Modeling water trading to support integrated green infrastructure and water resources management in an arid watershed

Mengxiang Zhang and Dr. Ting Fong May Chui

Department of Civil Engineering
The University of Hong Kong

Email: mxzhang6@connect.hku.hk

May. 25, 2022

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THE UNIVERSITY OF HONG KONG

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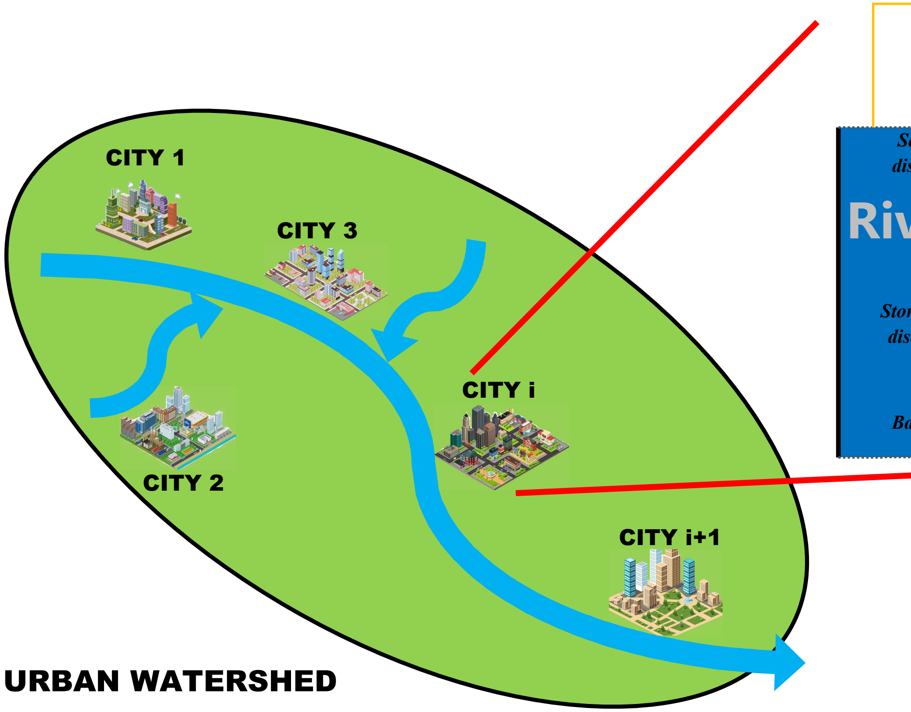
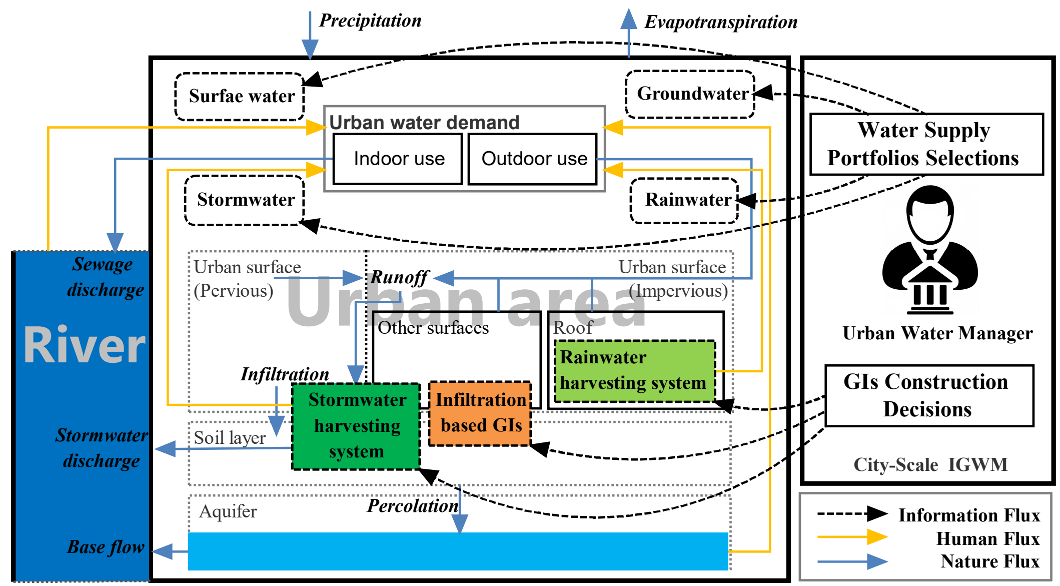
Background

