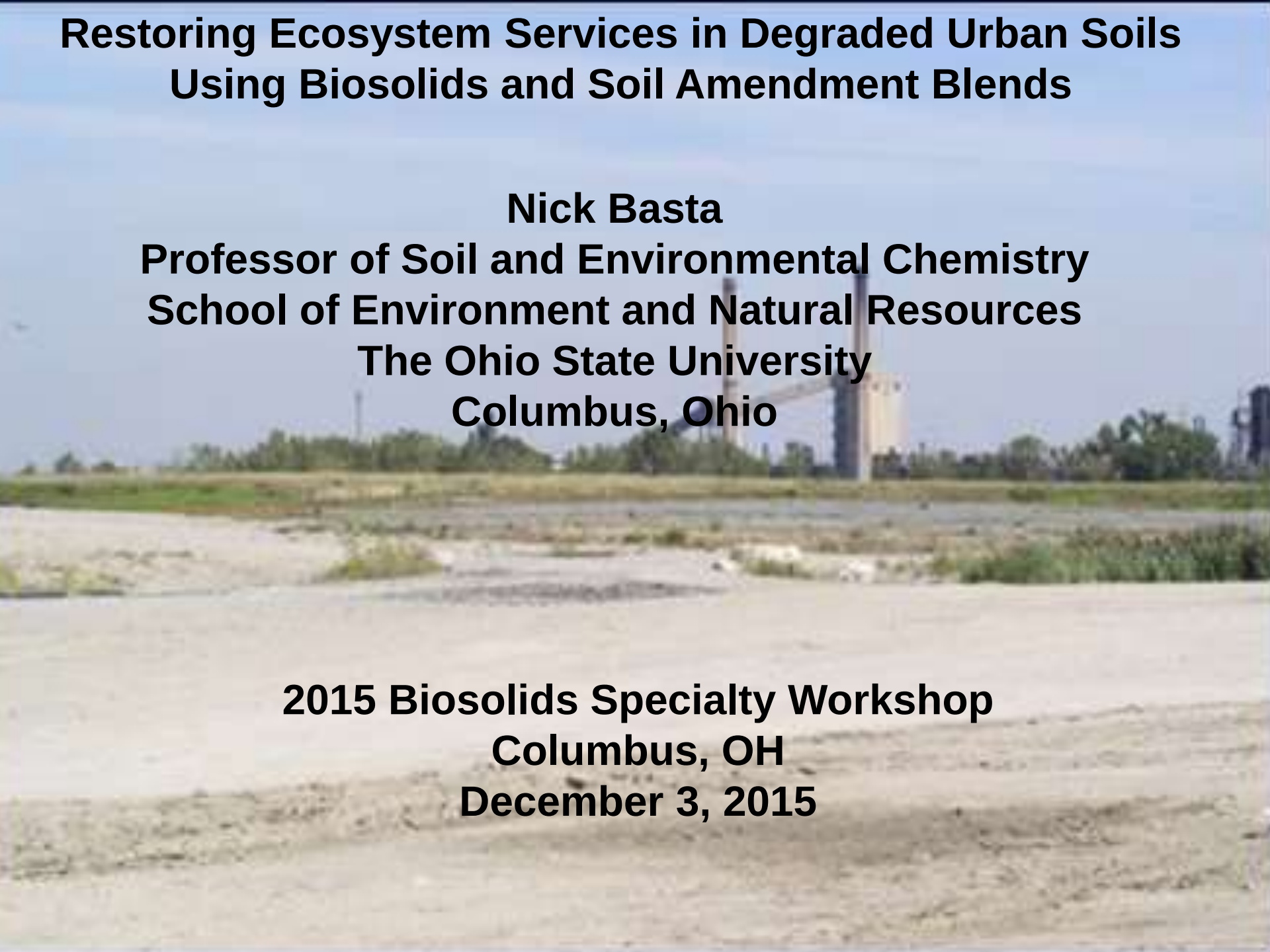
Restoring Ecosystem Services in Degraded Urban Soils Using Biosolids and Soil Amendment Blends



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2015 Biosolids Specialty Workshop
Columbus, OH
December 3, 2015

School of Environment and Natural Resources
Ohio State University

<u>Environmental Science / Ecosystem Science</u>
Terrestrial Wildlife and Ecology
Soil Science
Wetland Science / Ecosystems
Forest Ecosystems
Stream, Lake Ecosystems and Fisheries
Environmental Law, Policy and Social Science

School of Environment and Natural Resources
Soil Environmental Chemistry Program




Research program

- **Soil/Environmental contaminant chemistry; ecotoxicology emphasis on environmental media (air, soil, dust, water, food) exposure and human and ecological risk assessment**
- **Development and evaluation of soil remediation technologies**
- **Beneficial use of organic residuals including biosolids**

Personnel :
full time staff
Research Scientist; Research Assoc. /Laboratory Manager;
5 Research Assistants
3 graduate students and 5 part-time laboratory assistants

Revitalization of Degraded Urban Soils

Many urban soils and brownfields have lost their soil quality. These soils have lost their essential "ecosystem services, to support vegetation, support the food chain (earthworms for birds, etc), and recycle waste materials (dead vegetation, excess nutrients).

Degraded soils in Calumet, IL

High Quality Soil is the Foundation of a Healthy Ecosystem

Soil Quality: The capacity of a soil to function to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.

High Demand for High Quality Soil

Topsoil Excavation from Farmland
"borrowed soil"
destruction of vital Natural Resource
Lower quality subsoil being used as value of farmland topsoil hits record highs

Solution: Manufactured Soil Blends
Compost, Animal Manure, Biosolids, and/or other bioproducts

Using Biosolids / Byproducts to Revitalize Degraded Land / Brownfields in Chicago

MWRDGC scientists are international leaders in restoration using their biosolids products

Unique Aged EQ Biosolids

Evaluating Biosolids Soil Blends and Compost for Soil Restoration and Revitalization in the Calumet Region

