

LES PHYTOTECHNOLOGIES AU SERVICE DES CITOYENS DE LA VILLE DE SHANGHAI

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**SOCIÉTÉ QUÉBÉCOISE DE PHYTOTECHNOLOGIE
MONTRÉAL
11 JUIN 2020**





Ce que nous allons voir aujourd'hui :

- 1) Le Jardin botanique de Chenshan en bref.**
- 2) La Chine, Shanghai et son environnement.**
- 3) La recherche sur les marais filtrants.**
- 4) La recherche en phytoremédiation.**
- 5) Conclusions.**



A close-up photograph of green fern fronds with long, narrow, lanceolate leaflets, set against a dark green background.

Shanghai Chenshan Botanical Garden

March 31st, 2007 : The project was officially started !

April 26th, 2010: The garden was open to the public !



Mission

"To conserve plants in Eastern China, discover sustainable ways of using them, and share our knowledge and enthusiasm with the public."

沈

Shen

砖

Zhuan

公

路

Road



上海辰山植物園 导游图

Guide Map

N

2号门
Entrance No.2

3号门
Entrance No.3

展览温室
Conservatory

辰山
Chenshan

岩石和药用植物园
Rock Garden and Medicinal Plants Garden

科研中心
Research Center

欧洲植物区
European Plant Zone

油料植物园
Oil Plants

纤维植物园
Fiber Plants

染料植物园
Dye Plants

蔬菜园
Vegetable Garden

华东区系园
Flora of East China Garden

东湖
East Lake

西湖
West Lake

综合馆
Main Building

207 ha

辰

Chen

塔

Tower

公

路

辰

Chen

花

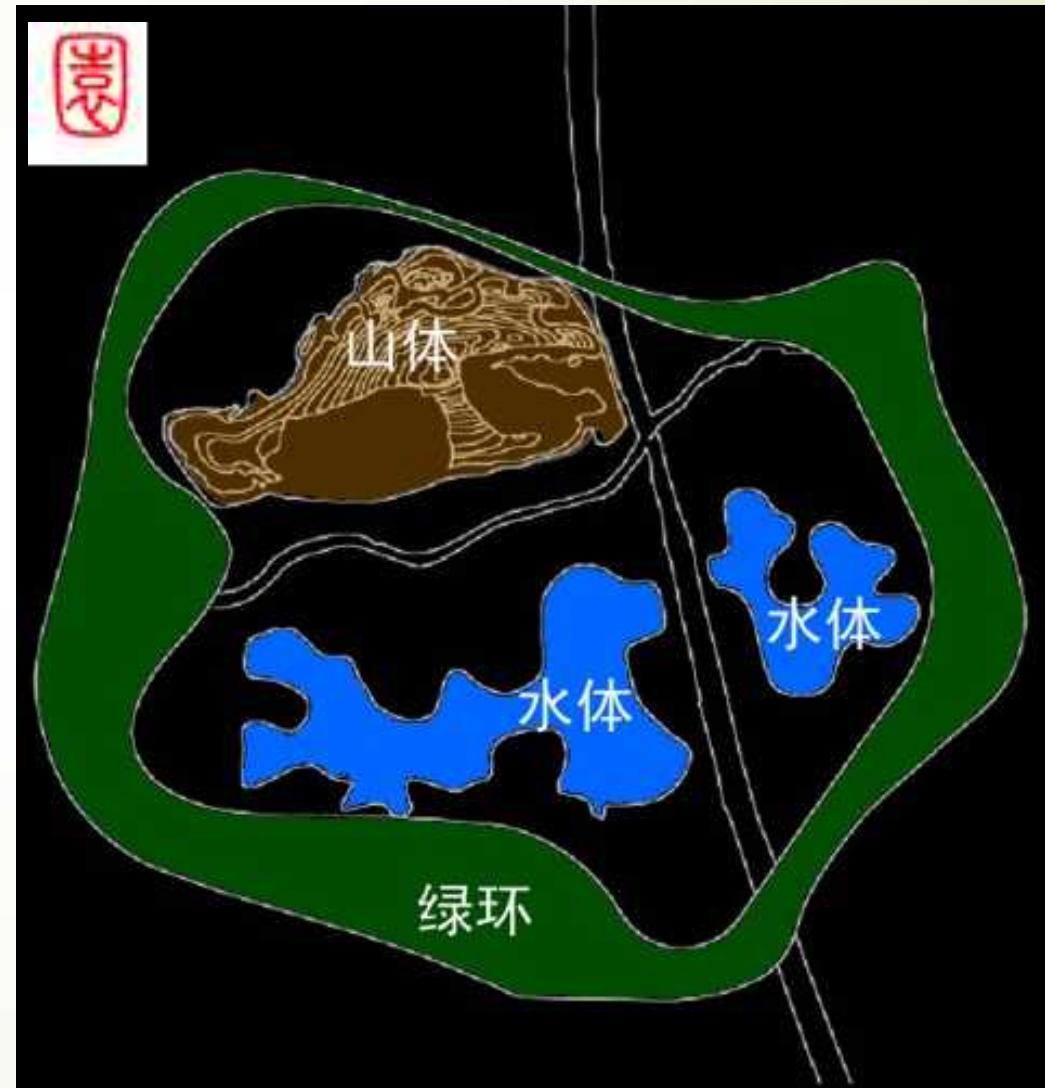
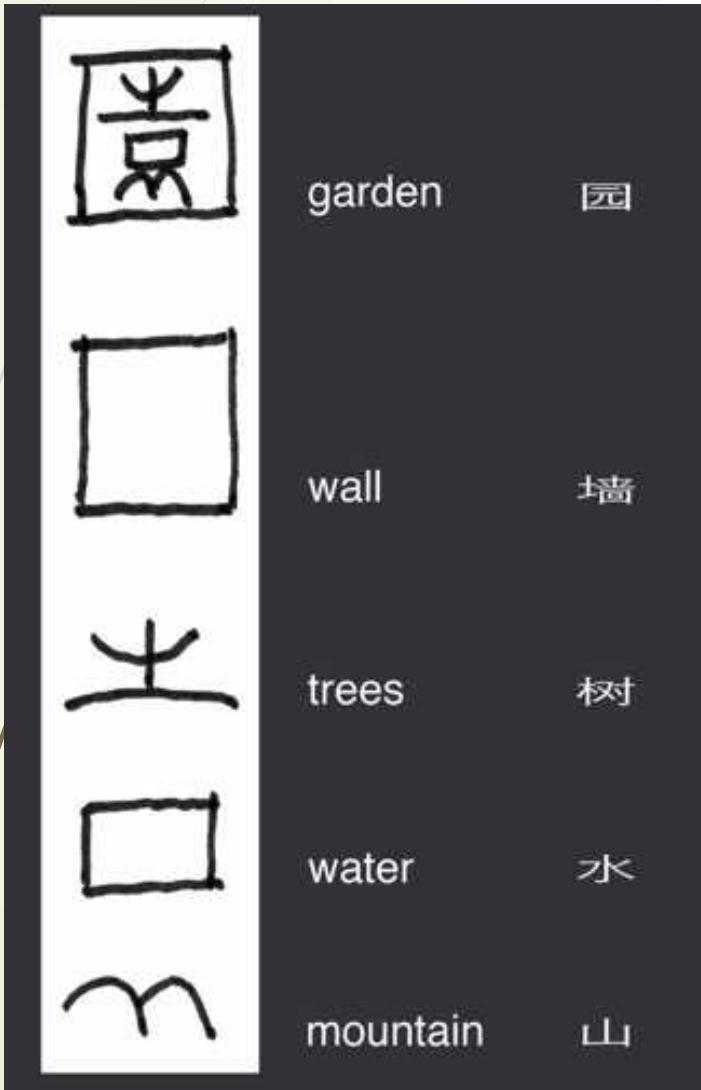
Hua

公

Road

路

Road



上海辰山植物園导游图

Guide Map



$8,875 \text{ m}^2$



$5,200 \text{ m}^2$



$6,880 \text{ m}^2$

辰

花

公

路

Jardin de pluie (Biorétention)



