Ecosystem Functions and Ecosystem Services – Ecosystem Services of Riparian Ecosystems

Frank M. THOMAS, Birgit KLEINSCHMIT

Geobotany, University of Trier

Ecosystem Functions and Ecosystem Services – Definitions

Reiss et al. (2009), *Trends in Ecology and Evolution* **24:** 505-514:

Ecosystem functions (ESF) = ecosystem processes:

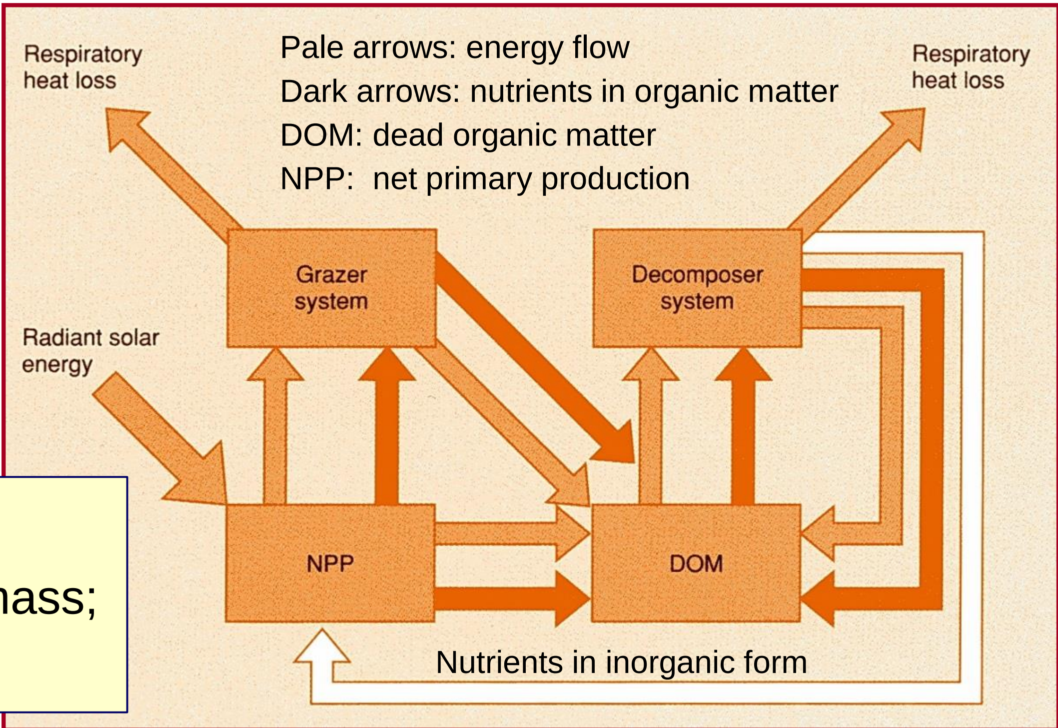
"Changes in energy and matter over time and space through biological activity … governed by the interplay of abiotic factors, [mediated] by organisms."

"**Ecosystem functioning:** the joint effects of all processes that sustain an ecosystem."

Key ecosystem processes:

- Primary productivity;
- Resource consumption;
- Trophic interactions;
- Respiration;
- Decomposition.

(from: Begon et al. 2006, Ecology. Blackwell)



ESF studied in riparian forests:

- Production of above-ground tree biomass;
- Water use.

Ecosystem Services – Definition

Millenium Ecosystem Assessment (Hassan et al. 2005, vol. 1):

"**Ecosystem services** are benefits people obtain from ecosystems."

Ecosystem services (ESS) comprise:

- Provisioning services (PS): e.g., production/storage of food, water, fiber, fuel;
- Supporting services (SS): e.g., biomass production, nutrient cycling, soil formation;
- Regulating services (RS): e.g., mitigation of disturbances and catastrophic events;
- Cultural services (CS): e.g., recreation, education, spiritual benefits.

ESS studied in riparian forests:

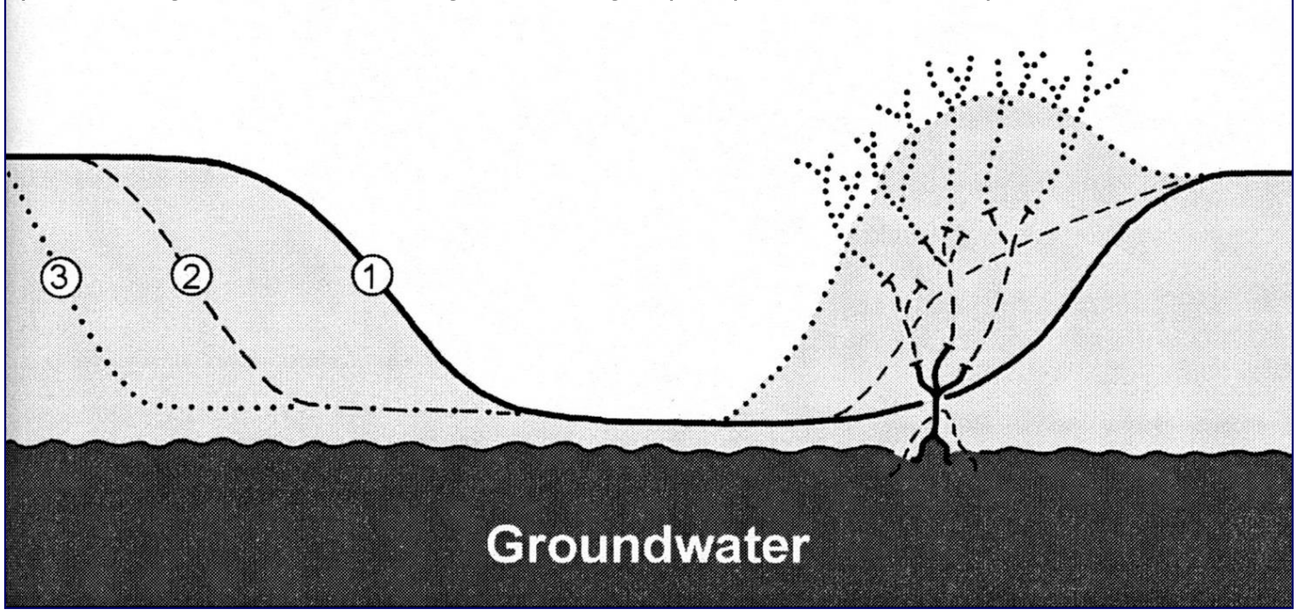
- PS, SS: Production of above-ground tree biomass;
- RS: Shelter from sand drift.

Populus euphratica is a phreatophyte …

... "a plant that **habitually obtains its water supply from the zone of saturation**, either directly or through the capillary fringe."

(Meinzer 1923, U.S. Geological Survey Water-Supply Paper 494).