Ohio State University

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Dr. Richard Dick

Dr. Roman Lanno

Dawn Busalacchi

Jennifer Tvergyak

Metropolitan Water Reclamation District

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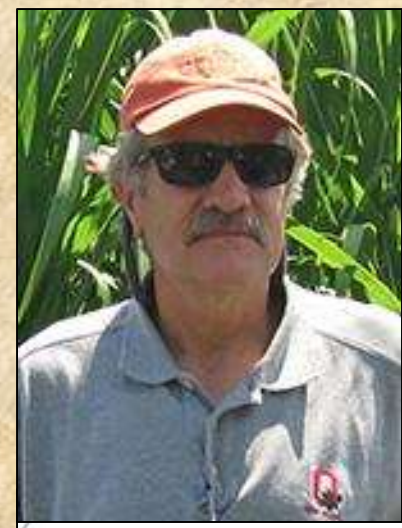
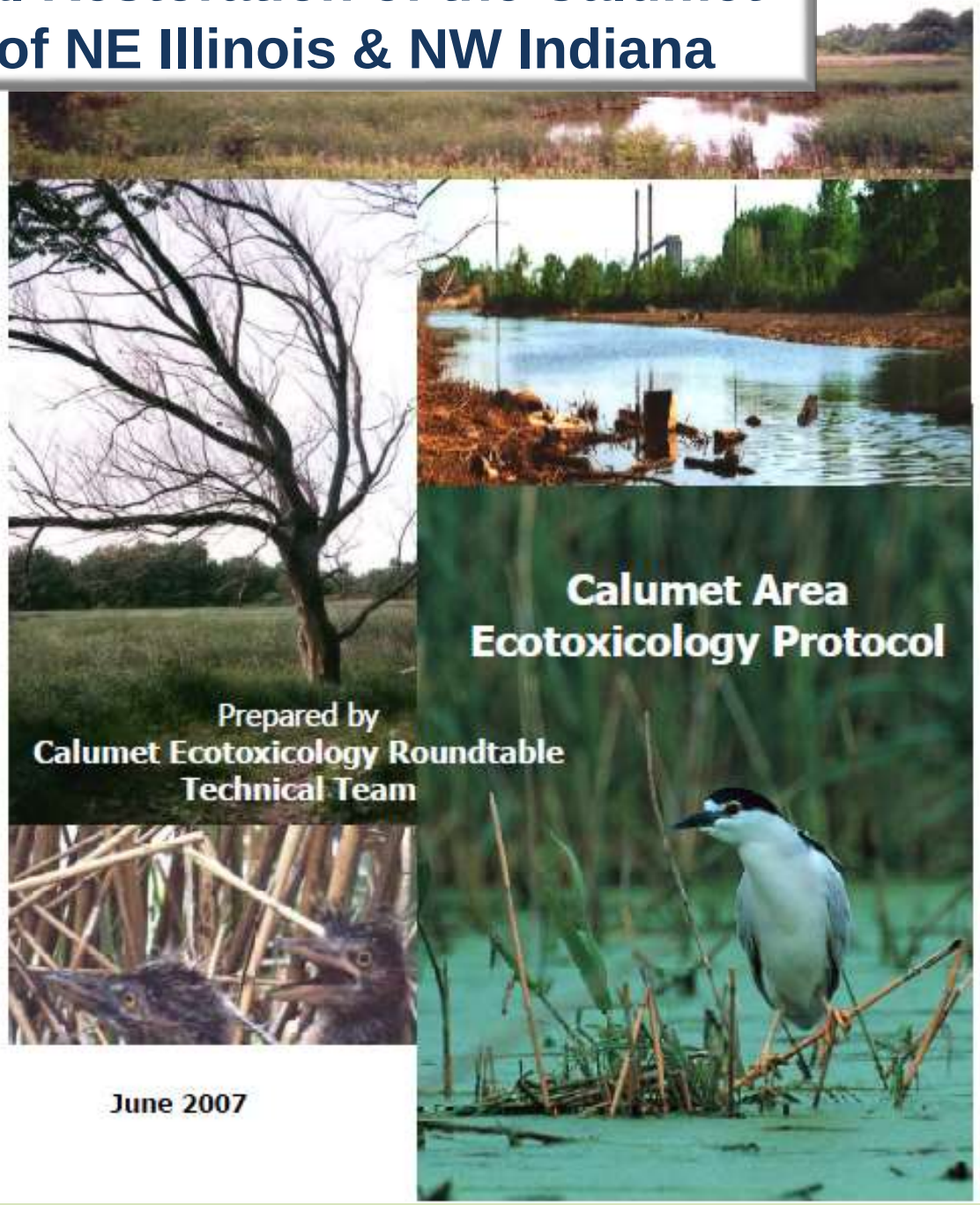
Evolution, Ecology and Organismal Biology



Ecological Restoration of the Calumet Region of NE Illinois & NW Indiana

Developed by many city, state, and federal agencies and area stakeholders

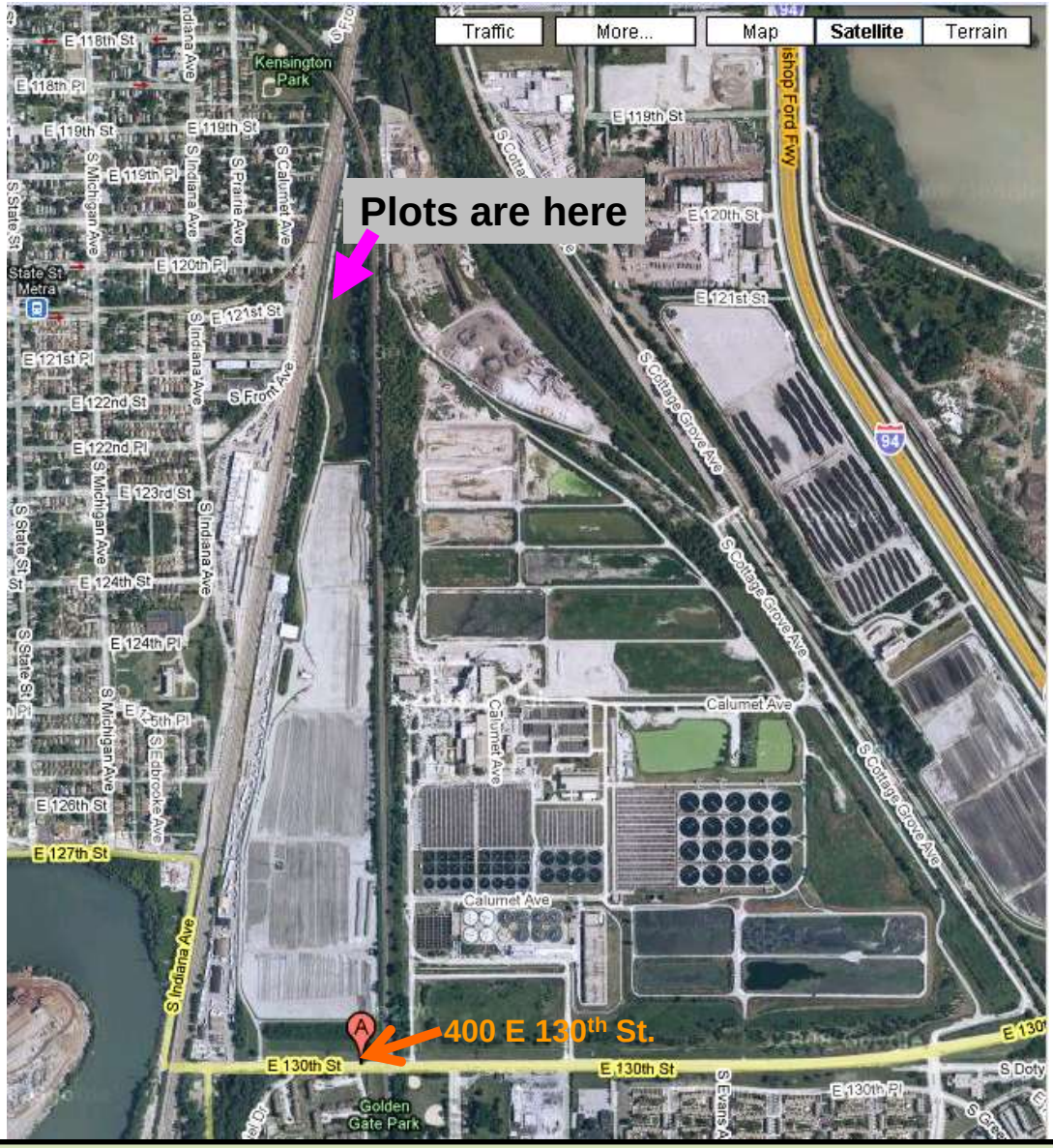
- Established SITE SPECIFIC Background, Threshold (NOAEL) & Benchmark (LOAEL) levels of contaminants in soil, sediment and surface waters of the region
- Our data was compared against THESE LEVELS
- recommended resurfacing with 2 inches of compost



