Restoration of riparian vegetation in the Hunhe River basin, Liaoning, China

Shuai Yu[†]
Jinlei Zhu[‡]

19.12.2018

[†] Institute of Applied Ecology, Chinese Academy of Sciences
[‡] Institute of Landscape and Plant Ecology, University of Hohenheim

Acknowledgements

Analysis of Nitrogen and Phosphorus Content Characteristic in Woody Plant and Vegetation Restoration Research in Riparian Zone of Hun River

By

Shuai Yu

A Dissertation Submitted to

The University of Chinese Academy of Sciences

In partial fulfillment of the requirement

For the degree of

Doctor of Ecology

Institute of Applied Ecology, Chinese Academy of Sciences

May, 2015

Outline

Introduction

Deforestation in Amazon

https://earthobservatory.nasa.gov/world-of-change/Deforestation

What is conservation biology?

Conservation biology is the study of attempts to protect and preserve biodiversity*.

*https://www.nature.com/subjects/conservation

What is conservation biology?

Conservation biology is the study of attempts to protect and preserve biodiversity*.

It focuses on

- both the biological and social factors that affect the success of conservation efforts,
- determining ecosystems and species whose conservation is a high priority.

*https://www.nature.com/subjects/conservation

What is conservation biology?

Conservation biology is the study of attempts to protect and preserve biodiversity*.

It focuses on

- both the biological and social factors that affect the success of conservation efforts,
- determining ecosystems and species whose conservation is a high priority.

It has two central goals

- to evaluate human impacts on biodiversity,
- to develop practical approaches to prevent the extinction of species [2].

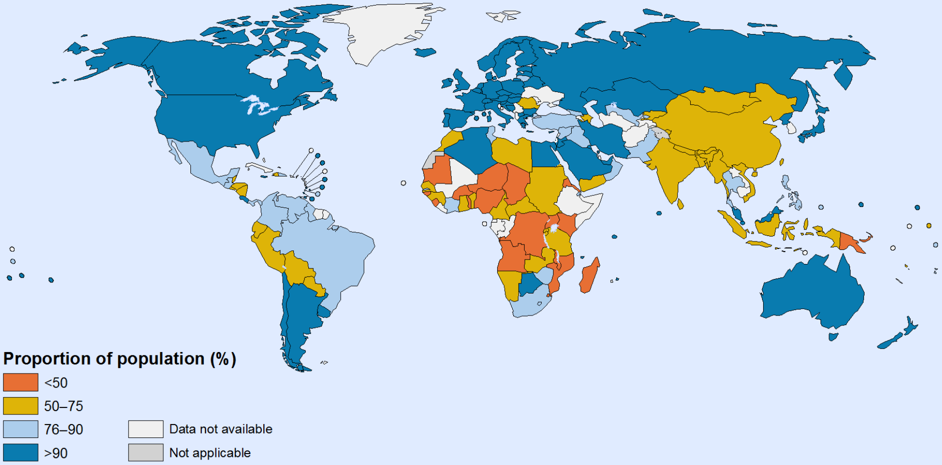
*https://www.nature.com/subjects/conservation

Why to preserve biodiversity?

- Modern extinction rates are at 100 to 1000 times greater than background extinction rates calculated over the eras [1].
- Existing species go extinct at a rate 1000 times that of species formation*.
- The primary cause of today's loss of biodiversity is habitat alteration caused by human activities.

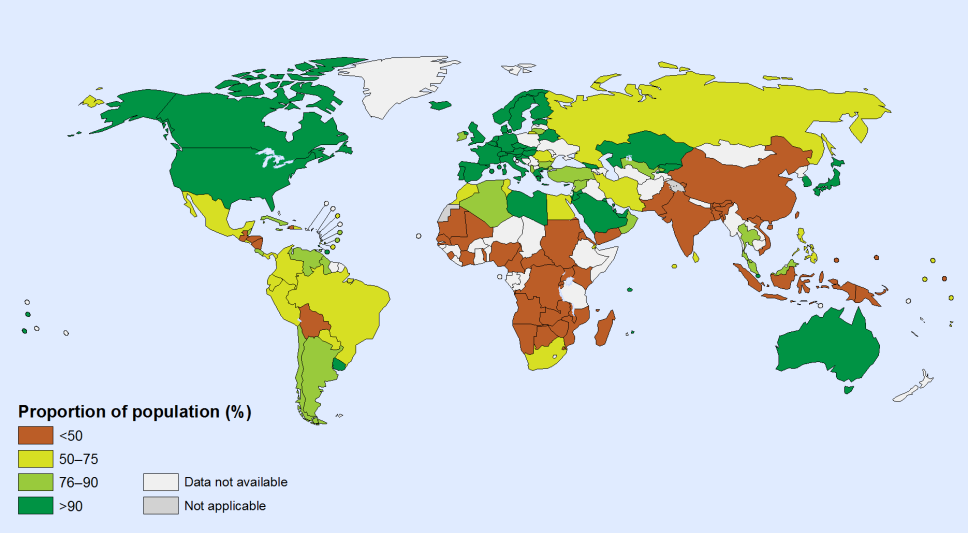
*https://www.nature.com/scitable/knowledge/library/conservation-of-biodiversity-13235087

