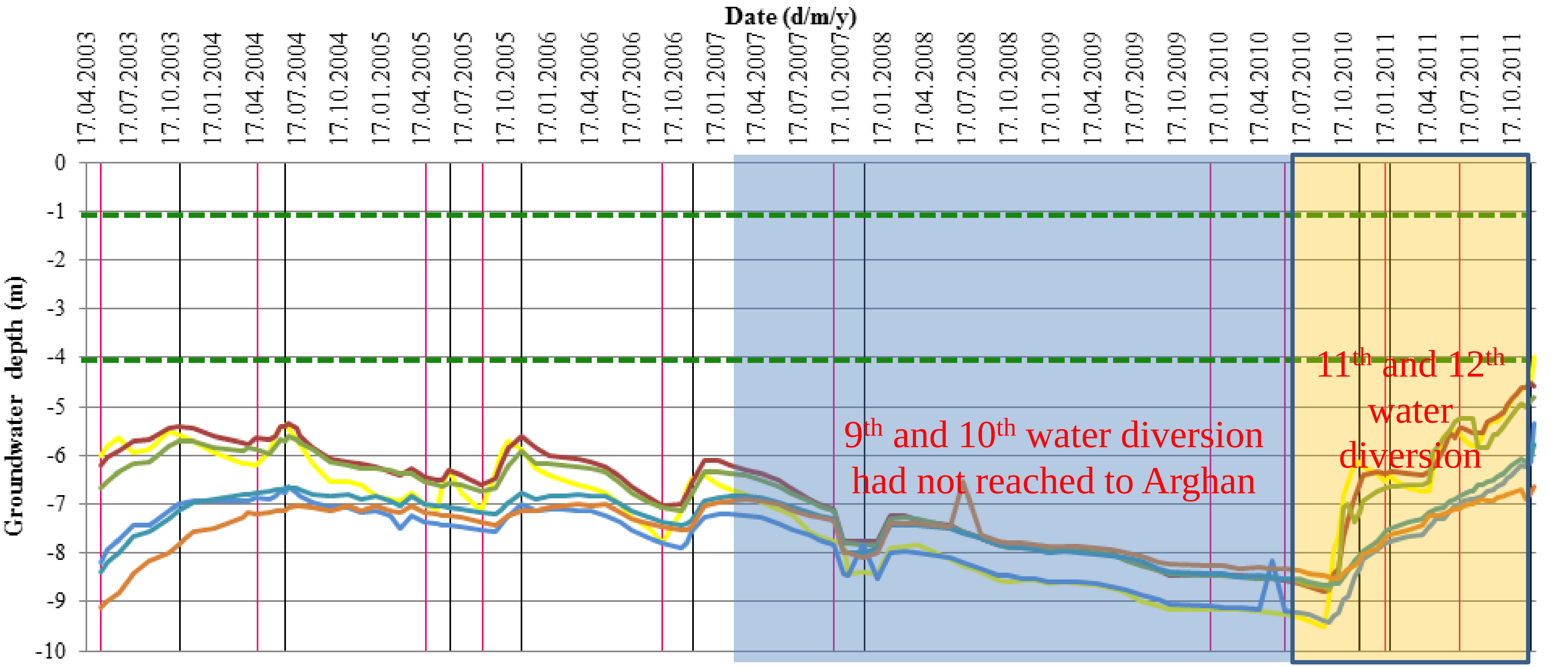
Hydrological response



Groundwater depth before and after water diversion (annual average groundwater depth within a 300 m distance of the river channel). Source: data for the years 1973, 1989 and 1997 obtained from (Song et al., 2000), data for the period after water diversion (from May 2000) provided by TRAB

Dynamics of groundwater depth during the water diversion

Rises and falls of groundwater occurred as the result of Water diversion project



Duration of the 11th and 12th water diversion accounted for 24 % of the total duration.

Volume of the 11th and 12th water diversion accounted for 20 % of the total water voulme.

Trend test for groundwater depth variation

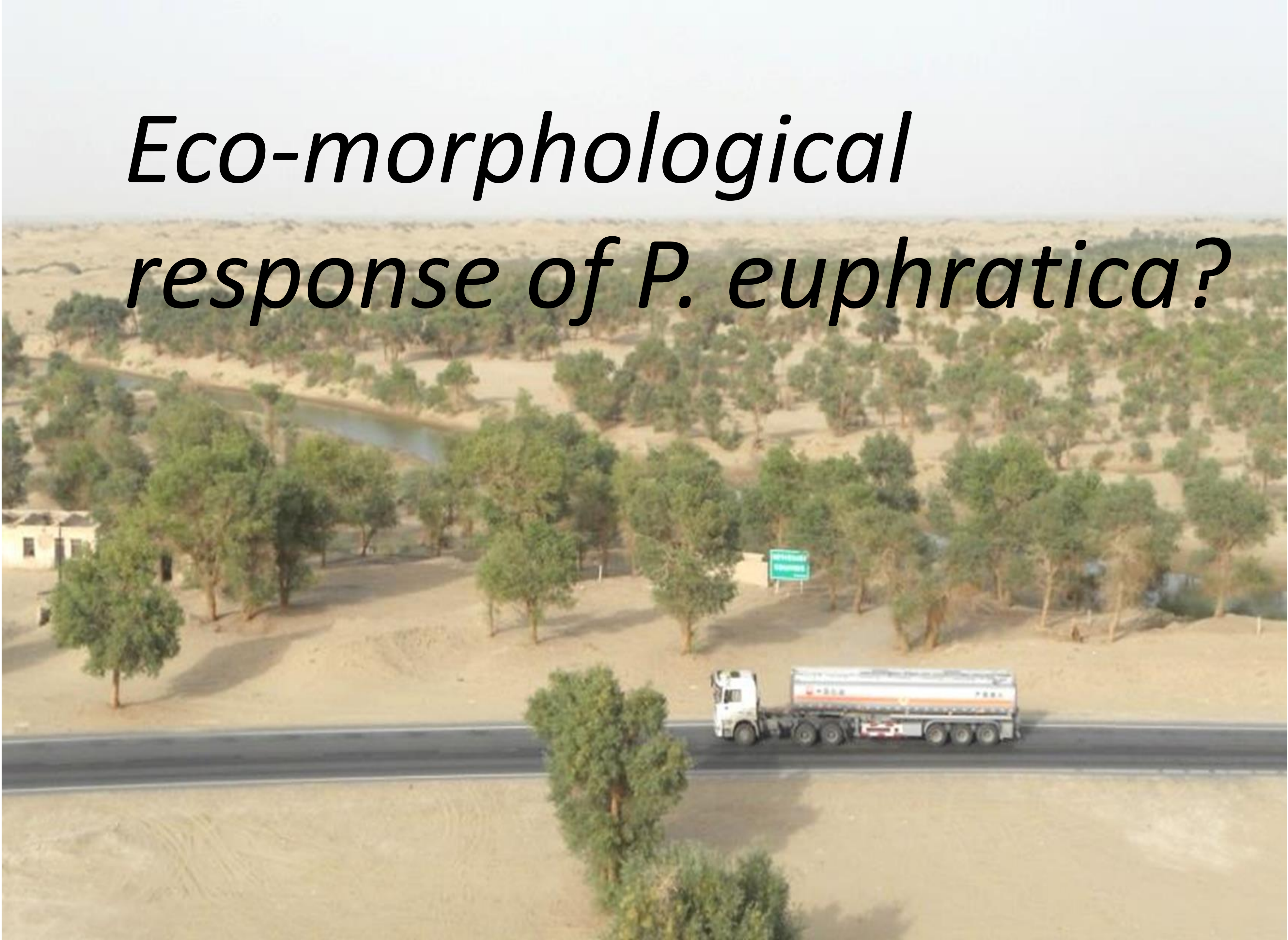
The Mann-Kendall test is a non-parametric approach that has been widely used for the detection of trends in different fields of research, including hydrology and climatology (Ampitiyawatta and Guo, 2009)

Well ID/Distance	Data set from January 2003 to December 2011					
	S	Var(*S*)	*Z*	*P* value	Trend	significance
G2/50 m	-1691	96735.66	-5.434	0.0000006	decreasing	significant
G3/150 m	-1865	96726.34	-5.993	0.00000002	decreasing	significant
G4/300 m	-1854	96728.00	-5.957	0.00000002	decreasing	significant
G5/500 m	-1746	96730.66	-5.611	0.0000002	decreasing	significant
G6/750 m	-1440	96720.00	-4.627	0.0000371	decreasing	significant
G7/1050 m	-647	96715.00	-2.077	0.037778	decreasing	significant

