The Related Research on Urban Runoff LID BMPs Control for Sponge city

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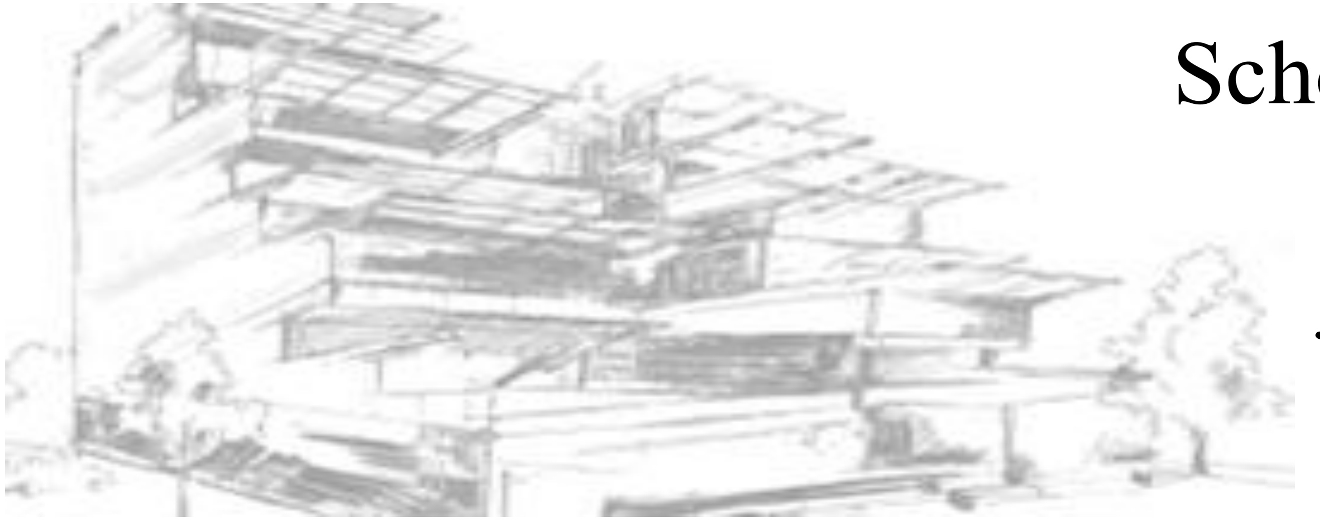
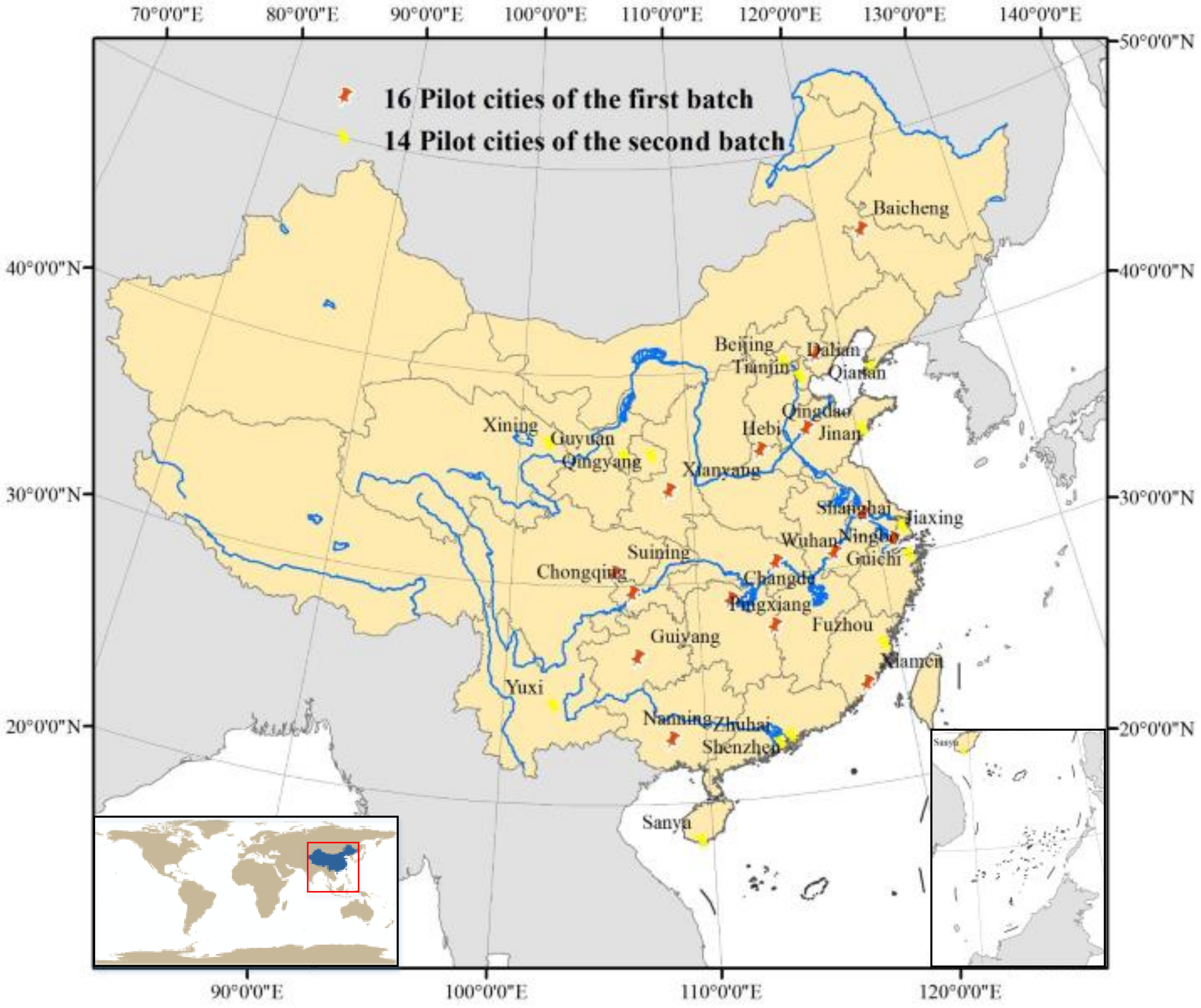


Contents

Sponge city in China

- **It has been a national policy and movement in late 2013**
- **30 National pilot cities**
- **1000 billion RMB Yuan market**



Principle and means of Sponge city

Infiltration — Conserving groundwater

Retention — Reducing peak flow

Storage — Creating conditions for stormwater recycling

Absorbing function of sponge

Principle and means of Sponge city

Purification — Reducing pollution loads

Utilization — Utilizing rainwater resources

Drainage — Discharging into the water bodies safely

Resources utilization and water safety

Technical Route

Source reduction

LID facilities in all feasible land use surface type open space, rooftops, parking lots, sidewalks, and so on.