Proportion of population using improved drinking water sources (%), 1990



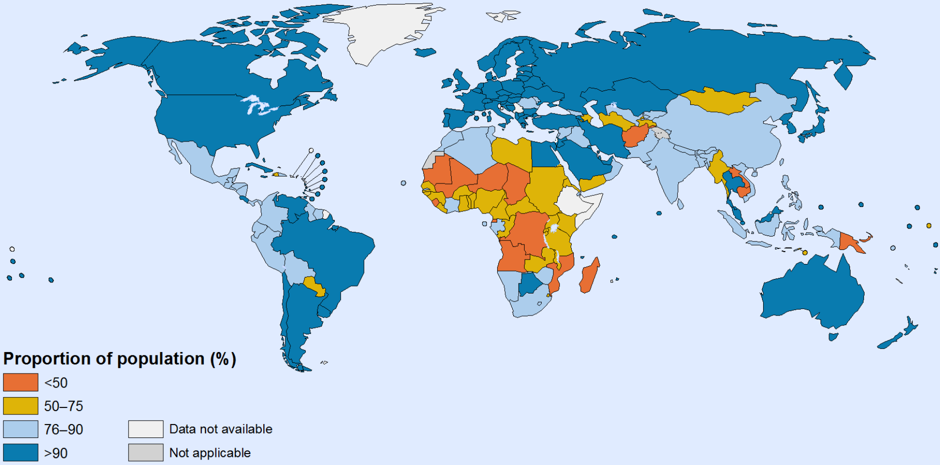
http://gamapserver.who.int/mapLibrary/Files/Maps/Global_water_1990.png

Proportion of population using improved sanitation facilities (%), 1990



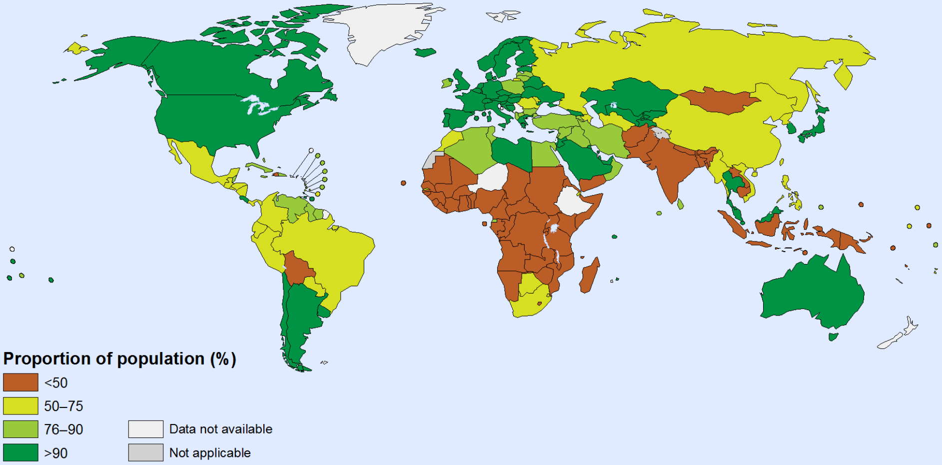
http://gamapserver.who.int/mapLibrary/Files/Maps/Global_sanitation_1990.png