(from: Runge M. 2004; in: Runge M, Zhang X (eds.), Shaker, Aachen)

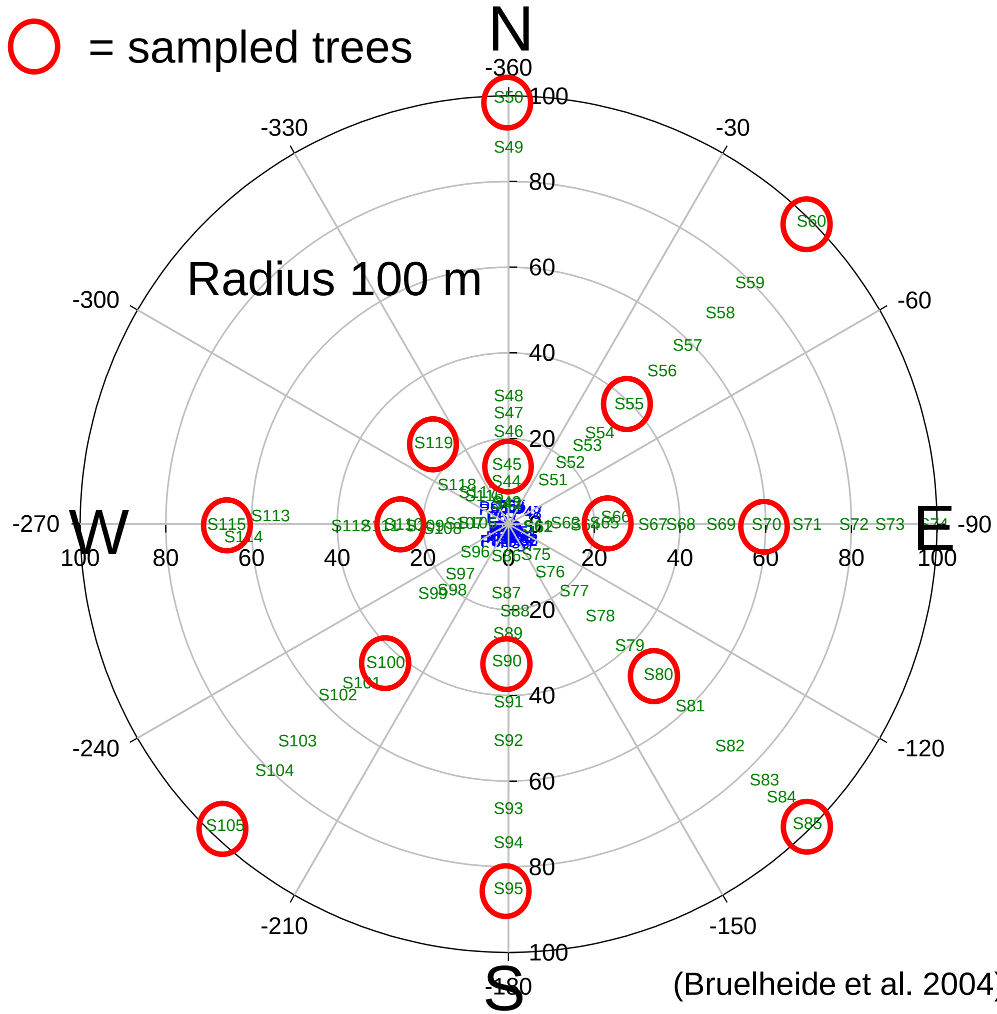


① Establishment of seedlings (generative phase);
② Shoots partly covered with sand (or decrease in the groundwater level) (onset of vegetative phase);
③ Dune formation.

Rapid root growth of *P. euphratica*

(M. Manegold)

In *Populus euphratica*, root suckers can form extensive clones

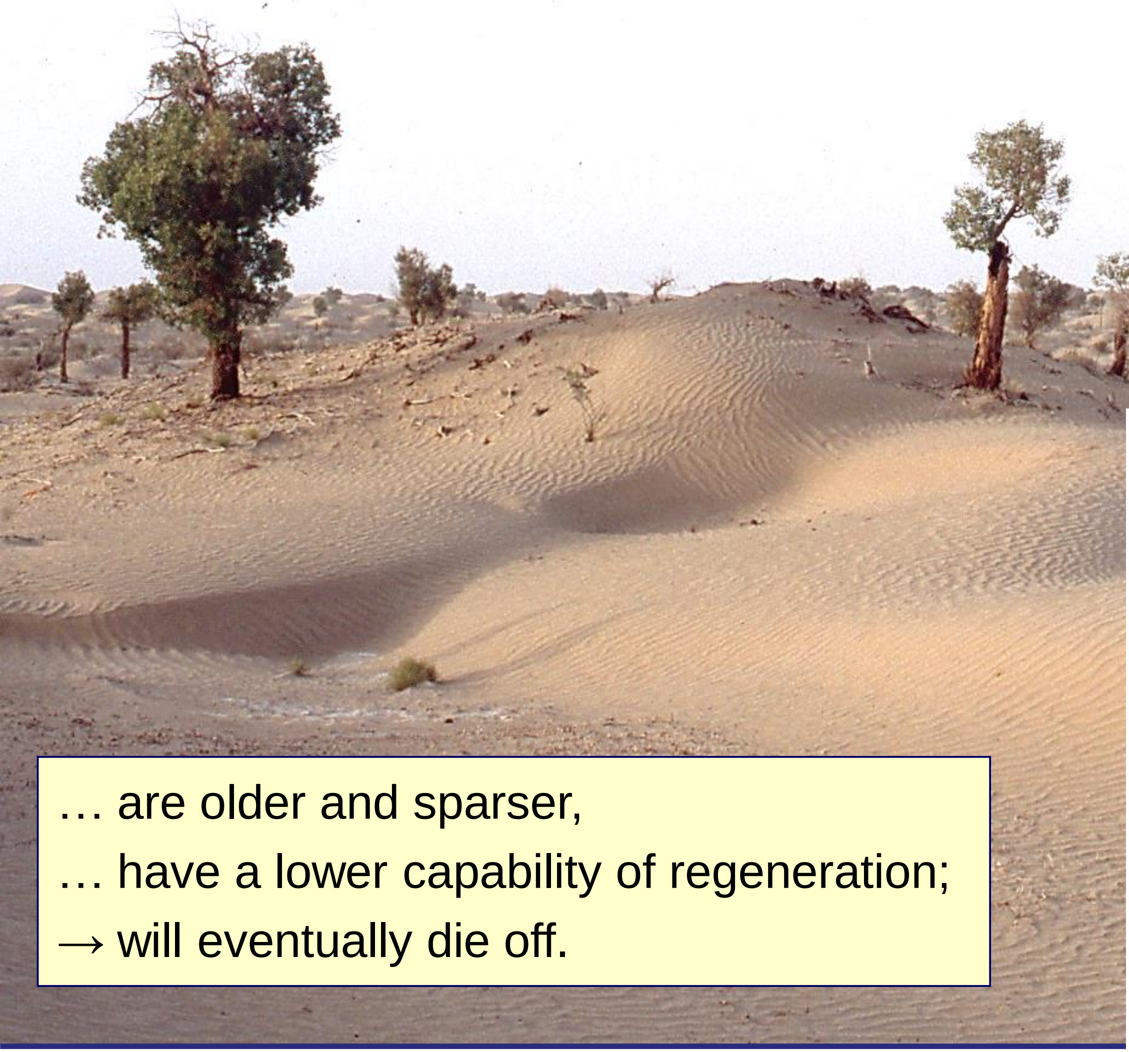


(Bruelheide et al. 2004)

Clone size of *Populus euphratica*:
up to 121 ha (Vonlanthen et al. 2010, *Am J Bot*)

→ **Vegetative regeneration gains importance (but is increasingly hampered) with increasing distance to the groundwater.**

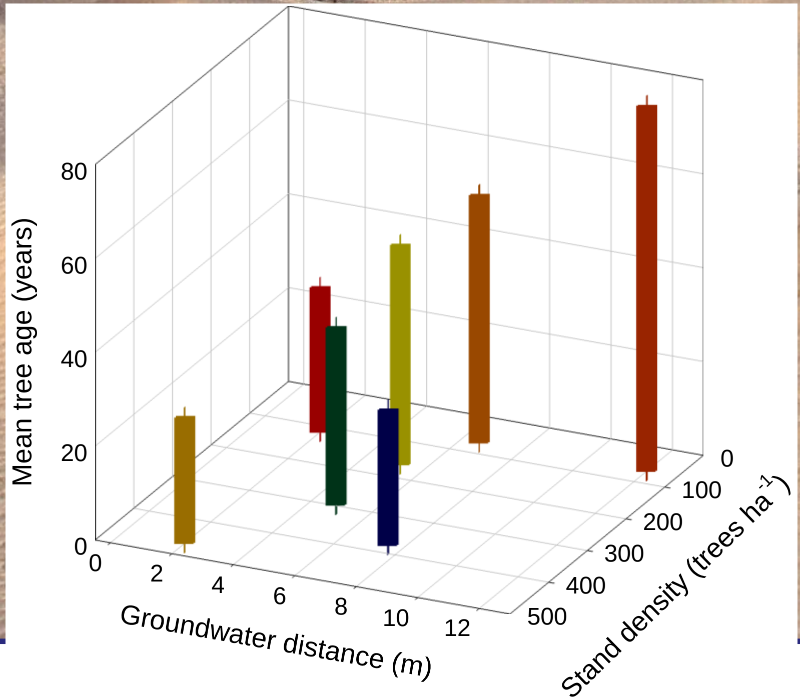
Populus euphratica stands growing at larger distances to the groundwater …



