Nature Based Solutions for Sustainable Urban Storm Water Management in Global South: A Short Review

Presented By : Mr. Fahad Ahmed

Corresponding author : Dr. Ho Huu Loc

(hohuuloc@ait.asia)

Co- Authors:

Mr. Shashwat Sharma

Dr. Ming Fai Chow

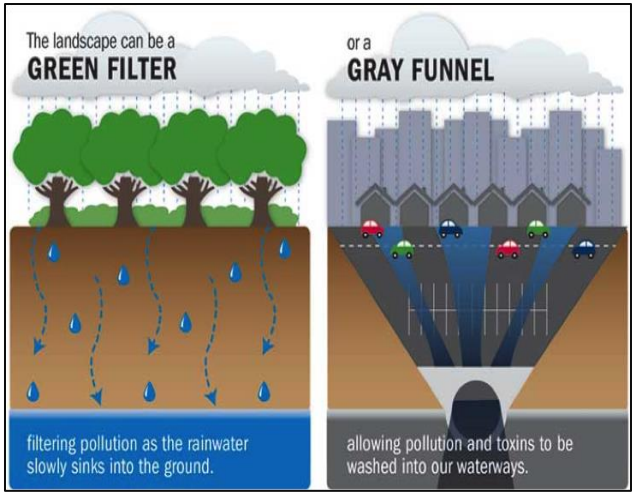
Water Engineering & Management
School of Engineering and Technology
Asian Institute of Technology, Thailand

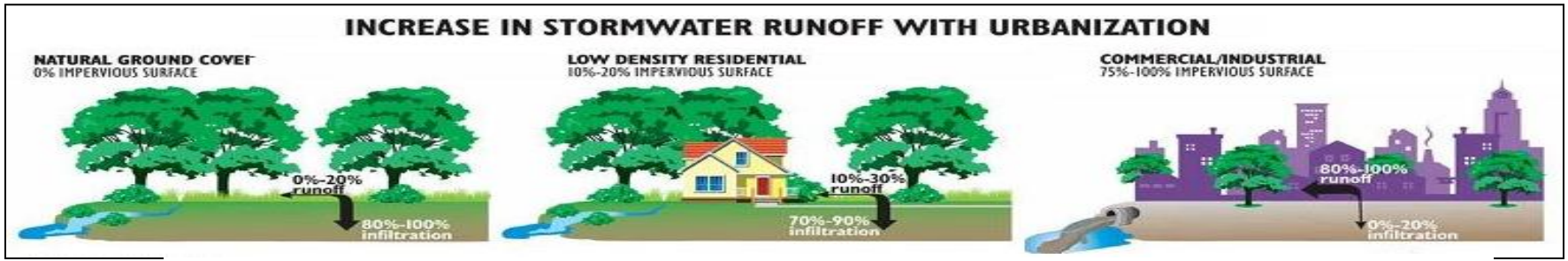
CONTENT

1. Introduction
2. Methodology
3. Results and Discussions
   I. The Literature
   II. The “Old” Concepts
   III. The “New” Waves
   IV. Future Outlooks
4. NBS Project in Asian Institute of Technology (AIT) Thailand
5. Conclusions

Introduction - Background

- In 2050, 68% urban population may increase.
- Climate change will increase severity of rainfall events - escalating dangers of flooding.
- More release of contaminant into waterways.
- Traditional stormwater management techniques control flooding - lack sufficient water quality management





Source: (UNDESA, 2012 ; Revi et al., 2014 ; Muerdter et al., 2018)

Introduction - NBS as Sustainable approach

- Challenges for The Global South - Aging infrastructure, Depleted resources, changing precipitation due to climate change.
- Solution - Change in urban water management and urban planning.
- Need of integrated urban infrastructure solutions - Enable the city to act as a “sponge”
- NBS “A Sustainable approach” - Bio retention systems can potentially attenuate peak flows by 80 % to 96 % reduction.