Proportion of population using improved drinking water sources (%), 2000



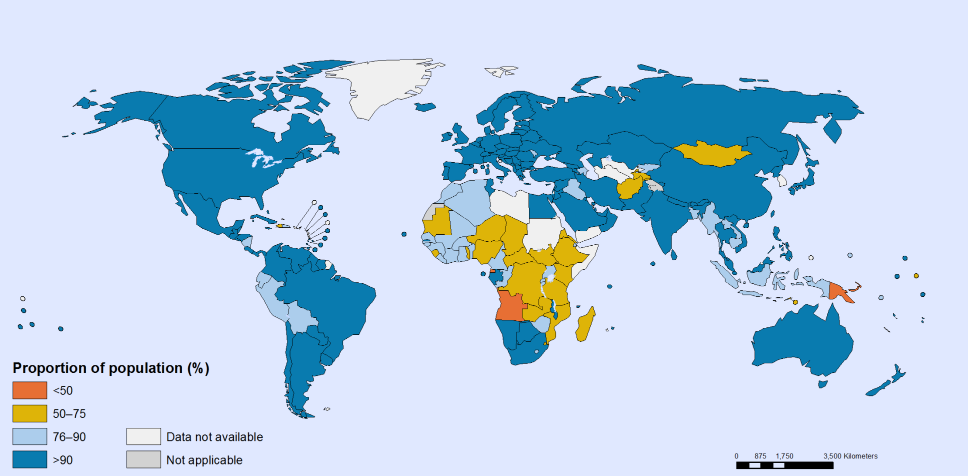
http://gamapserver.who.int/mapLibrary/Files/Maps/Global_water_2000.png

Proportion of population using improved sanitation facilities (%), 2000



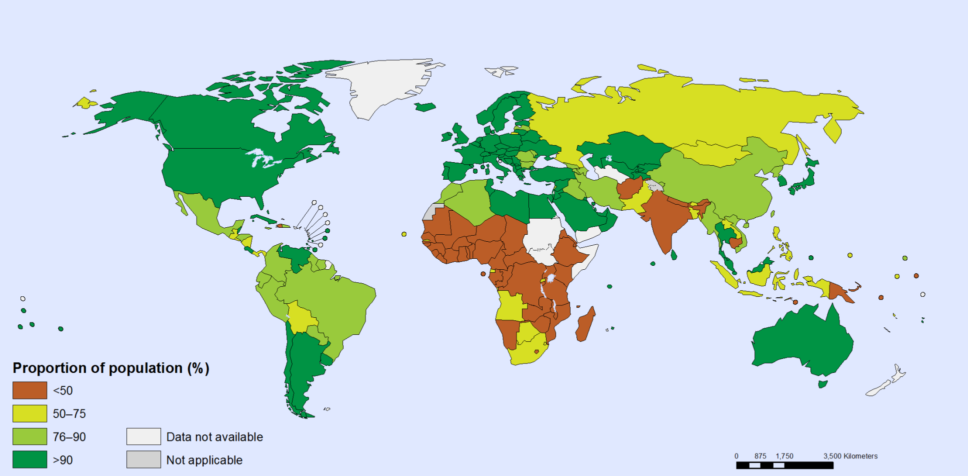
http://gamapserver.who.int/mapLibrary/Files/Maps/Global_sanitation_2000.png

Proportion of population using improved drinking water sources (%), 2015



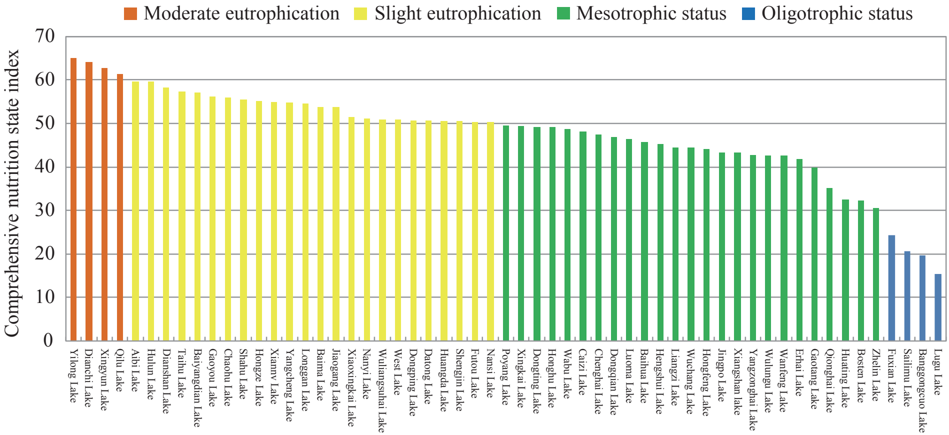
http://gamapserver.who.int/mapLibrary/Files/Maps/Global_water_2015.png