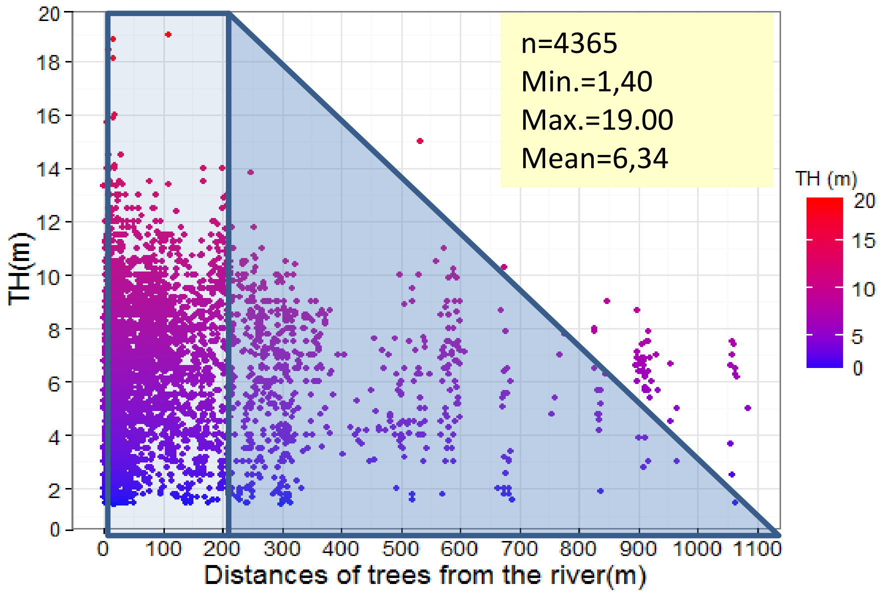
Mann-Kendall statistic (*S*)
The variance statistic (Var(s))
The test statistic (*Z*)
The Probability Value (*P value*)

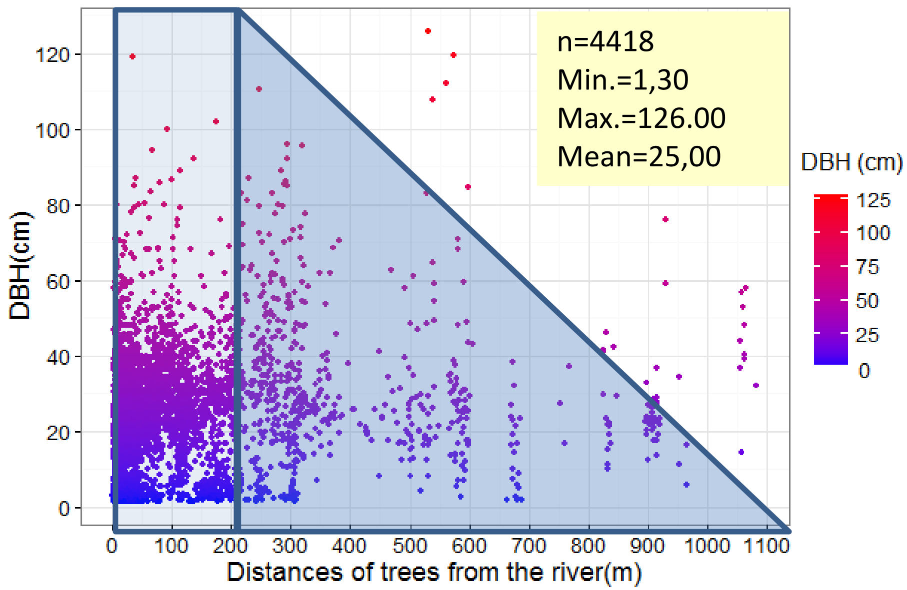
A positive (resp., negative) value of *Z* indicates an upward (resp., downward) trend

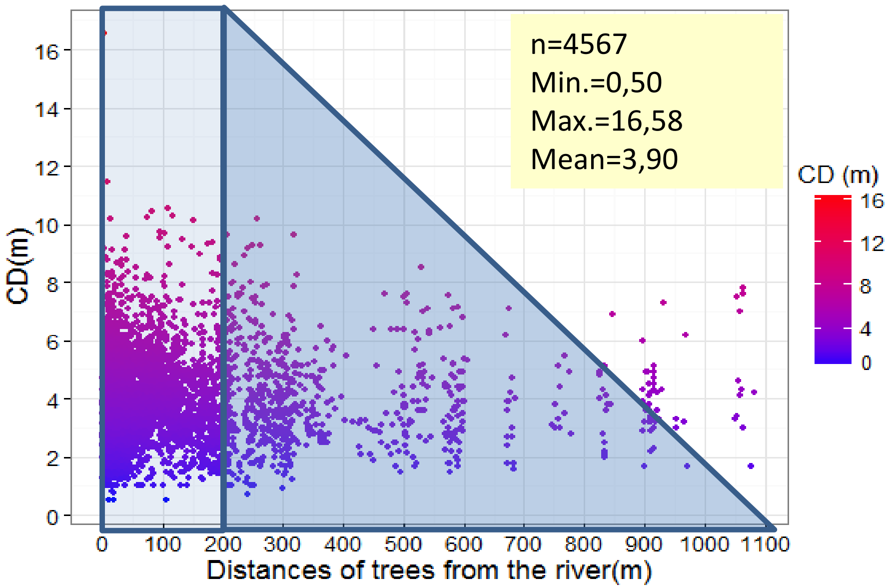
Eco-morphological response of P. euphratica?



Structure of *P. euphratica* forest





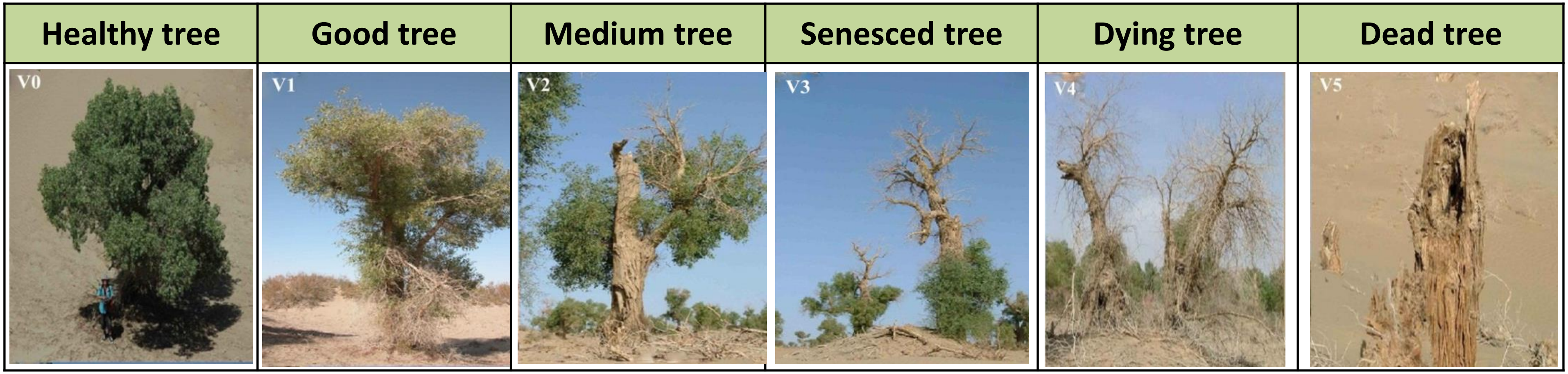


Within 200 m distance to the river, structures of TH, DBH and CD were relatively diverse. A large variation of these parameters occurred within this corridor. It means that the effects of water diversion on vegetation recovery were significant. Over 200-m distance to the river course, the variations started to become simpler.

Vitality level of *P. euphratica*

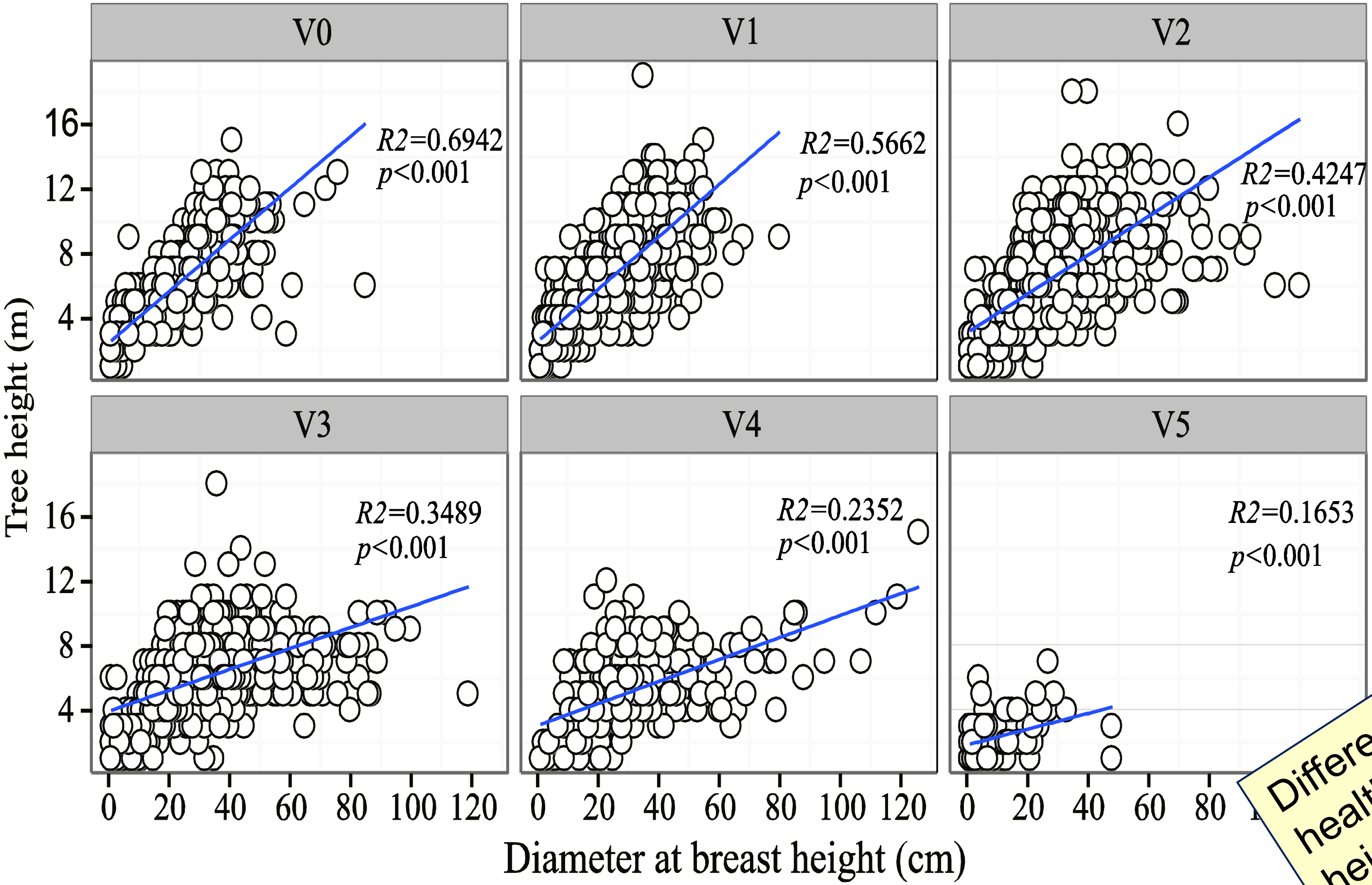
Tree vitality is an integrated concept associated with forest physiology, ecology and morphology, and refers to the growth status and trends of forests and shrubs (including crown, leaves, stems, and branches), as well as to the extension of canopy (Heidingsfeld N 1993, Schulz and Hartling 2003, Halik et al, 2009, Aishan et al., 2015).