Source: (Griffiths et al., 2020 ; Winston et al., 2016)

Introduction - NBS (Definition)

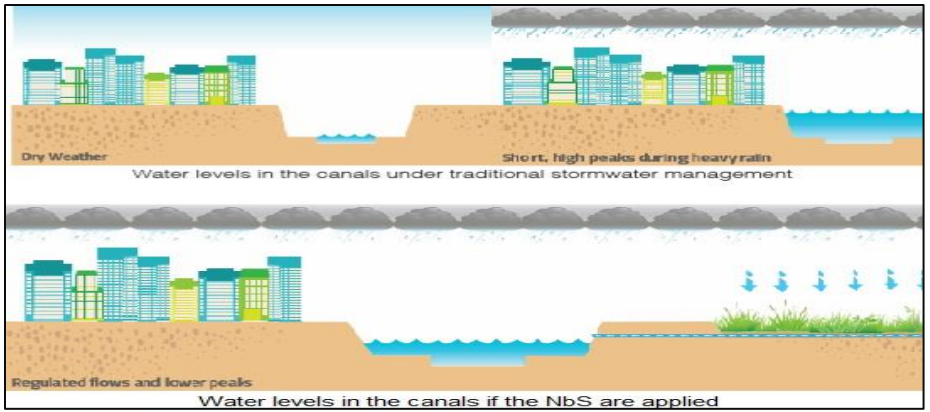
- Nature Based Solutions (NBS) – Solutions using nature and ecosystem services provide:

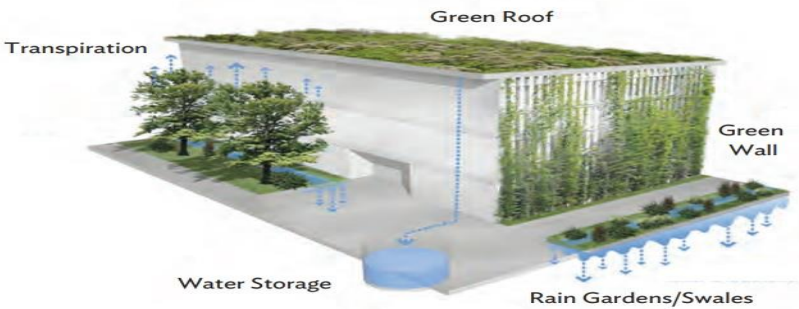
i. Economic benefits

ii. Social benefits

iii. Environmental benefits

(European Commission (EC), 2015)





- NBS using close to nature practices aim:

i. To return water flow regimes as close as possible to the natural level.

ii. To convert the hydrology of the altered basins back into its pre-development pristine conditions.

Methodology

- The following methodology was adapted for the study:

Data base	Scopus
Keywords	Nature based Solutions, Low Impact Development, Green Infrastructure, Urban water Management, Water Sensitive Urban Design
Publication period	2000 to 2021
Focused Regions	Global South : China, Hong Kong, Thailand, Malaysia, Brazil, and Africa,

Methodology - Comparison Of Different NBS Techniques With Benefits

SN	NBS Technique	Description	Benefits
1	Rainwater harvesting / Rain Barrels	Rain barrels are the containers which collect stormwater from roofs and the water can be reused for potable or non-potable purposes in dry periods.	i. Additional water supply source ii. Prevent urban flooding
2	Green roofs	Green roofs have soil layer and a special drainage mat material which convey surplus stormwater from the roof to the drainage system	i. Reduced runoff peaks and volumes ii. Lower flood risks iii. Insulation of heat transfer iv. Low cost for air-conditioning v. Reduced heat island effect vi. Reduced Air pollution vii. Increased biodiversity
3	Rain Gardens/ Bioretention systems	Rain Gardens or Bioretention systems are depressions in soil that contain vegetation in an engineered soil above a gravel / sand drainage bed. It provides storage, evaporation and infiltration.	i. Reduced runoff peaks and volumes ii. Improved water quality iii. Lower flood risks iv. Reduced Air pollution v. Prevent urban flooding vi. Increased biodiversity

Methodology - Comparison Of Different NBS Techniques With Benefits

4	Pervious pavements	Permeable pavements are the pavements made by gravel and paved by porous concrete or paving block or porous bricks which can infiltrate rainwater and convey water to drainage system.	i. Reduced runoff peaks and volumes ii. Lower flood risks iii. Improved water quality iv. Prevent urban flooding
5	Infiltration trenches	Infiltration trenches are the narrow ditches filled with gravel to intercept runoff from the impervious area present at upslope.	i. Reduced runoff volumes ii. Lower flood risks iii. Prevent urban flooding
6	Vegetative swales	Vegetative swales are the channels with sloping sides covered with vegetation or grass. It collects the stormwater and conveys and infiltrates it.	i. Reduced runoff peaks and volumes ii. Lower flood risks iii. Improved water quality iv. Prevent urban flooding