Biorétention

排水明沟



Biorétention

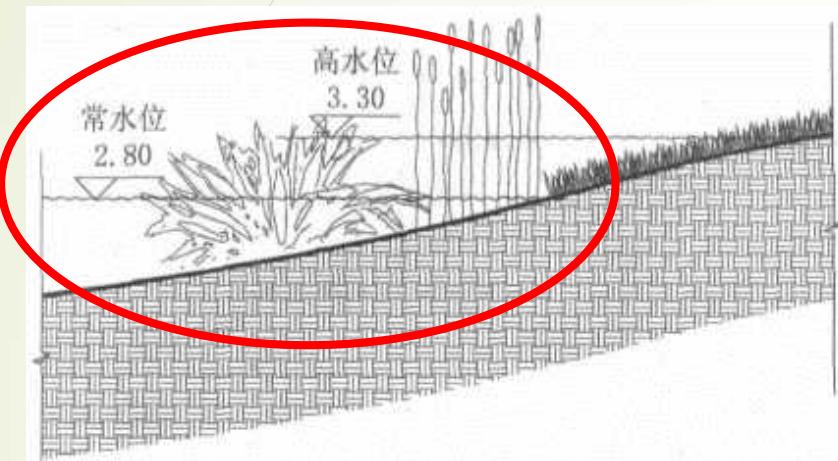


图 6 生态水岸剖面图

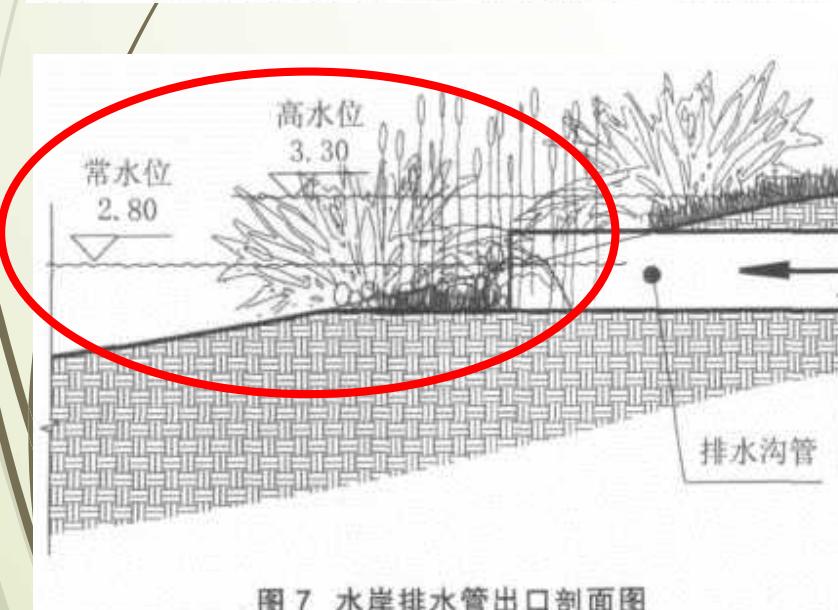


图 7 水岸排水管出口剖面图



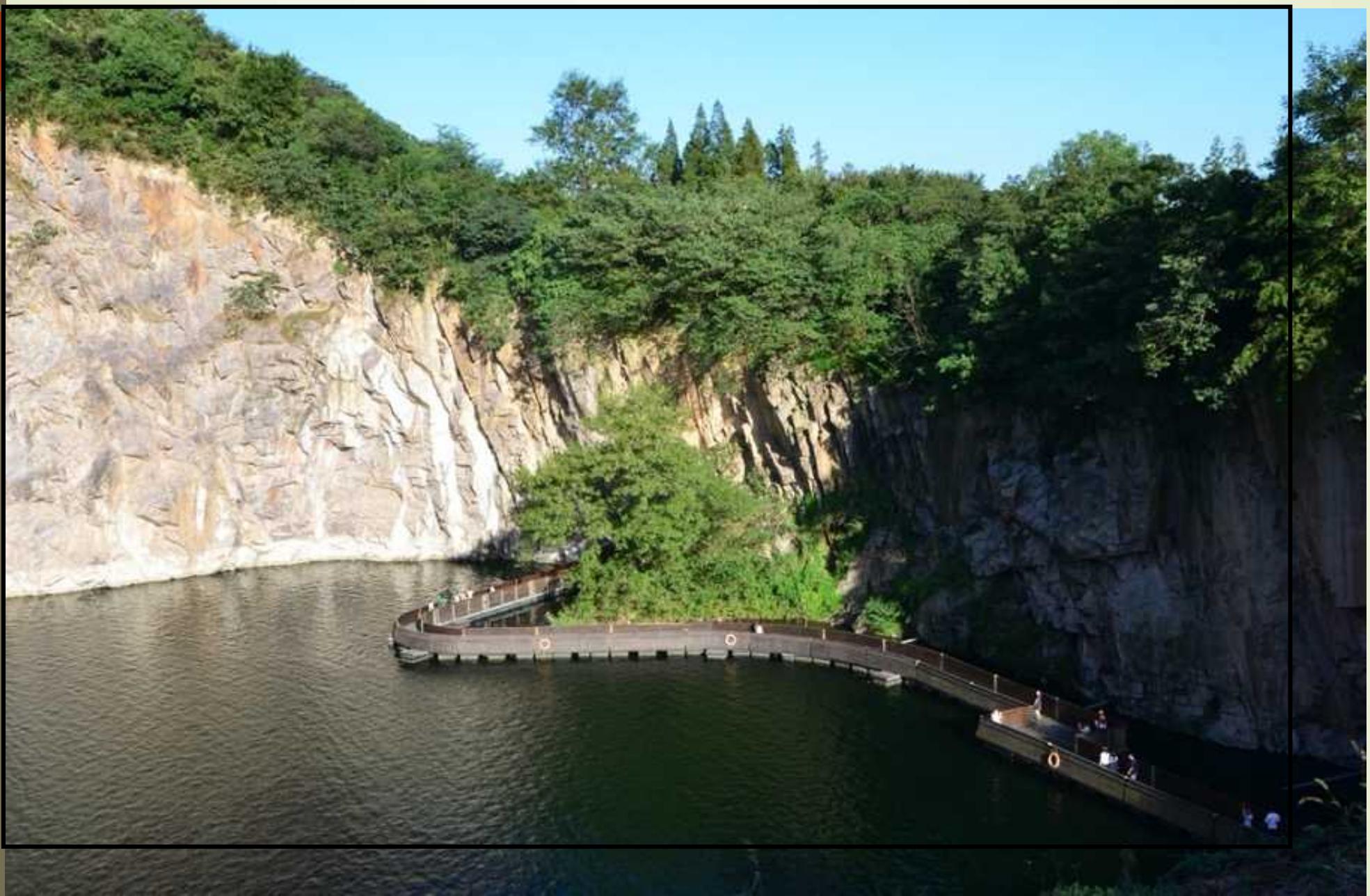




张伟









“ Grass Concert”

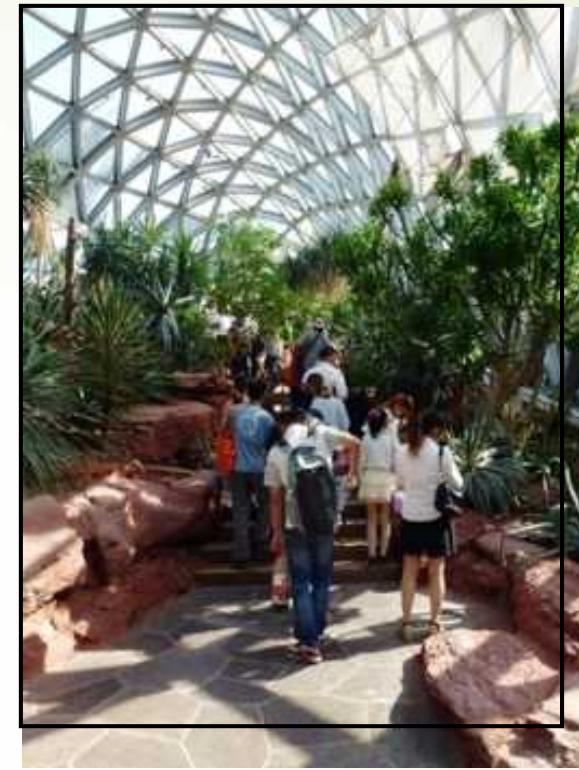


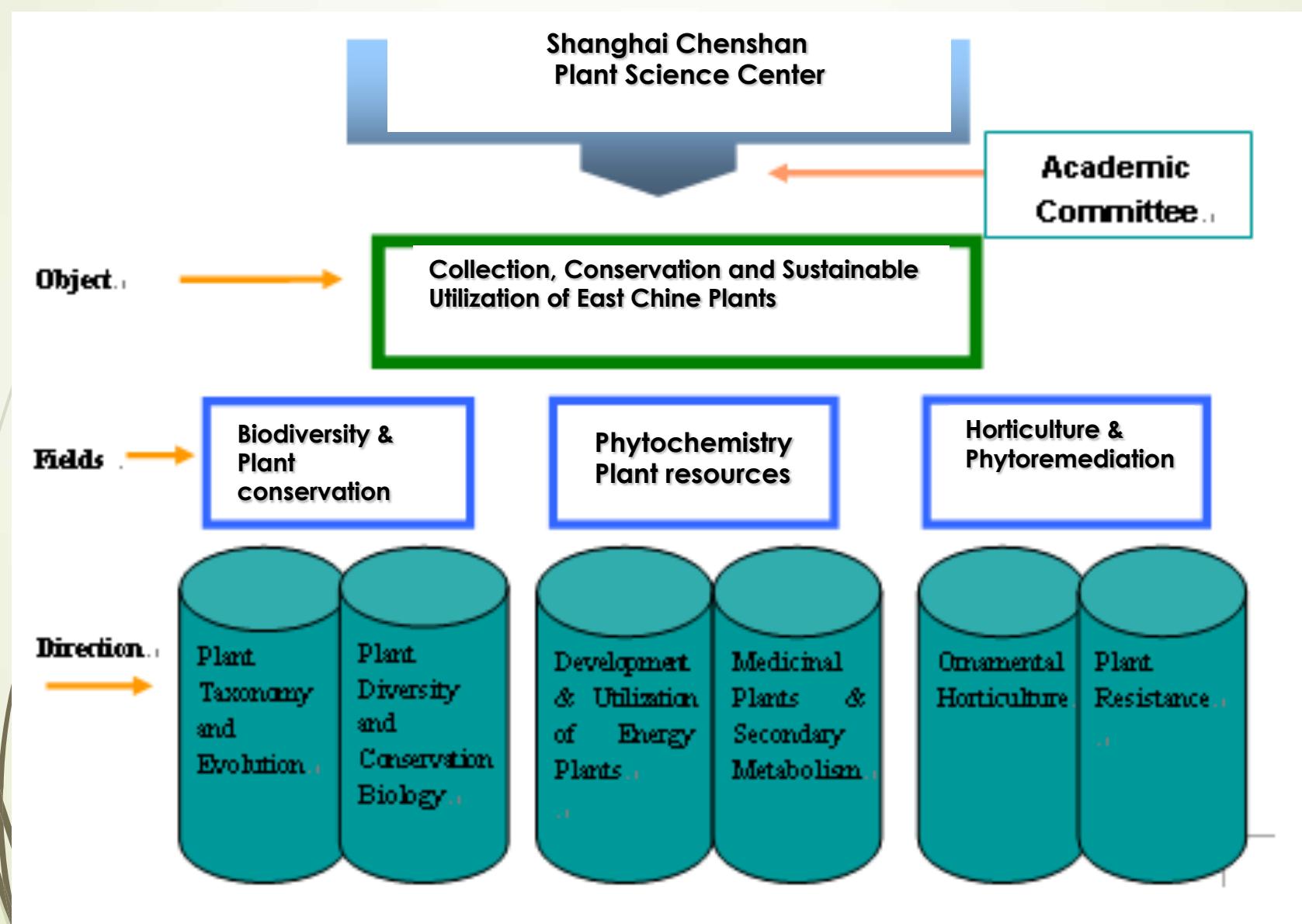


Succulent and Desert plants.

Rare and Exotic plants.

Indoor Gardens





Urban horticulture and phytotechnologies

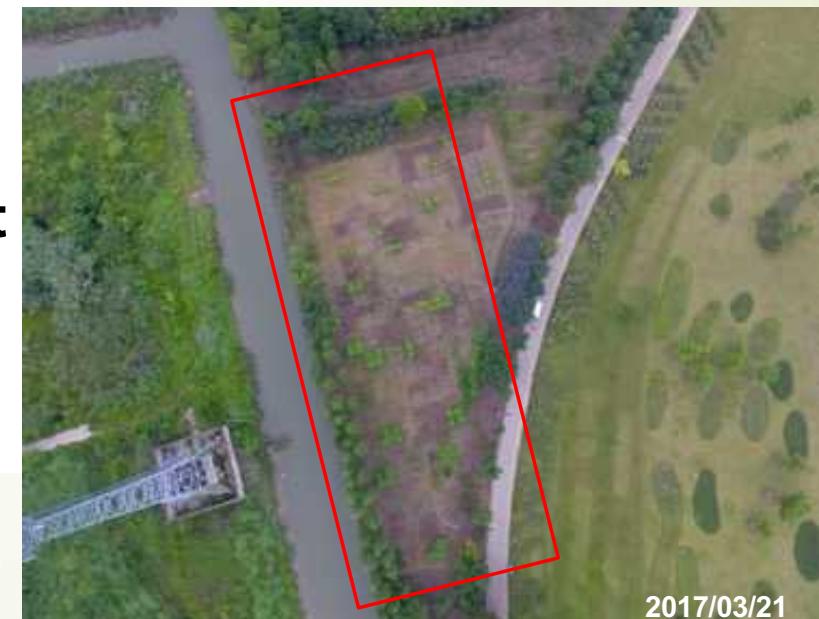
1) 水平潜流人工湿地提升研究

Species selection, species combination and growth development analysis in a very large scale constructed wetland.



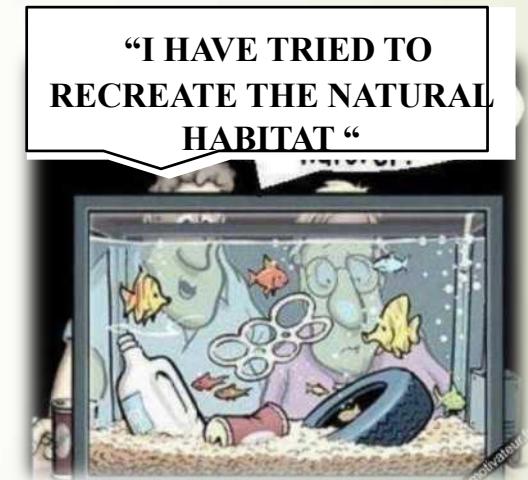
2) 重金属污染土壤植物修复技术研究

- a) Phytoextraction of trace elements (Zn, Cu, Pb) by 30 selected shrubs species.
- b) Establishment and growth improvement of the promising species.
- c) Use of willow microcuttings for phyto-remediation.

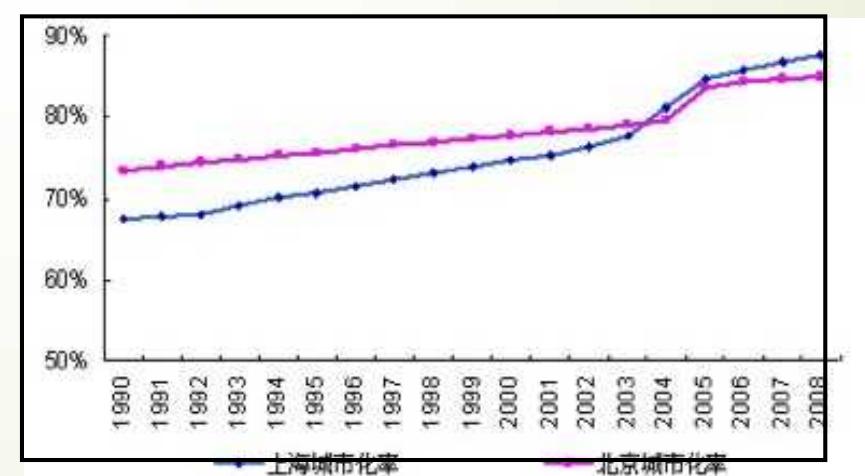


Shanghai, le contexte

Contexte



Contexte



Contexte

Population explosion



Traffic jam

交通拥堵



Environmental pollution

资源匮乏



Resource scarcity



Shanghai ville verte malgré tout !



Projets de marais filtrants



La situation:

- ❖ En Chine, dans les grandes villes comme Shanghai:
 - ❖ Pénurie d'eau potable;
 - ❖ Demande grandissante pour traiter les eaux des canaux et étangs;
- ❖ Cette eau de surface est caractérisée par de faibles concentrations de contaminants.