Process control

- **Green infrastructure.**
- **Gray infrastructure.**

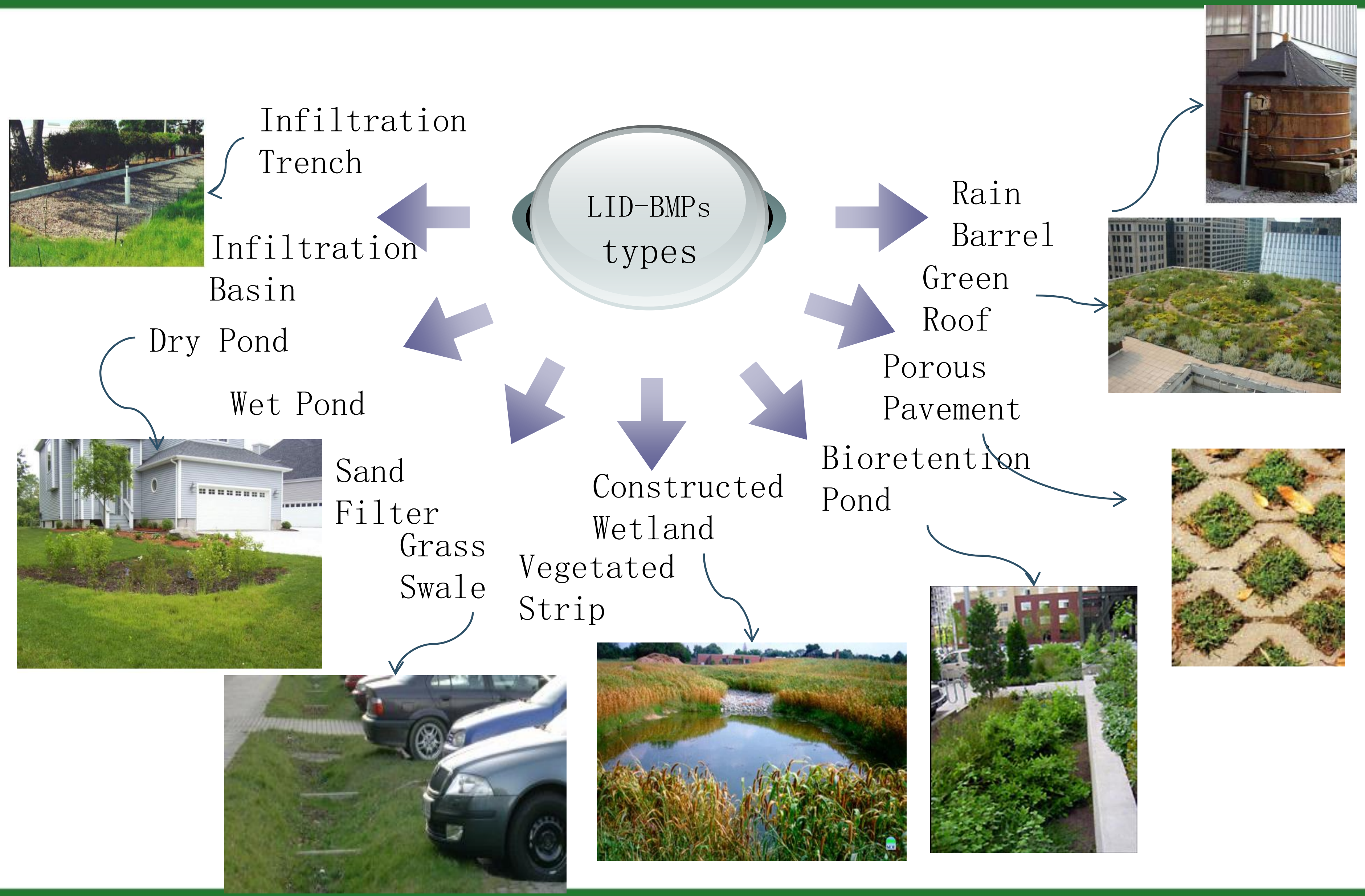
Systematic remediation/development

- **Watershed scale**
- **Integrated Approach**

LID is not Sponge city
However，LID must be essential part of Sponge city

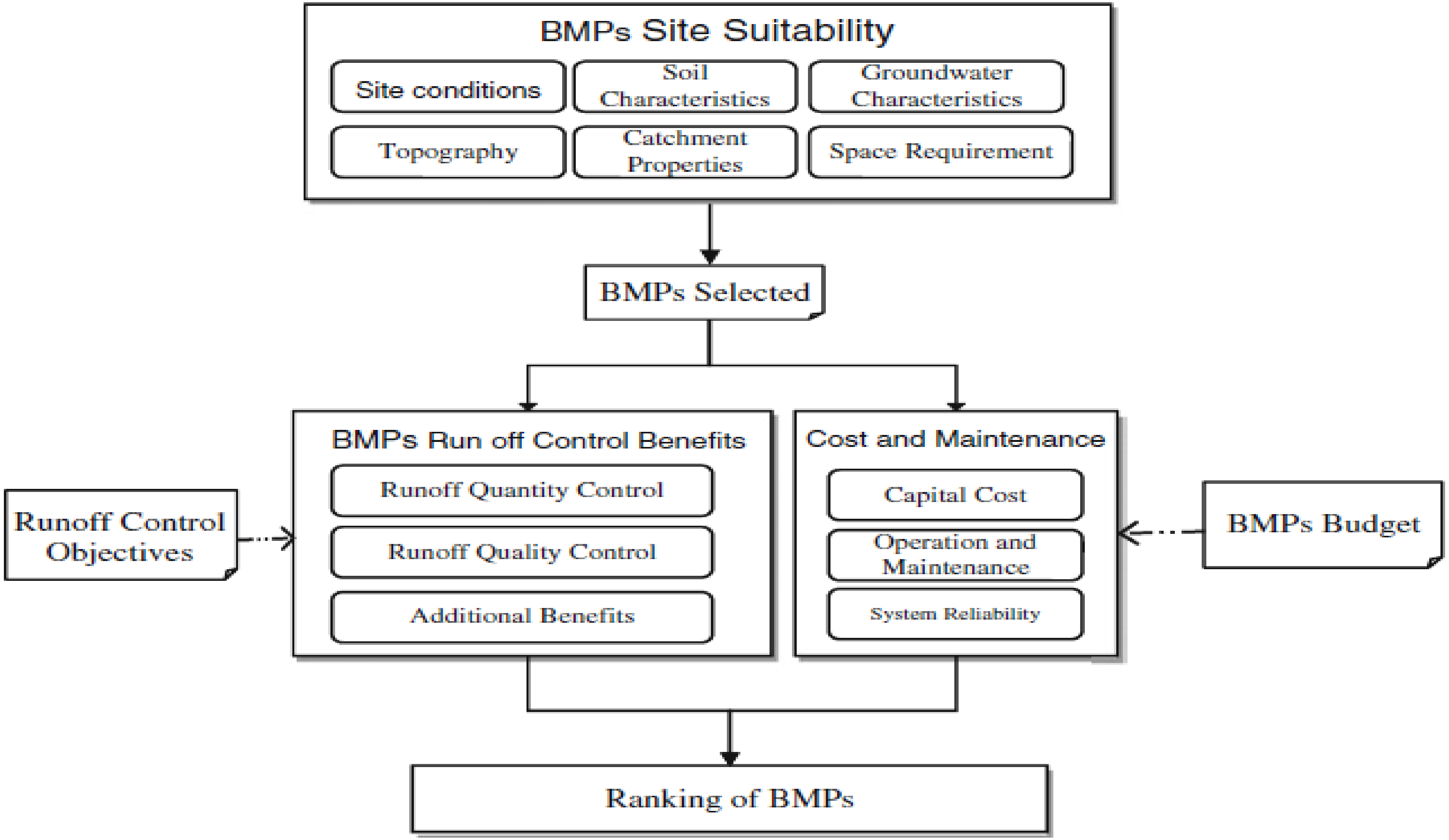
Contents

Selection of suitable LID BMPs



Selection of suitable LID BMPs

- A multi-criteria index ranking system for urban runoff LID BMPs selection



Selection of suitable LID BMPs

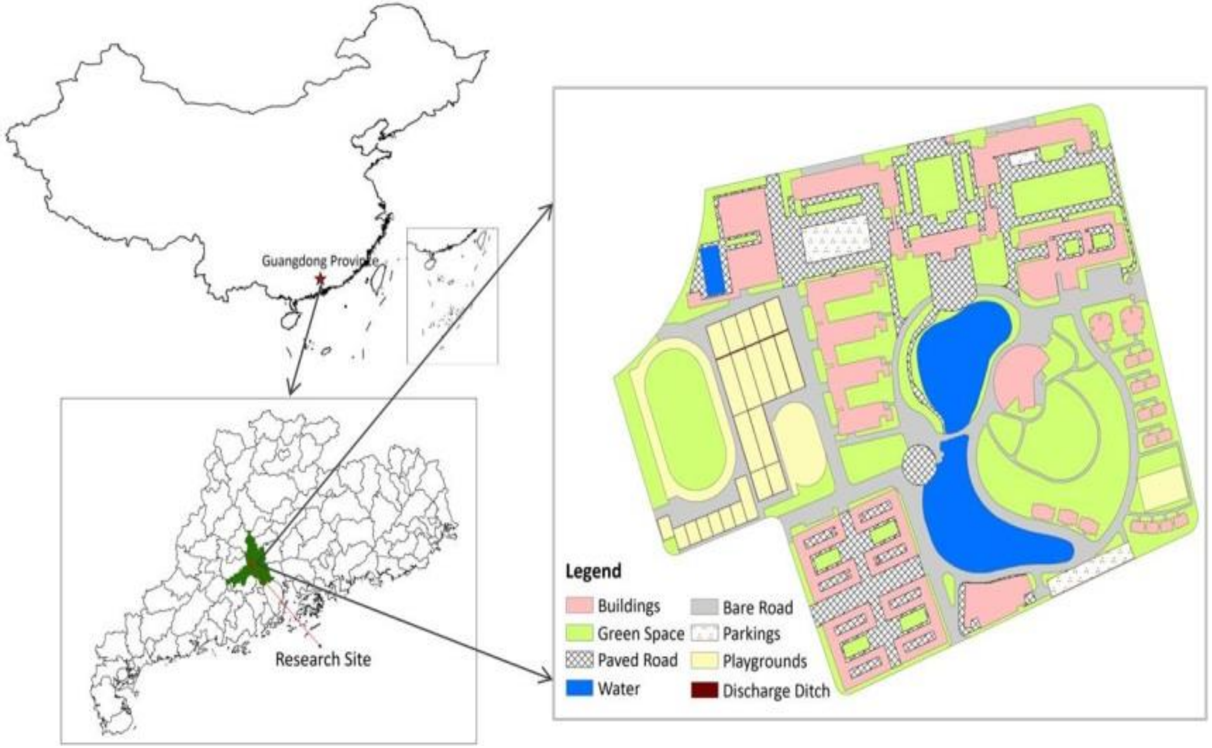
- LID-BMPs selection Software

Haifeng JIA, Hairong Yao, Ying Tang, Shaw L. YU, Jenny X. Zhen, Yuwen Lu. *Development of A Multi-Criteria Index Ranking System for Urban Stormwater Best Management Practices (BMPs) Selection*. Environmental Monitoring and Assessment. 2013, 185(9):7915-7933

Contents

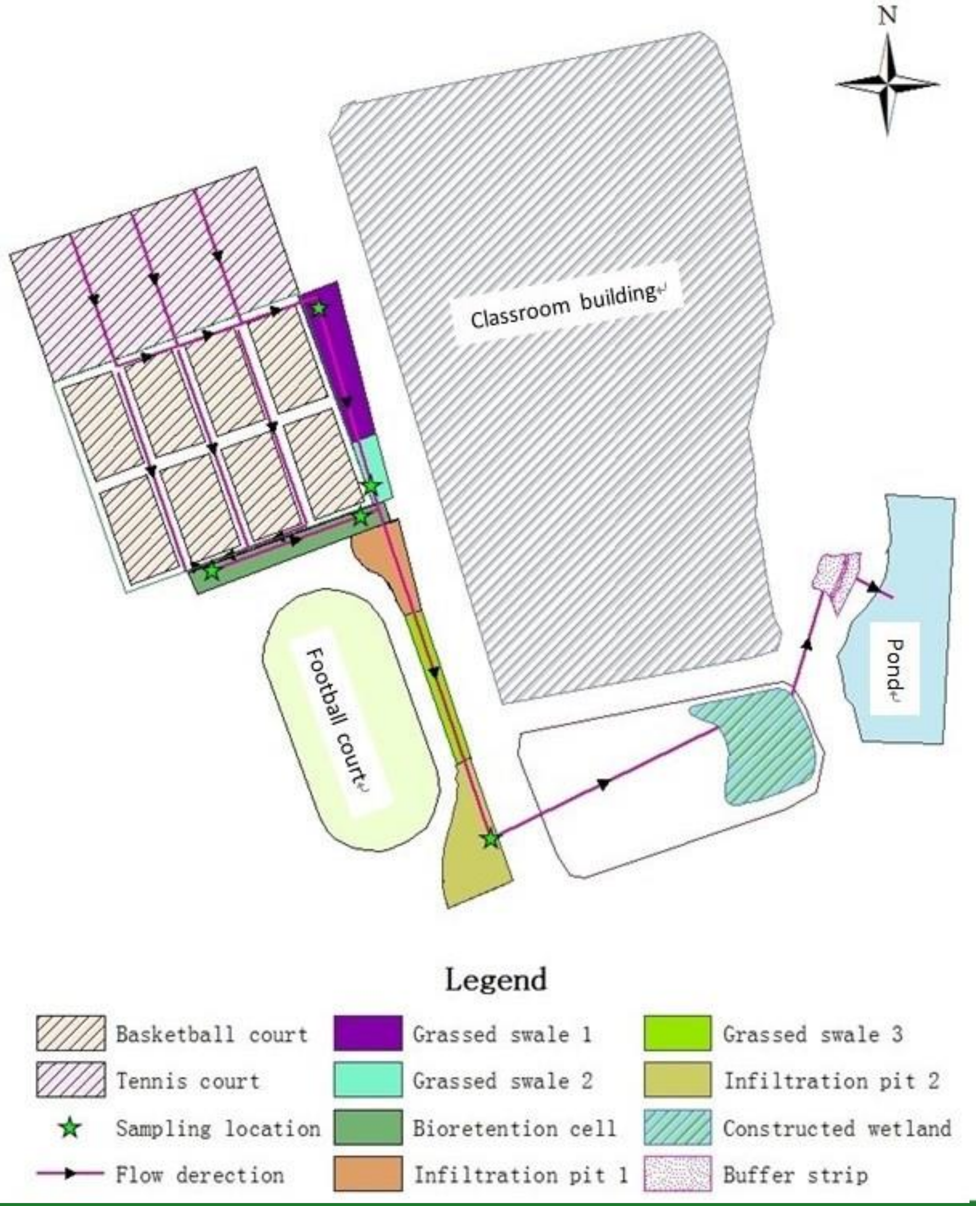
Field Test Site

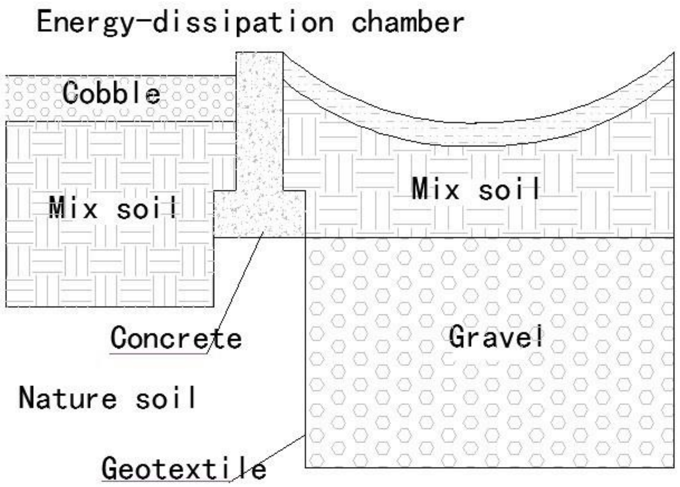
The test site is on the campus of Guangdong vocational college of environmental protection in **Foshan**, Guangdong province in southern China.