Results and Discussions

- **The Literature**
- Some Noteworthy research on sustainable water management techniques in the global south is presented.
- Number of papers reviewed: 20
- Geographical coverage: China, Hong Kong, Thailand, Malaysia, Brazil, and Africa.
- Number of studies and Terminologies used:

Country	**Number of Studies**	**Terminologies used**
China and Hong Kong	10	LID, Sponge city
Malaysia	4	MSMA, BMP
Thailand	2	NBS, BMP, EBA
Brazil	2	LID
Ethiopia (East Africa):	1	Others
South Africa	1	Others
Total	20	

Results and Discussions - Applications of NBS in Global South

SN	Documents	Study aims	Geographical region	Methods	Terminologies	Type of NBS	Key Findings
1	Mai and Huang.,2021	To investigate the performance of biochar-amended bioretention facilities	China	Physical Modelling	Sponge City and LID	Bio-retention system	NBS can effectively control runoff volume and remove rainfall-runoff pollutants
2	Vojinovic et al.,2021	To examine the efficacy of different types of NBS (i.e., small- and large-scale NBS) and their hybrid combinations with grey infrastructure	Thailand	Interviews / Numerical modelling	NBS and EBA	Small-scale and Large-scale NBS	i. The effectiveness of small-scale NBS is limited to smaller rainfall events ii. The extreme events require combinations of different kinds of measures (hybrid measures)
3	Belle et al.,2018	To investigate the effectiveness of NBS to reduce drought, veld fires and floods using wetlands	South Africa	Questionnaires / interviews / field observations.	Others	Wetlands	Healthy wetlands are effective buffers in reducing disaster risks such as drought, veld fires and floods
4	de Macedo et al.,2019a	To assess the performance of a bioretention basin in a subtropical climate area	Brazil	Monitoring / Analysis	LIDs	Bio-retention system	i. Delayed and reduced peak flows. ii. Retained greater volume of runoff

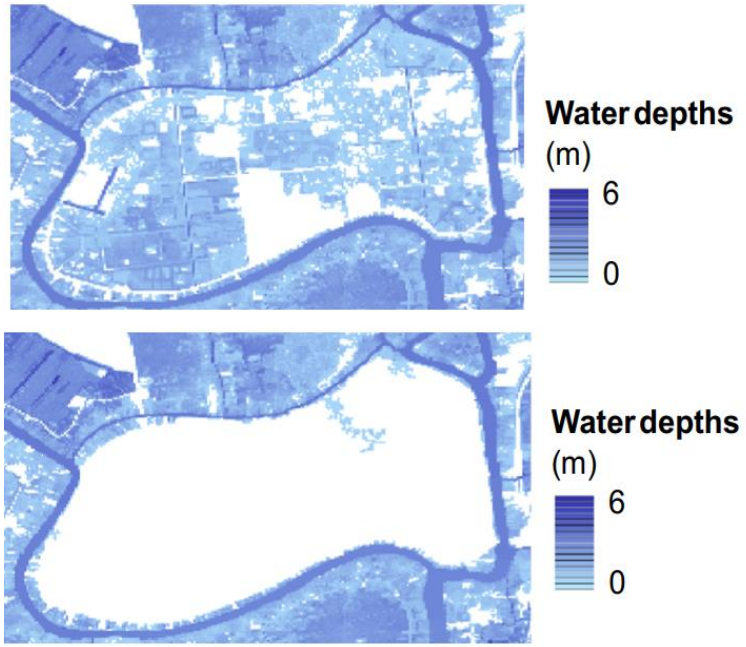
Results and Discussions - Applications of NBS in Global South

- Vojinovic et al.,2021
- Case study in Ayutthaya, Thailand
- Three scenarios:

1. Combination of small-scale NBS and local grey infrastructure measures
2. Combination of large-scale NBS and local grey infrastructure measures
3. Combination of small- and large-scale NBS and local grey infrastructure measures

- Scenarios were evaluated using hydrodynamic modelling.