Objectifs de cette recherche:

- 1- Évaluer le comportement de différentes macrophytes, couramment utilisées dans un marais filtrant alimenté par une eau faiblement chargée;**
(typique des rivières et canaux de la région de Shanghai);
- 2- Évaluer la performance et le développement des macrophytes durant la période de mise en service en mesurant le gradient de développement des plantes;**
(Impossible à mesurer dans un mésocosmes et ne pouvant se faire que sur un site experimental à grande échelle)
- 3- Comparer la performance globale d'un marais composé d'une seule espèce (monoculture) vs un marais composé de plus d'une espèce (polyculture).**

Nos hypothèses sont :

- 1- Il y a une différence significative de performance entre les différentes espèces étudiées et les marais en polyculture donnent de meilleurs résultats que les marais en monoculture;**
- 2- La composition en nutriments de l'eau usée qui alimente les marais a un effet sur la biomasse totale produite la performance globale d'épuration;**
- 3- La biomasse produite par les macrophytes ainsi que sa distribution le long du filtre sont grandement modifiées au cours des années qui suivent la mise en service;**

1- Pilot “sub-surface flow” in Chenshan Botanical Garden Shanghai

- 14 separated parallel units, 13m long by 4.5m wide,
- Total filter bed surface of 58.5m²

2- Bed description

- Each bed filled with 60 cm of river gravel ($\varnothing = 10$ mm)
- Clumps of 5 common macrophytes were planted
(two replicates) in March 2016

Phragmites australis

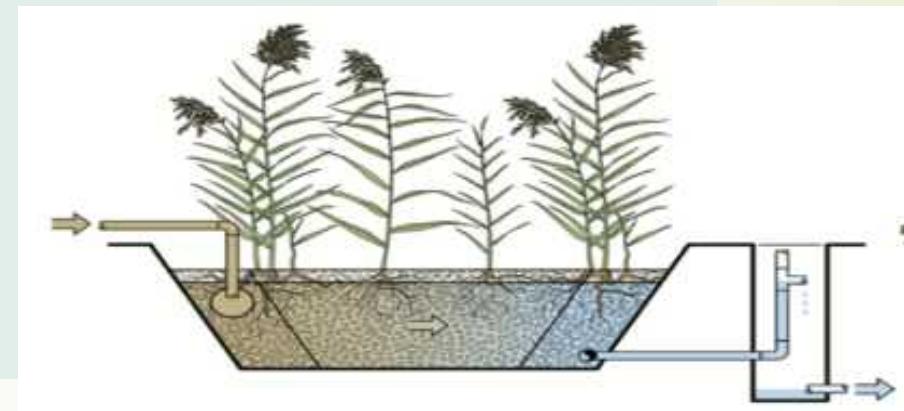
Typha orientalis

Cyperus alternifolius

Thalia dealbata

Arundo donax

Phragmites + Typha + Thalia



Subsurface – horizontal flow



2015





Feeding strategy

Feeding approximately 12-15h per day, five days a week, at the same hydraulic rate of 4 m³/d (or 5.6 cm/d)

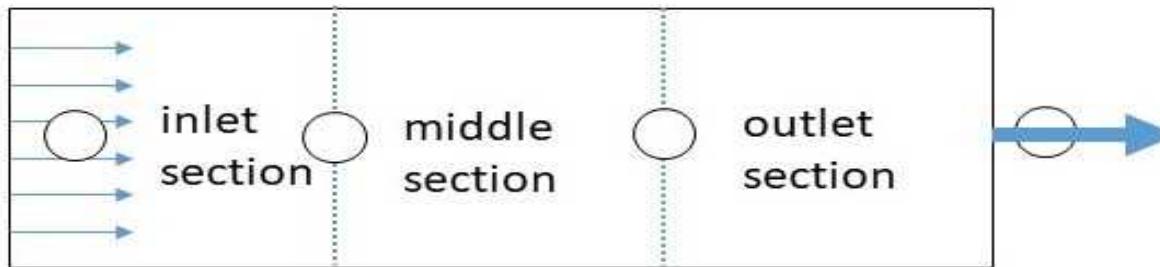
Each year, since 2016, from end of March until November, all units fed with water from an artificial lake in Chenshan Botanical Garden and adjust for a water typical of Shanghai river and canal.

Parameters	
COD (mg/L)	14.1 ± 1.4
BOD (mg/L)	6.9 ± 0.9
TN (mg/L)	9.84 ± 1.64
NH ₃ (mg/L)	6.86 ± 1.10
TP (mg/L)	1.85 ± 0.13
DO (mg/L)	7.9 ± 0.6
Turbidity (NTU)	3.8 ± 1.0
pH	7.4 ± 0.2
EC (µS cm)	525 ± 15

Experimental layout (for each bed: 4.5 m width x 13 m length):

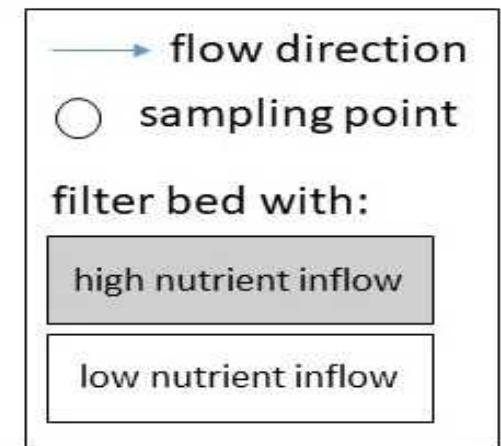
#1 <i>Thalia</i>	#2 <i>Arundo</i>	#3 <i>Cyperus</i>	#4 <i>Typha</i>	#5 Unplanted	#6 Polyculture	#7 <i>Phragmites</i>	#8 <i>Typha</i>	#9 <i>Cyperus</i>	#10 Polyculture	#11 <i>Phragmites</i>	#12 Unplanted	#13 <i>Thalia</i>	#14 <i>Arundo</i>
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Flow scheme and partitioning of each filter bed:

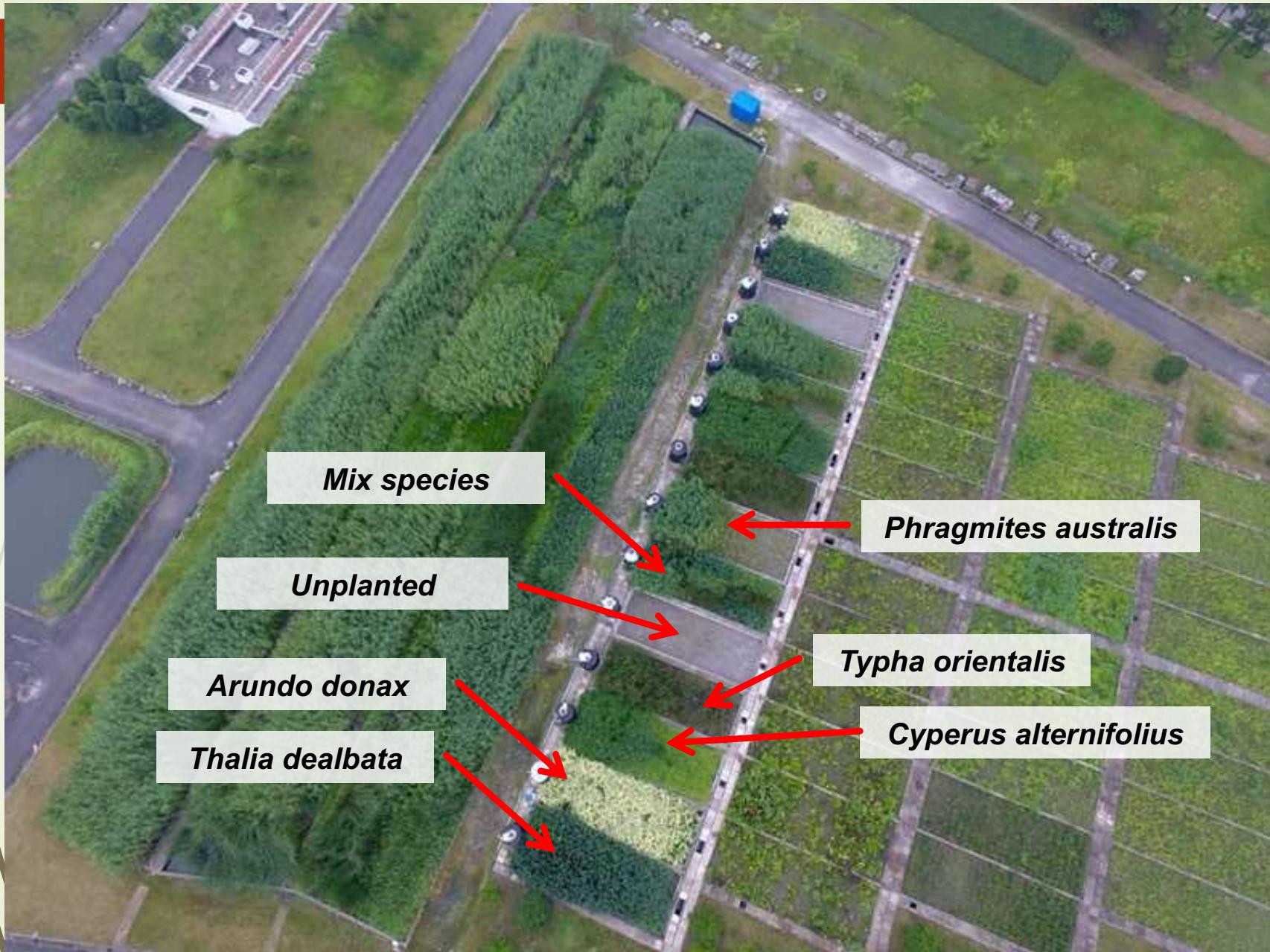


Planting scheme of polyculture beds (#6 & # 10)

<i>Typha</i>	<i>Thalia</i>	<i>Phragmites</i>
<i>Thalia</i>	<i>Phragmites</i>	<i>Typha</i>
<i>Phragmites</i>	<i>Typha</i>	<i>Thalia</i>