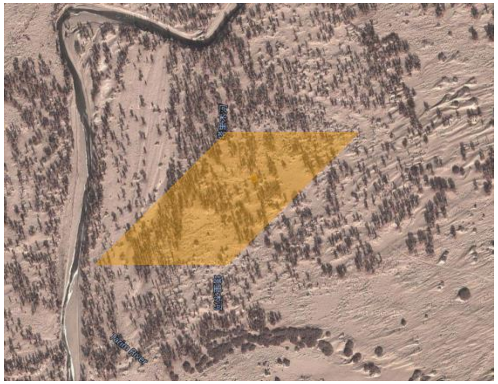
… are older and sparser,

… have a lower capability of regeneration;

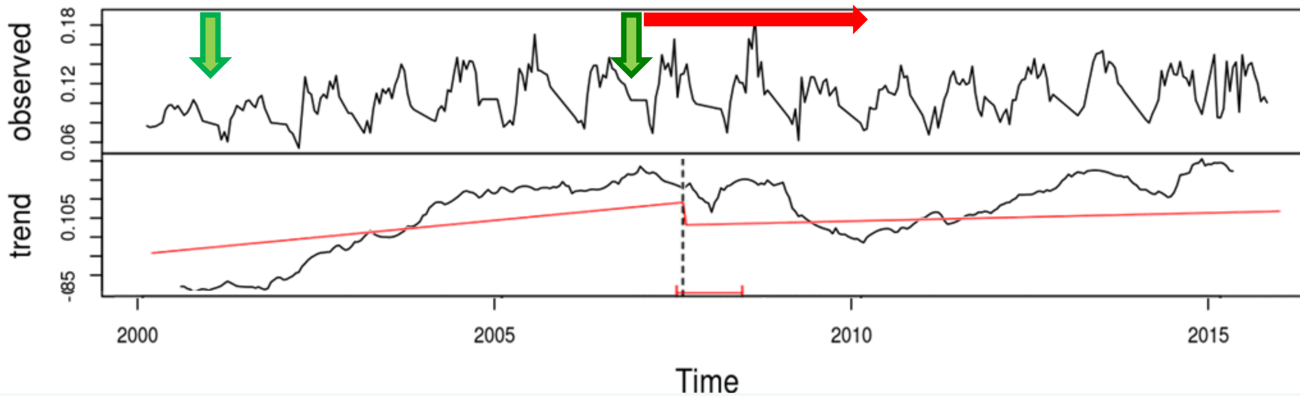
→ will eventually die off.



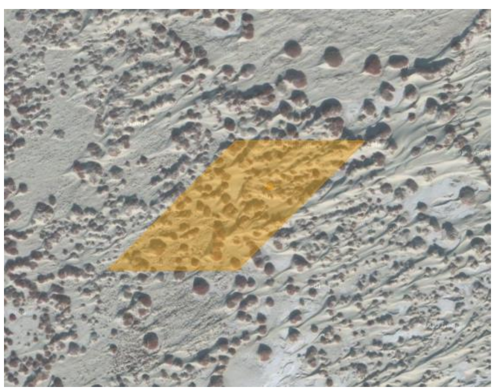
Trends in post-disturbance recovery rates of Tugai forest following drought

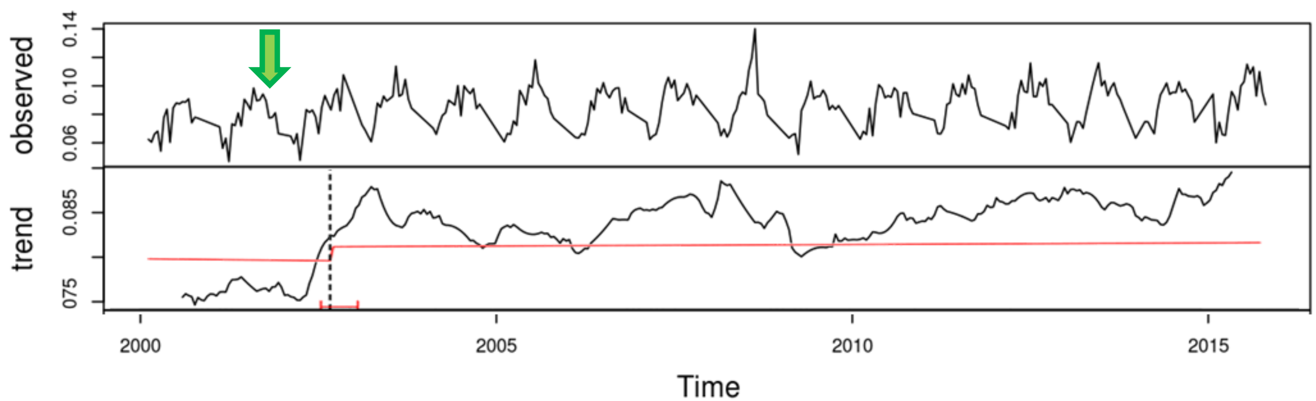


NDVI as aboveground biomass indicator



- MODIS time series NDVI, 250m, 16-days
- ***Populus*** – 330 m from Tarim (Arghan)
- positive trends with break in July 2007
- break after 8th water diversion (1 yr lag)

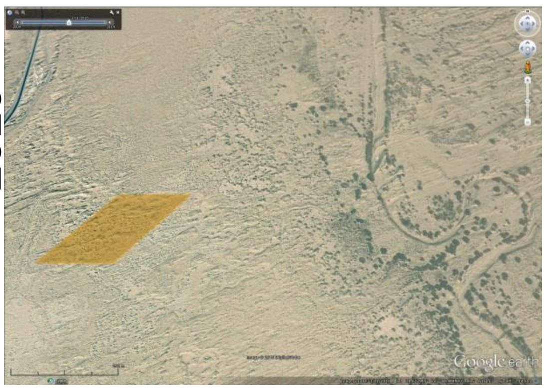




- MODIS time series NDVI, 250m, 16-days
- ***Tamarix*** – 1km from Tarim (near Korghan)
- strong positive trend after first water diversion
- followed by a trend break in Sept 2002
- steady state since then