Proportion of population using improved sanitation facilities (%), 2015



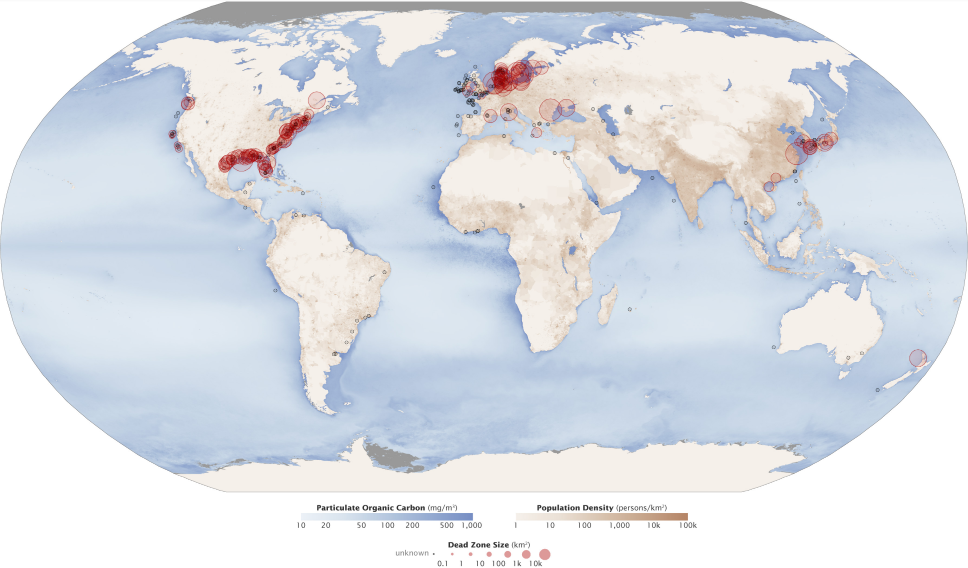
http://gamapserver.who.int/mapLibrary/Files/Maps/Global_sanitation_2015.png

Trophic level index of China's major lakes in 2017



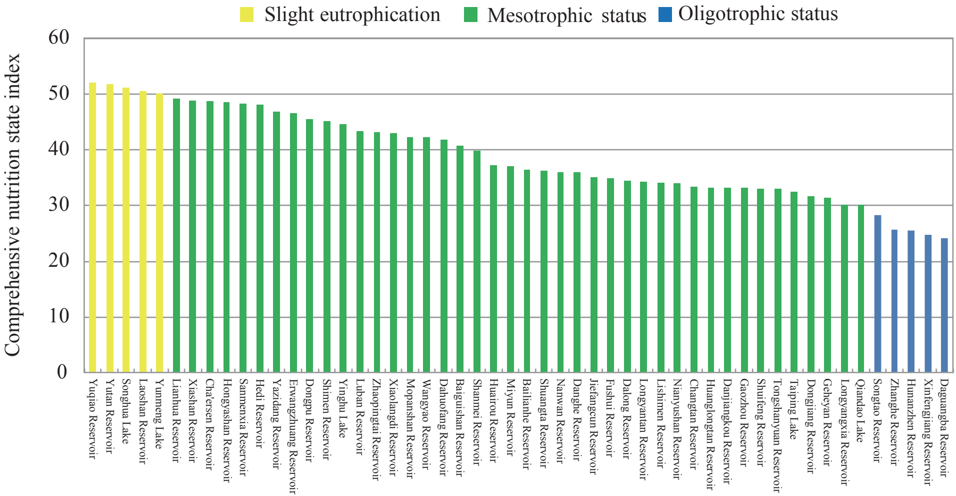
http://english.mee.gov.cn/Resources/Reports/soe/SOEE2017/201808/P020180801597738742758.pdf

Dead zones around the world



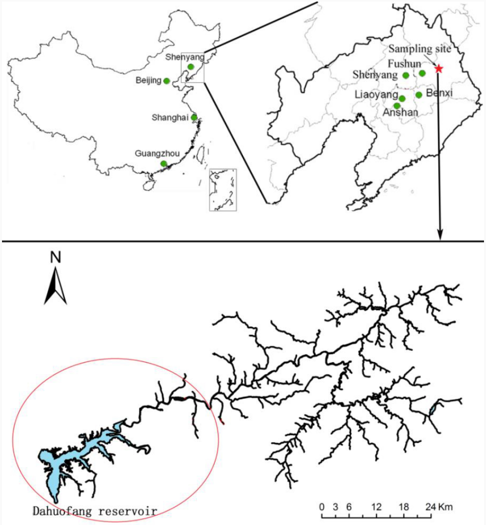
https://eoimages.gsfc.nasa.gov/images/imagerecords/44000/44677/dead_zones_lrg.jpg

Trophic level index of China's major reservoirs in 2017



Situation & Problems

Current situation



- Built in 1954–1958, first reservoir "Made in P. R. China" (not first one in China)
- Water source of city group in the lower reaches
- Surface: 110 km^2, 7 bil. m^3 water for 12 mil. people per year
- Dahuofang Water Tunnel, built in 2006–2009, 85.3 km long, 8 m in diameter, cost: $750 mil.*