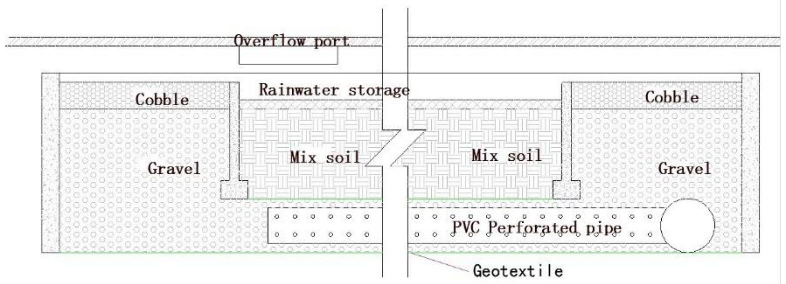
Campus

BMP Design and Construction



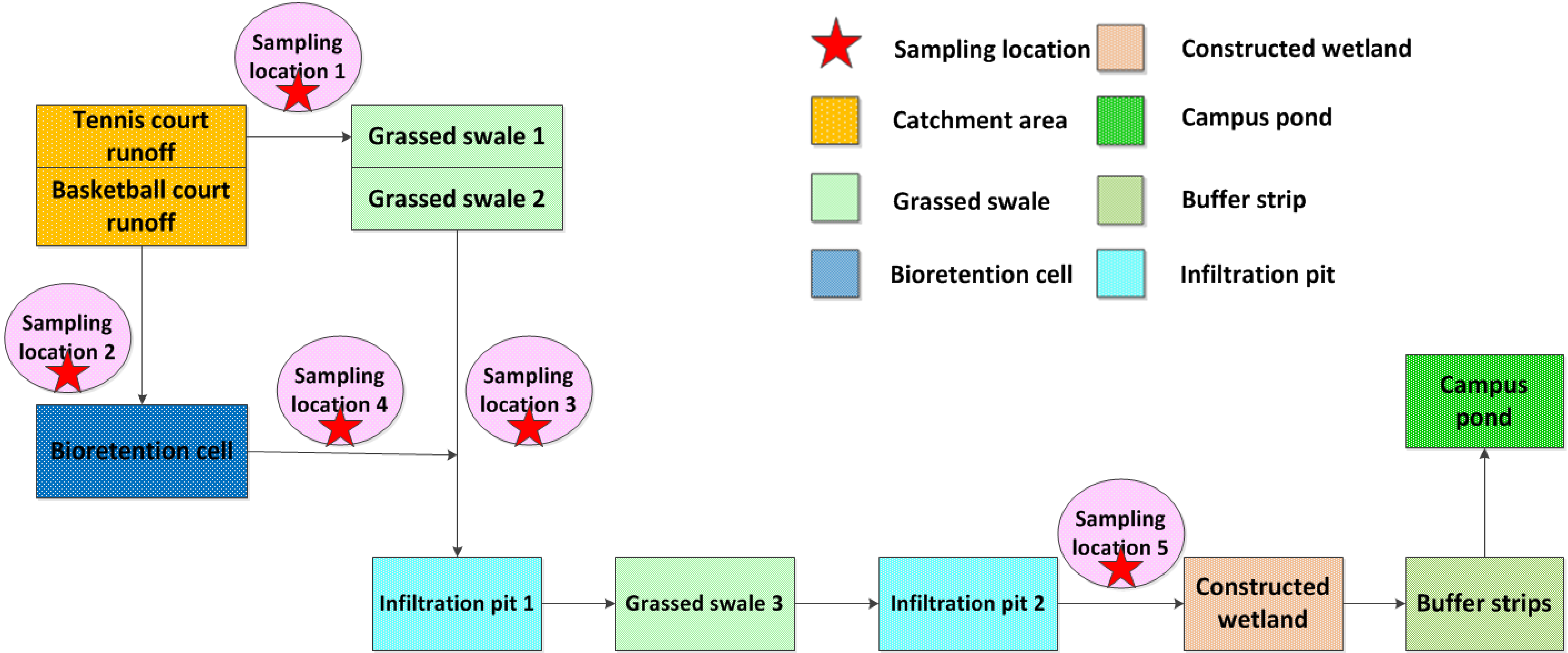


The profile of Grassed swale



The profile of Bioretention

Design of the Sampling Program



Schematic of Sampling Locations

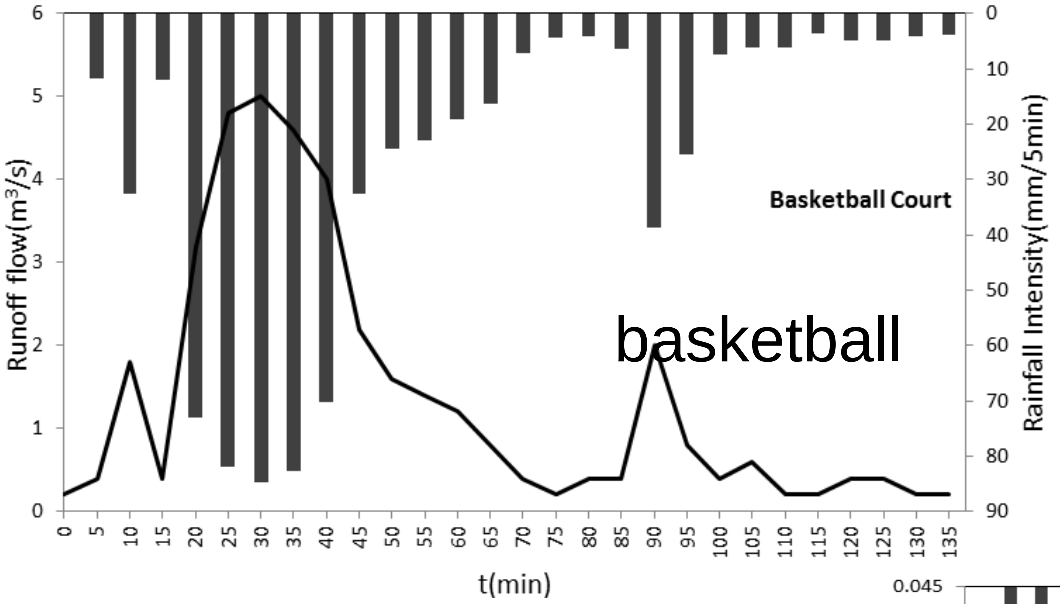
JIA Haifeng, et al. Field Monitoring of an LID-BMP Treatment Train System in China, Environmental Monitoring and Assessment. 2015, 187(6):4595.

Design of the Sampling Program

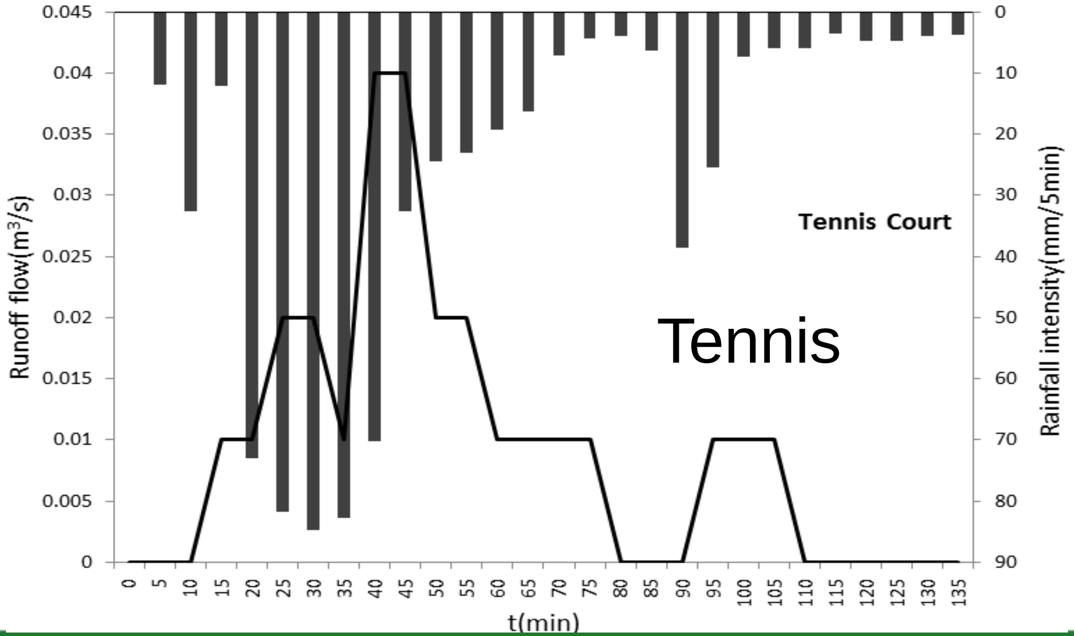
- Water quality parameters analyzed included pH, COD, NH_3-N, TSS, TN, TP, Cu and Zn.
- A total of 19 storm events were monitored, of which 10 produced outflows from the BMPs from May,2012 - Sept. 2013

- Runoff Control Performance
  - Volume Reduction
  - Peak Reduction
- Pollutant Removal Performance
  - Bioretention Cell Removal Efficiency
  - System Removal Efficiency