Project Objectives

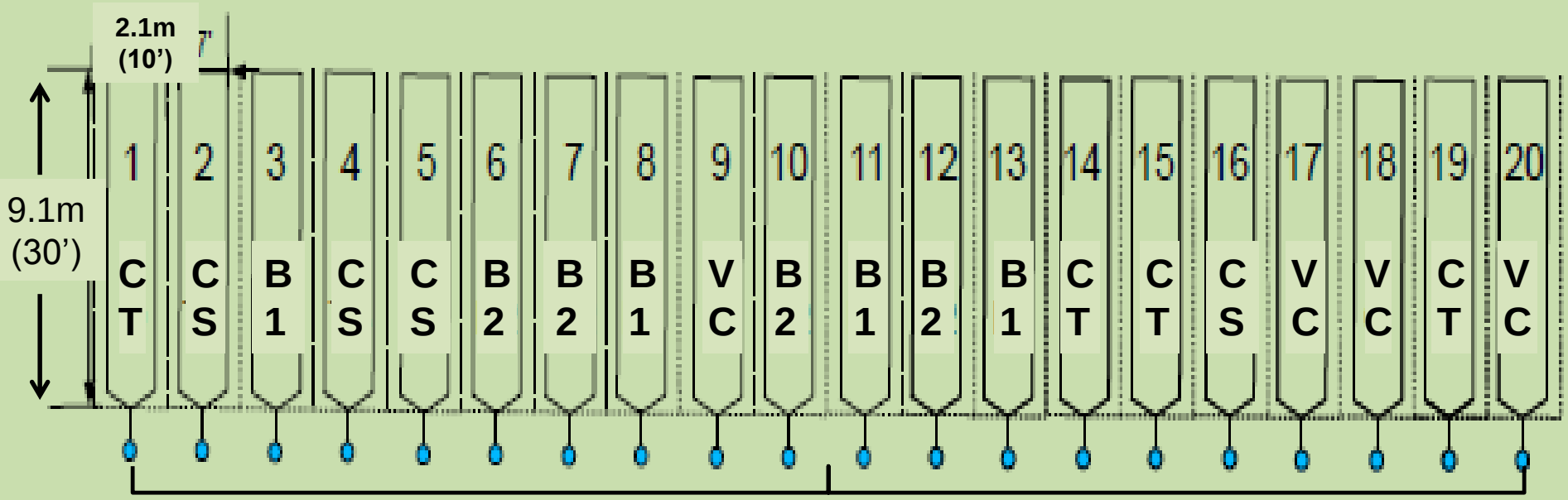
USFWS had concerns about the use of biosolids as a restoration material in the Calumet area. Vegetative compost (2 inches applied to surface) was proposed.

Therefore, this study compares biosolids / blends to vegetative compost performance in restoring ecological function to degraded sites, while minimizing environmental impact



Research Field Location in Calumet, Illinois

Experimental Design - Randomized Runoff Plots



Down slope

Runoff Collection Barrels

4 Treatments+ control - 4 Replicates

CS = Control soil VC = Vegetative compost 2.5 cm/ 1 in

B1 = Biosolids 2.5cm/ 1 in B2 = Biosolids 5.1 cm/ 2 in

CT = Combination treatment of biosolids 2.5 cm/ 1 in + WTR + biochar

Soil Treatment/Blend Materials

MWRD Biosolids

Vegetative Compost

Water Treatment Residual (WTR) - added to bind excess soluble P

Biochar – added to absorb potential organic contaminants

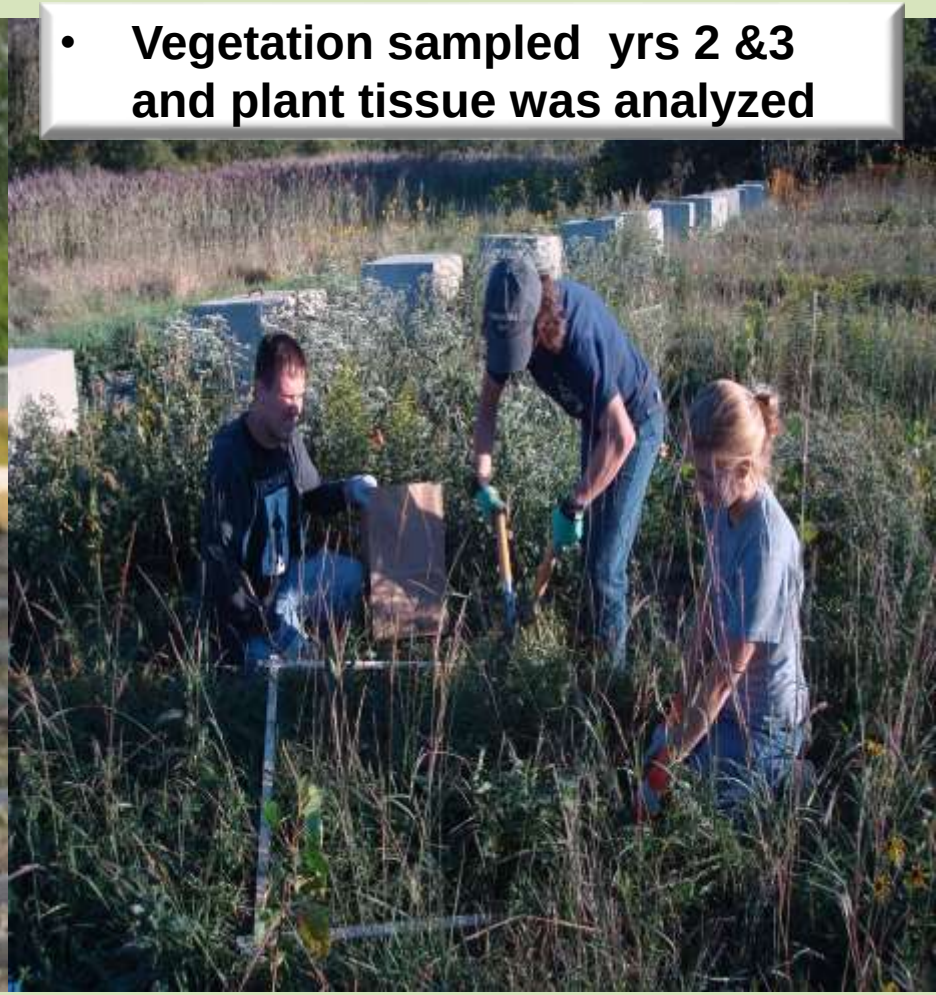
Aaron Mali and Oulu Coquie rototill in the Soil Treatments