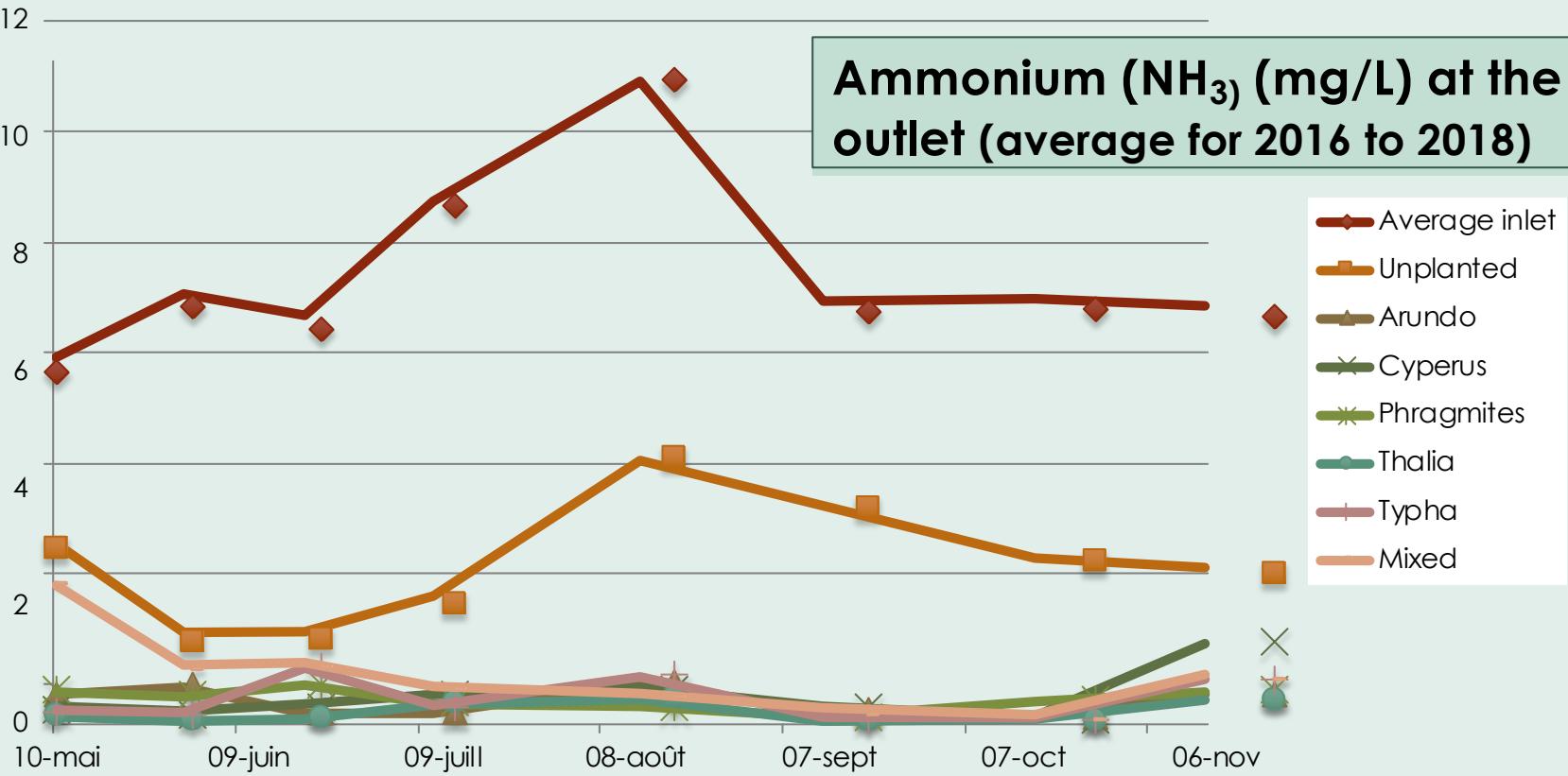




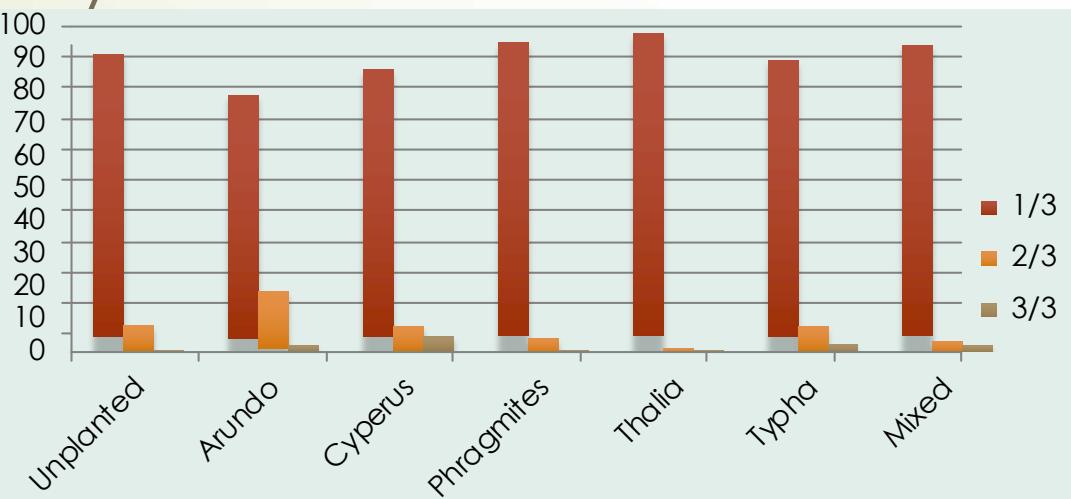


- 
- ❖ **Sampling and analysis**
 - ❖ Treatment performance monitored every 2 weeks
 - ◆ Inflow 1/3, 2/3 and outflow grab samples collected simultaneously, filtered and processed on the same day
 - ❖ **Parameters measured immediately after sampling:**
 - ❖ O₂, T°, pH, turbidity, conductivity
 - ❖ Parameters measured according to APHA (2005):
 - ◆ COD, BOD₅, NH₃-N, TN and TP
 - ❖ **Evapo-transpiration**
 - ❖ Estimated by evaluating volume of water that refills the basin after one or two days have elapsed since feeding
 - ❖ **1m² patch of plants were sample from inlet to outlet**
 - ❖ Analysed for biomass and nutrients content

Ammonium (NH_3) (mg/L) at the outlet (average for 2016 to 2018)



% of the NH_3 removal in each of the 3 CW sections

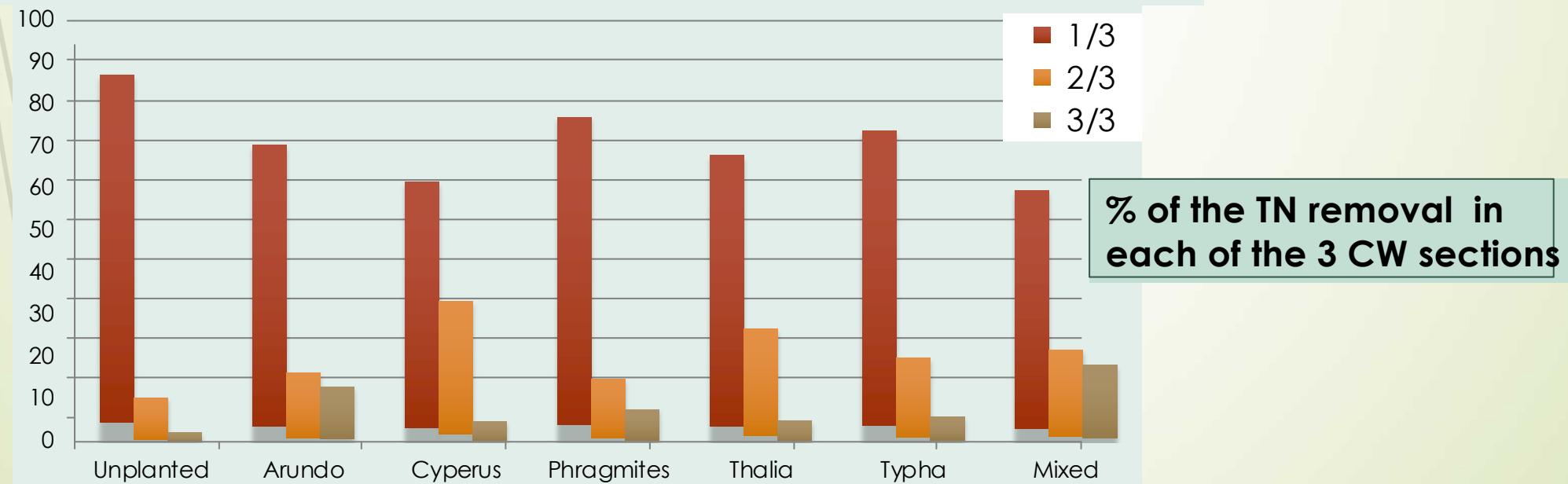
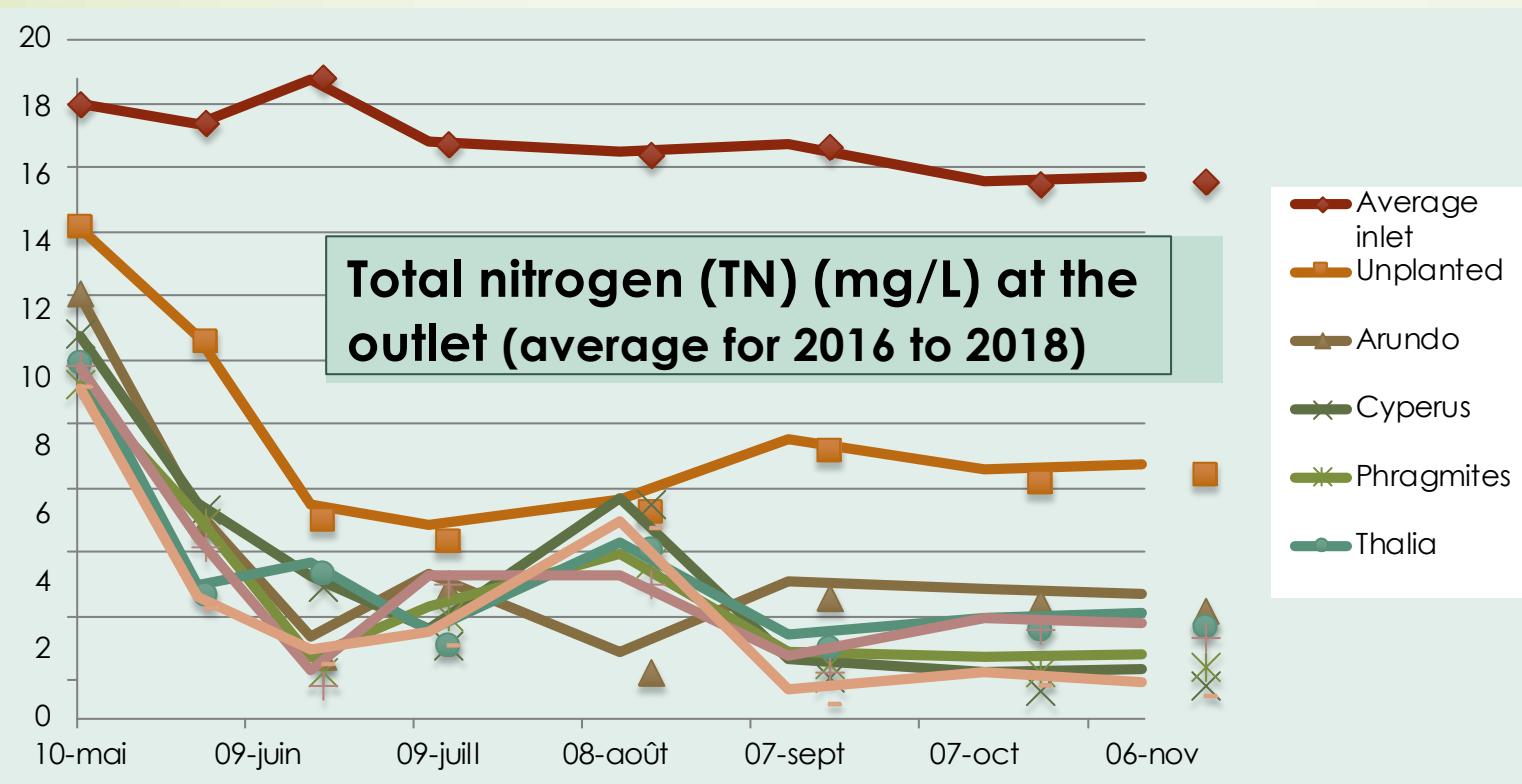


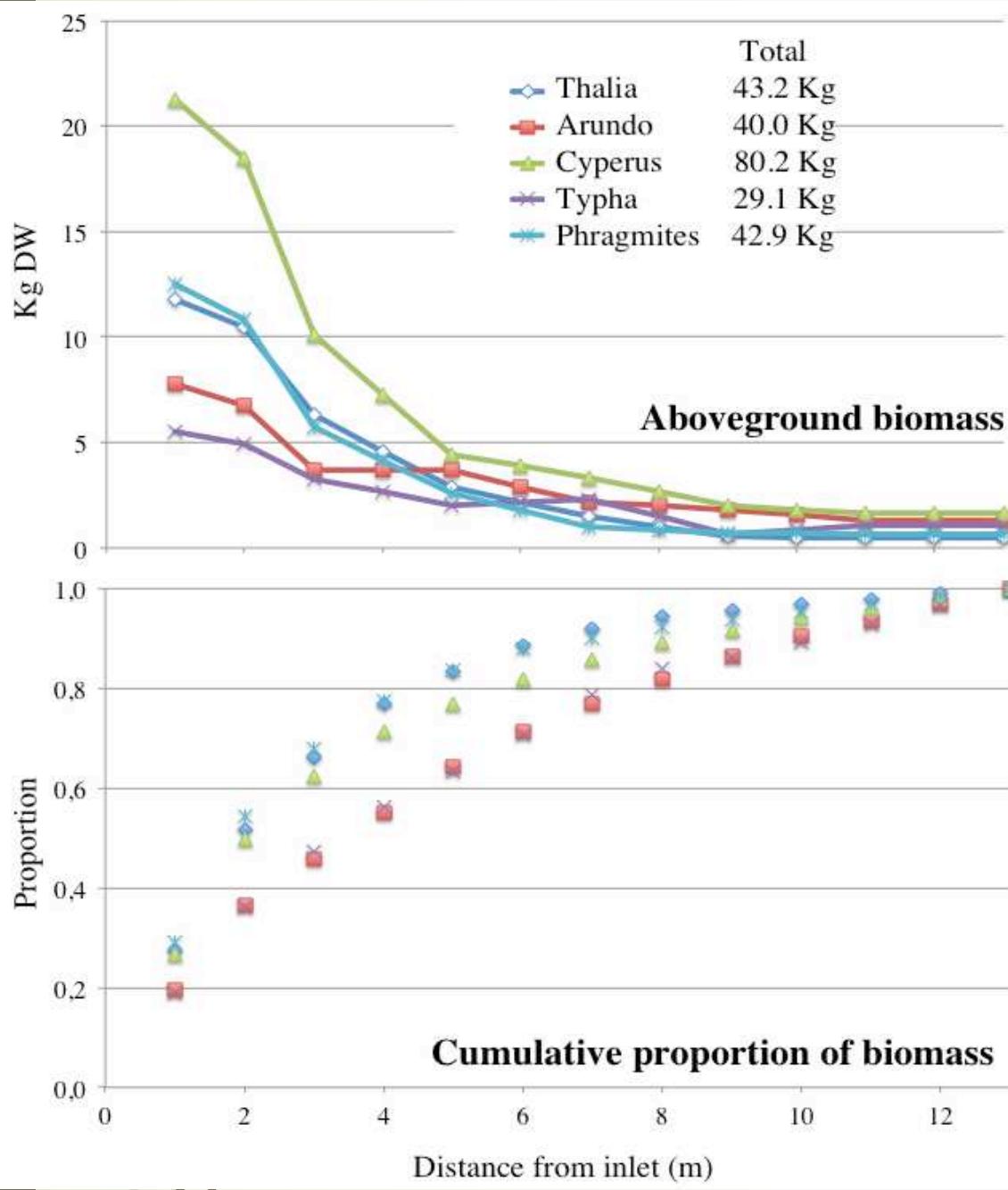
Average concentrations observed at inlet/outlet expressed in mg/L⁻¹