Trends in post-disturbance recovery rates of Tugai forest following drought

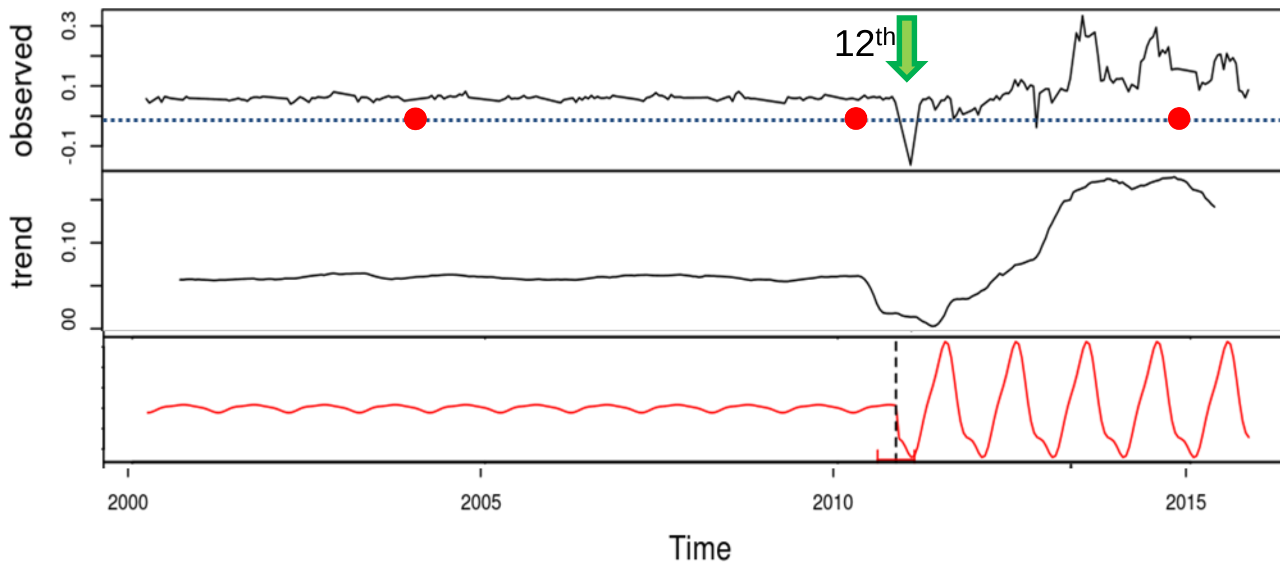
2010



2014
2004

River regulation

NDVI as aboveground biomass indicator

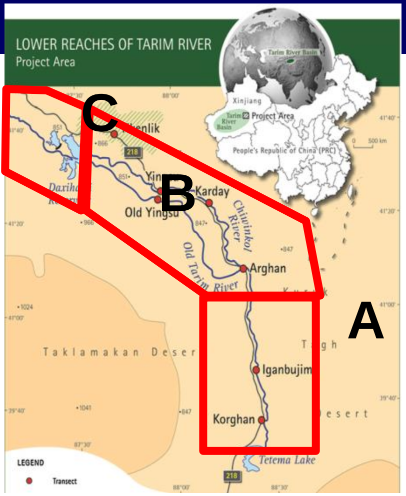


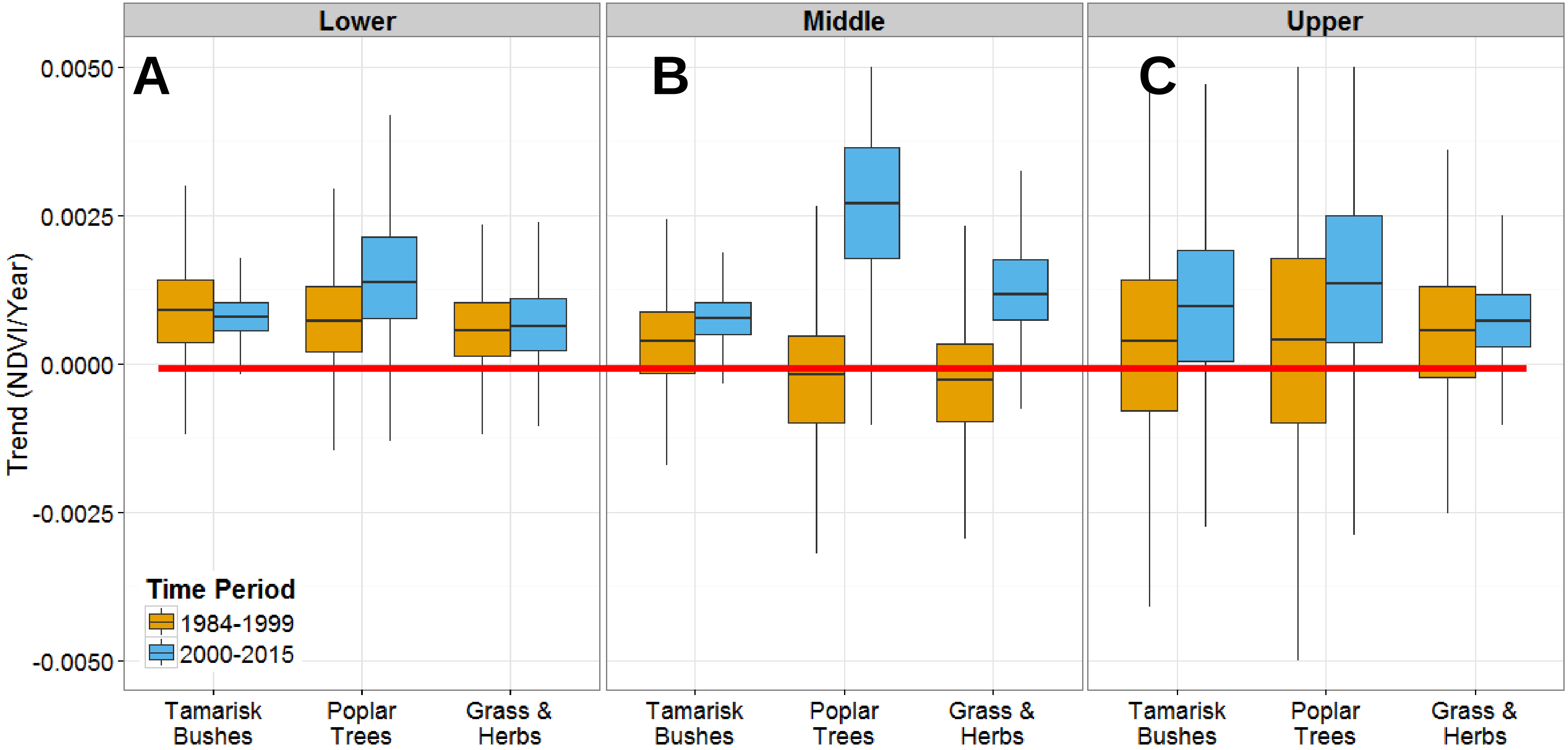
- MODIS time series NDVI, 250m, 16-days
- **Herbaceous (reed)** – 900 m from Tarim (near Korghan)

- after flooding (12th water diversion) <u>strong</u> positive trend
- land cover change from desert (barren) to steppe
- triggered due to river regulation?