- Scenario 3 to provide flood protection, biodiversity and socio-economic benefits

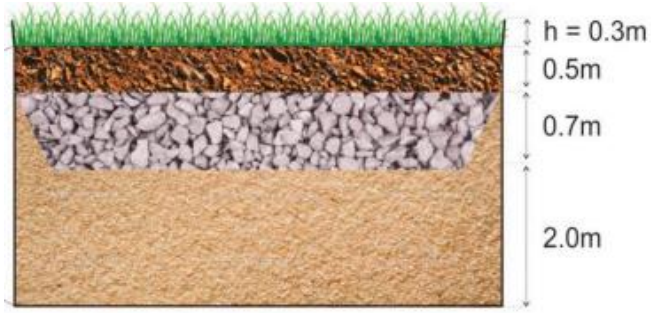


Effectiveness of large-scale NBS (above) vs Effectiveness of hybrid measures (below) for 2011 flood event

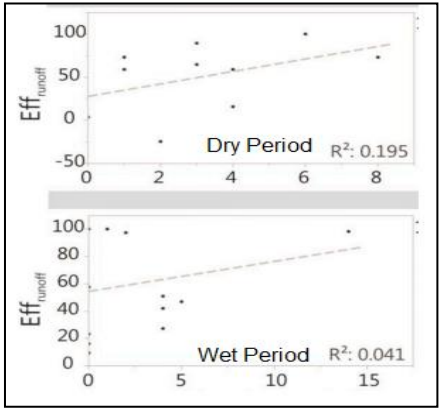
Results and Discussions - Applications of NBS in Global South

- de Macedo et al.,2019a
- Case study in Sao Carlos, Brazil
- Performance of a bioretention system analyzed through 29 precipitation events.
- Runoff retention efficiency: 9% to 100.
- Higher efficiency for dry period: 73%.
- Lower efficiency for wet period: 61%.
- Dry period performance affected by the previous soil moisture.
- Most important variables for wet period: Total Precipitation and Maximum Rainfall intensity.

- Bioretention system retained greater amount of runoff volume



Internal composition of bioretention system



Linear regression and correlation for Runoff retention efficiency

Results and Discussions - The "Old" Concepts

- **Low Impact Development (LID)**
  - Term generally used in North America and New Zealand.
  - Used by "Barlow et al. (1977)" for the first time in USA.
  - LIDs - Approaches for reducing impervious cover and maintaining or retaining natural areas through site design.

- **Use in Global South for Urban water management:**

  - Study conducted by: Macedo et al. (2019a and 2019b).
  - Location: Brazil
  - **Study outcomes:**

1. Reduced peak flows,
2. Greater amount of runoff volume retained.
3. Significant peak flow attenuation.

Results and Discussions - The "Old" Concepts

- **Best Management Practice (BMP)**
  - Term generally used in United States of America and Canada.
  - BMP :

1. Approach that address one or both of the water quality and quantity concerns.
2. Link non-structural interventions with structural deployments to achieve the overall goal of pollution control.

- **Use in Global South for Urban water management:**

  - Study conducted by: Goh et al., 2017 and Chang et al., 2018
  - Location: Malaysia
  - **Study outcomes:**

1. NBS are Potential application for nutrient rich stormwater in mixed land.
2. NBS – A long-term solution for floods and runoff quality control.

Results and Discussions - The “Old” Concepts

- **Sustainable Urban Drainage Systems (SUDS)**
  - Term generally used in United Kingdom.
  - Described in an extensive set of standards published in 2000 (CIRIA, 2000).
  - SUDS - A collection of technologies for draining stormwater that are more environmentally friendly than traditional approaches.

- **Water Sensitive Urban Design (WSUD)**
  - Term generally used in Australia.
  - Used by “Mouritz (1992)” for the first time in Australia.
  - WSUDS - cover all aspects of integrated urban water cycle management, including water supply, sewerage, and stormwater management.

Results and Discussions - The “New” Waves

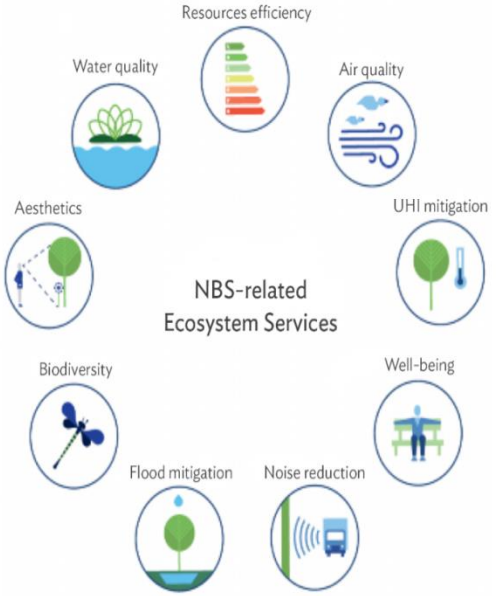
- **Nature Based Solutions (NBS)**

- NBS - Activities to protect, sustainably manage, and restore natural and modified ecosystems in ways that effectively and adaptively solve societal concerns, providing both human welfare and biodiversity benefits (IUCN, 2020).
- NBS can help in three areas (According to WWAP 2018):