Results and Discussion

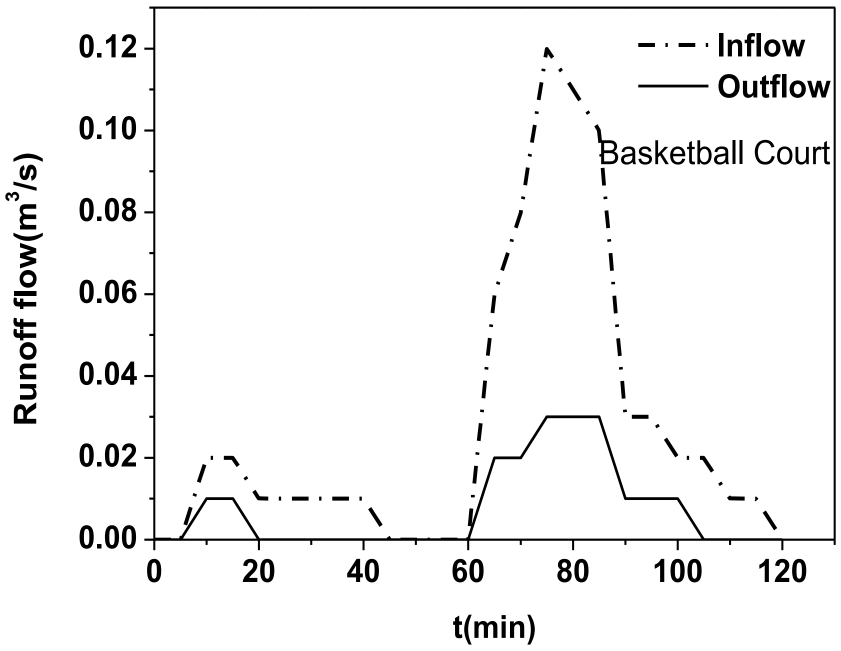


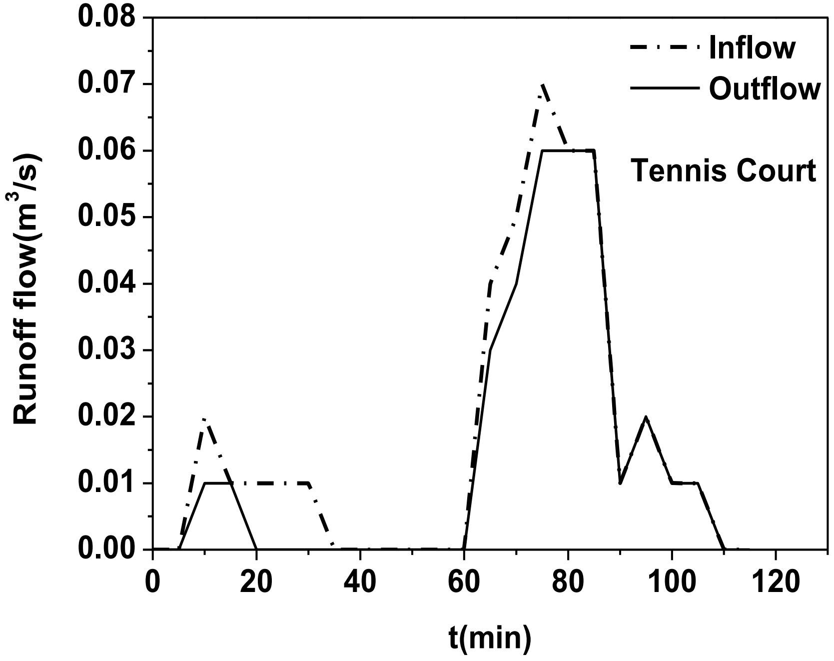
Rainfall Hyetograph for the May 18, 2012 Storm



Runoff Hydrograph for the May 18, 2012 Storm

Runoff Control Performance



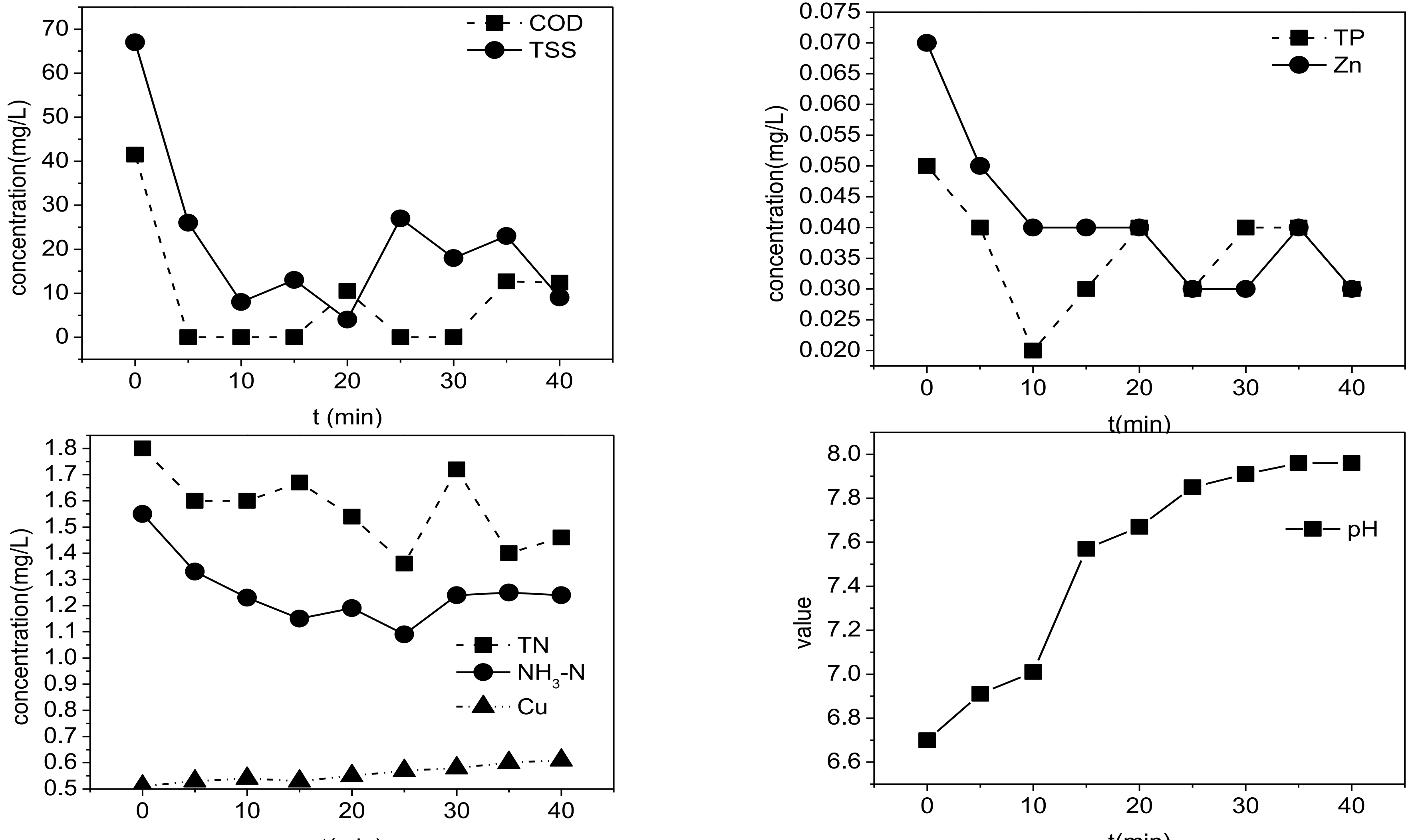


Inflow and outflow hydrographs for the bioretention cell for the May 27, 2012 storm

Inflow and outflow hydrographs for the grassed swale for the May 27, 2012 storm

- bioretention cell is quite efficient in reducing the runoff peak and volume,
- while the swale is much less effective for a relatively large storm

Pollutant Removal Performance



Pollution concentrations of inflow to the bioretention cell for the May 20, 2012 storm

Bioretention Cell Removal Efficiency

Overall removal efficiency for bioretention cell

Pollutant	TN	NH_3-N	Zn	Cu	COD	TSS	TP
2012 Removal rate （%）	44.29	46.67	100.00	69.45	17.93	-29.62	-29.76
2013 Removal rate （%）	59.43	62.18	*	*	-	36.44	0.00
Total Removal rate （%）	48.61	51.10	100.00	69.45	17.93	-10.75	-21.26

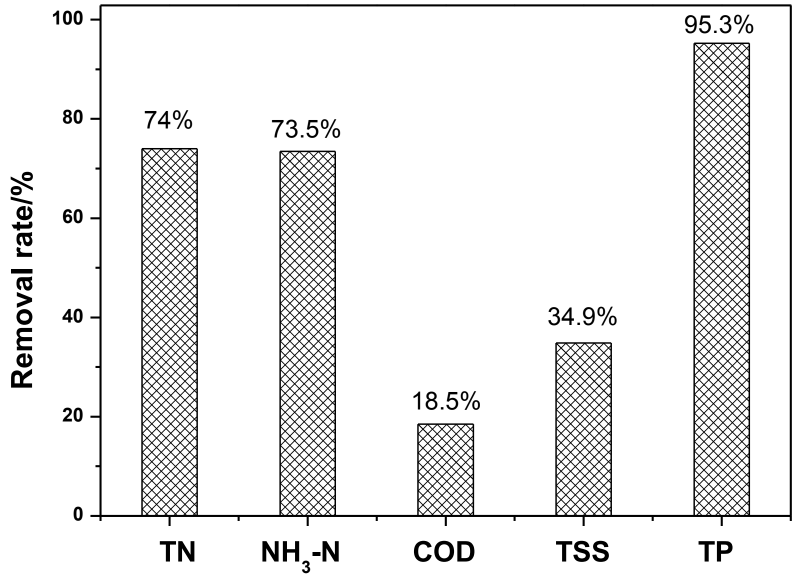
- ：less than detection limit; *: no sampling

- significant removal rates for NH_3-N, TN , Zn and Cu; fare removal rate for COD; negative removal rate for TSS, TP.
- the pollutants removal rates in 2013 were higher than that in 2012, especially the removal rate for TSS which changed from negative to positive.
- The results show that the performances of bioretention cell need one year operation to stabilize.

System Removal Efficiency

	Inflow		Outflow	Removal rate*(%)
	Grassed swale 1	Bioretention cell	Infiltration pit 2	
COD/ kg	3.02	0.80	3.11	18.52
NH_3-N/ kg	0.49	0.13	0.17	73.48
TN/ kg	0.96	0.25	0.31	74.00
TSS/ kg	8.44	3.11	7.53	34.85
TP/ g	0.07	0.71	0.04	95.26

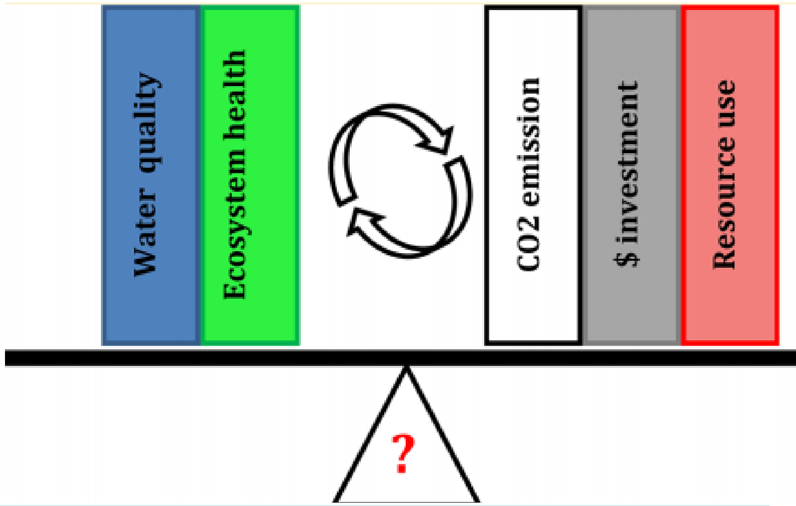
- significant removal rates for NH_3-N, TN ,TP.



Contents

Why should it be optimized?