*https://en.wikipedia.org/wiki/Dahuofang_Water_Tunnel

Main problems

- Water pollutants: NH_3-N (9.73 mg/L, 3.87 times higher) and TP (0.84 mg/L, 1.1 times higher)

Main problems

- Water pollutants: NH_3-N (9.73 mg/L, 3.87 times higher) and TP (0.84 mg/L, 1.1 times higher)
- River bank damaged, riparian vegetation destroyed

Main problems

- Water pollutants: NH_3-N (9.73 mg/L, 3.87 times higher) and TP (0.84 mg/L, 1.1 times higher)
- River bank damaged, riparian vegetation destroyed
- Wetland degraded, soil and water conservation capacity decreased

Main problems

- Water pollutants: NH_3-N (9.73 mg/L, 3.87 times higher) and TP (0.84 mg/L, 1.1 times higher)
- River bank damaged, riparian vegetation destroyed
- Wetland degraded, soil and water conservation capacity decreased
- Water-conservation-stands (WCS) structure single and simple, ecological functions lost

Solutions

Project workflow

<table>
<tr><td colspan="3">Channel near river mouth</td></tr>
<tr><td>N, P accumulation ability</td><td>Plant comprehensive evaluation</td><td rowspan="2">Vegetation patterns construction</td></tr>
<tr><td colspan="2">Plant selection</td></tr>
</table>

Figure 1: Project workflow.

Project workflow

<table>
<tr><th colspan="3">Channel near river mouth</th></tr>
<tr><td>N, P accumulation ability</td><td>Plant comprehensive evaluation</td><td rowspan="2">Vegetation patterns construction</td></tr>
<tr><td colspan="2">Plant selection</td></tr>
</table>

<table>
<tr><th colspan="2">Area around reservoir</th></tr>
<tr><td>Wetland modification</td><td>Relationship between stand structure and conservation capacity</td></tr>
</table>

Figure 1: Project workflow.

Project workflow

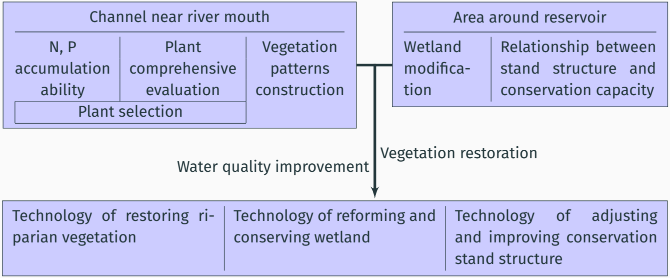


Figure 1: Project workflow.

Project workflow

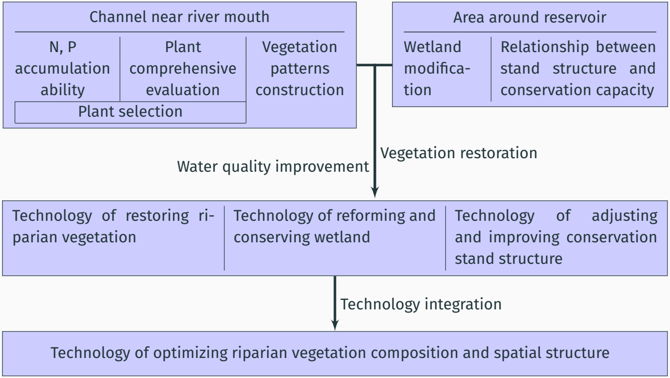


Figure 1: Project workflow.

Project workflow

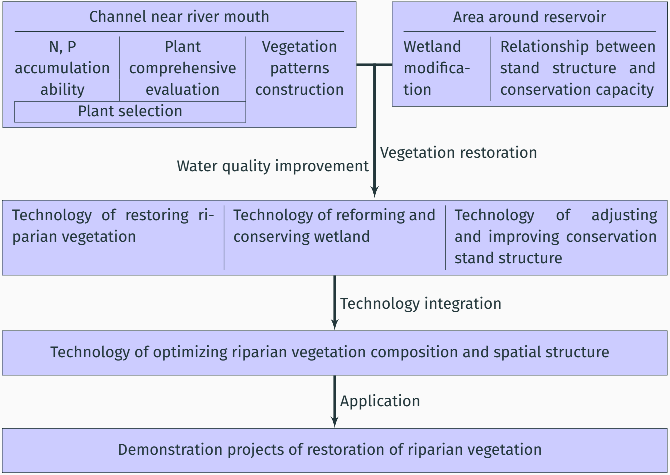


Figure 1: Project workflow.