Plot installation and rainfall runoff collection

- **Runoff collected for every rainfall event, for 3 yrs and analyzed for TSS, pH, EC, N, P and dissolved metals**
- **Microconstituents (PPCPs) analyzed by AXYS Analytical Labs**

Plots were seeded with 33 native grass, legume and forb species from Cardno JFNew

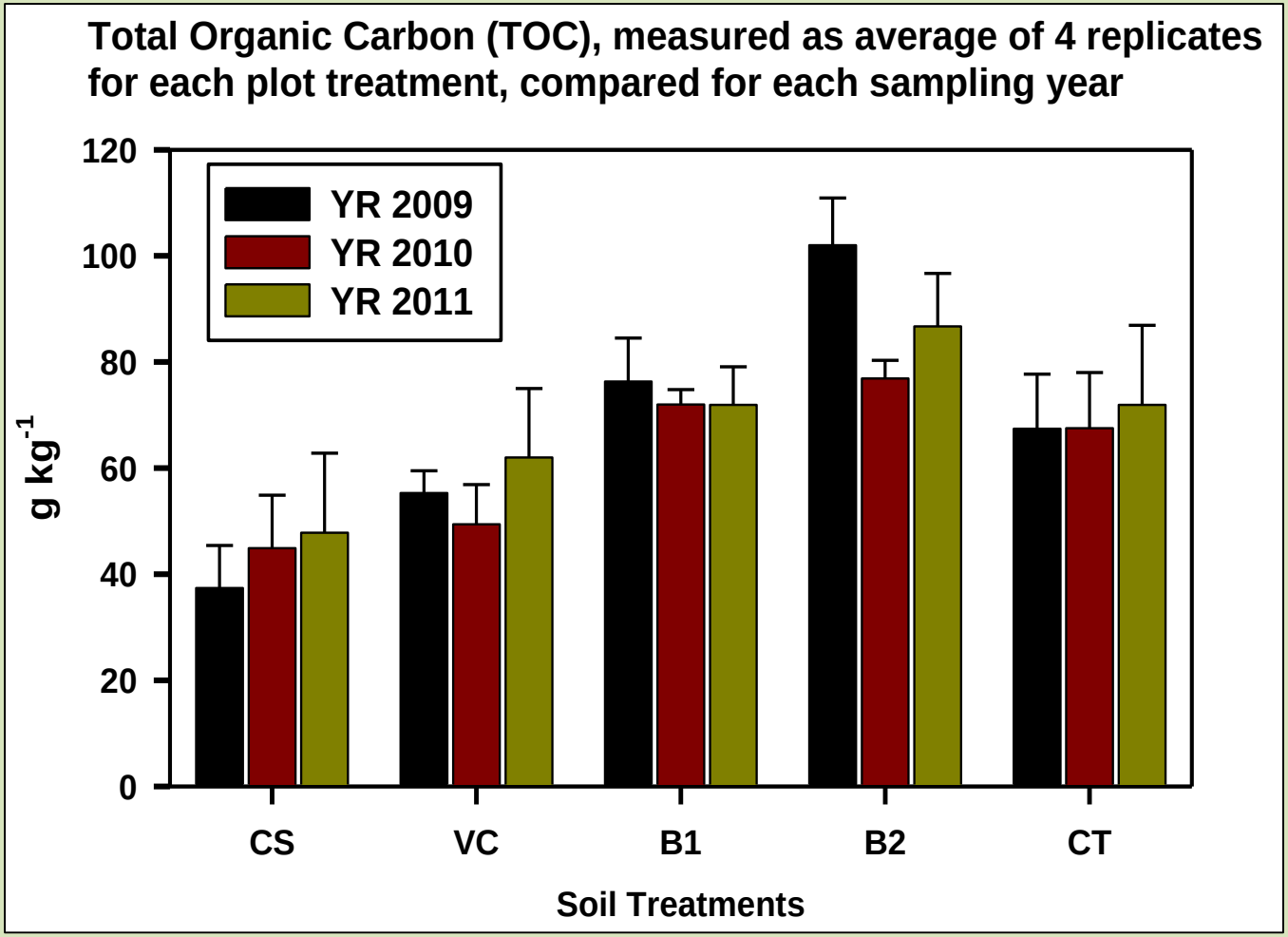
- **Vegetation sampled yrs 2 &3 and plant tissue was analyzed**



- **Soils sampled annually and analyzed for multiple constituents**
- **Laboratory earthworm bioassay conducted to measure mortality and reproductive endpoints**

➢ ***Results....***

Select soil quality measures



Biosolids increased soil organic carbon, total N, plant available N (PAN) more than compost treatment