1x

	2016	2017	2018					
	COD	TKN	TP	COD	TKN	TP	COD	TKN
Inlet	13.3	7.1	1.0	15.3	8.3	1.6	15.5	7.3
Unplanted	9.7	4.4	0.4	9.3	4.2	0.9	5.0	4.7
<i>Arundo</i>	8.8	2.4	0.2	10.8	3.0	0.7	1.2	2.6
<i>Cyperus</i>	8.5	3.2	0.1	10.0	2.2	0.1	0.8	1.3
<i>Phragmites</i>	8.9	3.0	0.2	11.4	2.1	0.7	0.4	0.9
<i>Thalia</i>	8.5	2.9	0.1	8.8	2.8	0.3	1.0	1.5
<i>Typha</i>	9.1	3.1	0.1	10.7	2.4	0.7		1.6
Mixed	9.3	2.9	0.1	11.2	2.0	0.6		1.3

Inlet	15.7	15.9	3.3	16.8
Unplanted	8.5	7.1	1.5	11.1
<i>Arundo</i>	11.7	3.7	0.7	10.2
<i>Cyperus</i>	9.8	3.3	0.3	4.2
<i>Phragmites</i>	10.8	2.9	0.8	2.2
<i>Thalia</i>	9.5	3.4	0.4	3.8
<i>Typha</i>	11.5	3.2	0.6	4.9
Mixed	11.3	2.4	0.9	2.8





Plant biomass was not equally distributed

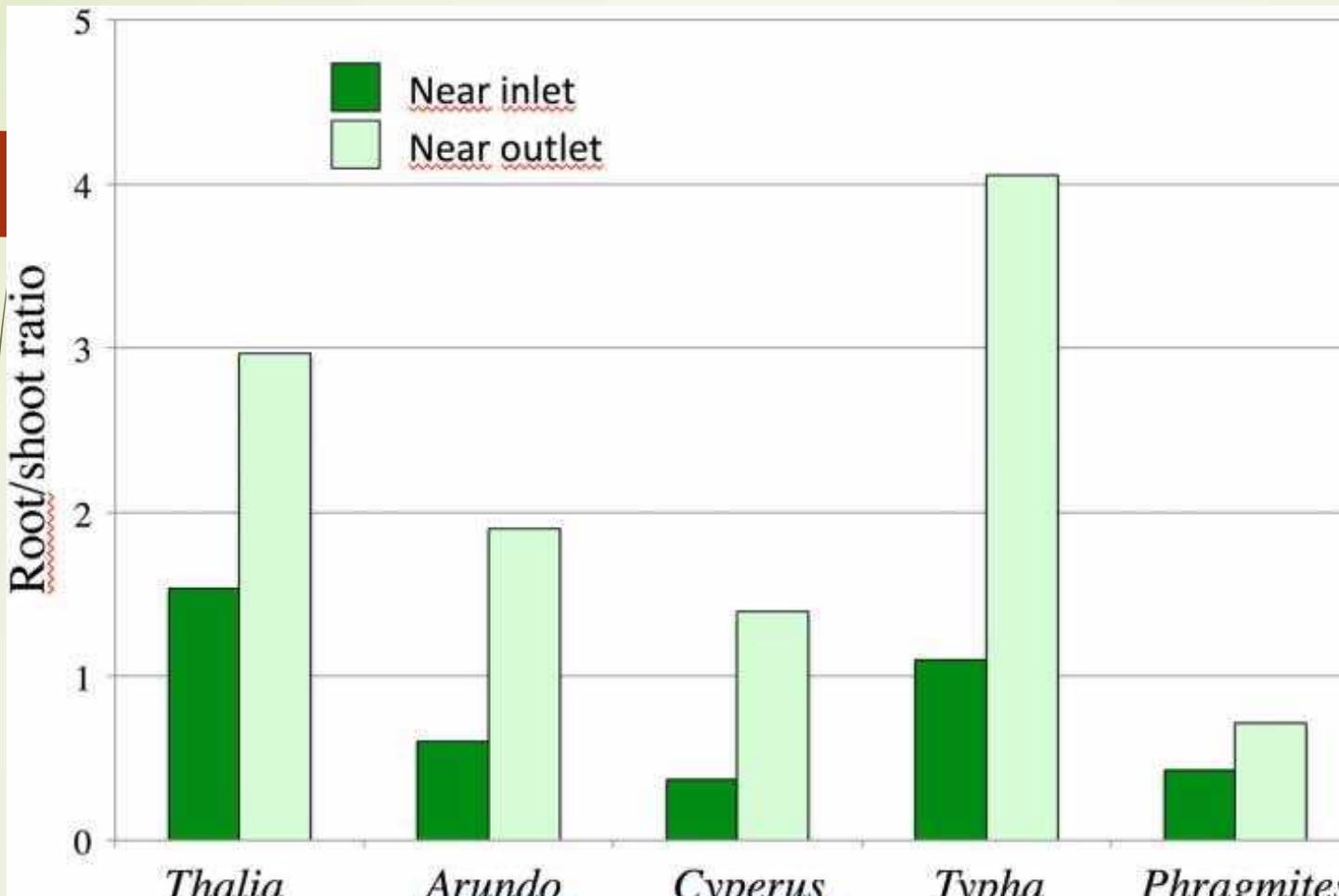
Strong decreasing gradient.

Thalia, *Cyperus* and *Phragmites* more than 50% of total biomass in 1st “2 meters”

Cyperus more biomass than others

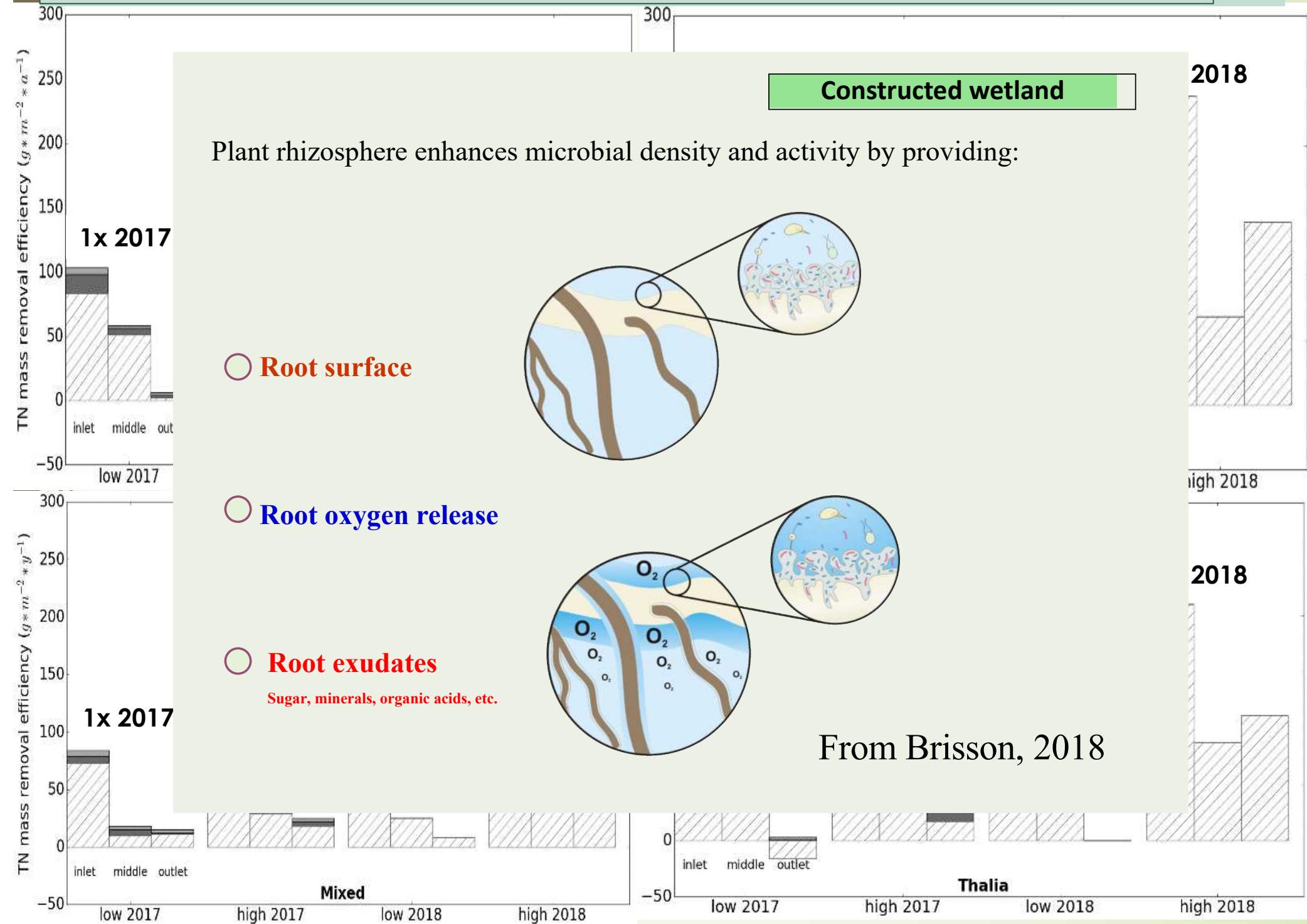
Cyperus also accumulated the most nitrogen and phosphorus in its aboveground biomass
(data not shown)





- ▶ Le ratio “biomasse souterraine/biomasse aérienne” augmente de l’entrée vers la sortie et ce, pour toutes les espèces ;
 - ▶ Les plantes augmentent leur énergie vers les racines pour “explorer” davantage le substrat à la recherche de nutriments ;
 - ▶ Signes évident de carences nutritives ;
- permet d'optimiser le design de la surface nécessaire (¥ !)

Répartition de l'azote total enlevé dans les différents bassins pour 2017 et 2018. (Bilan de masse)



EN CONCLUSION:

1) *Phragmites* a été la meilleure plante parmi les espèces étudiées;

2) Choisir une seule espèce :

- * N'est pas la meilleure solution pour une réduction optimale du phosphore et de l'azote;
- * Toutefois, dans notre dispositif experimental, un marais planté en polyculture est efficace mais pas davantage que la meilleure espèce qu'il contient qui serait plantée en monoculture;

3) Si le fauchage des plantes est la méthode retenue pour l'enlèvement des nutriments, nos résultats confirment que la comparaison de la productivité (biomasse) n'est pas suffisante pour déterminer l'efficacité globale du marais;

4) Cette étude nous a permis de déterminer la surface optimale d'un marais filtrant pour une eau usée typique des rivières et canaux de la région de Shanghai

Gilles Vincent, Kankan Shang, Guowei Zhang, Florent Chazarenc & Jacques Brisson. 2018.
Plant growth and nutrient uptake in treatment wetlands for water with low pollutant concentration. Water Science & Technology 77(4): 1072 - 1078.

Katharina Tondera, Florent Chazarenc, Kankan Shang, Gilles Vincent, Florent Chazarenc & Jacques Brisson. 2019. *Design criteria for horizontal flow wetlands treating water with low nutrients content.* Novatech. 1-4.

Katharina Tondera, Kankan Shang, Gilles Vincent, Florent Chazarenc, Yonghong Hu & Jacques Brisson. 2020. *Effect of plant species and nutrients loading rates in treatment wetlands for polluted river water under sub-tropical climate.* Water, Air and Soil Pollution (under revision)

Projets de phytoremédiation

La performance des végétaux pour la phytoextraction de contaminants inorganiques doit être évaluée en fonction des six caractéristiques suivantes :

- 1) Capacité d'adsorption et de translocation des contaminants élevées ✓.**
- 2) Forte tolérance aux conditions typiques des sols contaminés✓**
- 3) Bien adaptés aux conditions pédoclimatiques de la région ✓**
- 4) Établissement et maintien facile ✓**
- 5) Production de biomasse élevée ✓**
- 6) Biomasse facile à récolter et à gérer ✓**



Research projects in phytoremediation conducted by the «Ecological Phytoremediation Research Group» at Chenshan.