Experiments on N, P accumulation ability

Table 1: Experimental plants

Plant	Number
Tree	27
Shrub	21
Herb	20
Total	68

Table 2: Experimental design

Treat-ment	TN	TP
	(mg/L)	
LN	14	0
HN	56	0
LP	0	3
HP	0	12
NP	14	3

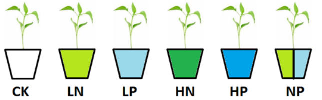


Fig 1. Pot Experiment Treatment

CK= Control
LN= Low Nitrogen
LP = Low Phosphate
HN=High Nitrogen
HP=High Phosphorus
NP=Nitrogen and Phosphorus

N, P accumulation ability of the plants

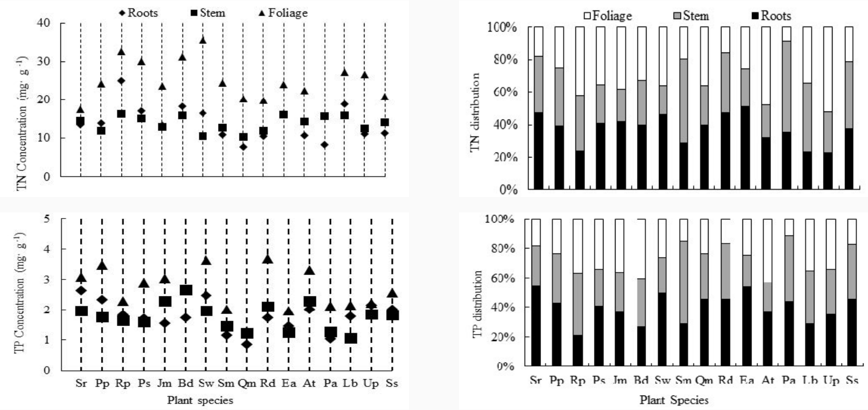


Figure 2: Concentration and distribution of total nitrogen (TP) and total phosphorus (TP) in plants [3].

Plant selection protocol (Analytic Hierarchy Process)

	Criteria	A-B W_i	Index	B-C W_{ij}	A-C TW
Comprehensive evaluation index (A)	Resistance (B_1)	0.47	Cold tolerance (C11)	0.31	0.14
			Poor soil tolerance (C12)	0.12	0.05
			Shade tolerance (C13)	0.23	0.10
			Flooding tolerance (C14)	0.24	0.11
			Drought tolerance (C15)	0.11	0.05
	Ecological (B_2)	0.44	N absorbing ability (C21)	0.23	0.10
			P absorbing ability (C22)	0.21	0.11
			Biomass accumulation (C23)	0.38	0.18
			Water conservation ability (C24)	0.09	0.04
			Soil conservation ability (C25)	0.10	0.05
	Aesthetic (B_3)	0.08	Leaf shape (C31)	0.20	0.02
			Flower shape (C32)	0.09	0.01
			Fruit shape (C33)	0.08	0.01
			Canopy shape (C34)	0.43	0.04
			Shape in winter (C35)	0.20	0.02

A–B: λ_{max} = 3.0037, CI = 0.0036, RI1 = 0.58, CR = 0.0620 $<$ 0.1; B_1–C: λ_{max} = 5.4118, CI1 = 0.0919, RI1 = 1.12, CR1 = 0.0820 $<$ 0.1
B_2–C: λ_{max} = 5.2180, CI2 = 0.0587, RI2 = 1.12, CR2 = 0.0524 $<$ 0.1; B_3–C: λ_{max} = 5.3876, CI3 = 0.0865, RI3 =1.12, CR3 = 0.0772 $<$ 0.1
Total rank: CI = $W_1 * CI1 + W_2 * CI2 + W_3 * CI3$ = 0.0349, RI = $W_1 * RI1 + W_2 * RI2 + W_3 * RI3$ = 0.8651, CR = 0.0403 $<$ 0.1