Green infrastructures (GIs) have been developed in many countries, such as the U.S.A., U.K., China, and Australia, to capture rainwater for water supply.





IGWM

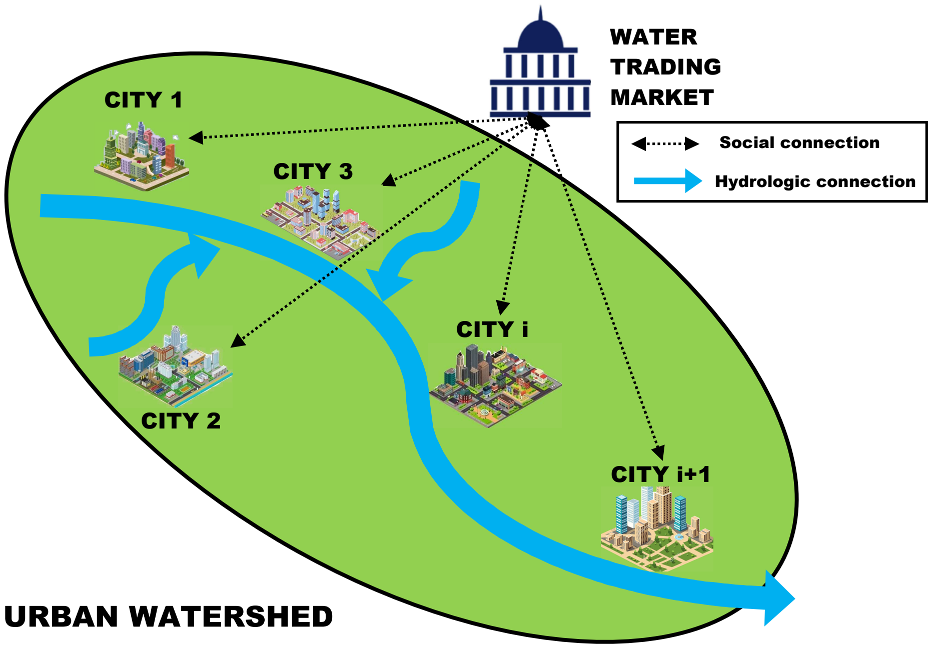
GIs planning & operations
+
Urban water system operations
= Integrated GIs and water resources management (IGWM)

Motivation

- Need to explore externalities of IGWM on socio-hydrological environments of a watershed.
- Need to design appropriate policies to regulate dynamics induced by IGWM activities of multiple cities for sustainability.

Research Topic

Design and anaylsis of a water trading scheme for IGWM in a watershed that consists of multiple urban areas



Research Problems

- **Problem 1:** What is the optimized water trading scheme for IGWM ?
- **Problem 2:** How would the scheme affect watershed socio-hydrologic environments ?
- **Problem 3:** What is the role of GIs in the scheme ?