De 2015 à 2017

Évaluation de la tolérance à trois contaminants inorganiques (Cu, Pb et Zn) pour 12 arbustes et arbres ornementaux couramment utilisés en horticulture urbaine ainsi que leur capacité à effectuer leur potentiel de phytoextraction;

De 2017 à 2019

Évaluation du potentiel de phytoextraction pour 14 espèces d'arbres dans des parcelles contaminées par trois contaminants inorganiques (Cu, Pb et Zn ensemble)

De 2017 à 2019

Utilisation de micro-boutures de Salix afin de mesurer leur capacité d'établissement et de phytoextraction;

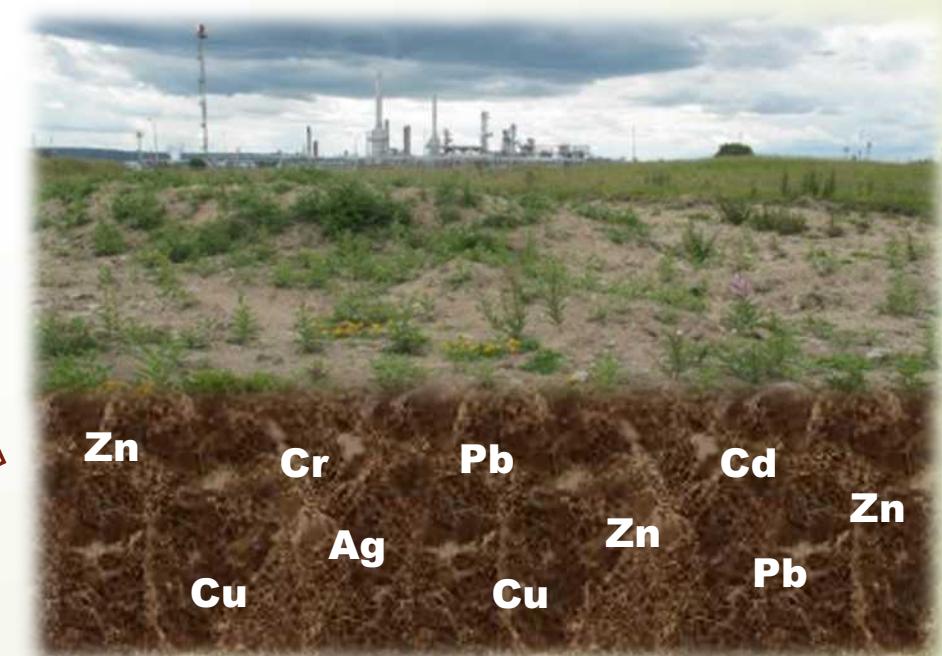
Le contexte

Plant selection is difficult:

Hydroponic and pot trials are not representative of field conditions;

1) Root system of plants cultivated in such conditions is constrained and forced to develop in the presence of pollutants ;

2) Field trials on post industrial contaminated soils are always very heterogeneous and make interpretation difficult.



Methode

Cr, Ni, **Cu, Pb, Zn** and Cd

	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
China ⁽¹⁾ Mean (Range)	149.6 (95.0 - 196.8)	238.7 (53.3 - 408.4)	655.0 (294.5 - 1,450.0)
Shanghai ⁽²⁾ Mean (Range)	196.8 (17.0 - 117.5)	294.0 (28.0 - 4,443.0)	733.8 (82.0 - 2,136.0)

⁽¹⁾ B. Wei & L. Yang. 2010. A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchemical Journal* (94): 99-107.

⁽²⁾ G. Shi et al. 2008. Potentially toxic metal contamination of urban soils and roadside dust in Shanghai, China. *Environmental Pollution* (156):251-260

Metals	Mean TE concentrations (mg/kg) measured at the beginning (2015)	
Cu_{HN03}	1128	75.5 (Control)
Pb_{HN03}	840	93.3 (Control)
Zn_{HN03}	2453	83.6 (Control)
	Cu_{HN03}	Pb_{HN03}
Cu+Zn+Pb	521	1468
		Zn_{HN03}
		1300

March 2015



Methode

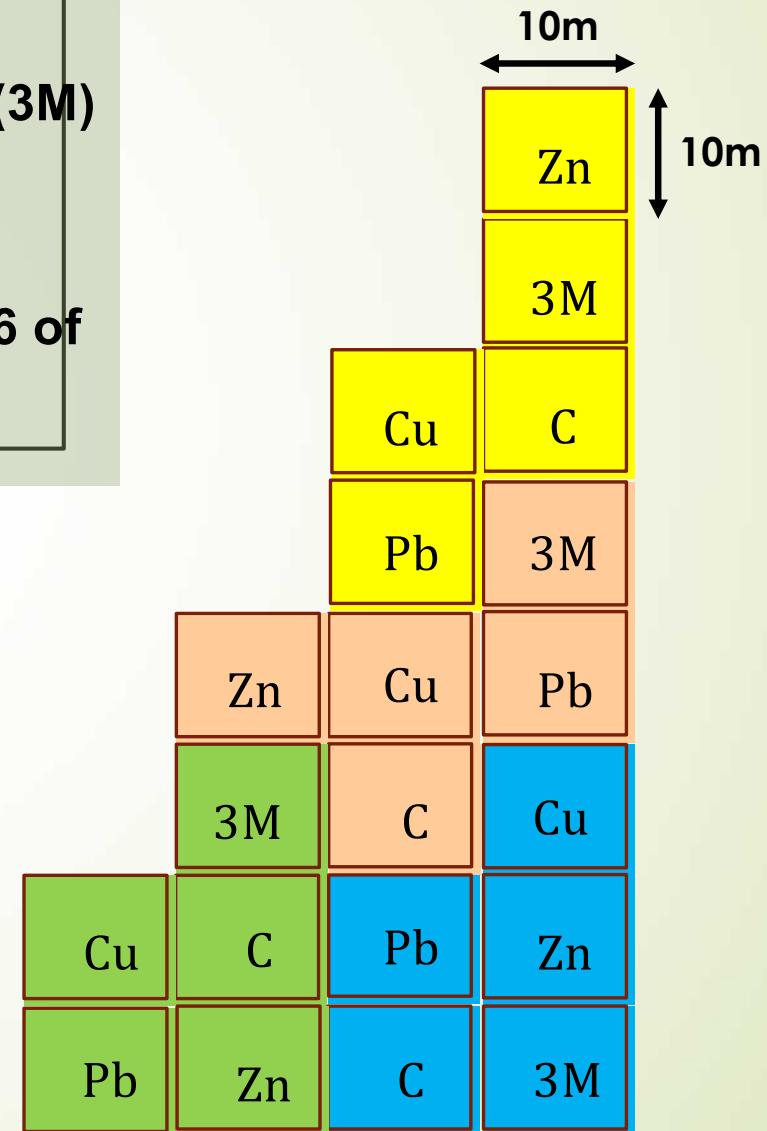
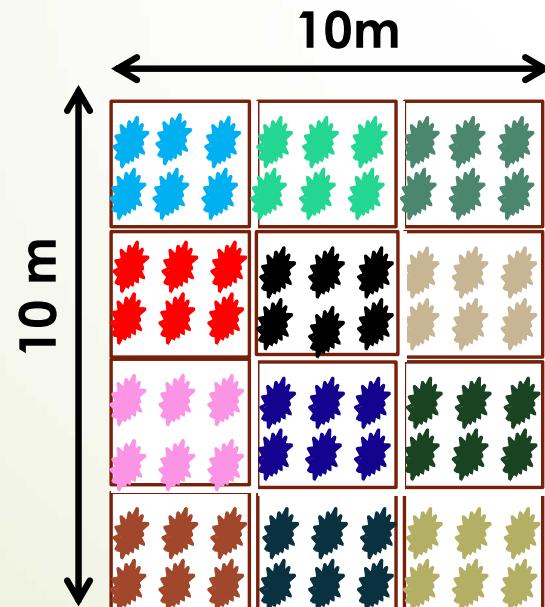


November 2014

Methode

Comprised 4 blocks in which 5 treatments were randomized:

- Plots contaminated by Cu, Pb Zn and three metals together (3M) plus a control (C);
- In each plot, 12 “one and 2-years old shrubs seedlings” (6 of each) were planted randomly.



Methods





Species	Family	Life form
<i>Euonymus japonicus</i> (Japanese spindletree)	Celastraceae	Evergreen
<i>Hibiscus mutabilis</i> (Confederate rose)	Malvaceae	Deciduous
<i>Hibiscus hamabo</i> (Rose mallow)	Malvaceae	Deciduous
<i>Nandina domestica</i> (Sacred bamboo)	Berberidaceae	Evergreen
<i>Nerium indicum</i> (Oleander)	Apocynaceae	Evergreen
<i>Photinia x fraseri</i> (Photinia)	Rosaceae	Evergreen
<i>Pittosporum tobira</i> (Australian laurel)	Pittosporaceae	Evergreen
<i>Rhododendron pulchrum</i> (Lovely azalea)	Ericaceae	Semi- Evergreen
<i>Salix integra</i> (Dappled willow)	Salicaceae	Deciduous
<i>Senna corymbosa</i> (Buttercup bush)	Leguminosae	Semi- Evergreen
<i>Spiraea japonica</i> (Japanese meadowsweet)	Rosaceae	Deciduous
<i>Weigelia florida</i> (Rose Weigelia)	Malvaceae	Deciduous