List of selected plants

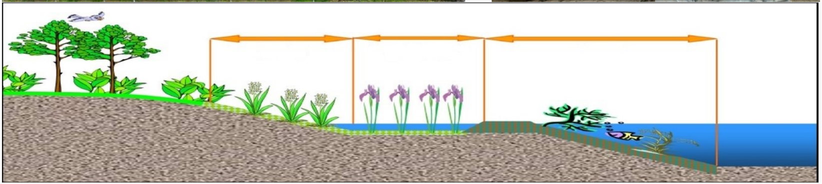
Tree	Shrub	Herb
1. *Ulmus pumila*	1. *Lespedeza bicolor*	1. *Phragmites australis*
2. *Syringa reticulate*	2. *Lonicera chrysantha*	2. *Artemisia capillaris*
3. *Salix matsudana*	3. *Sambucus williamsii*	3. *Sparganium stoloniferum*
4. *Robinia pseudoacacia*	4. *Sorbaria sorbifolia*	4. *Impatiens noli-tangere*
5. *Salix babylonica*	5. *Amorpha fruticose*	5. *Polygonum persicaria*
6. *Juglans mandshurica*	6. *Salix viminalis*	6. *Iris pseudacorus*
7. *Berberis dielsiana*	7. *Acer ginnala*	7. *Acorus tatarinowii*
8. *Morus alba*	8. *Salix integra*	8. *Monochoria korsakowii*
9. *Fraxinus mandschurica*	9. *Flueggea suffruticosa*	9. *Iris sanguinea*
10. *Acer mono*	10. *Euonymus maackii*	10. *Lythrum salicaria*

Effects of tending intensity on species diversity and water-holding capacity of WCS

Table 3: Effects of tending intensity on species diversity and water-holding capacity of water-conservation stands (WCS)

Treatment	Species number						Water storage (t/hm^2)	
	First year			Second year				
	Tree	Shrub	Herb	Tree	Shrub	Herb	Total	Non-capillary
CK	14	7	3	15	7	3	1022	220
Weak	15	7	3	16	8	3	1054	260
Medium	16	8	4	18	8	4	1085	295
Intense	18	8	4	20	10	5	1100	324

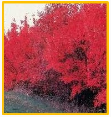
Technology: restore riparian vegetation near river mouth



- Reservoir shoal:
  Salix viminalis, *Iris sanguinea*, *Phragmites australis*, *Sparganium stoloniferum*, *Artemisia capillaris*, *Polygonum persicaria*
- Barren area:
  Salix viminalis, *Lespedeza bicolor*, *Sorbaria sorbifolia*, *Artemisia capillaris*, *Polygonum persicaria*, *Iris sanguinea*
- Flat fertile area:
  Juglans mandshurica, *Fraxinus mandschurica*, *Ulmus pumila*, *Sorbaria sorbifolia*, *Lonicera chrysantha*, *Sambucus williamsii*, *Impatiens noli-tangere*, *Sparganium stoloniferum*, *Iris pseudacorus*, *Phragmites australis*, *Monochoria korsakowii*, *Lythrum salicaria*
- Steep hilly area:
  Salix viminalis, *Berberis dielsiana*, *Robinia pseudoacacia*, *Salix babylonica*, *Syringa reticulate*, *Amorpha fruticosa*, *Sorbaria sorbifolia*

Vegetation type	Distance/ density
Tall tree	4–6 m
Dwarf tree	2–3 m
Shrub	1–2 m
Herb	0.4–1.2 m
Macrophyte	2–10 / m^2

Technology: reform and conserve wetland around reservoir

Ecological protection zone Terrestrial Partial fenced area	Buffer zone Water 40–90 cm Buffer ponds	Shoal Water $<$ 40 cm Littoral zone	Reservoir
Ulmus pumila *Fraxinus mandschurica* *Acer ginnala*	*Nelumbo nucifera* *Alisma plantago* *Lythrum salicaria* *Iris sanguinea*	*Scirpus validus* *Typha angustifolia*	

Technology: adjust and improve structure of WCS

Chinese pine (*Pinus tabulaeformis*) stand:

- Block thinning
- Interplant distance 3.5 m
- Forest gap 10–15%
- Dominant with young and mid-aged trees

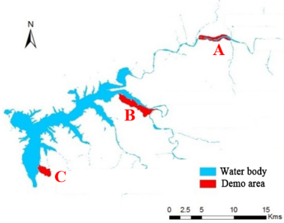
Larch (*Larix gmelinii*) stand:

- Selection-felling with strip reform
- Replant Chinese pine and local broadleaf trees
- Canopy density 0.5–0.7
- Mixed coniferous forest dominant with trees and shrubs

Application

Demonstration projects and evaluation

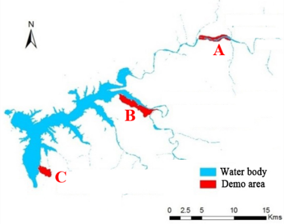
- **A** Restoration of riparian vegetation near the river mouth, 3 km^2



- **A** Riparian vegetation near the river mouth restored

Demonstration projects and evaluation

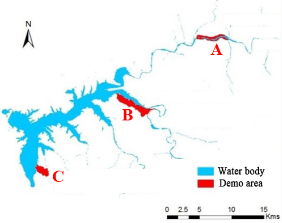
- **A** Restoration of riparian vegetation near the river mouth, 3 km^2
- **B** Reform and conservation of wetland around the reservoir, 5 km^2