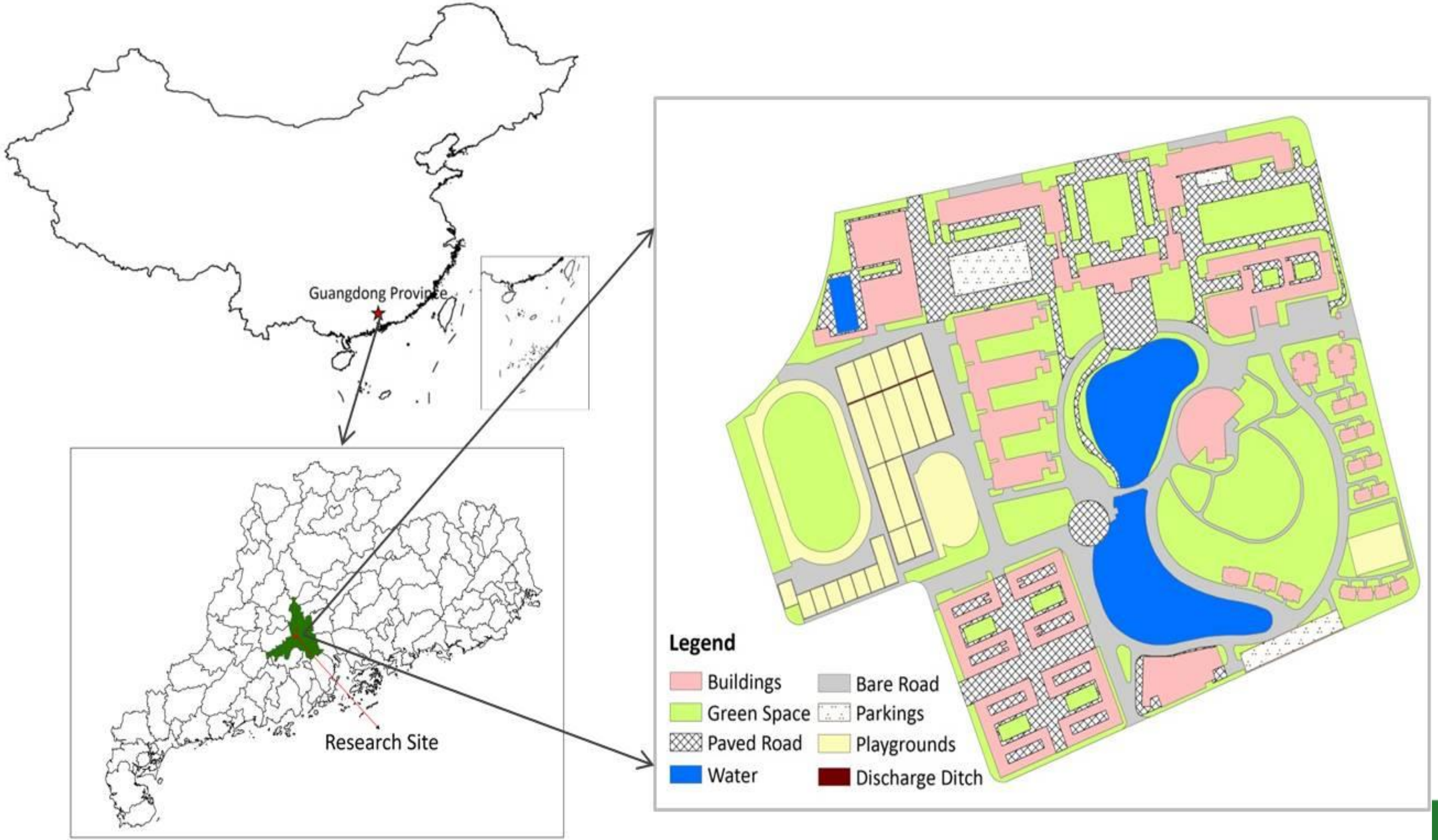
- The types and connection methods of LID facilities are diverse. The existing planning is usually subjective , which requires multi-objective optimization of layout considering economic and environmental benefits.



Methods	Limitations	References
scenario analysis	strong subjectivity, far from pareto optimum	Ahiablame L. M., Engel B. A., Chaubey I. Effectiveness of low impact development practices in two urbanized watersheds: Retrofitting with rain barrel/cistern and porous pavement[J]. Journal of Environment
non-dominated sorting genetic algorithm-II	long calculation time, complex mechanism, premature convergence	Jia H., Yao H., Tang Y., et al. LID-BMPs planning for urban runoff control and the case study in China[J]. Journal of Environmental Management, 2015, 149:65-76
Method-MCGS	Fast and reliable optimization	XU Te, ENGEL Bernard A., SHI Xinmei, LENG Linyuan, JIA Haifeng□. Marginal-cost-based greedy strategy (MCGS): Fast and reliable optimization of low impact development (LID) layout. Science of the Total Environment. 2018 (640–641): 570–580.

A Case study in Foshan city based on NSGA-II)

- Guangdong College of Environment Protection: New campus in Foshan city



Case Study Introduction

- Climate
  - Subtropical monsoon climate, Plenty of sunshine
  - Annual average temperature 22-23℃,
  - Annual rainfall: 1622mm
- Rainfall in Typical year
- Topography
- Land use
- Drainage system
- Soil characteristics

Layer	Soil type	Height of layer（m）	Top level of layer（m）
artificial filled soil	人工填土 artificial filled soil	0.40-8.60	
第四系全新统冲洪积层 Quaternary holocene alluvial layer	淤泥质粉质粘土 Soft silty clay	0.50-5.50	0.00-8.40
第四系全新统坡洪积层 Quaternary holocene alluvial layer	粘土 Clay	0.60-9.50	0.00-7.20
第四系上更新统冲洪积层 Quaternary epipleistocene alluvial layer	粉砂 Silty sand	0.50-6.70	5.00-11.50
	粘土 Clay	0.90-7.70	0.40-12.50
第四系残积层 Quaternary eluvium	粉质粘土 Silty clay	0.80-25.10	0.00-12.40
第三系地层 下伏基岩 Tertiary underlying rock	强风化泥质砂岩/砂质泥岩 Strong-weathered rock	0.80-33.30	0.00-28.50
	中等风化泥质砂岩/砂质泥岩 medium-weathered rock	0.50-11.70	7.70-37.30
	微风化泥质砂岩/砂质泥岩	0.60-5.70	10.00-42.00

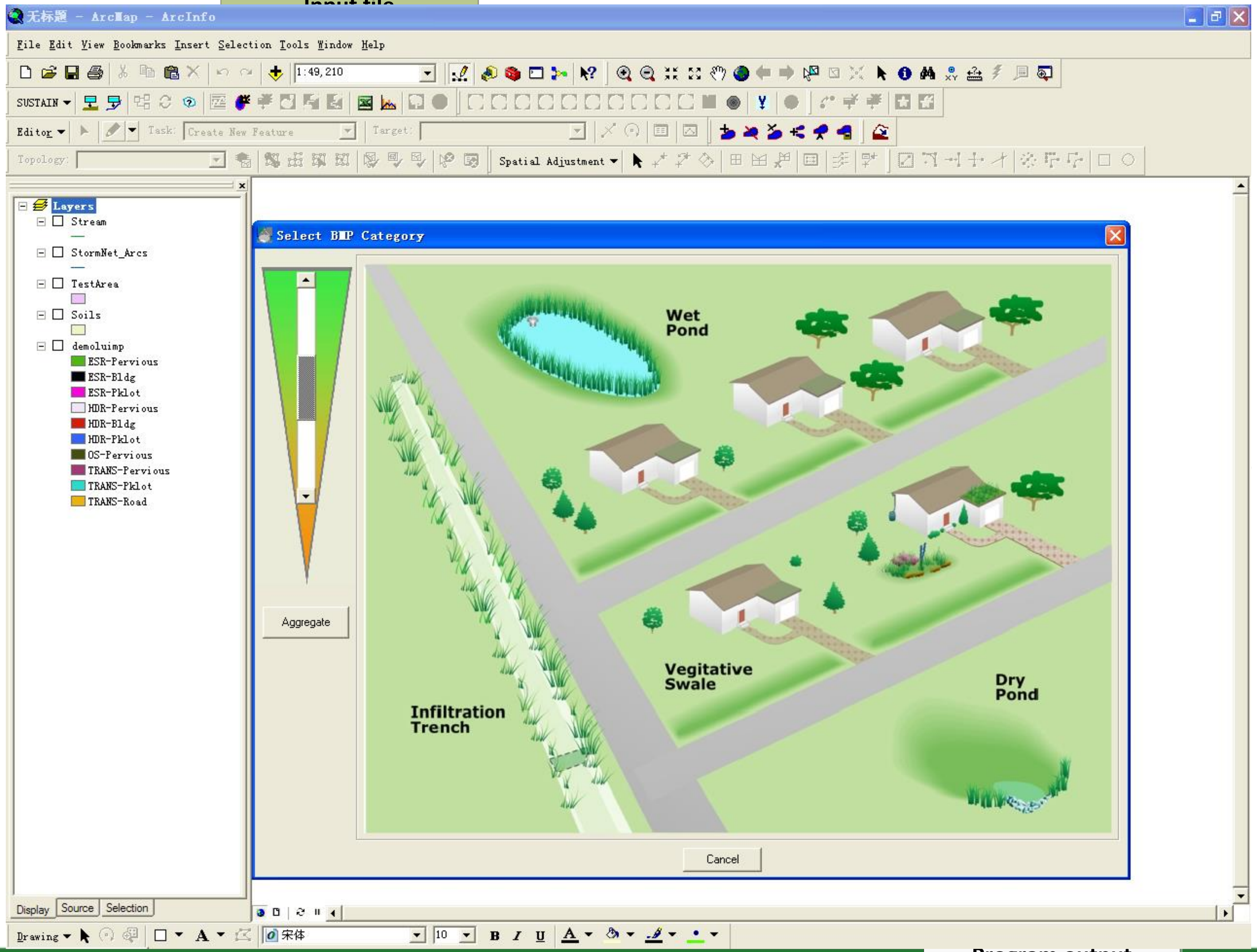
Preliminary selection of suitable LID BMPs

BMPs	Landuse and Location			Soil	Groundwater	Topography	Watershed characteristics		Space
	Landuse type	Pollution load intensity	Special requirement	type	Groundwater level to bottom of BMPs facility	Slope (%)	Service areas (hm)	Ratio of impervious areas (%)	occupied (hm)
Infiltration Trench	R,C,S,T,G	medium	Building buffer distance >3m Stream buffer distance >30m	A-B	>3	<15	<2	>0	medium
Infiltration Basin	R,C,S,G	medium	Stream buffer distance >30m	A-B	>3	<15	1-4	>0	Large
Dry Detention Pond	R,C,S,G	medium	Higher topography Stream buffer distance >30m	A-D	>1.22	<10	>4	>0	large
Wet Detention Pond	R,C,S,G	medium	Stream buffer distance >30m	A-D	>1.22	<10	>6	>0	large
Vegetated Filter Strip	R,C,S,M,T,G	high	Around Impervious surface Road buffer distance <30m	A-D	>0.61	<5	-	>0	medium
Grassed Swale	R,C,S, T,G	medium	Around Impervious surface Road buffer distance <30m	A-D	>0.61	0.5-5	<2	>0	medium
Constructed Wetland	R,C,G	medium	Stream buffer distance >30m	B-D	>1.22	4-15	>10	>0	large
Sand Filter	R,C,M,T	medium	Stream buffer distance >30m	A-D	>0.61	<10	<40	0-50	small
Green Roof	R,C,M	low	Flat roof	-	-	<4	-	-	-
Rain Barrel	R,C	low	Building buffer distance	-	-	-	-	-	small