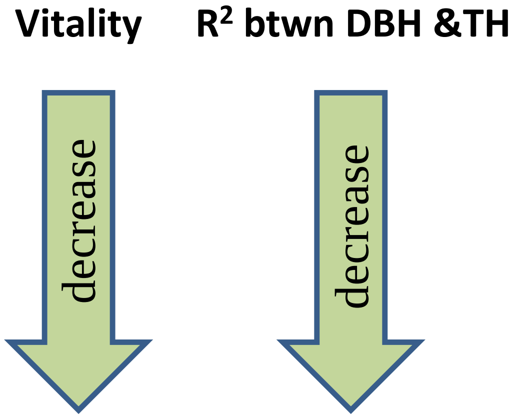
Code	Vitality class	Leaf loss (%)	Overall status and crown features of *P. euphratica*
V0	Healthy tree	=<10	High-vitality tree that is (almost) without signs of damage; healthy full primary crown; leaves usually dark green
V1	Good tree	11-25	Crown slightly damaged, but still in good condition, less than 25% loss of crown
V2	Medium tree	26-50	Crown moderately damaged, with some primary and secondary crown present; crown loss of 50%
V3	Senesced tree	51-75	Crown heavily damaged; tendency towards deterioration (e.g. extant dried leaves); crown loss under 75%
V4	Dying tree	76-99	Primary crown severely damaged; missing or secondary crown also damaged; evidence of residual vitality (for example, single green leaves); tree almost strays
V5	Dead tree	100	Standing dead wood; no evidence of (residual) vitality
V6	Fallen tree	100	Lying dead wood, stumps



Vitality & TH-DBH relationship

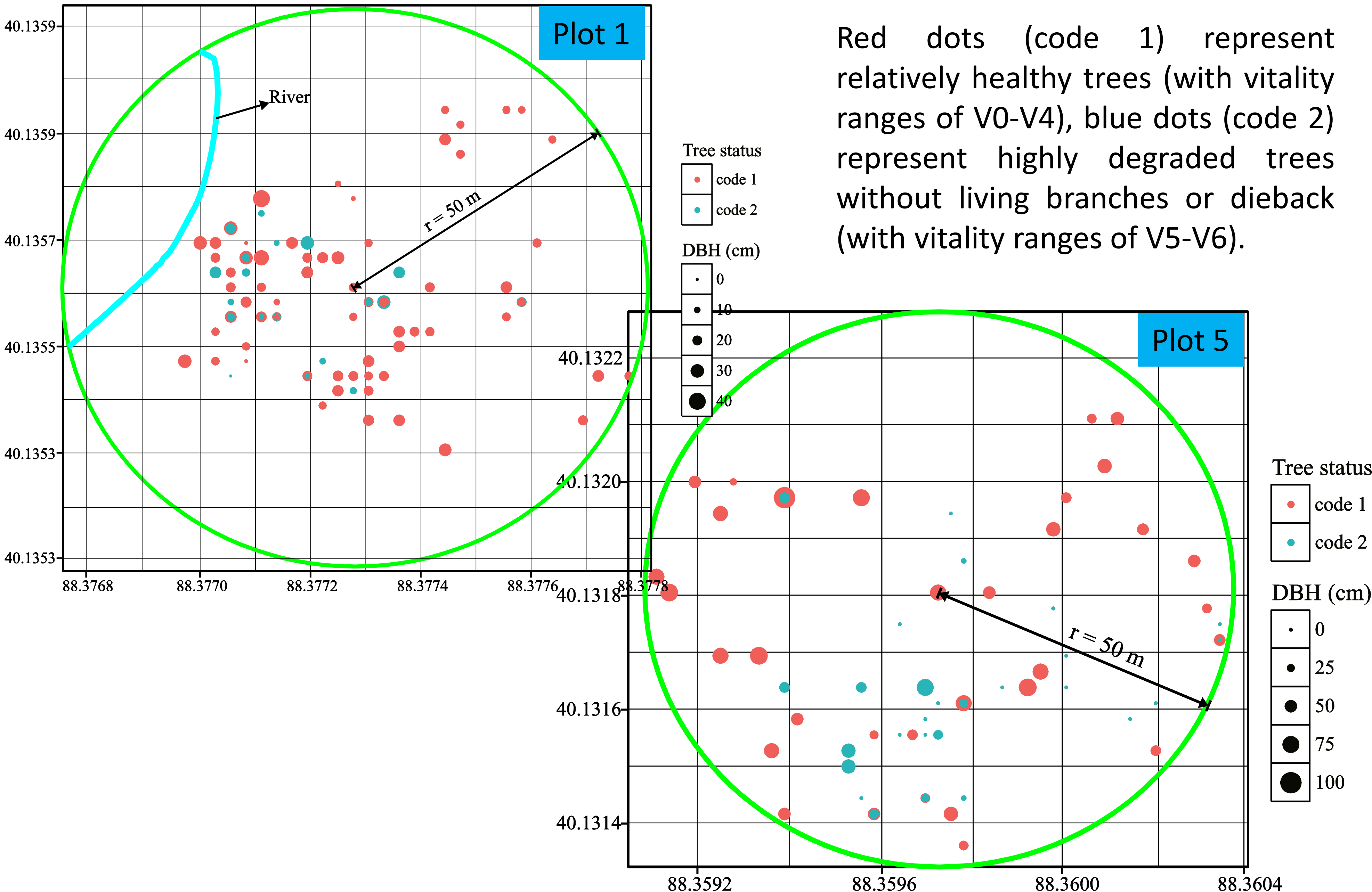
Correlation coefficient would be a new parameter for detecting degradation degree of *P. euphratica* riparian forests





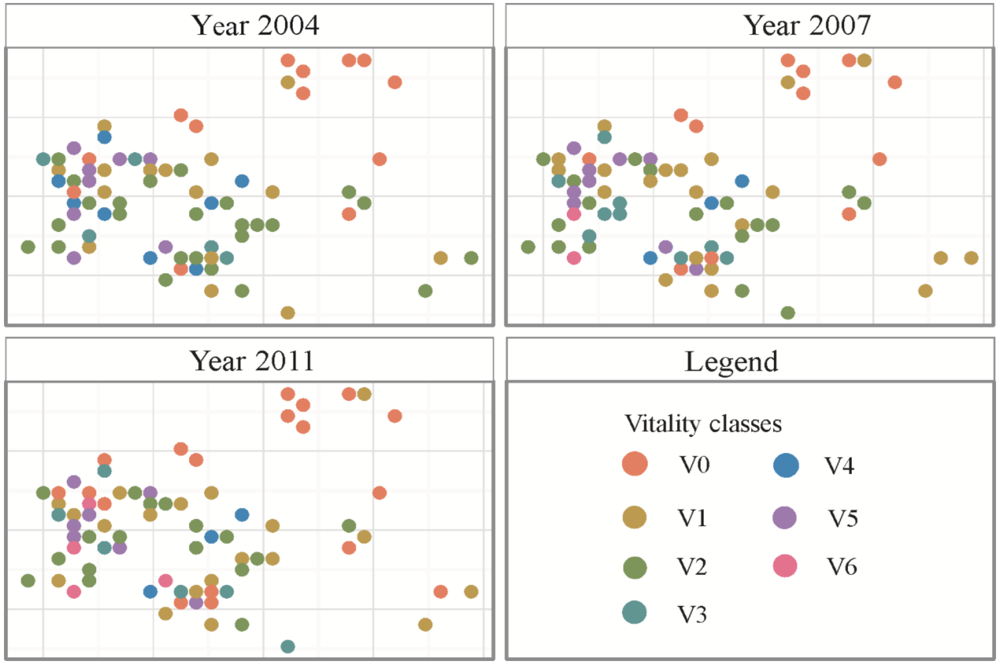
Differentiate degraded trees from healthy trees by determining the height-diameter correlation coefficient??