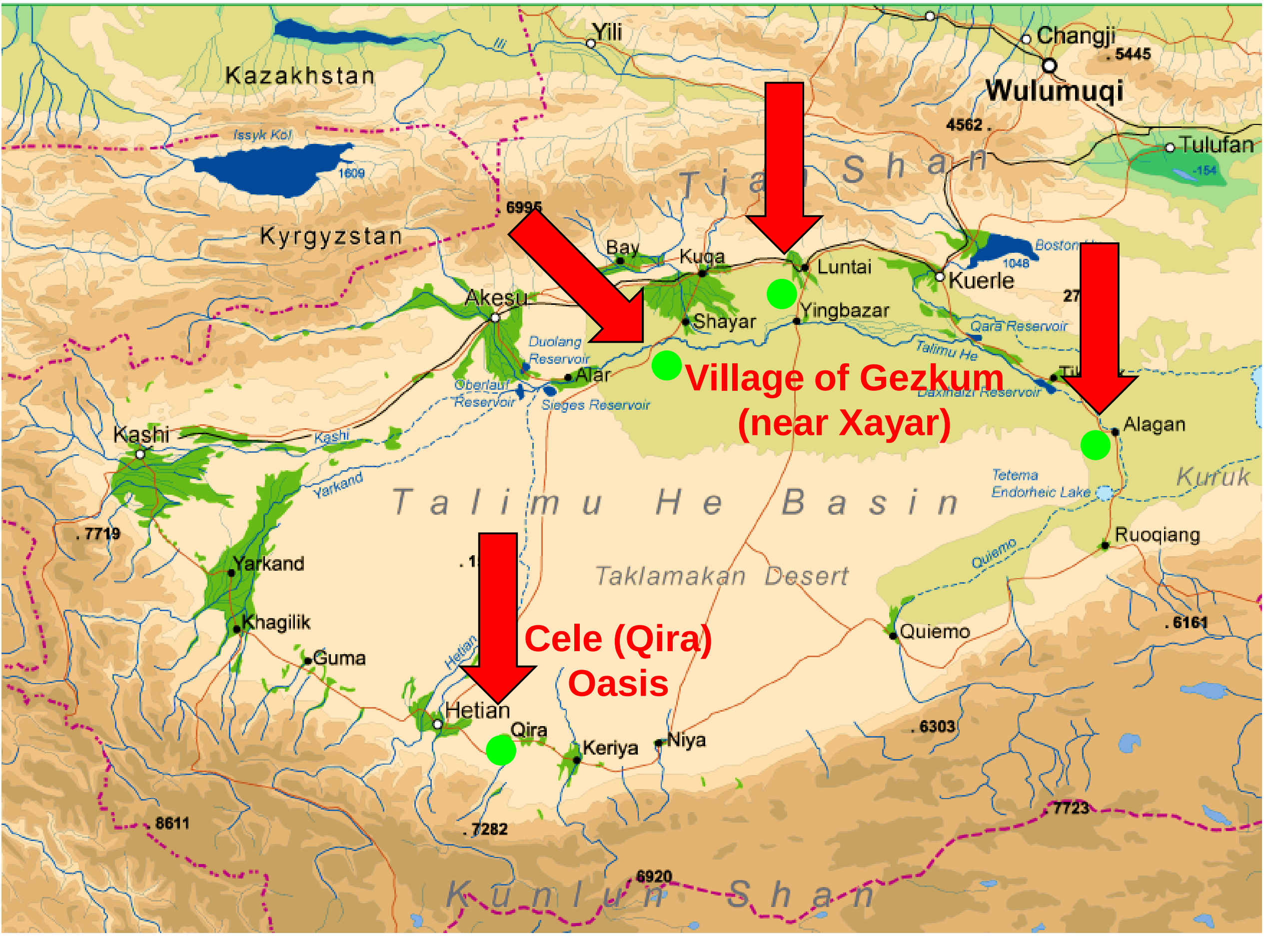
Trends in post-disturbance recovery rates of Tugai forest

- **Two time periods** under investigation (1984-1999 & 2000-’15) with Landsat Sensor
- More than 1/2 of poplar & grass area has negative trend before water diversion (middle section)
- Upper & Middle section have highest trend increase after water diversion





Riparian *Populus euphratica* forests: study sites



<u>Hyper-arid climate</u>:

Annual precipitation:
33 – 104 mm;

Annual mean temperature:
11 °C;

Annual potential evaporation:
ca. 2600 mm.

Projects:	Xayar:	SuMaRiO (2011 – 2015)
	Cele:	EU INCO-DC, 1998 – 2001

Structure of the *Populus euphratica stands*

X = Xayar; Y = Yingbazar, A = Arghan; 1 → 3: decrease in water supply

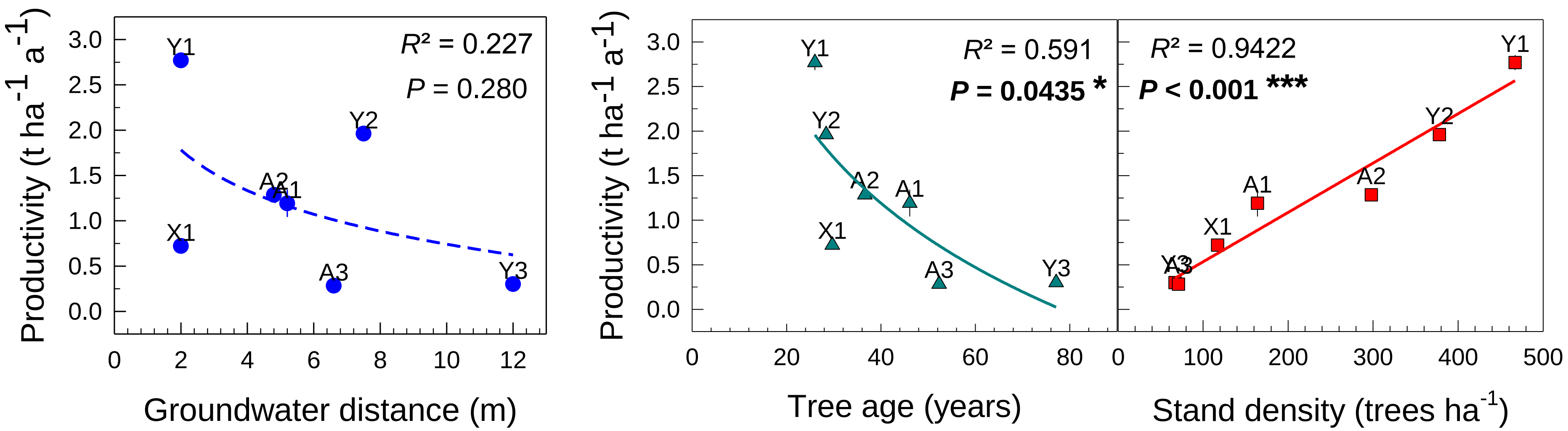
(Data from Diploma Theses of J. Ahlborn and P. Schäfer)

Site and plot	Y1	X1	A1 (+ tEW[1])	A2	A3	Y2	Y3
Distance to groundwater (m)	2.0	2.0	≈ 5.0	≈ 5.0	6.6	7.5	12.0
Tree age (years; 3-year average)	26	30	46	37	52	28	77
Stand density (trees ha $^{-1}$)	467	121	166	257	59	378	67
Tree cover (%)	81	20	31	29	5	35	6
Basal area (m^2 ha^{-1})	18.7	5.9	15.9	16.4	5.8	15.7	13.3
Total above-ground tree biomass (t ha^{-1})	55.6	13.9	28.0	25.6	6.9	31.3	15.6

[1] temporary "ecological water"

→ Larger groundwater distance → older, sparser stands; lower biomass.