Simulation and optimization tool : SUSTAIN

SUSTAIN: System for Urban Stormwater Treatment and Analysis INtegration

Input file



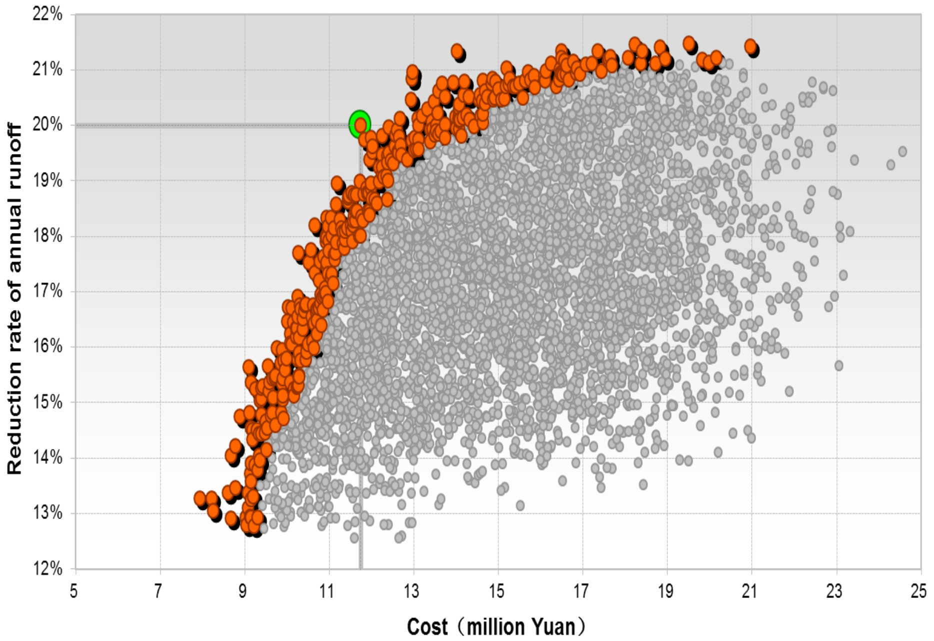
Program output

Basic scenario: the previous development scheme

- Drainage System simplification
  - Reclassification of Landcover : Roof; Road; Grass; water
- Basic scenario
  - Water Quantity simulation
    - Total runoff
    - Peak flow
  - Water Quality simulation
    - COD
    - SS
    - TN
    - TP

LID scenarios

- LID-BMPs design and optimization



JIA Haifeng, **YAO** Hairong, TANG Ying, YU Shaw L, Richard Field; Anthony N. Tafuri. *LID-BMPs planning for urban runoff control and the case study in China*. Journal of Environmental Management. 2015，149 : 65-76.

A Fast and reliable optimization Method

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Marginal-cost-based greedy strategy (MCGS): Fast and reliable optimization of low impact development (LID) layout

Te Xu [a], Bernard A. Engel [b], Xinmei Shi [a], Linyuan Leng [a], Haifeng Jia [a,*], Shaw L. Yu [c], Yaoze Liu [b]

[a] School of Environment, Tsinghua University, Beijing, China
[b] Department of Agricultural & Biological Engineering, Purdue University, West Lafayette, IN, USA
[c] Department of Civil & Environmental Engineering, University of Virginia, Charlottesville, VA, USA

Method-MCGS

Marginal-Cost based on Greedy Strategy，MCGS

- In economics, marginal cost (MC) measures the opportunity cost that arises when producing one more unit of a good. Expanded to a USWM system, the marginal cost of placing an extra ratio of a certain LID practice can be defined as:

$$MC_{i,t} = -\frac{dC_i}{dU}|_{S_{t-1}} \approx -\frac{C_{i,t}-C_{t-1}}{U_{i,t}-U_{t-1}}|_{\varphi_{i,t}=S_{i,t-1}+\Delta}$$

$\boldsymbol{S_t}$:a vector that represents placing ratios of each LID practice at the –th stage

U :environmental indicators

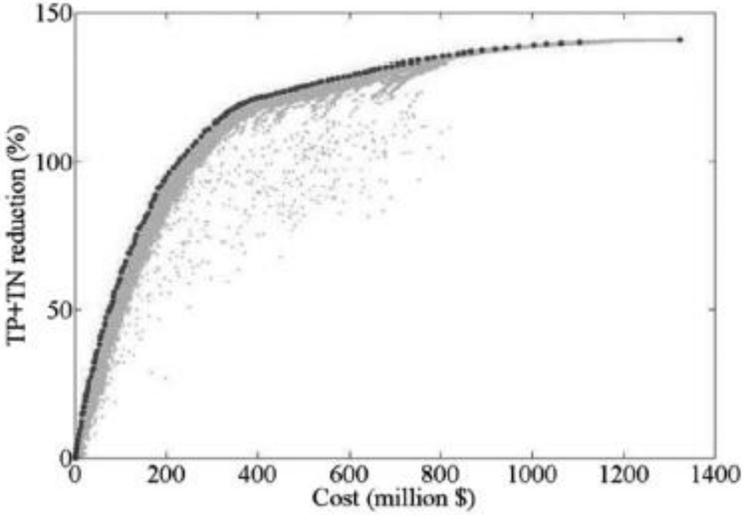
C :economic indicators

$\boldsymbol{\varphi}$:decision variable

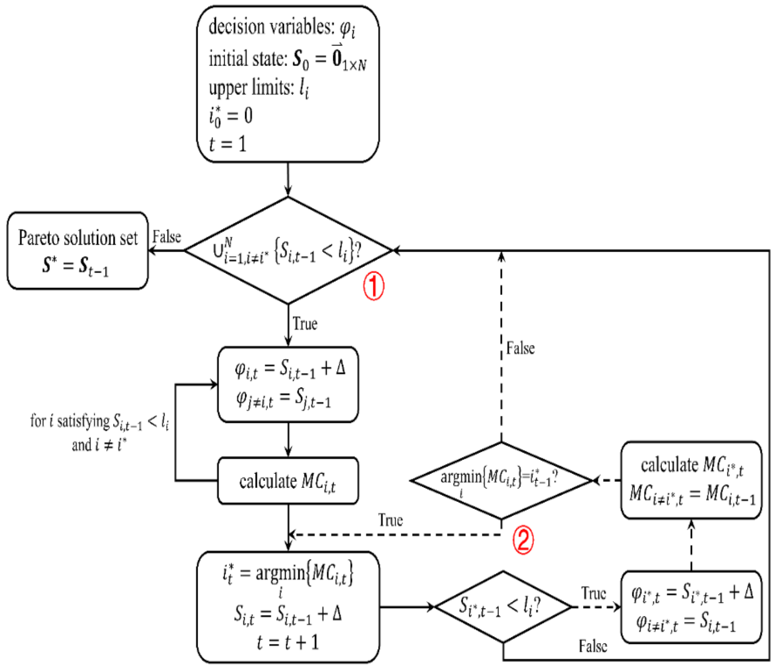
- According to this definition, the economic law of increasing MCs can be expressed as the following two conditions

$$\frac{\partial MC_i}{\partial \varphi_i} \geq 0$$

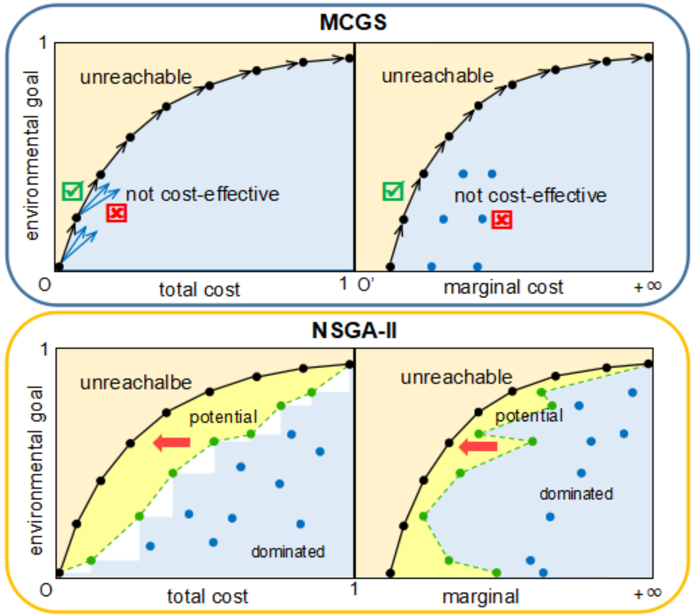
$$\frac{\partial MC_j}{\partial \varphi_i} \geq 0, \forall j \neq i$$



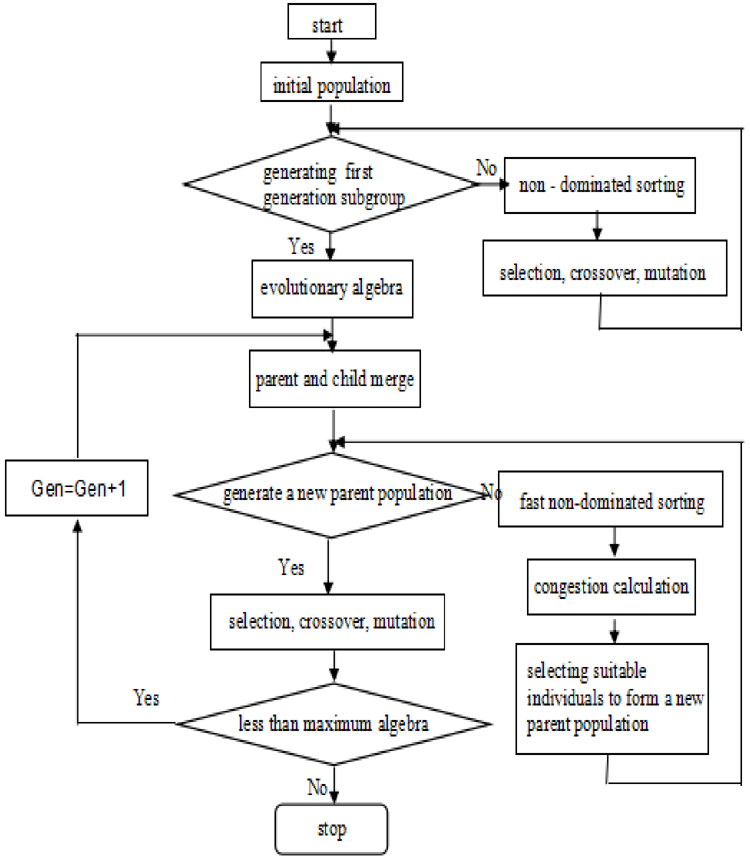
MCGS & NSGA



Programming flowchart of Marginal-Cost-Based Greedy Strategy. Digit One with the solid arrows represents the output loop. Digit Two with the dashed arrows represents the inner loop.