- **A** Riparian vegetation near the river mouth restored
- **B** Wetland around the reservoir recovered

Demonstration projects and evaluation

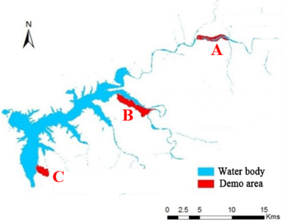
- **A** Restoration of riparian vegetation near the river mouth, 3 km^2
- **B** Reform and conservation of wetland around the reservoir, 5 km^2
- **C** Adjustment and improvement to the structure of WCS, 2 km^2



- **A** Riparian vegetation near the river mouth restored
- **B** Wetland around the reservoir recovered
- **C** Structure of conservation stand improved

Demonstration projects and evaluation

- **A** Restoration of riparian vegetation near the river mouth, 3 km^2
- **B** Reform and conservation of wetland around the reservoir, 5 km^2
- **C** Adjustment and improvement to the structure of WCS, 2 km^2



- **A** Riparian vegetation near the river mouth restored
- **B** Wetland around the reservoir recovered
- **C** Structure of conservation stand improved

Evaluation

- Number of plant species increased by 30%
- Water- and soil-conservation capacity increased
- Water quality improved: typical pollutants reduced by 20%
- Removal of TN and TP: 4.12 t/y

Take home message

- This study showed how to systematically select plant species for riparian vegetation restoration.
- It provides experience and knowledge for improving spatial vegetation structure of water-conservation stands.
- The study was successful, but it cost a lot.

Questions?

Scan to download the slides

Thanks for listening!

List of 68 plant species used in this study

Tree

1. *Ulmus pumila*
2. *Syringa reticulate*
3. *Salix matsudana*
4. *Robinia pseudoacacia*
5. *Salix babylonica*
6. *Juglans mandshurica*
7. *Berberis dielsiana*
8. *Morus alba*
9. *Fraxinus mandschurica*
10. *Acer mono*
11. *Fraxinus rhynchophylla*
12. *Prunus padus*
13. *Ulmus davidiana*
14. *Armeniaca mandshurica*
15. *Pterocarya stenoptera*
16. *Aralia elata*
17. *Quercus mongolica*
18. *Malus baccata*
19. *Gleditsia microphylla*
20. *Crataegus pinnatifida*
21. *Acer negundo*
22. *Celtis bungeana*
23. *Populus alba*
24. *Acer truncatum*
25. *Betula allegheniensis*
26. *Tilia mandschurica*
27. *Salix koreensis*

Shrub

1. *Lespedeza bicolor*
2. *Lonicera chrysantha*
3. *Sambucus williamsii*
4. *Sorbaria sorbifolia*
5. *Amorpha fruticose*
6. *Salix viminalis*
7. *Acer ginnala*
8. *Salix integra*
9. *Flueggea suffruticosa*
10. *Euonymus maackii*
11. *Lonicera maackii*
12. *Philadelphus pekinensis*
13. *Cerasus tomentosa*
14. *Corylus heterophylla*
15. *Actinidia arguta*
16. *Rosa davurica*
17. *Ampelopsis glandulosa*
18. *Euonymus alatus*
19. *Rhamnus ussuriensis*
20. *Acanthopanax sessiliflorus*
21. *Celastrus flagellaris*

Herb

1. *Phragmites australis*
2. *Artemisia capillaris*
3. *Sparganium stoloniferum*
4. *Impatiens noli-tangere*
5. *Polygonum persicaria*
6. *Iris pseudacorus*
7. *Acorus tatarinowii*
8. *Monochoria korsakowii*
9. *Iris sanguinea*
10. *Lythrum salicaria*
11. *Potentilla cryptotaeniae*
12. *Polygonatum odoratum*
13. *Viola mandshurica*
14. *Corydalis bungeana*
15. *Astilbe chinensis*
16. *Trrifolium repens*
17. *Arisaema peninsulae*
18. *Ranunculus chinensis*
19. *Bidens biternata*
20. *Agrimonia pilosa*

References i

C. Hambler and M. R. Speight.
Extinction rates and butterflies.
Science, 305(5690):1563–1565, 2004.

E. O. Wilson.
The diversity of life.
Cambridge, Mass.: Harvard University, 1992.

S. Yu, W. Chen, X. He, Z. Liu, and Y. Huang.
Biomass accumulation and nutrient uptake of 16 riparian woody plant species in northeast china.
Journal of forestry research, 25(4):773–778, 2014.