Above-ground wood production of poplar stands in the last 3 years of analyses

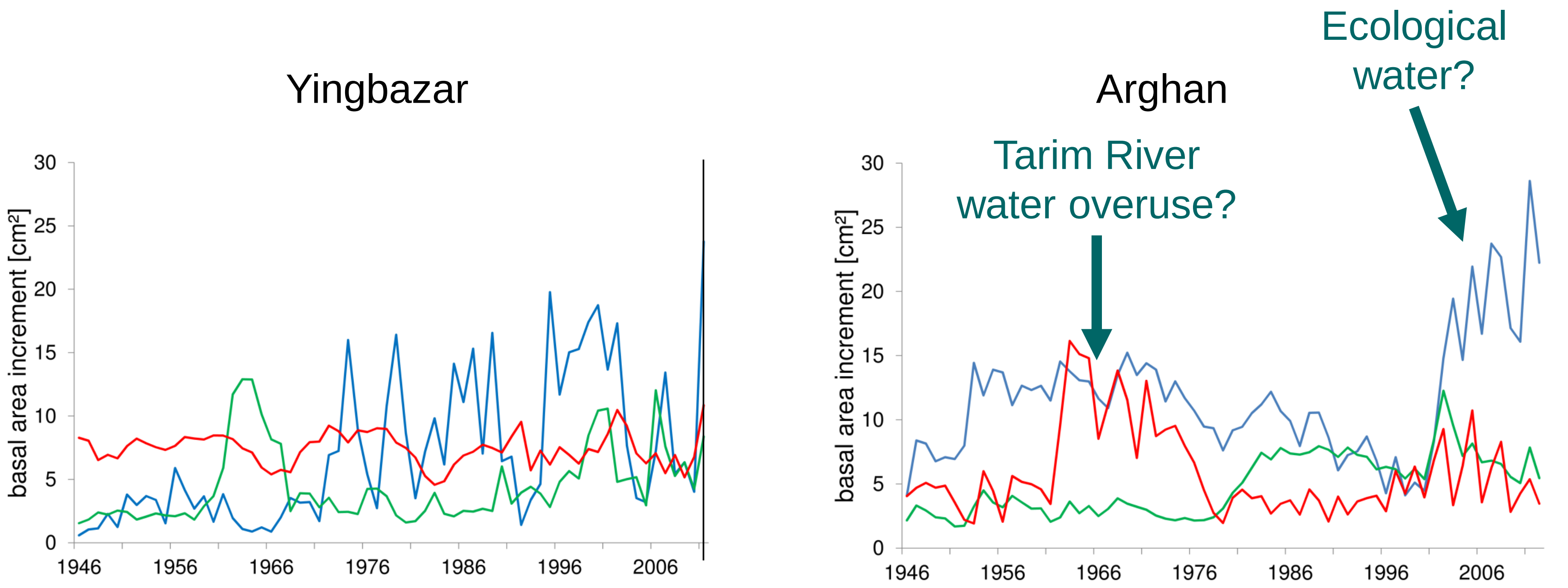


Wood production calculated using tree-ring analyses and allometric regressions adopted from Chen & Li (1984), *For. Sci. Technol. Xinjiang* **3**: 8-16

- Productivity within the range of typical woody desert vegetation (≤ 2.6 t ha^{-1} a^{-1}),
- but lower than in young (20-yr-old) coppice stands (≤ 6.1 t ha^{-1} a^{-1}; Qira site);

→ Significant relationships with tree age and stand density via groundwater distance.

Groundwater distances: long-term BAI increment



Small distance to GW (Y1, A1)

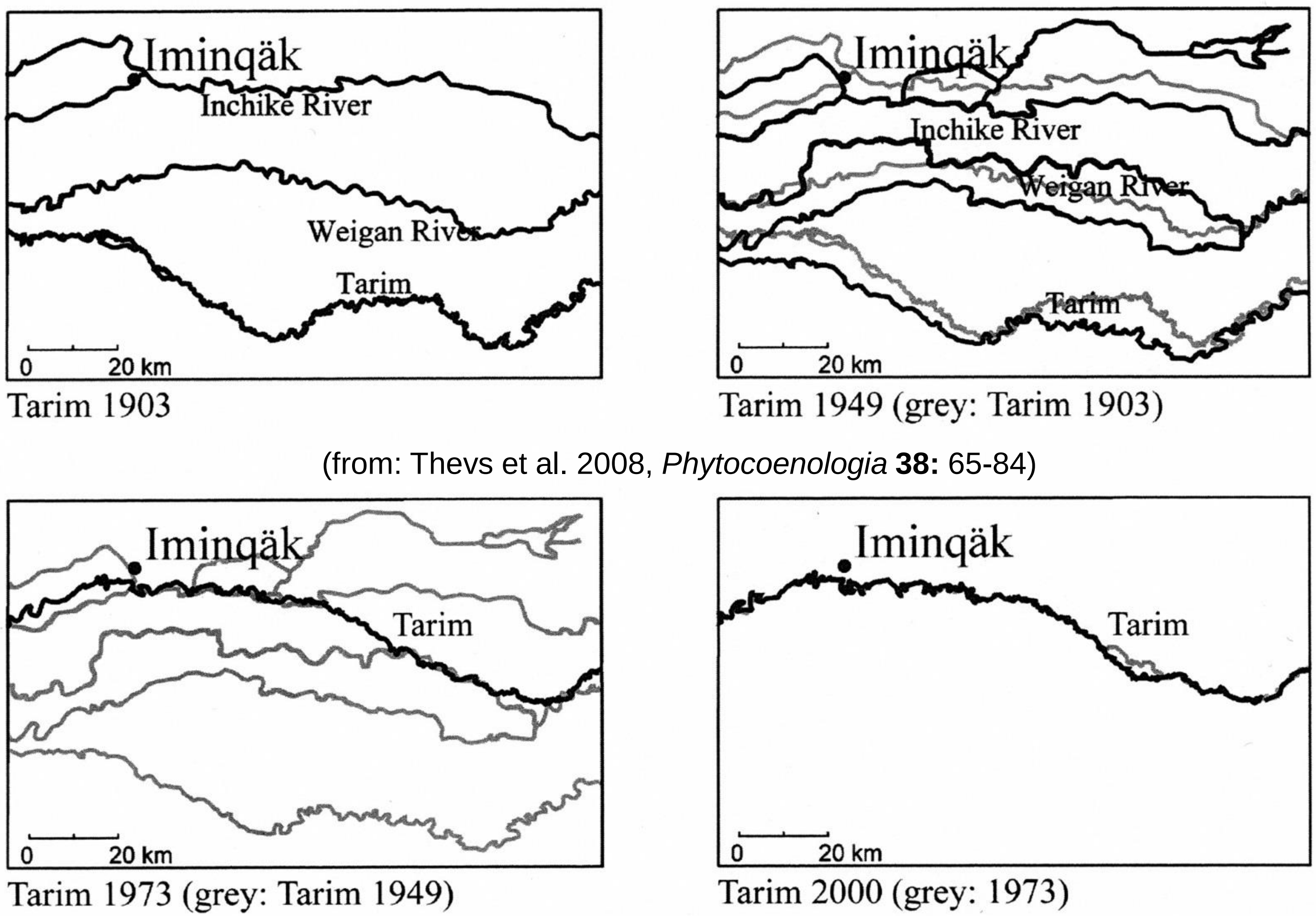
Intermediate distance to GW (Y2, A2)

Large distance to GW (Y3, A3)

→ Trees at small groundwater distance → potentially larger basal area increment.

Changes in the course of the Tarim River

Middle reaches



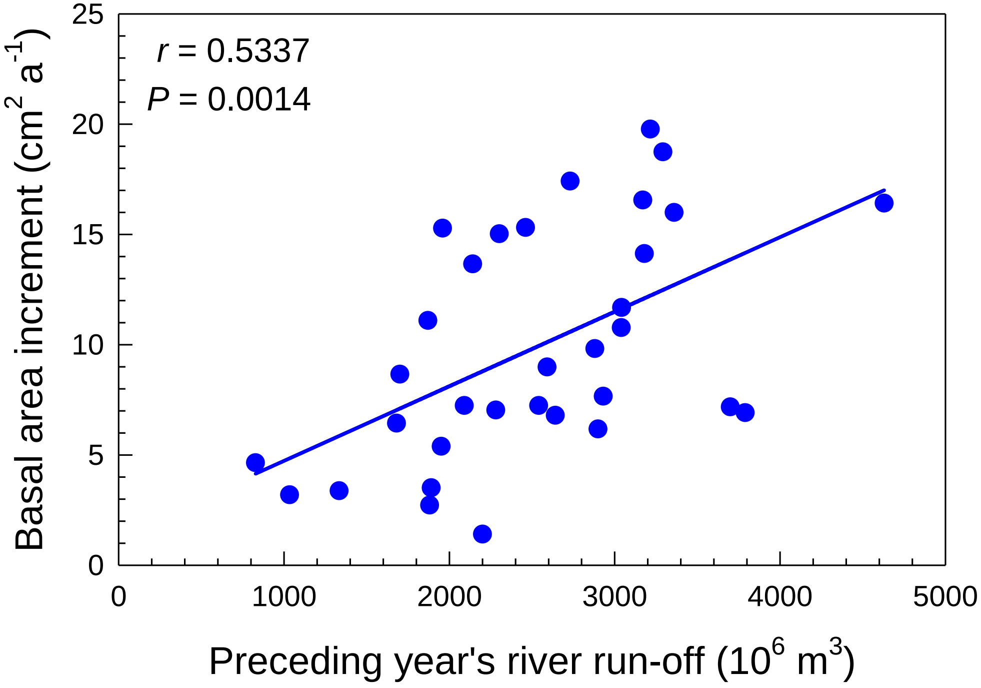
(from: Thevs et al. 2008, *Phytocoenologia* **38:** 65-84)

→ ± unchanged river course only since 1973.