1. Enhanced water availability.
2. Improved water quality.
3. Reduced water-related risks.

- Singapore and Lisbon - transitioning from concrete "grey" infrastructure to "blue and green" infrastructure (Cui et al., 2021).

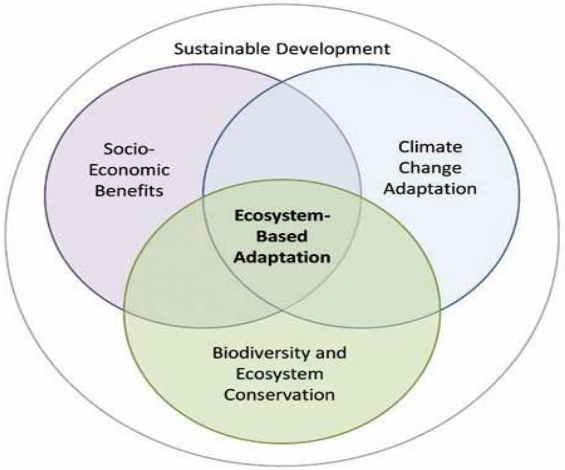
- By implementing NBS turned ecological challenges into opportunities.



Results and Discussions - The "New" Waves

- **Ecosystem Based Adaptation (EBA)**
  - Leverage ecosystems and processes to achieve adaptation goals.
  - Tool for improving soil and water conservation strategies and agricultural development.

EBA structural measures	EBA Non-structural measures
Filter strips	No-tillage
Sediment ponds	Nutrient management strategies
Grassed rivers	
Grade stabilization structures	
Stream stabilization structures	
Agricultural management methods	



  - **Some EBA Benefits:**

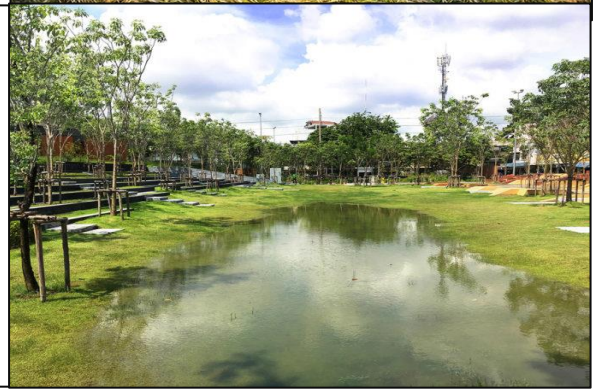
1. Restricting nutrient and sediment input in rivers and streams (Gathagu et al., 2018).
2. EBA combat watershed deterioration in Thailand (Babel et al., 2021).

Results and Discussions - The “New” Waves

NATURE BASED SOLUTIONS PROJECTS IN KINGDOM OF THAILAND

- **Puey Ungphakorn Centenary Hall and Park**
- Location: Thammasat University, Pathumthani.
- Area: 60,000 square meter.
- NBS Type: Green Roof Urban Farm.