	Year	Plot soil treatment				
		CT	VC	BS1	BS2	CT
		mg kg^{-1}				
As	2009	13.4b†	12.8ab	12.3ab	12.2a	11.9a
	2010	17.5b	13.2a	13.7a	13.1a	14.1a
	2011	11.4a	12.1a	12.7ab	13.5b	14.0b
Ba	2009	204a	183a	234ab	332b	221a
	2010	203b	136a	209bc	251c	227bc
	2011	128a	130a	189c	210c	182b
Be	2009	1.20c	1.11b	1.14b	0.90a	1.00ab
	2010	NA‡	NA	NA	NA	NA
	2011	0.37c	0.12a	0.23b	0.20b	0.28bc
Cd	2009	1.36a	1.33a	1.51a	2.47b	1.65a
	2010	1.05ab	0.78a	1.3bc	1.86d	1.6cd
	2011	0.98a	0.88a	1.29bc	1.43c	1.19ab
Co	2009	3.26b	2.43a	2.52a	2.40a	2.43a
	2010	14.9b	11.2a	11.2a	10.0a	10.0a
	2011	BDL§	BDL	BDL	BDL	BDL
Cr	2009	47.2a	44.4a	52.1a	70.3b	52.1a
	2010	51.3a	39.5ab	53.9c	67.3d	56.5bc
	2011	31.4a	28.4ab	39.3c	50.8d	36.4bc
Cu	2009	52.1a	49.4a	103a	256b	122a
	2010	63.8a	52.8a	143b	209c	184bc
	2011	38.3a	39.5a	109bc	124c	89.3b
Mn	2009	NA	NA	NA	NA	NA
	2010	478a	468a	508a	486a	466a
	2011	387a	416a	458ab	526bc	540c
Mo	2009	7.61a	5.96a	8.5a	12.1b	8.58a
	2010	6.84b	4.92a	7.39b	8.98c	7.53b
	2011	4.72ab	4.21a	5.40b	7.03c	5.12b
Ni	2009	46.0b	34.8a	38.8ab	41.0ab	36.6a
	2010	41.4b	31.7a	35.2a	35.4a	32.2a
	2011	26.7c	23.8a	27.5c	28.7c	24.9b
Pb	2009	89.1ab	75.5a	83.2ab	99.8b	85.5ab
	2010	96.2c	68a	86.1bc	94.9c	86.8bc
	2011	50.3a	52.4a	70.7b	70.7b	62.6ab
Sb	2009	3.93a	3.92a	4.57a	4.61a	5.51a
	2010	NA	NA	NA	NA	NA
	2011	BDL	BDL	BDL	BDL	BDL
Se	2009	0.83a	1.46ab	1.84ab	3.82c	2.34b
	2010	NA	NA	NA	NA	NA
	2011	NA	NA	NA	NA	NA
V	2009	49.3b	51.6b	52.8b	44.9a	46.8ab
	2010	NA	NA	NA	NA	NA
	2011	40.6b	34.1a	36.2ab	37.4ab	37.5ab
Zn	2009	164a	159a	280a	609b	317a
	2010	200a	155a	393b	556c	490bc
	2011	110a	121a	277bc	311c	241b

†Means within parameter measured with same letter are not different
‡ Not analyzed
§ Below detect limit

Heavy Metal(loid)s in Soil

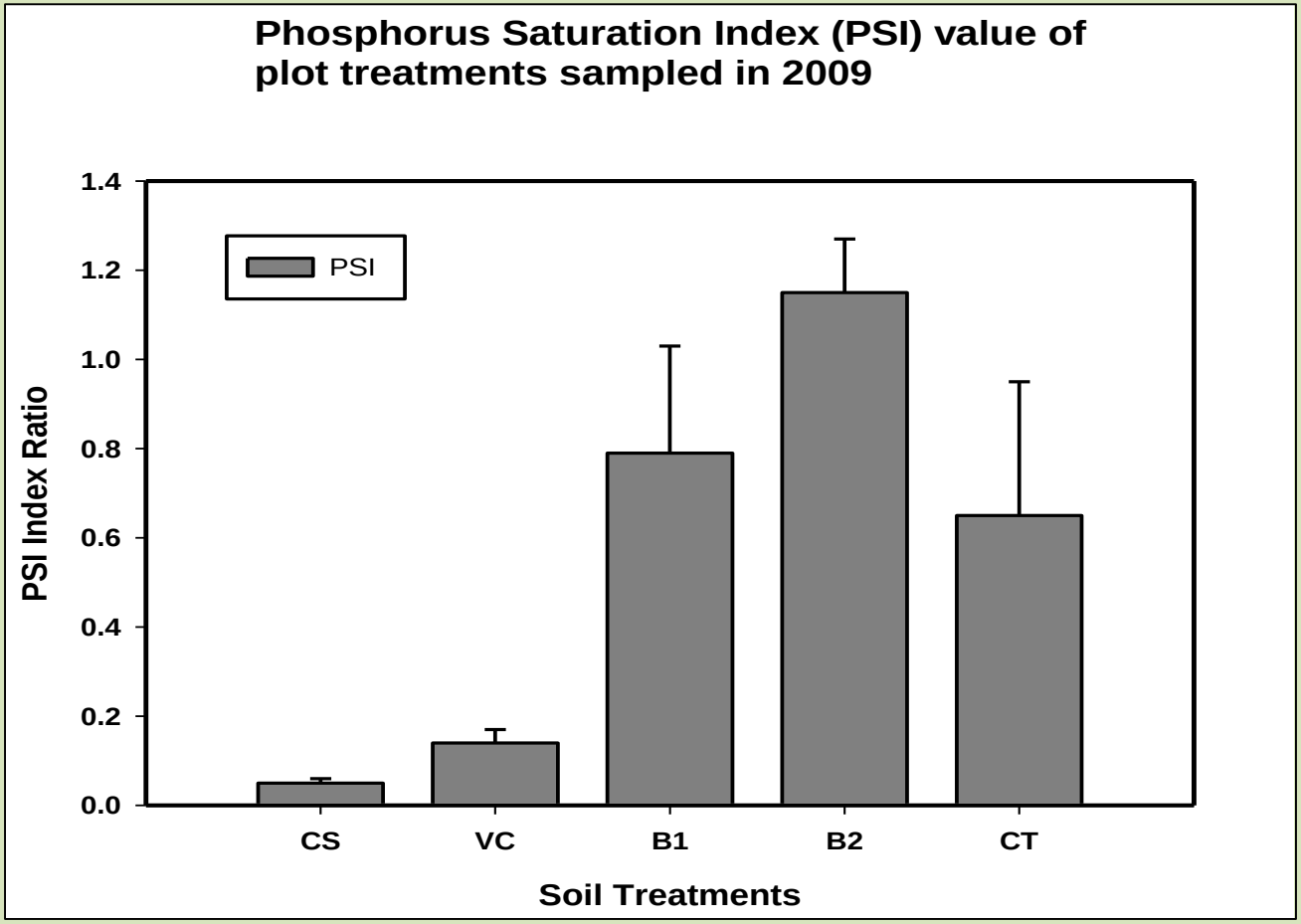
BS treatments increased soil Cu and Zn

these levels are below any concern (including USEPA Ecological Soil Screening Levels)

addition of Cu and Zn and other micronutrients are beneficial because these are essential plant nutrients

animals manure or biosolids provides micronutrients –compost doesn't

Biosolids Increased Soil Phosphorus



Phosphorus Saturation Index (PSI = (P_{ox})/ (Al_{ox} + Fe_{ox}); values over 1 have been correlated with potential transport of labile (soluble) P