Dynamics of tree vitality

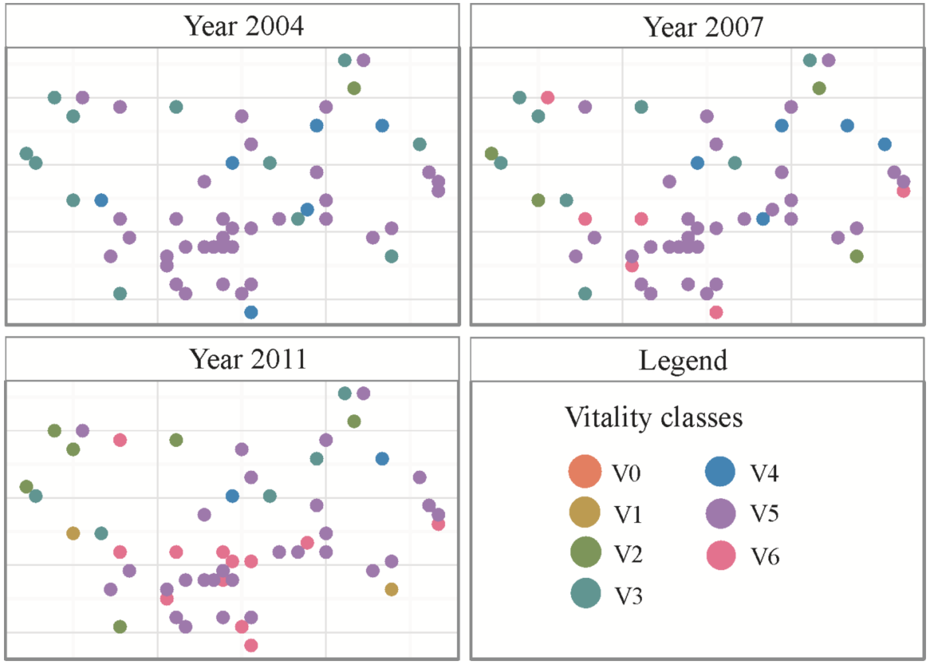


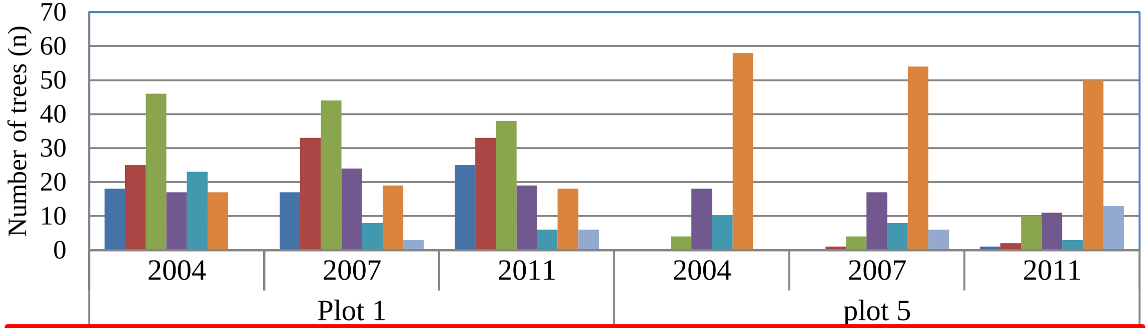
Red dots (code 1) represent relatively healthy trees (with vitality ranges of V0-V4), blue dots (code 2) represent highly degraded trees without living branches or dieback (with vitality ranges of V5-V6).

Plot 1/ next to the river way of the Tarim



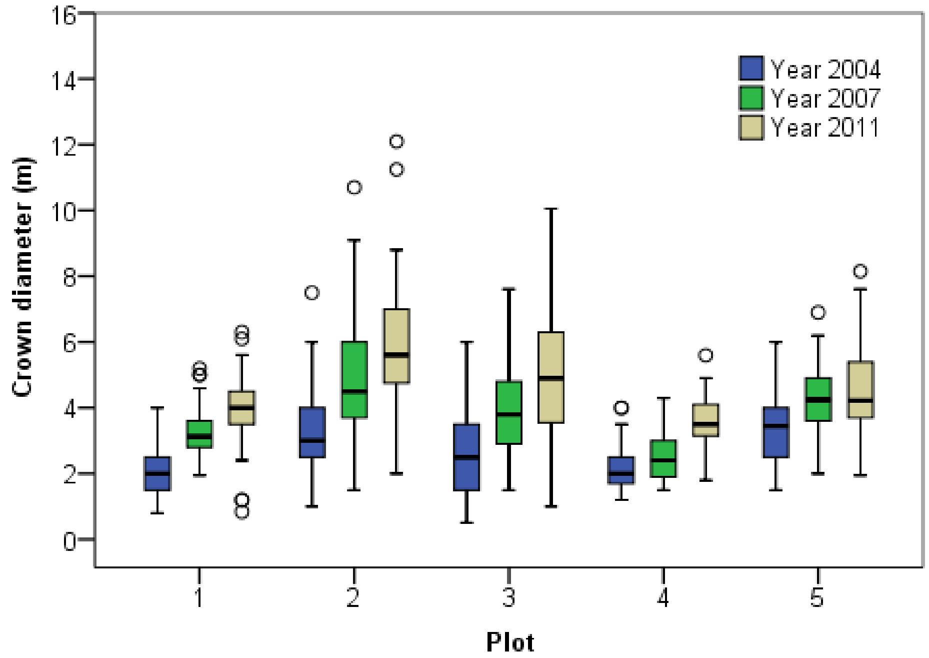
Plot 5/ near to the Taklamakan desert





	Plot 1			plot 5		
	2004	2007	2011	2004	2007	2011
V0	18	17	25	0	0	1
V1	25	33	33	0	1	2
V2	46	44	38	4	4	10
V3	17	24	19	18	17	11
V4	23	8	6	10	8	3
V5	17	19	18	58	54	50
V6	0	3	6	0	6	13

Changes in Crown Diameter



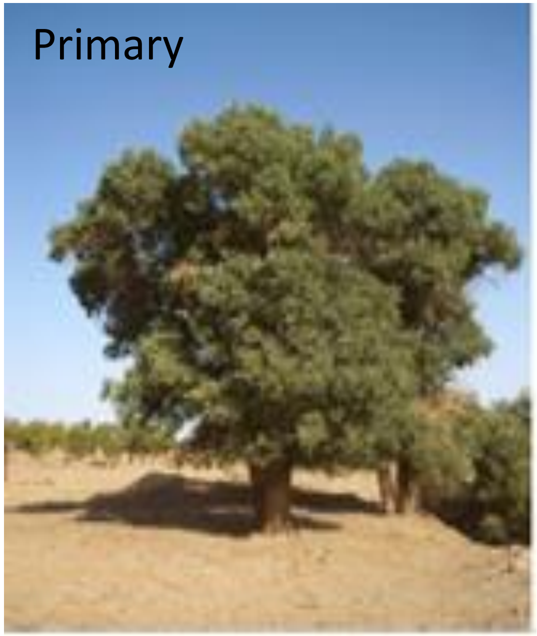
One way ANOVA followed by Tukey's post hoc test was applied to test the statistical differences between plots and temporal changes within plots

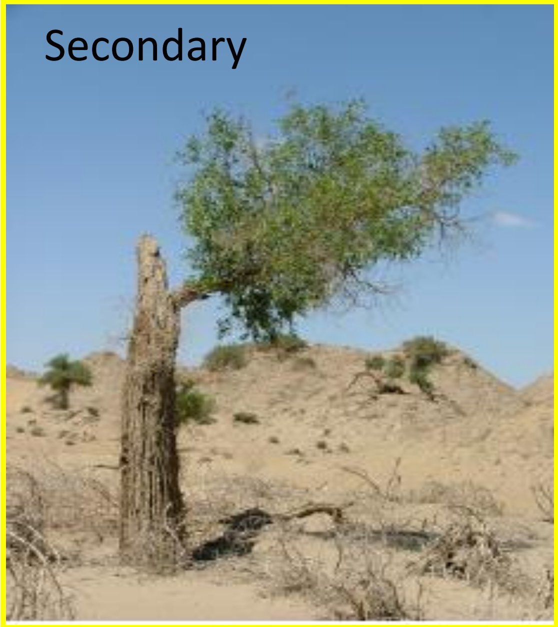
Statistical analysis of the variability between plots and of temporal changes within plots