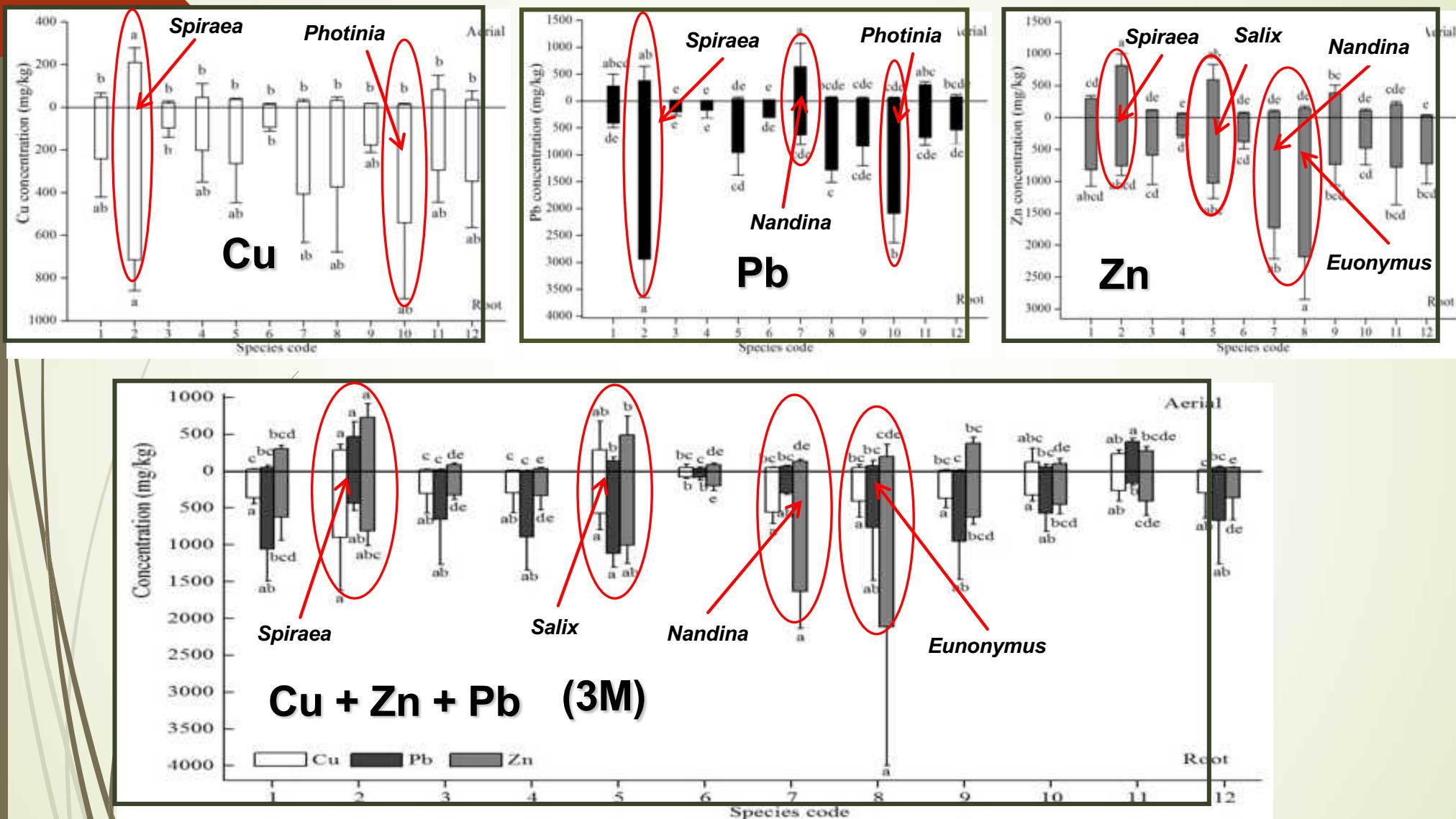
Ag

Cu

Zn

b

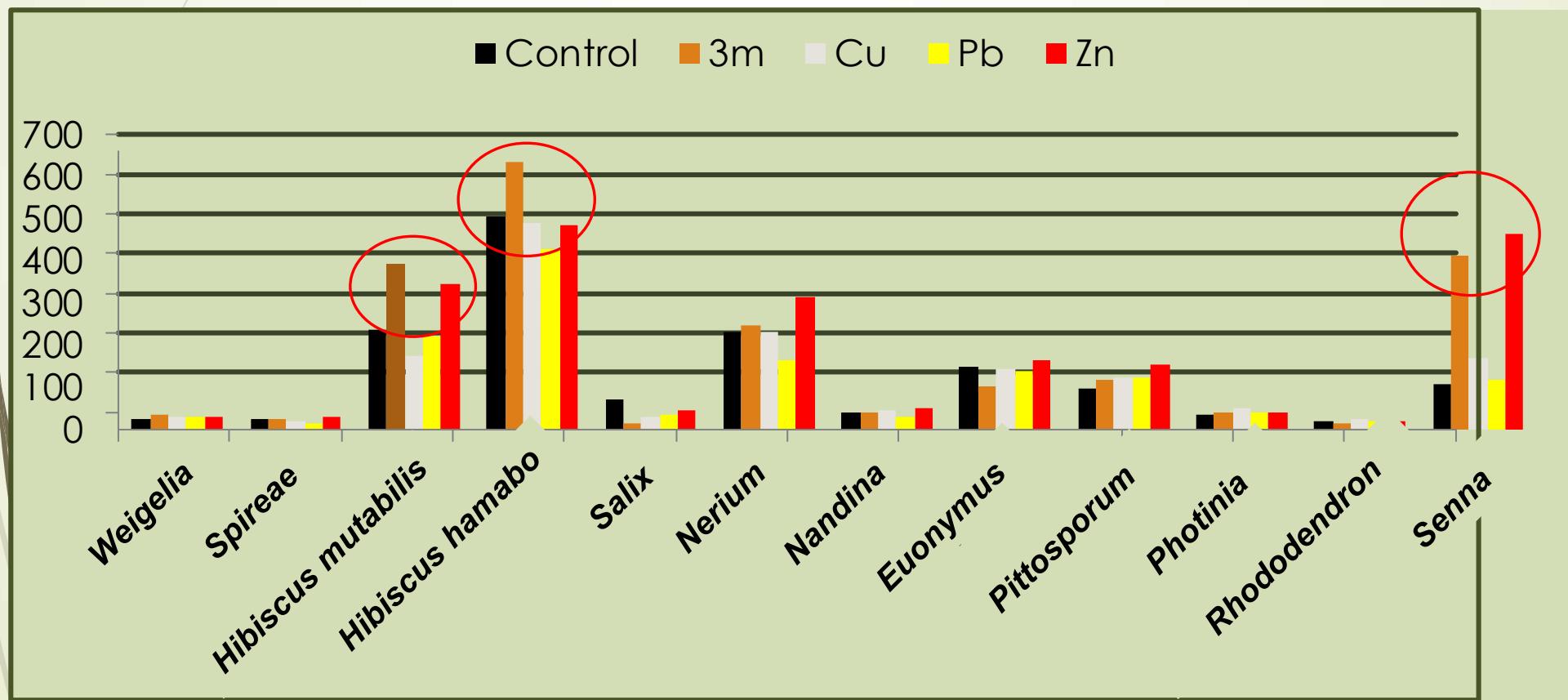
Metal concentrations in aerial and below ground parts at the end of 2015 for single and mixed contamination plots.



Vincent G, Shang K, Zhang G, & Labrecque M. 2018. Preliminary results of the tolerance to inorganic contaminants and phytoextraction potential of twelve ornamental shrub species tested on an experimental contaminated site. *Iforest*: 11: 442-448. doi:10.3832/ifor2716-011

Results

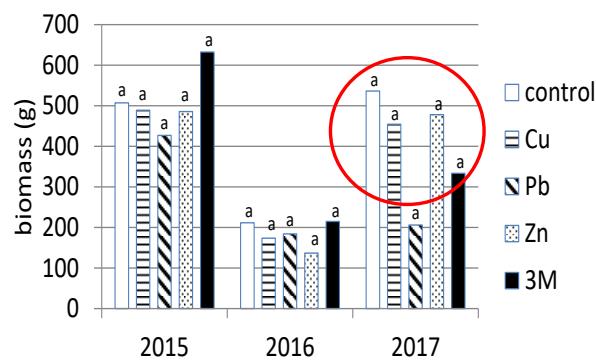
Comparison of aerial dry biomass produced at the end of the first growing season (2015).



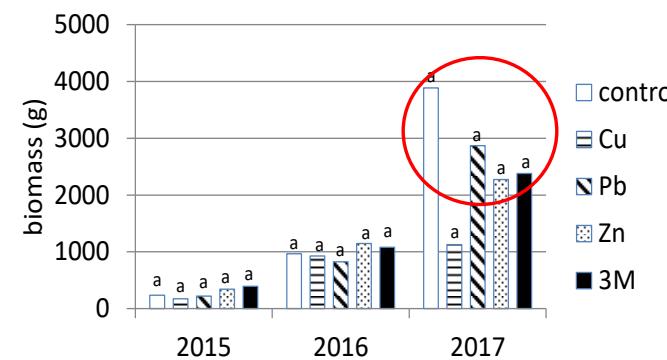
Results



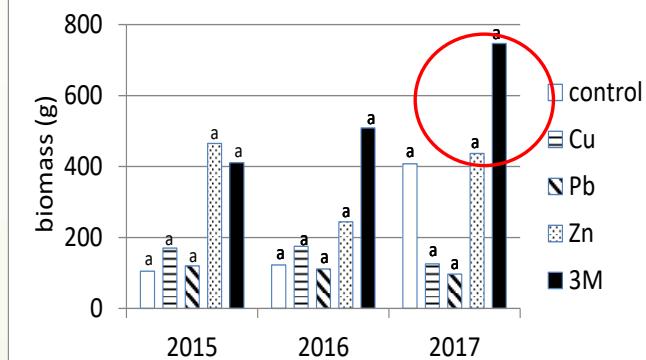
Hibiscus hamabo



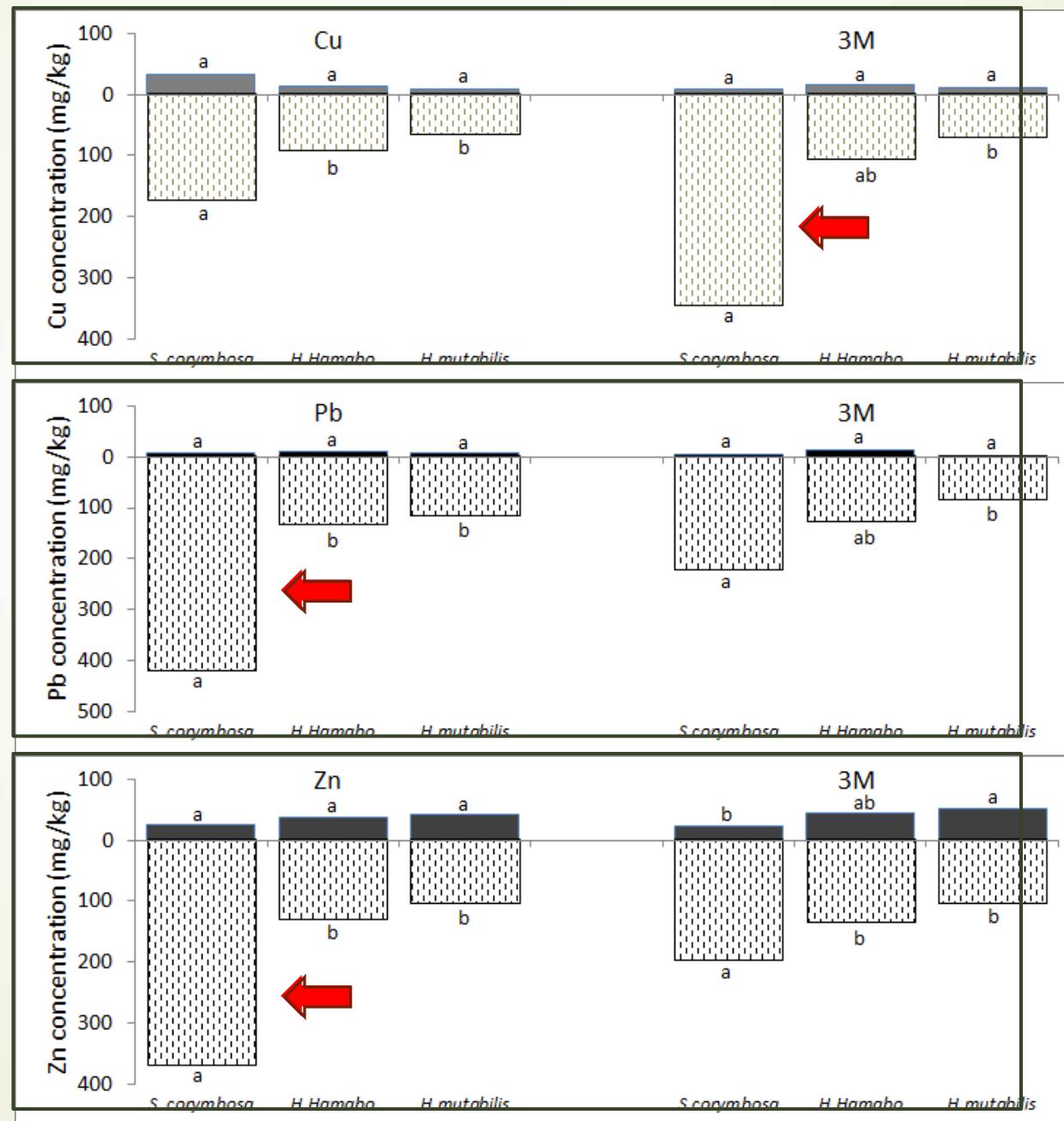
Hibiscus mutabilis



Senna corymbosa



Comparison of the concentrations of Cu, Pb and Zn in above and belowground parts, at the end of the third growing season (2017).



**Mean values in mg of copper, lead and zinc extracted after one growing season
(stems developed from three-year stumps) according to the different treatments**

Species	Treatment	Cu aerial (mg)	Pb aerial (mg)	Zn aerial (mg)
<i>Senna corymbosa</i>	Control	2,7	0,1	7,8
	Cu	5,8	0,2	6,4
	Pb	0,7	0,7	2,3
	Zn	2,5	0,1	11,1
	3M	6,9	4,5	19,3
<i>Hibiscus hamabo</i>	Control	6,9	n.d.	16,4
	Cu	6,1	0,6	12,6
	Pb	2,9	2,4	6,3
	Zn	6,7	0,7	20,5
	3M	4,3	1,5	11,5
<i>Hibiscus mutabilis</i>	Control	52,7	0,1	127,9
	Cu	10,2	0,9	25,4
	Pb	27,8	20,5	84,2
	Zn	21,8	0,1	72,8
	3M	27,2	6,2	133,9

Shang K, Hu Y, Vincent, G, & Labrecque M. 2020. Biomass and phytoextraction potential of three ornamental shrubs species tested over three years on a large-scale experimental site in Shanghai, China. International Journal of Phytoremediation. 22:10-19. doi:10.11080/15226514.2019.1632998

14 tree species selection for phytoextraction of multiple trace elements (3 Metals) in a large scale experimental site (2017-2019).