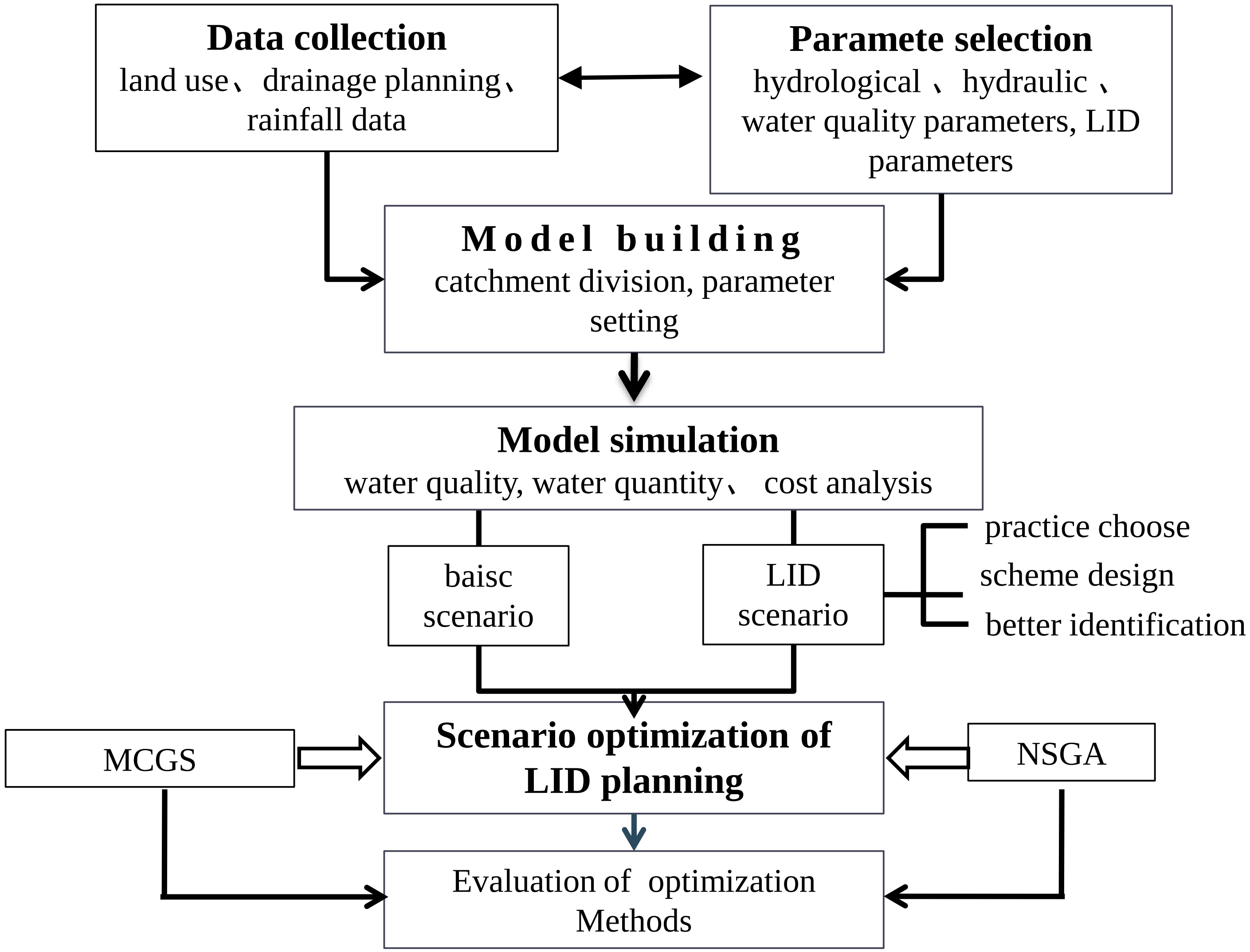


Graphical explanations and comparisons of NSGA-II (right) and MCGS (right).

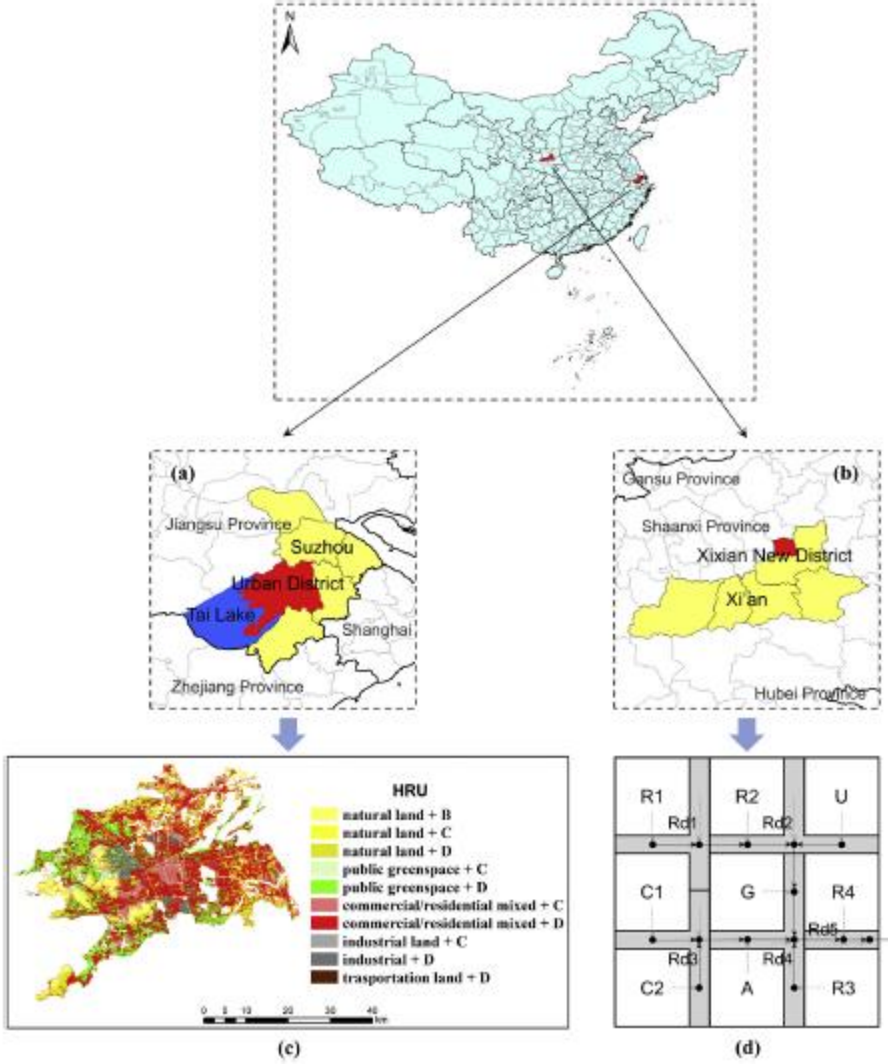


Programming flowchart of NSGA

Case study



Data collection
land use、drainage planning、rainfall data
Paramete selection
hydrological 、hydraulic 、water quality parameters, LID parameters
Model building
catchment division, parameter setting
Model simulation
water quality, water quantity、 cost analysis
baisc scenario
LID scenario
practice choose
scheme design
better identification
MCGS
Scenario optimization of LID planning
NSGA
Evaluation of optimization Methods



(a)
Jiangsu Province
Suzhou
Urban District
Tai Lake
Shanghai
Zhejiang Province
(b)
Gansu Province
Shaanxi Province
Xixian New District
Xi'an
Hubei Province
HRU
natural land + B
natural land + C
natural land + D
public greenspace + C
public greenspace + D
commercial/residential mixed + C
commercial/residential mixed + D
industrial land + C
industrial + D
trasportation land + D
R1
R2
U
Rd1
Rd2
C1
G
R4
Rd5
Rd3
Rd4
Outfall
C2
A
R3
(c)
(d)

Contents

LCA evaluation of LID BMPs

Bioretention Cell with Gravel Inlet Chamber

Grassed Swale

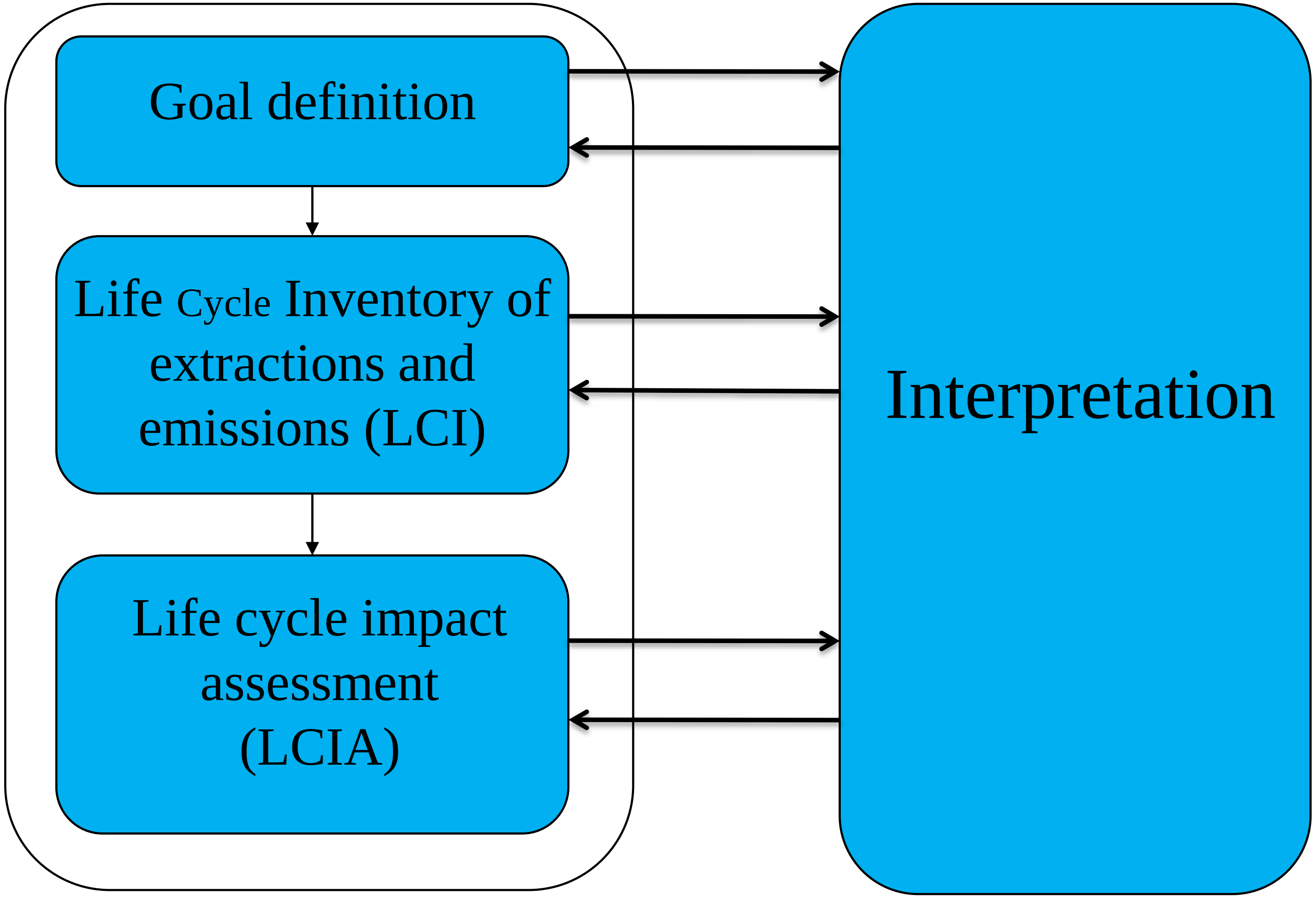
Constructed Wetland

Infiltration Pit

Source	Parameter					
	TSS (%)	NH_3-N	TN	TP	Cu	Zn
Removal efficiencies in 2013 in this study	36.44	62.18	59.43	0.00	69.45[a]	100[a]
Li et al. (2008)	93		63	57	63	95
Brown et al. (2011)	82	54	19	44		
Center for Watershed Protection (2007)	59		46	5	81	
Chapman et al. (2011)	87		63	67	80	
Geosyntec, Inc et al. (2011)	77	76	72	73		
Mangangka et al. (2015) (long dry period (>6 days))	80.78	82.21	40.93	75.33		
Mangangka et al. (2015) (short dry period (<6 days))	61.81	49.31	38.70	36.42		
Chen et al. (2013)			56			
Trowsdale and Simcock (2011)	45–70					