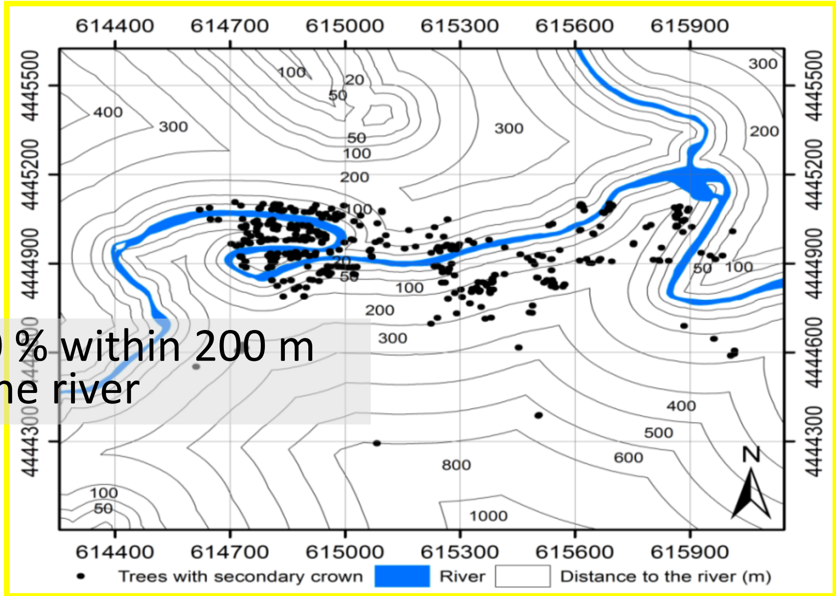
Parameter	Year	Plot (P)				
		P1	P2	P3	P4	P5
CD	2004	2.15±0.68BCc	3.26±1.30Ac	2.60±1.31Bc	2.31±0.74Bc	3.54±1.28Ab
	2007	3.48±2.69Bb	4.91±1.94Ab	3.84±1.35Bb	3.67±1.26Bb	4.87±1.77Aa
	2011	3.96±0.92Ca	5.88±2.10Aa	5.01±1.94Ba	4.84±1.27Ba	4.46±1.51Ba

Values are given as mean ± SD; the different uppercase letters indicate statistically significant differences between the investigated plots, while the lowercase letters refer to statistically significant differences between measuring years, based on ANOVA ($P < 0.05$). CD = crown diameter.

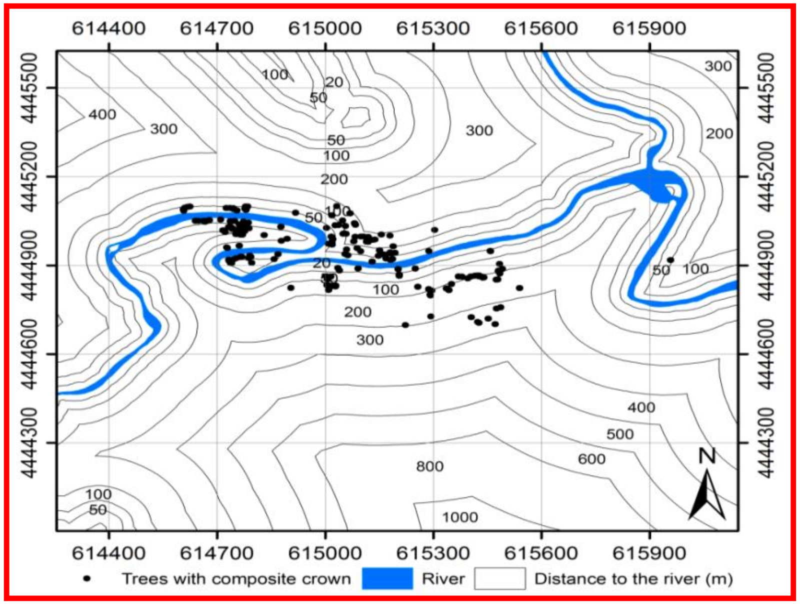
Re-establishment of tree crown







408 trees, 90 % within 200 m distance to the river

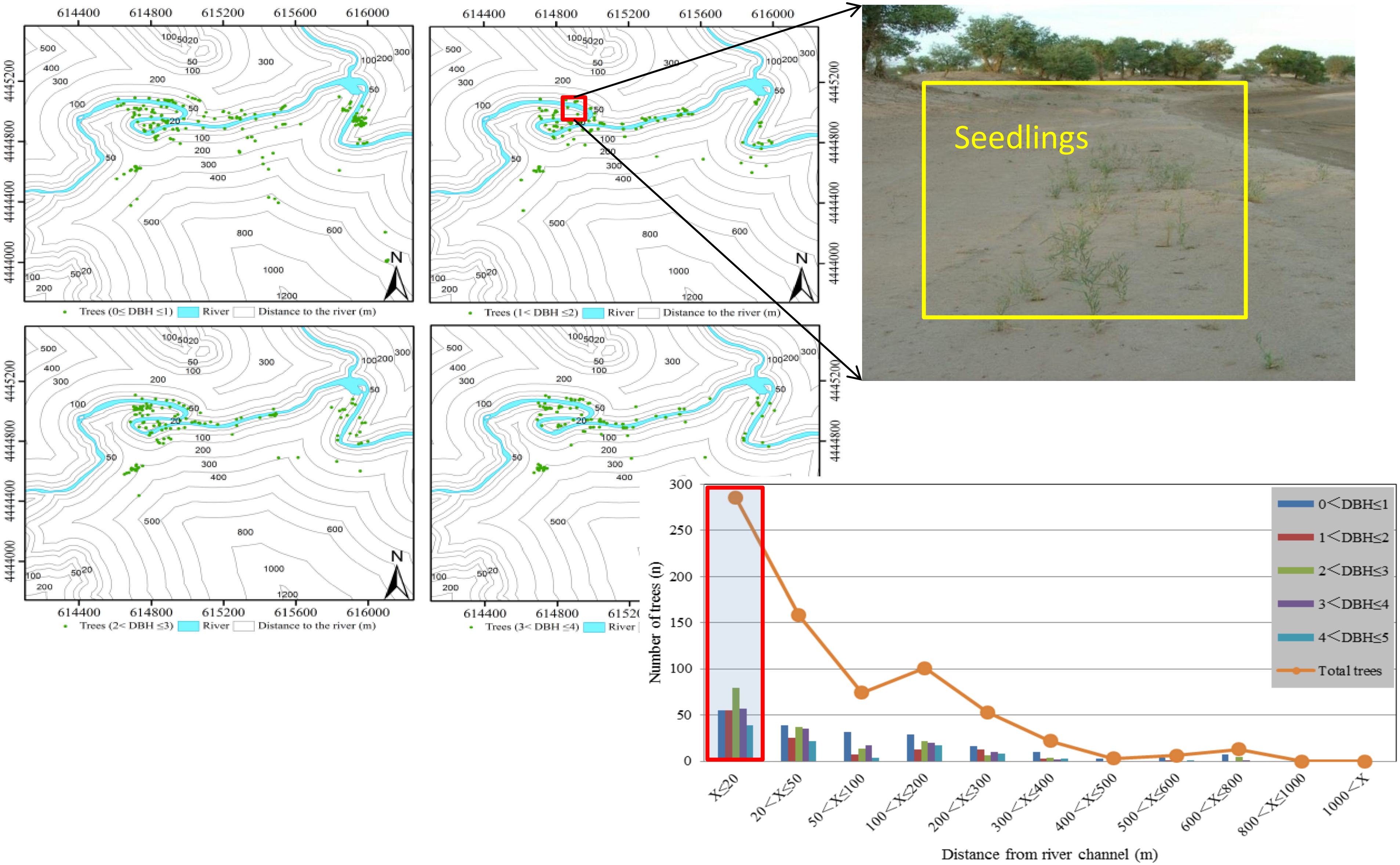


Temporal mismatch between water diverting time and seed dispersal time of riparian forests

Month / Diversion	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1st					From 14/05	√	till 13/07					
2nd	√	till 14/02									from 03/11	√
3rd (1st period)				√	√	√	till 06/07					
3rd (2nd period)									from 12/09	√	till 17/11	
4th							from 20/07	√	√	√	till 10/11	
5th (1st period)			√	√	√	√	till 11/07					
5th (2nd period)									from 12/09	√	till 07/11	
6th (1st period)				From 22/04	√	till 25/06						
6th (2nd period)								√	till 15/09			
7th (1st period)				From 18/04	√	till 07/06						
7th (2nd period)									√	√	till 02/11	
8th									from 25/09	√	√	
9th										from 15/10	till 21/11	
10th					from 12/05	till 20/06						
11th						from 25/06	√	√	√	√	till 11/11	
12th (1st period)	07-25/01											
12th (2nd period)						from 25/06	√	√	√	√	till 23/11	

Legend				
	(green)	Vegetation growing season	(blue)	Water diverting time
	(yellow)	Seed rain season for *P. euphratica*	√	Diverting time throughout the month