Study site Yingbazar:

basal area increment related to river run-off

Populus euphratica stand at a close distance to the groundwater (Y1; 2.0 m); 1971 – 2005; river run-off of the preceding years:

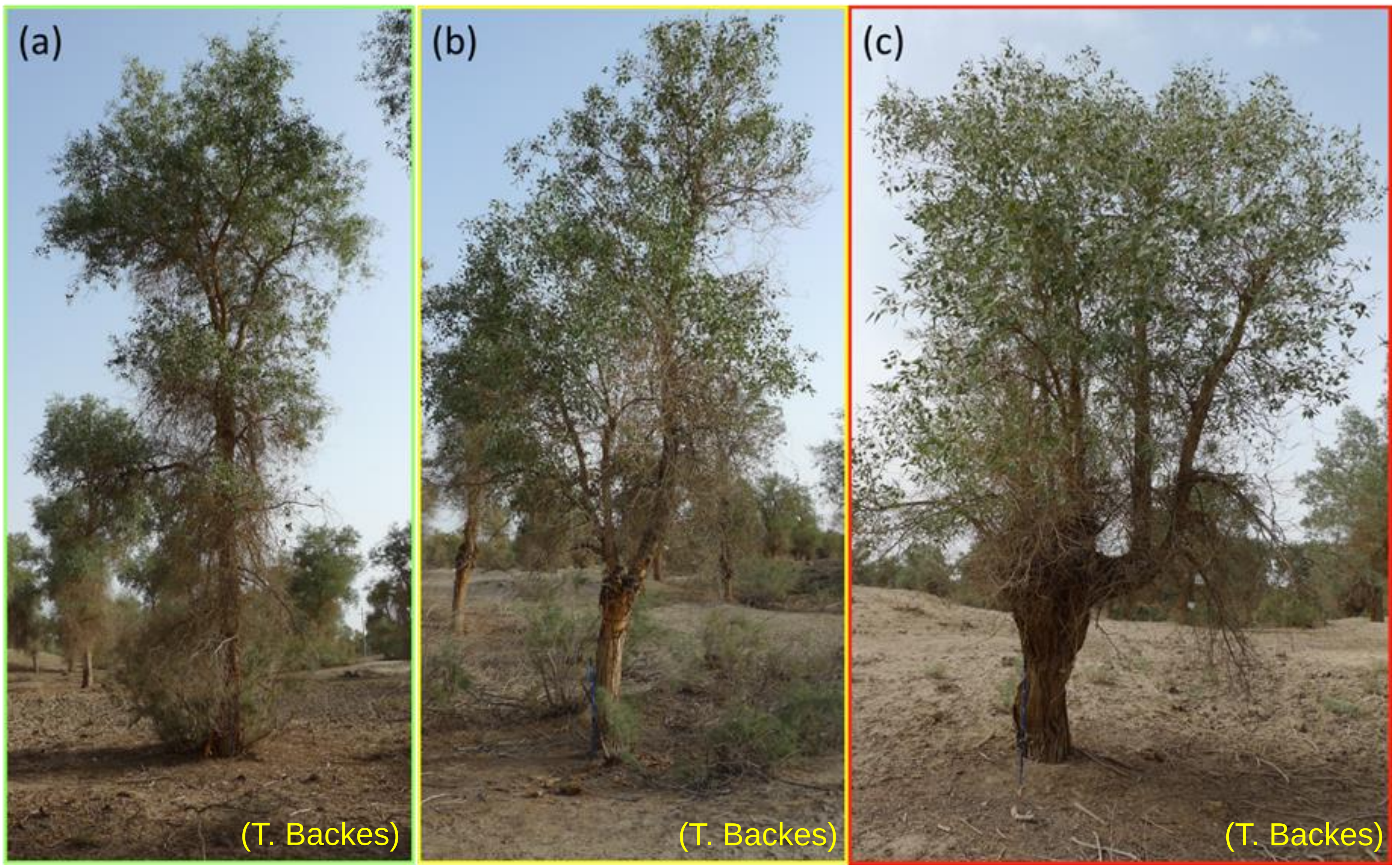


→ **Stands with close distance to the groundwater suffer significantly from a decrease in water supply;**

! **No such relationships in plots with larger distances to the groundwater.**

(Data from Diploma Thesis J. Ahlborn and from Thevs et al. 2008, *Phytocoenologia* **38:** 65–84)

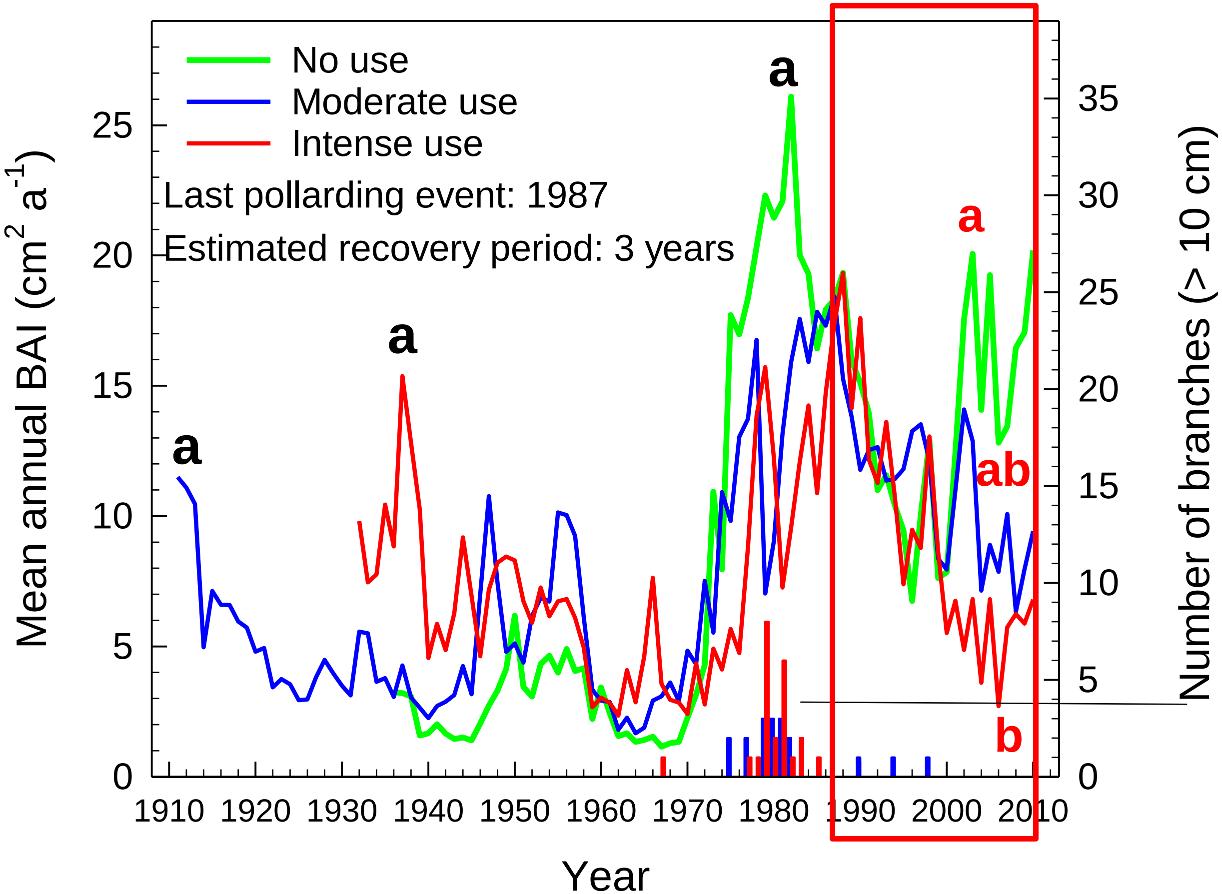
Study site Xayar:
Effects of use intensity (wood harvest by pollarding)



No pollarding (tree height: 11.9 m)	Moderate pollarding (tree height: 7.3 m)	Intense pollarding (tree height: 6.4 m)

Study site Xayar:

Use intensity and basal area increment



→ **Pollarding: smaller BAI** (intense use, 1987-2010).