BS2 a concern; BS1 less concern

Soil Enzymes as an indicator of soil nutrient cycling

Biological function	Soil Enzyme	Ecosystem service	Response		
			CS	VC	BS
Chitin degradation	N-Acetyl- β-glucosaminidase	C & N Nutrient cycling; N fixation	-	+	++
Glucose availability	β-glucosidase	Microbial energy source; indirect heavy metal indicator	-	+	++
Inorganic N metabolism	Amidase & urease	Supplies N to microbes	-	-	-
P availability	Acid & alkaline phosphatase	P release for plant nutrition	-	+	++
Sulfate metabolism	Arlysulfatase	Indirect indicator of fungi; potential degradation of microconstituents	-	-	+
Broad based nutrient	Fluorescein diacetate (FDA)	Overall indicator of healthy soil biological activity	-	-	+

Select soil enzyme findings

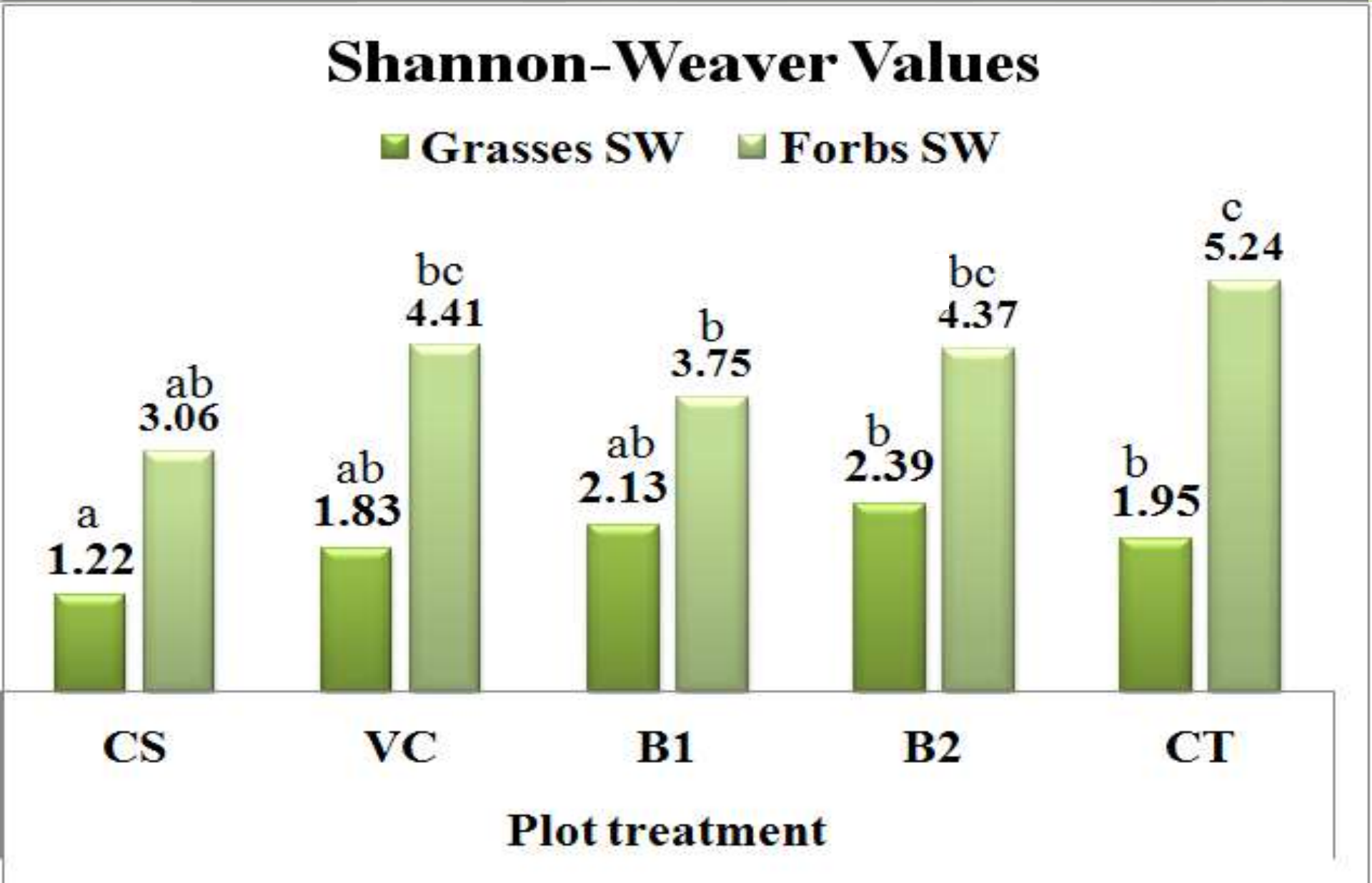
- **Biosolids and compost had a positive effect on soil enzymatic activities and microbial function**

- **Biosolids treatments tended to have higher amounts of fungal biomass compared to control, as well as lower stress biomarkers**