Establishment of juvenile seedlings

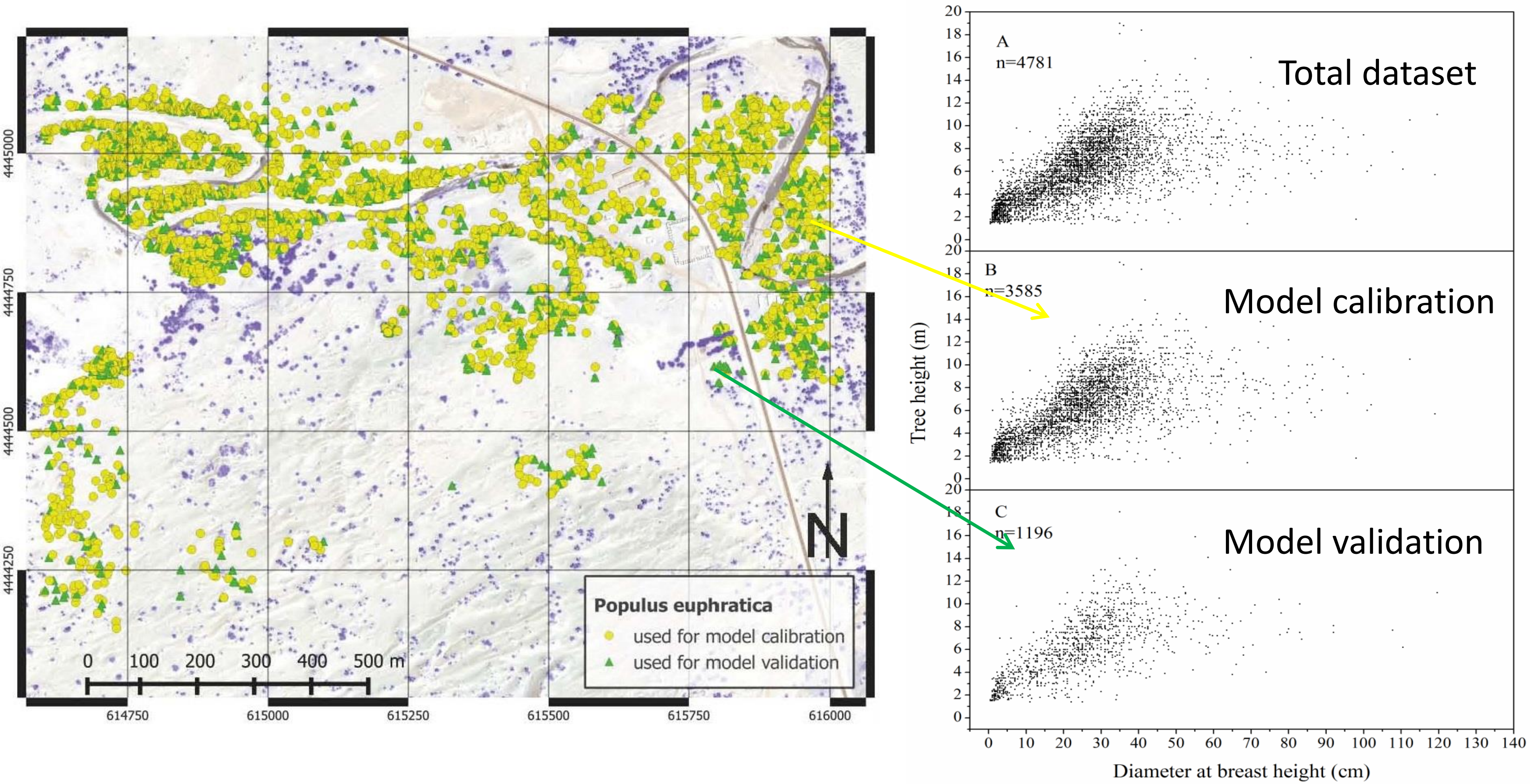


Conclutions on the assessment of hydrological and eco-morphological responses

- Water diversion events have played a positive role but with very low success
- Differentiating the degraded *P. euphratica* trees from the healthy trees by determining the height-diameter correlation coefficient
- The responses of eco-morphological indices of trees within short distance from the river were noticeable.
- Water diversion events have achieved preliminarily step of making site conditions favorable for forest recovery within 200 m distance to the river.
- The water diverting time should be closely coordinated with Phenological characteristics of Tugai forests for generating juveniles.

Modeling height-diameter relationship for *P. euphratica*

Height-diameter models are very useful to predict the heights of the unmeasured trees in the field site reducing the cost and time of data collection.



Candidate models

Table 1: Summary statistics of all sampled trees, trees for model calibration and model validation

	Number of trees	***DBH (cm)***				***Tree height (m)***			
		Mean	**Min.**	**Max.**	**SD**	**Mean**	**Min.**	**Max.**	**SD**
Sampled tree data	4781	24.66	0.50	126.00	15.489	6.14	1.40	19.00	2.659
Model calibration	3585	24.59	0.50	119.00	15.339	6.16	1.40	19.00	2.663
Model validation	1196	24.88	0.50	126.00	15.949	6.11	1.40	18.10	2.648

Note: Min. = minimum, Max. = maximum, SD = standard deviation, DBH = diameter at breast height outside bark.

Table 2: Nonlinear height diameter models selected for this study

Model No. & equation	Model No. & equation
(1) $TH = 1.3 + a/(1 + b \times e^{-c \times DBH})$	(6) $TH = 1.3 + DBH^2/(a + b \times DBH + c \times DBH^2)$
(2) $TH = 1.3 + a(1 - e^{-b \times DBH})^c$	(7) $TH = 1.3 + a \times DBH^{b \times DBH^{-c}}$
(3) $TH = 1.3 + a(1 - e^{-b \times DBH^c})$	(8) $TH = 1.3 + a \times e^{b/(DBH + c)}$
(4) $TH = 1.3 + a \times e^{-b \times e^{-c \times DBH}}$	(9) $TH = 1.3 + a/(1 + b^{-1} \times DBH^{-c})$
(5) $TH = 1.3 + a \times e^{-b \times DBH^{-c}}$	(10) $TH = 1.3 + a(1 - e^{-b \times DBH})$

Notes: *TH* = Tree height (m); *DBH* = Diameter at breast height outside bark (cm); *a*, *b*, *c*, *d* = parameters to be estimated; *e* = base of the natural logarithm (≈2.71828); 1.3 = a constant used to account that *DBH* is measured at 1.3 m above the ground.

Model performance criteria

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(H_i - \widehat{H_i})^2}{n-p}}$$

The root mean square error (RMSE)

$$AIC = n\,ln(RMSE) + 2p$$

The Akaike Information Criterion (AIC)

$$ME = \frac{\sum_{i=1}^{n}(H_i - \widehat{H_i})}{n}$$

The mean prediction error (ME)

$$MAE = \frac{\sum_{i=1}^{n}|H_i - \widehat{H_i}|}{n}$$

The mean absolute prediction error (MAE)

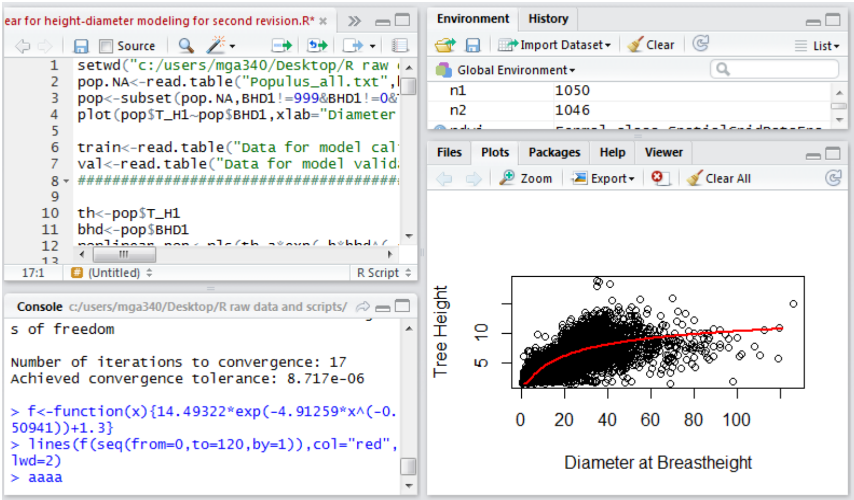
In the expressions, $\mathrm{H_i}$, $\widehat{\mathrm{H_i}}$ are the observed and predicted values, respectively, *n* is the number of observations used for fitting and validating the model, and *p* is the number of model parameters to be estimated.