(From: Lang et al. 2015, *For. Ecol. Manage.* **353:** 87–96)

A word on biodiversity …

3 – 5 relevés per plot, 400 m^2; T = tree layer, S = shrub layer, H = herb layer

Plant species	**Coverage (%)**					
	Y1	**Y2**	**Y3**	**A1**	**A2**	**A3**
Populus euphratica, T	18	15	3	11	13	2
Populus euphratica, S	1	2		0.3	0.3	
Tamarix ramosissima, S	1	0.2		4		< 0.1
Halimodendron halodendron, S	0.5					
***Lycium ruthenicum*, S**		**0.2**			**< 0.1**	
Cynanchum sibiricum, S	0.1					
Populus euphratica, H	0.1			< 0.1		
Tamarix ramosissima, H				< 0.1		
Phragmites australis, H	25					
***Glycyrrhiza inflata*, H**	**0.8**					
Cirsium cv. *arvense*, H	< 0.1					
Heteropappus altaicus (?), H	< 0.1					
Mean number of species	**6.7**	**2**	**1**	**1.6**	**1.2**	**0.8**

→ Riparian forests are species-poor, but can harbor important medicinal plants.

Conclusions

Supplementary water from river run-off fosters recovery of vegetation and enhances stem increment growth (up to a distance of ≈ 5 m above GW level?).

With increasing distance to the groundwater level …:

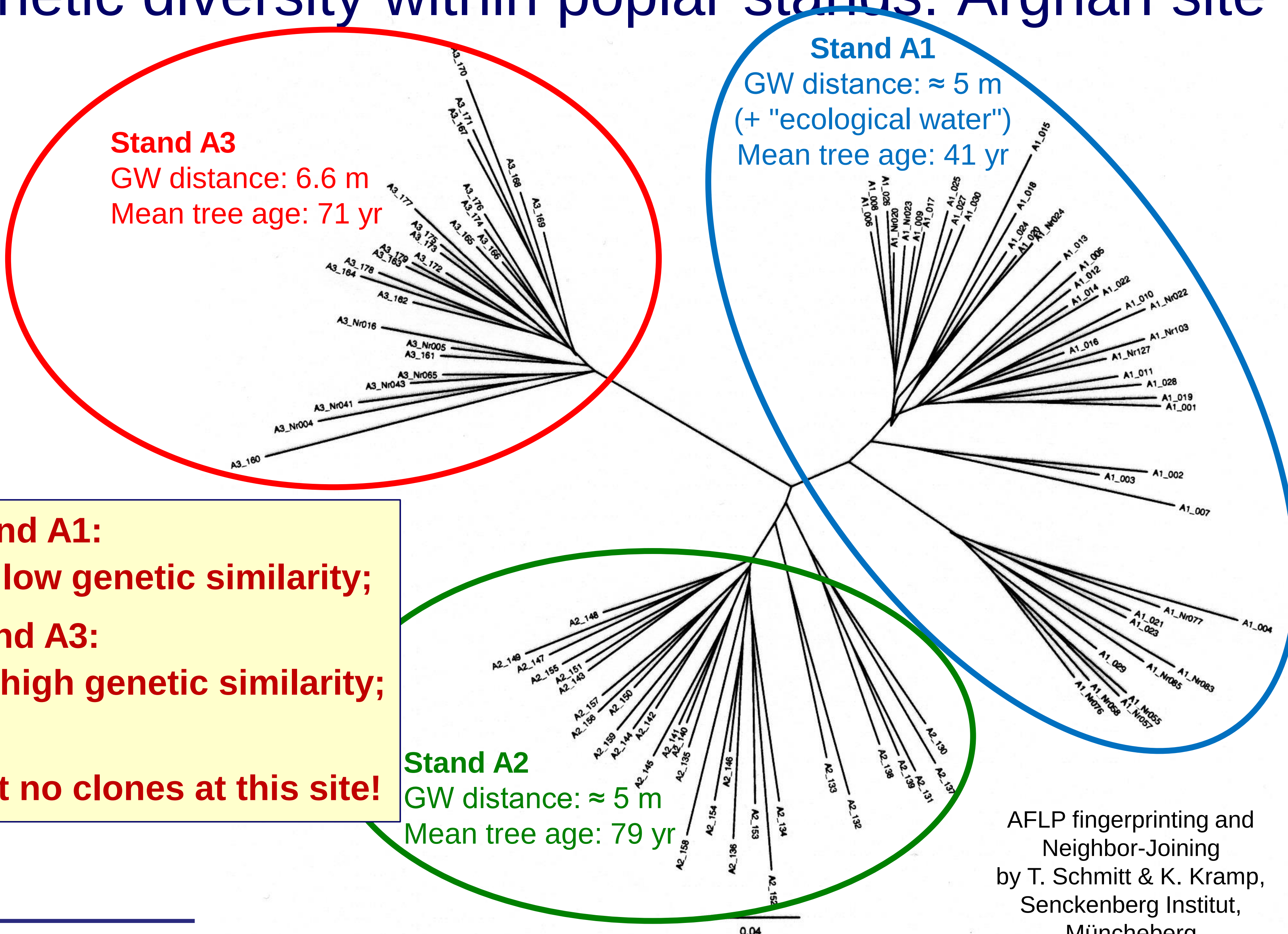
- …Poplar trees are older and lose their capability of generative (and vegetative) regeneration;
- …Poplar stands are sparser, genetically less diverse, display a reduced tree cover and produce less wood;
- …Tree growth becomes decoupled from water supply by the river;

→ **Redirection of water from stands close to the groundwater towards stands with larger distances to the groundwater might reduce growth in stands close to groundwater.**

- Poplar trees can tolerate moderate intensities of wood harvesting by pollarding → moderate pollarding should be permitted to make use of this renewable resource.


Acknowledgements:
BMBF, Sustainable Land Management, SuMaRiO, 01LL0918K
Thank you for your attention!

Genetic diversity within poplar stands: Arghan site



AFLP fingerprinting and Neighbor-Joining by T. Schmitt & K. Kramp, Senckenberg Institut, Müncheberg

→ **Stand A1:**
rel. low genetic similarity;

Stand A3:
rel. high genetic similarity;

but:
almost no clones at this site!

Recovery from pollarding

Index of resilience I_R:

ratio of the three-year averages of the annual BAI after and before the pollarding event;

$I_R \geq 1$: full recovery or increase in growth; $I_R < 1$: decline in growth after pollarding

Pollarding intensity	I_R (means ± 1 standard deviation)	Significantly different from 0?
Moderate	0.79 ± 0.36 **a**	No
High	0.91 ± 0.40 **a**	No

→ **Even intensely pollarded poplars are able to recover from pollarding.**