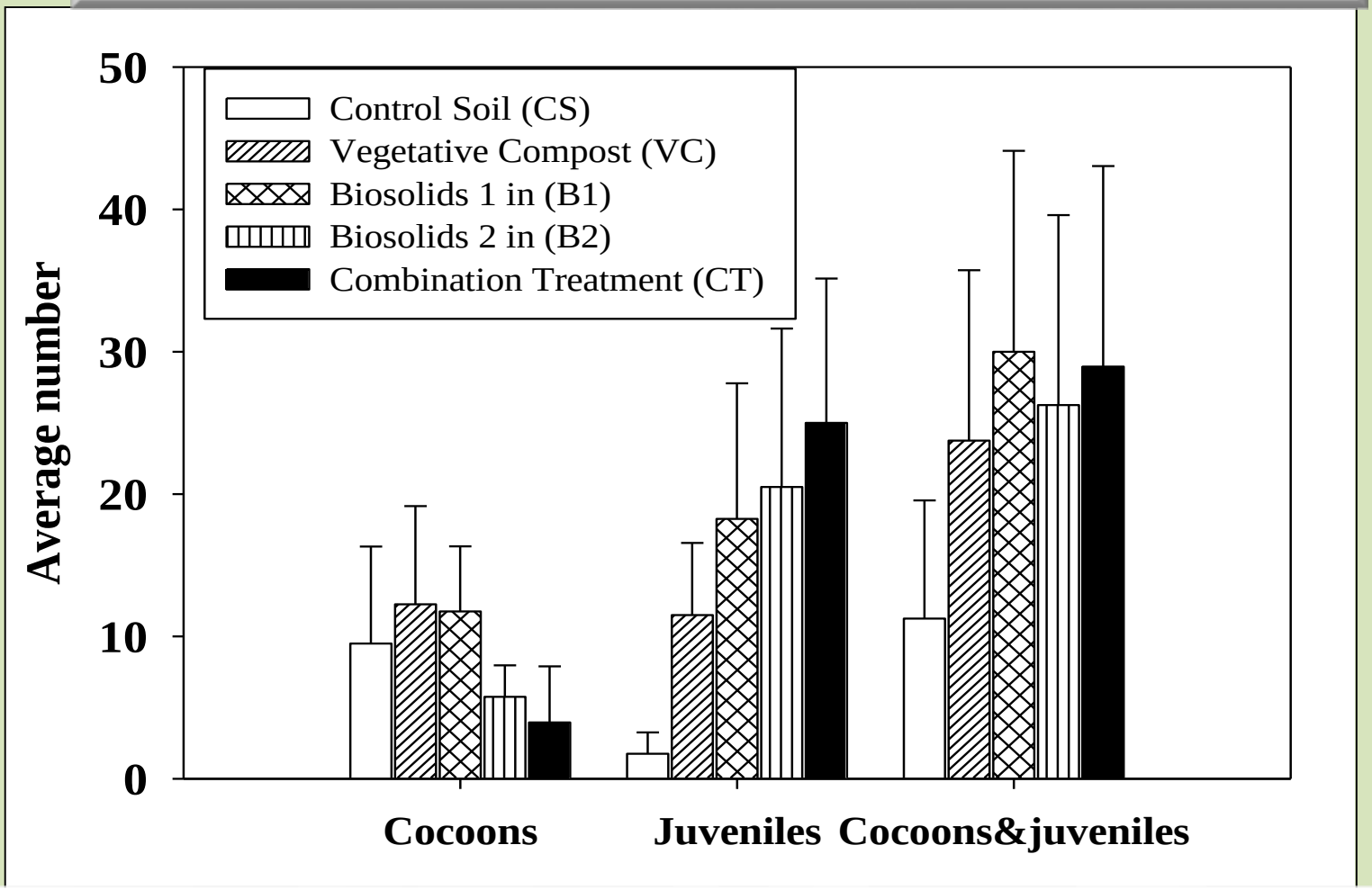
Vegetative Performance and Quality

- **Biosolids produced highest plant tissue N, thus improved protein content (nutrient) levels**
- **Biosolids DID NOT elevate trace metals in plants therefore no concern for ecosystem food chain transfer**

Both biosolids and VC improved plant diversity



Earthworm 56 Day reproductive bioassay



- Neither biosolids or compost increased earthworm mortality
- Both biosolids and compost treatments increased number of juveniles and earthworm reproductive success

Select runoff water measures

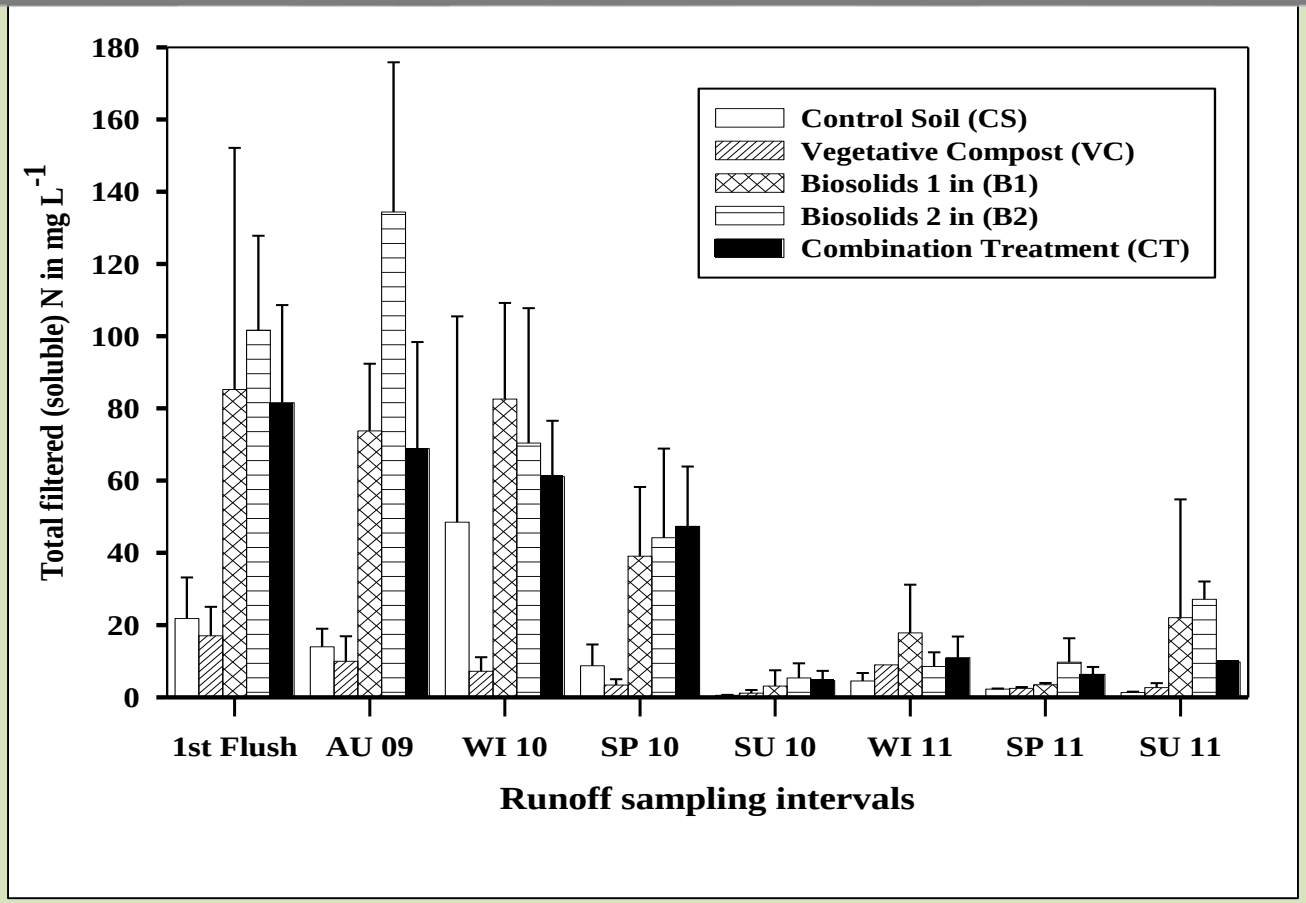
The 1st flush of runoff water (1st rainfall event) was tested for 14 dissolved metals:

- **As, Ba, Be, Cd, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, Se & Zn**

Findings:

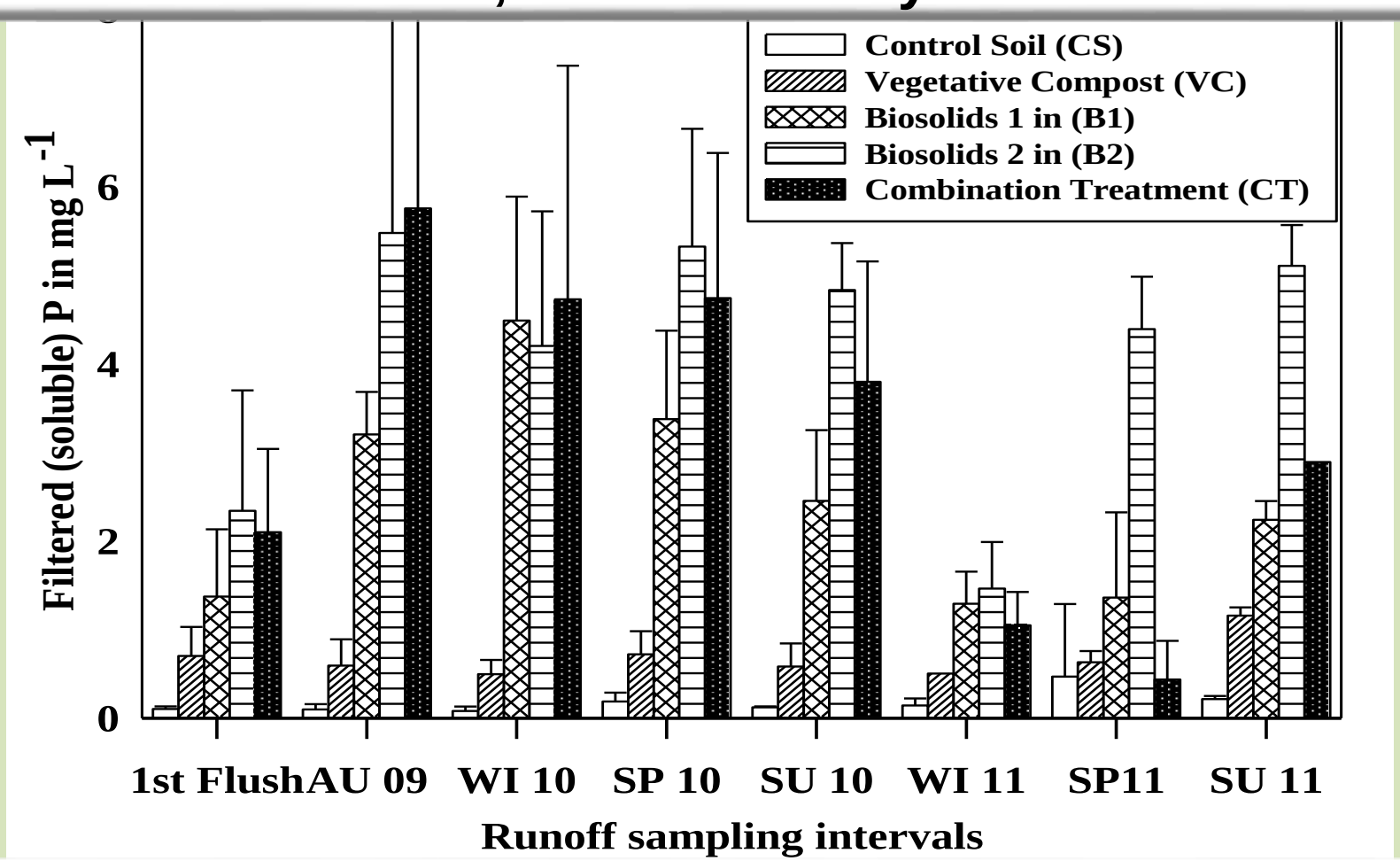
- **All metals below Calumet Ecotoxicology Protocols (LOAEL) except Cu for the 2-inch Biosolids .**
  No concern with BS1

Concentration of soluble total N in filtered runoff water sampled after 1st flush, and seasonally thereafter



Greater loss of soluble N associated with biosolids declined markedly to near background levels within 1 year

Concentration of soluble P in filtered runoff water sampled after 1st flush, and seasonally thereafter



- Biosolids increased runoff P compared to compost
- Application of additional WTR in 2nd year was starting to have an impact on P levels

Microconstitutents
Pharmaceuticals and Personal Care Products

- **119 PPCP were tested by Axys Analytical Labs**
- **20 compounds were measured above detection limits, concentrations ranged from approx 1 to 1760 ng L^{-1} (Ibuprofen)**
- **4 compounds detected in runoff from all treatments**
- **Concentrations were not above NOAEL (daphnia) and were below probable no-effect levels in literature (PNEC)**

Top 5 compounds, which were 10 times greater than detection limit

Compound	Control	Compost	B2	CT	NOAEL
			ng L^{-1}		
Carbamazepine	nd	nd	66.0 - 206	nd	25,000
DEET	57.9 - 420	57.9 – 86.5	43.0 - 154	58.2 - 176	_
Gemfibrozil	3.41 – 15.0	7.05 – 84.0	35.8 - 119	90.3 - 324	100,000
Ibuprofen	nd - 202	89.7 - 568	527 - 1760	854 - 1490	5000
Valsartan	nd – 17.3	nd – 78.0	58.4 - 200	102 - 233	_

Conclusions

- **Biosolids increased soil organic carbon and many soil quality measures more than compost**
- **Vegetative performance and community measures responded favorably to both compost and biosolids applications - biosolids response was more pronounced**
- **Microbial response to compost and biosolids applications were similar. Biosolids had greater nutrient cycling (enzymes) and fungal population than compost**

Conclusions

- **Soil invertebrates (earthworms) reproductive measures were increased by compost and biosolids**
- **The biosolids applied at the 2 in rate exhibited potential for P runoff. However 1 inch biosolids rate had much less concern. The WTR combined with biosolids showed some effect in reducing P runoff**
- **PPCP levels in runoff were not detected or very low. They were below LOAELs and PNECs in the literature**

Recommendations

- **Biosolids is recommended as a beneficial soil treatment at the 1 inch application rate.**

- **Use of best management practices to control erosion and runoff after establishment is essential. WTR should be used to reduce P in runoff.**

- **Vegetative compost balances the N:P ratio of biosolids, and biosolids contributes sustained release of plant nutrients, a combination treatment of both may be an optimal material, and merits further consideration**

Acknowledgements

Metropolitan Water Reclamation District of Greater Chicago or Funding this project and tirelessly helping with sample, data collection and research management









School of Environment and Natural Resources
Ohio State University

New Ecological Restoration Degree Program
B.S. Environmental Science /ER
M.S. and Ph.D. Environment Natural Resources ER
New faculty on board and hiring more

Other Good News on Campus

"There's nothing that cleanses your soul like getting the hell kicked out of you" -- Coach Woody Hayes

Thank you for your attention

More information?

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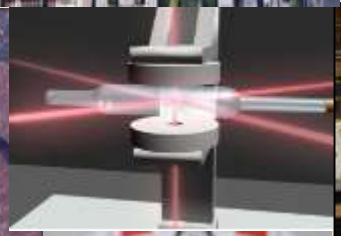

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