Parameter estimation and comparison of goodness of model fit for model calibration data set

Model	Parameter	Estimate	SE	*t*-value	*p*>|*t*|	RMSE	AIC
(1)	*a*	7.2587	0.0870	83.43	<0.0001	1.8232	2159.109
	b	6.5474	0.4025	16.27	<0.0001		
	c	0.1233	0.0043	28.48	<0.0001		
(2)	*a*	7.8178	0.1650	47.38	<0.0001	1.8529	2216.980
	b	0.0547	0.0042	13.15	<0.0001		
	c	1.1785	0.0702	16.80	<0.0001		
(3)	*a*	7.5789	0.1515	50.04	<0.0001	1.8499	2211.216
	b	0.0290	0.0031	9.277	<0.0001		
	c	1.1865	0.0429	27.63	<0.0001		
(4)	*a*	7.5219	0.1092	68.87	<0.0001	1.8326	2177.606
	b	2.3873	0.0836	28.56	<0.0001		
	c	0.0823	0.0032	25.60	<0.0001		
(5)	*a*	13.855	1.3071	10.60	<0.0001	1.8815	2271.929
	b	5.0476	0.2789	18.09	<0.0001		
	c	0.5249	0.0469	11.20	<0.0001		
(6)	*a*	0.9587	0.9273	1.034	0.301	1.8714	2252.707
	b	2.2626	0.1216	18.60	<0.0001		
	c	0.0917	0.0031	29.68	<0.0001		
(7)	*a*	0.0601	0.0163	3.686	0.00023	1.8722	2254.262
	b	2.6676	0.2169	12.29	<0.0001		
	c	0.1993	0.0069	28.64	<0.0001		
(8)	*a*	10.476	0.2871	36.49	<0.0001	1.8637	2237.922
	b	-20.1511	1.3605	-14.81	<0.0001		
	c	5.8828	0.7116	8.267	<0.0001		
(9)	*a*	9.1762	0.3382	27.13	<0.0001	1.8644	2239.174
	b	0.0219	0.0028	7.742	<0.0001		
	c	1.3138	0.0650	20.21	<0.0001		
(10)	*a*	8.0723	0.1474	54.77	<0.0001	1.8551	2219.364
	b	0.0456	0.0017	26.23	<0.0001		

RMSE and AIC test results for all models showed that the models (1) performed significantly better than the others

$$TH = 1.3 + a/(1 + b \times e^{-c \times DBH})$$



Model validation

Model	Parameter	Estimate	SE	t-value	p>|t|	RMSE	AIC
(1)	*a*	7.3217	0.1609	45.493	<2e-16***	1.8239	708.382
	b	6.1095	0.6256	9.766	<2e-16***		
	c	0.1146	0.0071	16.258	<2e-16***		
(2)	*a*	8.0165	0.3352	23.919	<2e-16 ***	1.8539	726.373
	b	0.0468	0.0069	6.817	1.49e-11***		
	c	1.0595	0.1089	9.732	<2e-16 ***		
(3)	*a*	7.7876	0.3174	24.539	<2e-16 ***	1.8527	725.619
	b	-0.0341	0.0061	-5.596	2.74e-08 ***		
	c	1.1053	0.0729	15.165	<2e-16 ***		
(4)	*a*	7.5944	0.2029	37.420	<2e-16 ***	1.8345	714.106
	b	2.2963	0.1367	16.800	<2e-16 ***		
	c	0.0767	0.0053	14.380	<2e-16 ***		
(5)	*a*	17.1333	3.9015	4.391	1.23e-05***	1.8761	740.298
	b	4.5962	0.3095	14.850	<2e-16***		
	c	0.4261	0.0767	5.558	3.39e-08***		
(6)	*a*	-1.6211	0.3536	-4.584	5.04e-06***	1.8660	734.000
	b	2.6103	0.1387	18.826	< 2e-16 ***		
	c	0.0864	0.0043	20.188	<2e-16 ***		
(7)	*a*	0.1394	0.0557	2.503	0.0124 *	1.8713	737.292
	b	1.9723	0.3097	6.369	2.73e-10 ***		
	c	0.1718	0.0154	11.185	<2e-16 ***		
(8)	*a*	10.6952	0.5302	20.172	<2e-16 ***	1.8591	729.672
	b	-22.1570	2.6224	-8.449	<2e-16 ***		
	c	6.9681	1.3625	5.114	3.68e-07 ***		
(9)	*a*	9.8420	0.7751	12.698	<2e-16 ***	1.8631	732.184
	b	0.0275	0.0055	5.039	5.42e-07 ***		
	c	1.1756	0.1071	10.972	<2e-16 ***		
(10)	*a*	8.1210	0.2662	30.510	<2e-16 ***	1.8541	724.531
	b	0.0437	0.0029	14.920	<2e-16 ***		

Note: Significance codes '***' 0.001, '**' 0.01, '*' 0.05

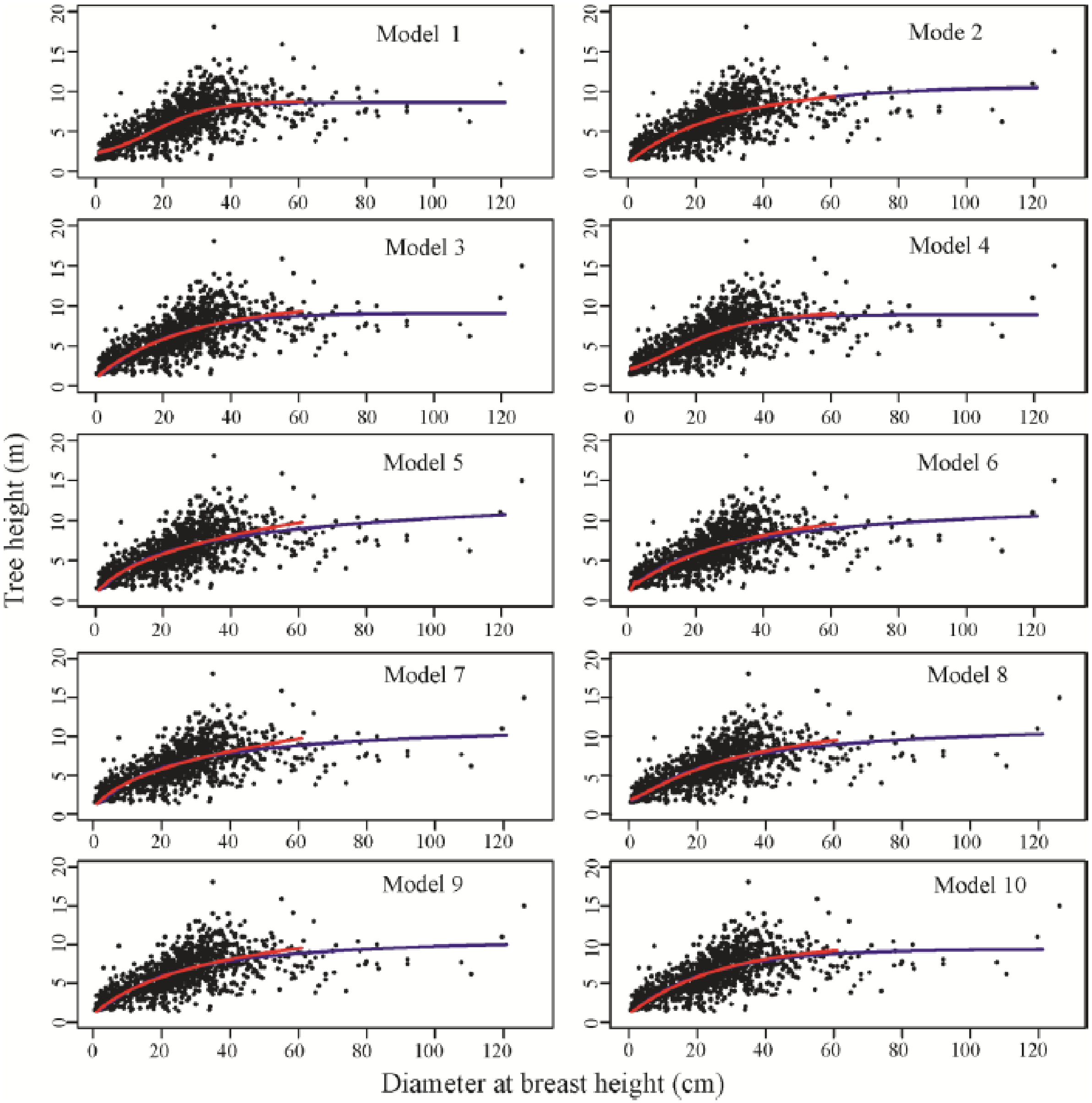


Fig. 6-4 Simulation of the height–diameter models (1)-(10) for the model validation data set of *P. euphratica*. The blue and red lines represent the model fitting for the entire validation data set and for the data subset with DBH ≤ 60 cm, respectively.