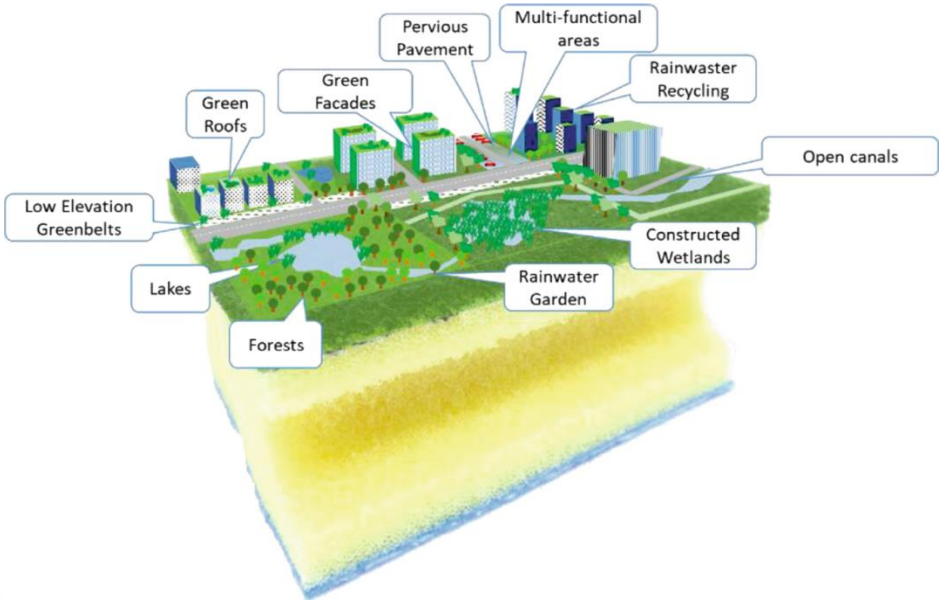
- **Chulalongkorn University Centenary Park**
- Location: Chulalongkorn University, Bangkok.
- Area: 44,800 square meter.
- NBS Type: Green roof, wetland, detention lawn and retention pond.



Results and Discussions - The “New” Waves

- **Sponge City Strategy**
  - Launched by Chinese central government in 2014 (MOHURD, 2014).
  - Similar to LIDs WSUDs and SUDS.
  - Intends to employ NBS to execute stormwater management by:

1. Reducing urban flood risk.
2. Capturing, purifying, and storing more rainwater for potable and non-potable uses.
3. Providing additional ecological advantages through shared green areas.



Future Outlooks

- Global south plagued by calamities: floods and droughts
- As they are economically weak – NBS for urban water management is essential.
- A system that can provide all benefits with low-maintenance is desirable.
- **“Building Back Better”**
- NBS - A response to impacts arising from COVID-19.
- NBS can:

1. Provide jobs.
2. Generate economic growth.
3. Restore the natural environment.
4. Support biodiversity.
5. Enhanced social interaction.
6. Promotion of physical activity.

A “Social distancing lawn” in Poland

- A global increase in the use of urban green spaces during the COVID-19 pandemic.

NBS Project in Asian Institute of Technology (AIT) Thailand

- **Overall objective**
  - To design a Nature-Based Solutions physical model for urban storm water management in Asian Institute of Technology, Thailand.
  - Type of NBS: Bioretention system.
  - Methods: MCDA, Numerical modelling (PSCWMM), Climate Resilient Cities (CRC) tools.

- **Contribution in prospective research**

1. WEM labs.
2. WEM students.
   - Pilot model - Implementation of NBS in Thailand.
   - Enhancement of biodiversity and aesthetics.
   - Other benefits:

1. Air quality control and improvement.
2. Improvement for the quality of life of residents.

Conclusions

- Global South - mostly made up of poor countries with weak economies.
- Issues – Climate change, overpopulation, rapid urbanization, anomalies in the hydrologic cycle, floods and droughts.
- Need of strategies for urban water management – NBS and EBA.
- Barriers - Associated costs and local people's desire.
- Bridges - Public awareness and collaboration from local government entities.

Some References

- CIRIA, (2000). Sustainable urban drainage systems - design manual for Scotland and Northern Ireland. Dundee, Scotland: CIRIA Report No. C521.
- Griffiths, J., Chan, F.K.S., Shao, M., Zhu, F., Higgitt, D.L., (2020). Interpretation and application of Sponge City guidelines in China. Philos. Trans. A. Math. Phys. Eng. Sci. 378, 20190222.
- MOHURD (2014) (Ministry of Housing and Urban-Rural Development of the People's Republic of China), Technical Guidelines for Sponge City Construction (in Chinese).
- Mouritz, M., (1992). Sustainable urban water systems; policy & pofessional praxis. Perth, Australia: Murdoch University.
- Muerdter, C.P., Wong, C.K., LeFevre, G.H. (2018). Emerging investigator series: the role of vegetation in bio-retention for stormwater treatment in the built environment: pollutant removal, hydrologic function, and ancillary benefits. Environ. Sci.: Water Res. Technol. 4 (5) 592–612.
- UNDESA. (2012). World Urbanization Prospects: the 2012 Revision.
- WWAP (United Nations World Water Assessment Programme)/UN-Water. (2018). The United Nations World Water Development Report 2018: Nature-Based Solutions for Water; UNESCO: Paris, France.