- **Materials production, consumption and transportation**
- **Maintenance and disposal can bring about environmental and economic burdens**

LCA evaluation of LID BMPs



LCA evaluation of LID BMPs

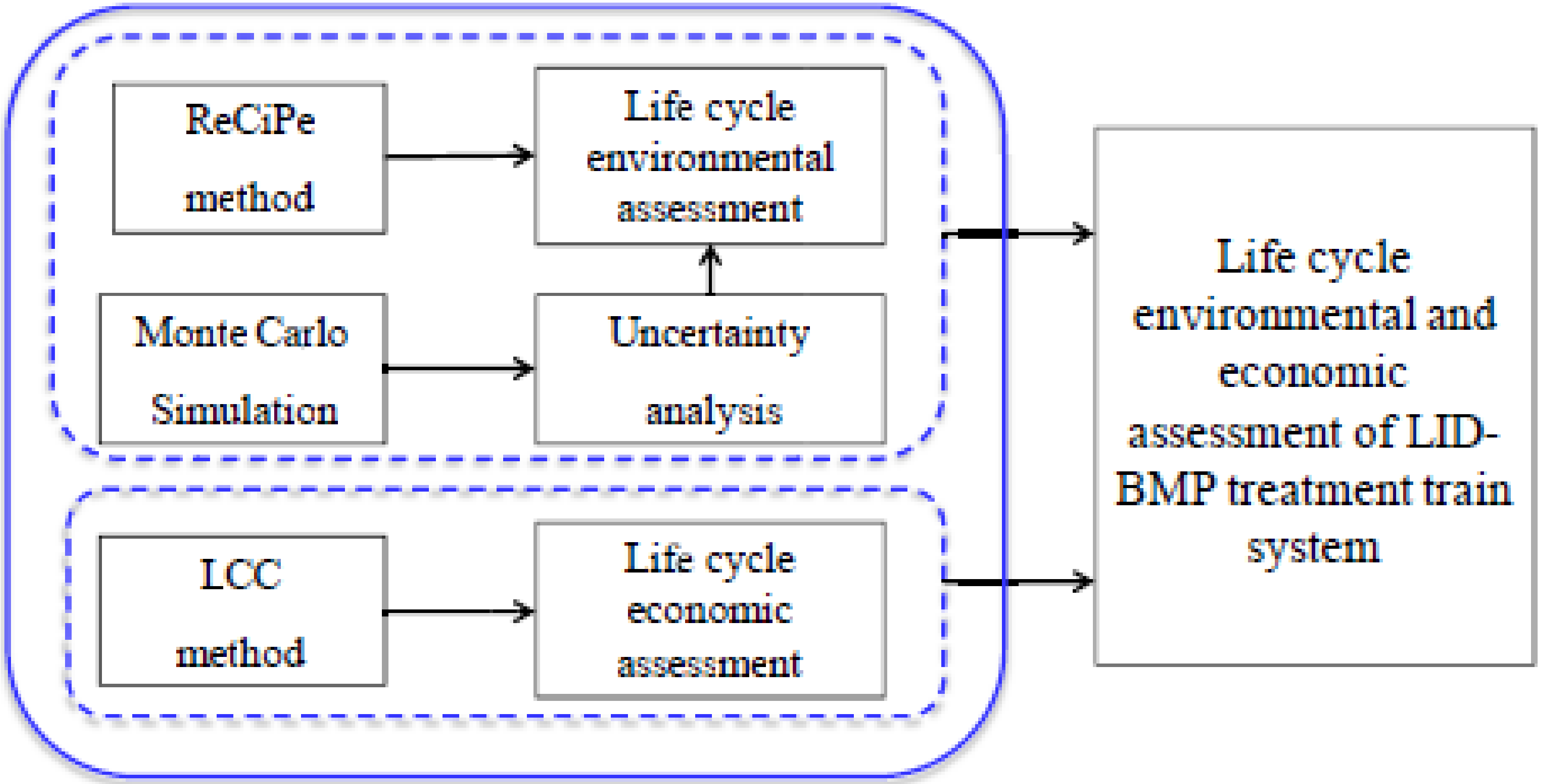


Fig. 1. Structure of the models.

LCA evaluation of LID BMPs

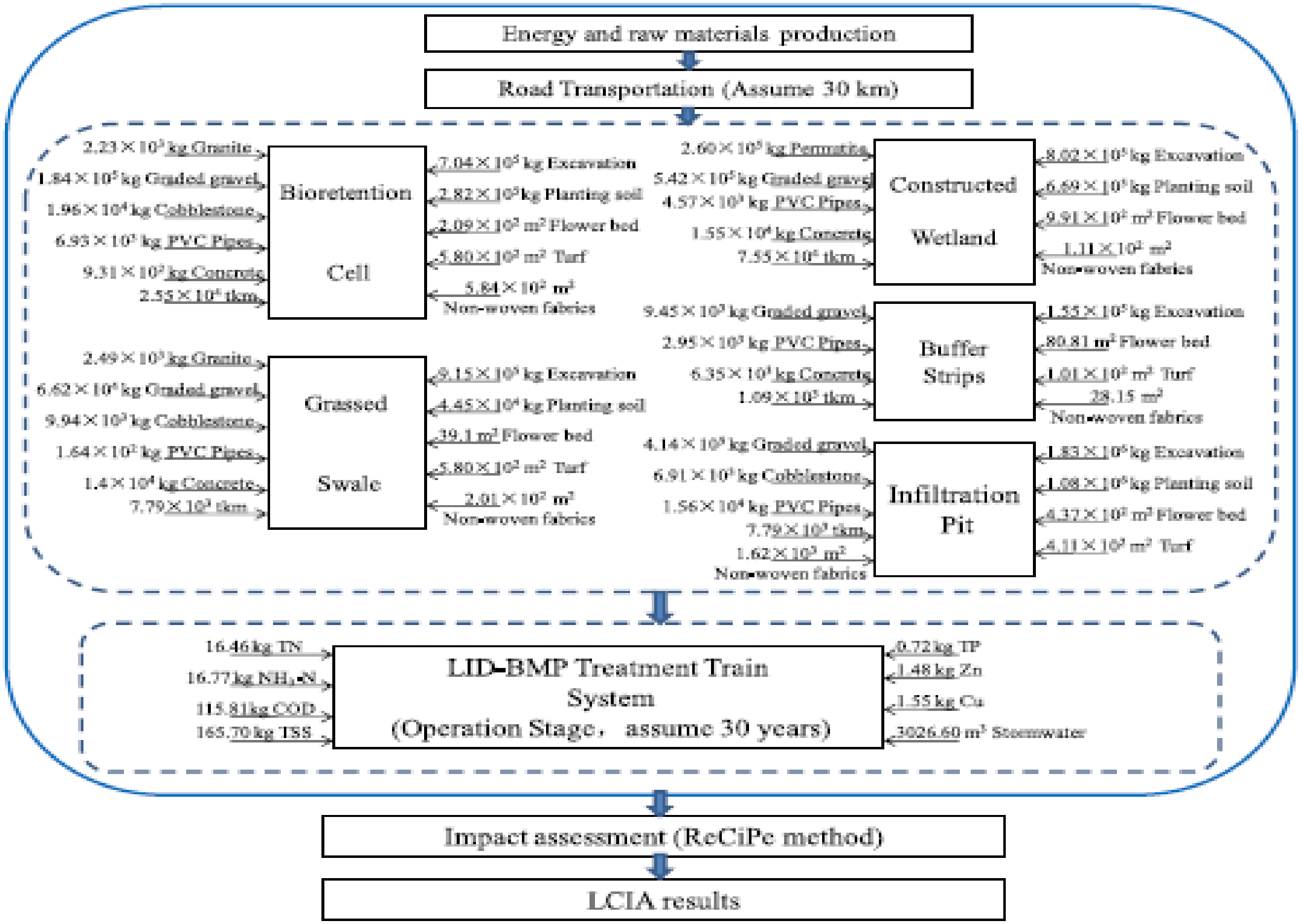


Fig. 2. System boundary and mass flow of LID-BMP practices.

XU Changqing, HONG Jinglan, JIA Haifeng*, etc. Life cycle environmental and economic assessment of a LID-BMP treatment train system: A case study in China. *Journal of Cleaner Production*, 2017,149 :227-237.

Recent published English papers in Sponge city and LID

- XU Te, ENGEL Bernard A., SHI Xinmei, LENG Linyuan, JIA Haifeng□. Marginal-cost-based greedy strategy (MCGS): Fast and reliable optimization of low impact development (LID) layout. Science of the Total Environment. 2018 (640–641): 570–580.
- JIA Haifeng, YU Shaw L. DAVIS Allen P. Green Infrastructure and Sponge City Research. Journal of Sustainable Water in the Built Environment. 2018, 4(4): 02018001
- JIA Haifeng, YU Shaw L, QING Huapeng. Low impact development and sponge city construction for urban stormwater management. Frontiers of Environmental Science & Engineering, 2017, 11 (4), 20.
- XU Changqing, HONG Jinglan, JIA Haifeng*, etc. Life cycle environmental and economic assessment of a LID-BMP treatment train system: A case study in China. Journal of Cleaner Production, 2017,149 :227-237.
- XU Te, JIA Haifeng, WANG Zheng, etc. SWMM-based methodology for block-scale LID-BMPs planning based on site-scale multi-objective optimization: a case study in Tianjin. Frontiers of Environmental Science and Engineering, 2017, 11: 1.
- JIA Haifeng*, WANG Zhen, ZHEN Xiaoyue,etc. China's Sponge City Construction: A Discussion on Technical Approaches. Frontiers of Environmental Science and Engineering, 2017,11(4): 18
- Han Yu， Jia Haifeng*. Simulating the spatial dynamics of urban growth with an integrated modeling approach: A case study of Foshan, China. Ecological Modelling, 2017, 353, :107-116. DOI: 10.1016/j.ecolmodel.2016.04.005

Recent published English papers in Sponge city and LID

- MAO Xuhui, et al. Assessing the ecological benefits of aggregate LID-BMPs through modelling. Ecological Modelling, DOI: 10.1016/j.ecolmodel.2016.10.018
- JIA Haifeng, et al. Field Monitoring of an LID-BMP Treatment Train System in China, Environmental Monitoring and Assessment. 2015, 187(6):4595. DOI:10.1007/s10661-015-4595-2
- JIA Haifeng, et al. LID-BMPs planning for urban runoff control and the case study in China. Journal of Environmental Management, 2015, 149 (1): 65-76.
- JIA Haifeng, et al. A closed urban scenic river system using stormwater treated with LID-BMP technology in a revitalized historical district in China. Ecological Engineering, 2014, 71:448-457.
- JIA Haifeng, et al. Development of A Multi-Criteria Index Ranking System for Urban Stormwater Best Management Practices (BMPs) Selection. Environmental Monitoring and Assessment, 2013, 185(9):7915-7933.
- JIA Haifeng et al. The advances of LID BMPs research and practices for urban runoff control in China. Frontiers of Environmental Science & Engineering, 2013, 7(5):709-720.
- JIA Haifeng, et al. Planning of LID-BMPs for urban runoff control: The case of Beijing Olympic Village. Separation and Purification Technology, 2012, 84:112-119.

Acknowledgement:

It is funded by 国家自然基金，国家水专项，北京市，佛山市，and USEPA

谢谢☺

Thank you