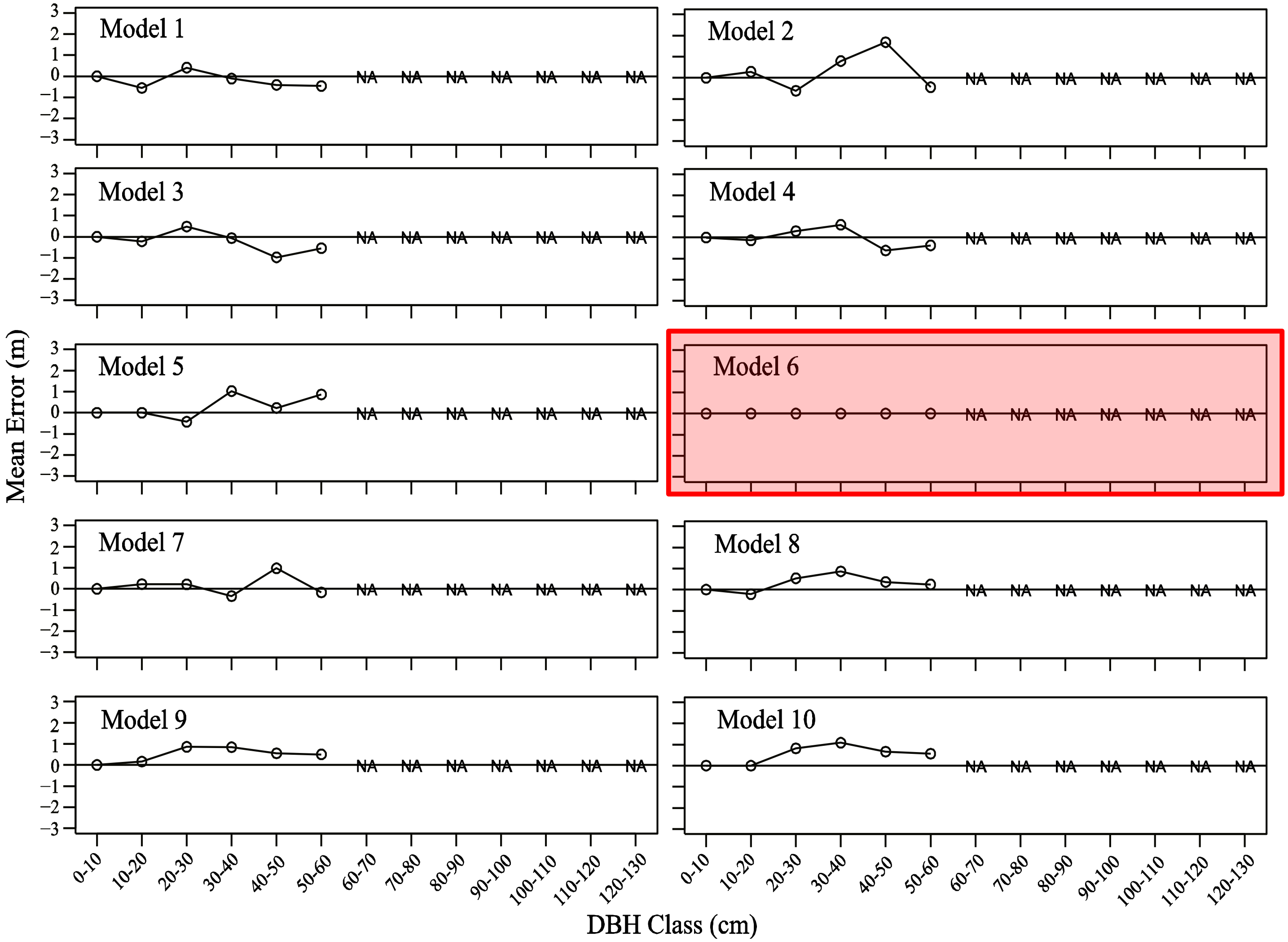
Model	ME	MAE
1	0.0059	1.3754
2	0.0289	1.3976
3	0.0426	1.3982
4	0.0078	1.3817
5	0.0233	1.4181
6	-0.0114	1.4097
7	0.0357	1.4158
8	0.0054	1.4006
9	0.0344	1.4059
10	0.0196	1.3972

Almost all models underestimated the tree heights except for Model (6). Comparing the MEs and MAEs of the models, Model (1) produced relatively smaller ME (0.0059) and MAE (1.3754) than the other models.

Model (6) ?

Mean prediction errors across tree DBH classes (in 10-cm intervals) for the model validation data set of *P. euphratica*

Model (6) generated significantly smaller mean prediction errors across all DBH classes



Conclusion on the modelling TH-DBH relationship

Considering all above mentioned camparative analyses for evaluating goodness of model fit

Model (1): $\mathrm{TH} = 1.3 + \mathrm{a}/(1 + \mathrm{b} \times \mathrm{e}^{-\mathrm{c} \times \mathrm{DBH}})$

and Model (6): $\mathrm{TH} = 1.3 + \mathrm{DBH}^2/(\mathrm{a} + \mathrm{b} \times \mathrm{DBH} + \mathrm{c} \times \mathrm{DBH}^2)$

are recommended as the suitable model for predicting tree height of *P. euphratica*.

Outlook and Future work

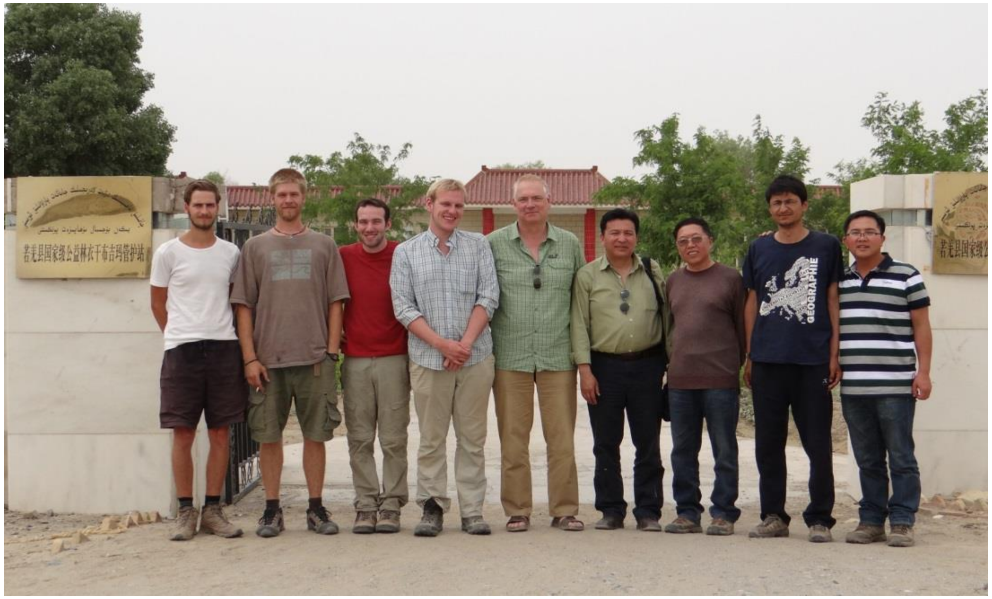
- To separate the effects of water diversion on stand parameters from the effects of other factors and natural growth.

- Ecological water seems to be ineffective for establishing juvenile stands. Majority of the renewed are root suckers. Therefore, it is importatant to study the reproductive strategy and development tendency of stands (and positive/negative effects on the riparian forests).

- We do not know below-ground structure of *Poplar* stands yet. what is happening in the below-ground ecosystem is still unclear. ! Given the long-term extreme water scarcity, *P. euphratica* might have developed more adaptive underbodies (roots) to survive (in comparison to its upper body).

- Mixed effect models for predicting tree height might be able to minimize the model limitation. For example. Including water availability as a parameter in the original height-diameter models.

Acknowledgements……



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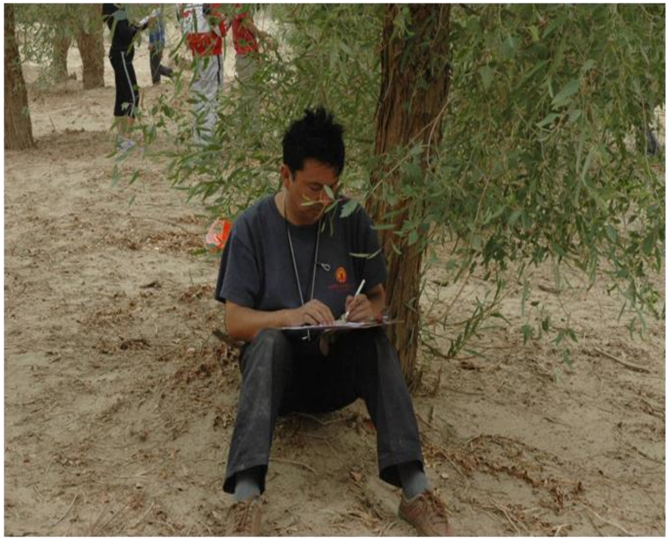



Publications

1.<u>**Tayierjiang AISHAN**</u>, Ümüt HALIK, Florian BETZ, Philipp GARTNER, Bernd CYFFKA (2015): Modeling height-diameter relationship for Populus euphratica Oliv. in the Tarim Riparian Forest Ecosystem, Northwest China. ***Journal of Forestry Research***, accepted.

2.<u>**Tayierjiang AISHAN**</u>, Ümüt HALIK, Florian BETZ, Tashpolat TIYIP, Jianli Ding, Yiliyasijiang NUERMAIMAITI (2015): Stand structure and height-diameter relationship of a degraded Populus euphratica forest in the lower reaches of the Tarim River, Northwest China**.** ***Journal of Arid Land***, 7(4): 544-554.

3.<u>**Tayierjiang AISHAN**</u>, Ümüt HALIK, Alishir KURBAN, Bernd CYFFKA, Martin KUBA, Florian Betz & Maierdang KEYIMU (2015): Eco-morphological response of floodplain forests (*Populus euphratica* Oliv.) to water diversion in the lower Tarim River, northwest China. ***Environmental Earth Sciences***, 73(2):533-545.

4.<u>**Tayierjiang AISHAN**</u>, Ümüt HALIK, Bernd CYFFKA, Martin KUBA, Abdulla ABLIZ & Aliya BAIDOURELA (2013): Monitoring the hydrological and ecological response to water diversion in the lower reaches of the Tarim River, Northwest China. ***Quaternary International***, 311: 155-162.

5.Martin KUBA, <u>**Tayierjiang AISHAN**</u>, Bernd CYFFKA, Ümüt HALIK (2013): Analysis of connections between soil moisture, groundwater level and vegetation vitality along two transects at the Lower Reaches of the Tarim River, Northwest China. ***Geo-Öko (Journal of Geoecology)*,** 34(1-2): 103-128.

Thank you all for your attention!