Species	Family
<i>Camptotheca acuminata</i> Decne.	<i>Nissaceae</i>
<i>Cyclocarya paliurus</i> (Batalin) Iljinsk.	<i>Juglandaceae</i>
<i>Firmania simplex</i> (L.) W. Wright	<i>Sterculiaceae</i>
<i>Koelreuteria paniculata</i> Laxm.	<i>Sapindaceae</i>
<i>Liquidambar formosana</i> Hance	<i>Altingiaceae</i>
<i>Morus alba</i> L.	<i>Moraceae</i>
<i>Paulownia fortunei</i> (Seem.) Hemsl.	<i>Paulowniaceae</i>
<i>Platanus x acerifolia</i> (Aiton) Wild.	<i>Platanaceae</i>
<i>Populus</i> sp. cv. "72"	<i>Salicaceae</i>
<i>Populus</i> sp. cv. "Zhong 2"	<i>Salicaceae</i>
<i>Populus</i> sp. cv. "2025"	<i>Salicaceae</i>
<i>Pterocarya stenoptera</i> C. DC.	<i>Juglandaceae</i>
<i>Rhus chinensis</i> Mill.	<i>Anacardiaceae</i>
<i>Salix rosthornii</i> Seemen	<i>Salicaceae</i>

2017

March 7th, Plantation



July 2nd



October 30th



2019



May 21st



September 11th



September 11th

Use of microcuttings for establishing willow vegetation cover for environmental applications such as phytoextraction (2017 - 2019)

Species	Family
<i>Salix matsudana x alba</i>	Salicaceae

Compost tested :

NC = Control (No compost)

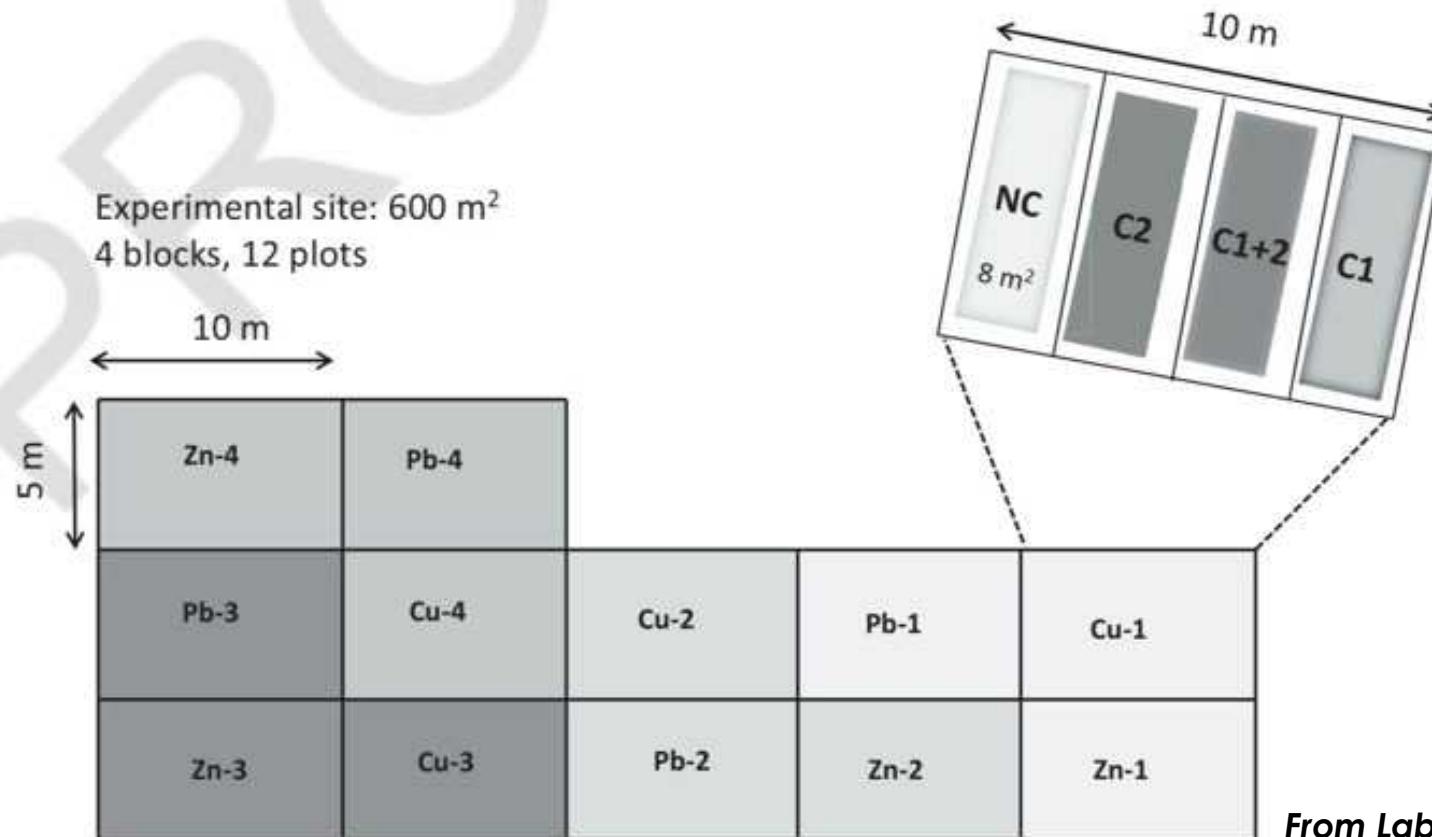
C1 = Garden waste compost (Chenshan)

C2 = Food waste compost.



Salix matsudana x alba
April 18th 2017





From Labrecque et al., 2020

Figure 1. Diagram illustrating the split-plot experimental design used to conduct the study. It comprised four blocks divided in three 10 m x 5 m plots, each corresponding to one treatment, soil spiked with Cu, Pb or Zn. Each plot was then divided in four subplots where the compost treatments were randomly set up (NC no compost, C1 compost 1, C2 compost 2).

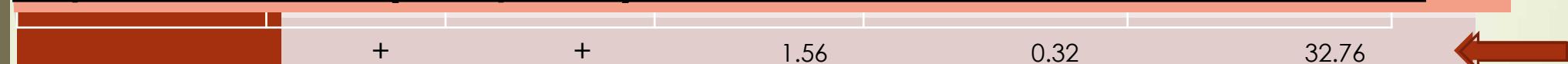
September 4th, 2018



Quantité moyenne de métaux extraits du sol (mg/m²) après neuf mois.

	Treatments		Extracted quantities (mg/m ²)		
Contaminant	Compost 1	Compost 2	Cu	Pb	Zn
Cu-spiked plots	-	-	0.24	0.07	1.09
		+	0.83	0.15	6.00
	+	-	1.06	0.33	8.51
	+	+	2.13	0.47	16.37
Pb-spiked plots	-	-	0.33	0.88	2.48
		+	0.76	0.59	4.02
	+	-	1.25	1.63	12.05

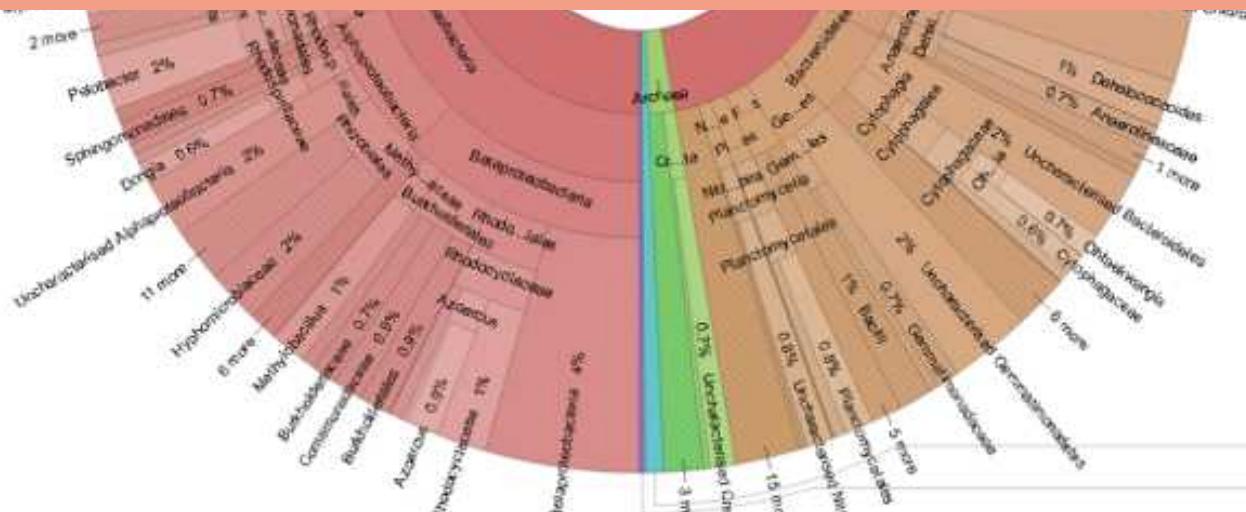
Labrecque, M. Hu Y, Vincent, G. & Shang K. 2020. The use of willow microcuttings for phytoremediation in a copper, zinc and lead contaminated field trial in Shanghai, China. International Journal of Phytoremediation. (sous presse).



Statistical significance			
Variables	Contaminant effect	Compost 1 effect	Compost 2 effect
Cu	Cu = Zn = Pb	Compost 1+ > Compost 1-	Compost 2+ = Compost 2-
Pb	Pb > (Zn = Cu)	Compost 1+ > Compost 1-	Compost 2+ = Compost 2-
Zn	Cu = Zn = Pb	Compost 1+ > Compost 1-	Compost 2+ = Compost 2-

- The greatest increases in genera or species due to metal treatment were observed in *Bacteroidetes*, *Actinobacteria*, *Chlamydiae*, *Nitrospirae* and *Proteobacteria* ;
 - Three metal treatment alone resulted in identification of 22 OTU (Operational Taxonomic Unit - genera or species) which were not detected in control soil. This analysis provides an insight of the complexity of the microbial world resisting anthropogenic pollution. This is an important step observing those organisms able to tolerate extreme stress and also a useful hint that such studies may find it rewarding to extend functional inquiry beyond a single kingdom.

Shumeng Kou, Gilles Vincent, Emilio Gonzalez, Fred Pitre, Michel Labrecque and Nicholas Brereton. 2018. The response of a 16S ribosomal RNA fragment amplified community to lead, zinc and copper pollution in a Shanghai field trial. *Frontiers in Microbiology* 9 (366): 1 - 23
doi:10.3389/fmicb.2018.00366



Conclusions.

- Un site experimental de très grande taille constitue un excellent outil pour évaluer le potentiel d'espèces utilisées pour la phytoremédiation;
- Plusieurs espèces d'arbustes et d'arbres de la flore locale de Chine ont montré une tolérance allant de moyenne à élevée sur des sites contaminés de Cu, Pb et Zn;
- Après trois saisons de croissance, *Hibiscus mutabilis*, *Hibiscus hamabo* et *Senna corymbosa* ont montré un très bon potentiel pour être utilisés en phytoremediation, essentiellement à cause de leur grande production de biomasse;
- Pour l'expérience débuté en 2017 avec 14 espèces d'arbres, *Pawlonia fortunei*, *Camptotheca acuminata*, *Pterocarya stenoptera* and *Populus* cv "72" ont aussi montré une très importante croissance avec une production de biomasse élevée lors de la deuxième année;
- L'utilisation de microboutures de saules, espèce reconnue pour son potentiel en phytoremédiation, est assurément une voie à explorer en Chine.

Conclusions

上海辰山植物园水土污
染修复的
植物选择与性能分析

Plant Species Selection and
Performance Analysis for Chenshan
Water and Soil Phytoremediation

上海辰山植物园
2019年6月

上海市绿化与市容管理局
科学技术项目工作报告

项目编号：G152426
项目名称：上海辰山植物园水土污染
修复的

植物选择与性能分析

项目负责人：Gilles Vincent
项目承担单位：上海辰山植物园
计划起止年月：2015年1月-2017年12月
实际起止年月：2015年1月-2018年7月
联系电话：021-37792288-377

2019年6月15日



上海辰山植物園
Chenshan Botanical Garden, Shanghai



中国科学院 上海辰山植物科学研究中心
CHINESE ACADEMY OF SCIENCES ShanghaiChenshan Plant Science Research Center



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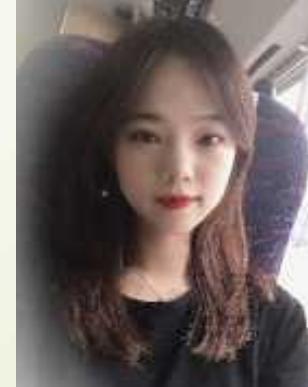
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《 谢谢大家 》