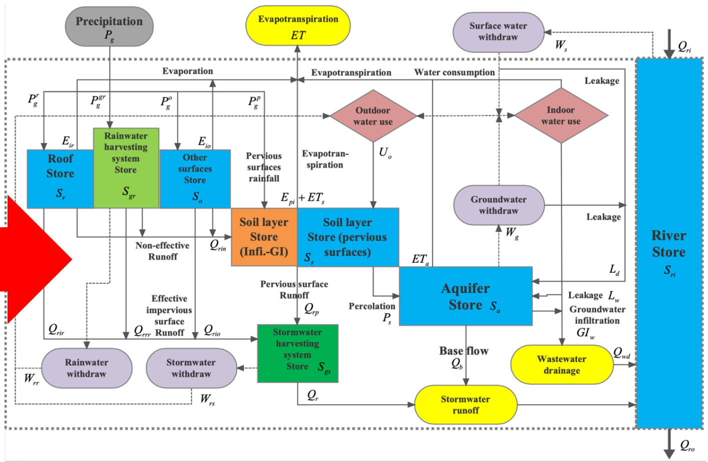
Multiagent system (MAS) framework for IGWM at watershed scale

$$\min_{x_i, y_i} TC_i = C_{gi} + C_{si} + C_{wi}$$

$$s.t. \begin{cases} C_{gi} = f_1(y_i), \\ C_{si}, C_{wi} = f_2(x_i), \\ g_1(y_i) \le 0, \\ g_2(x_i) \le 0, \\ x_i, y_i \ge 0 \end{cases}$$

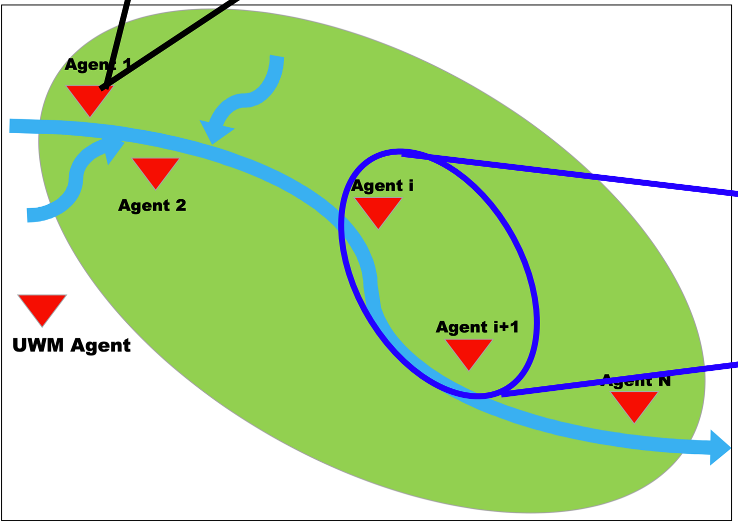
IGWM Optimization model

Coupling



Urban water balance simulation model

Agent-based model for city-scale IGWM



$$IQ^t(i+1) = c_1 \cdot OQ^t(i) + c_2 \cdot OQ^{t-1}(i) + c_3 \cdot IQ^{t-1}(i+1)$$

channel-flow routing model

Hydrologic connection

MAS for IGWM

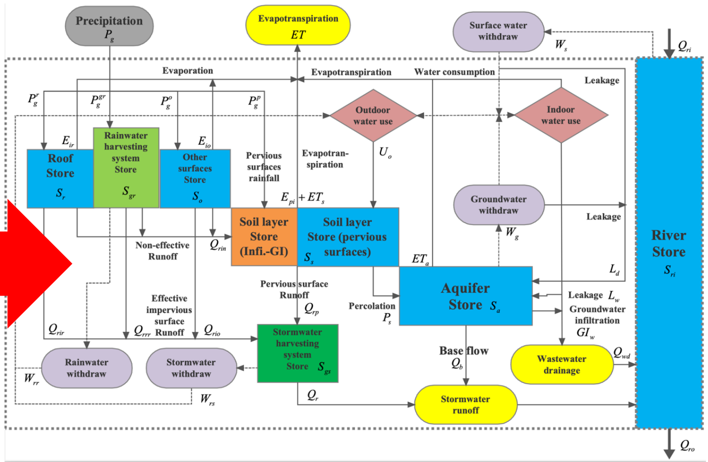
Water trading scheme for IGWM via extended MAS

Lotic marketable water right system

$$\min_{x_i, y_i, t_i} TC_i = C_{gi} + C_{si} + C_{wi} + C_{ti}$$

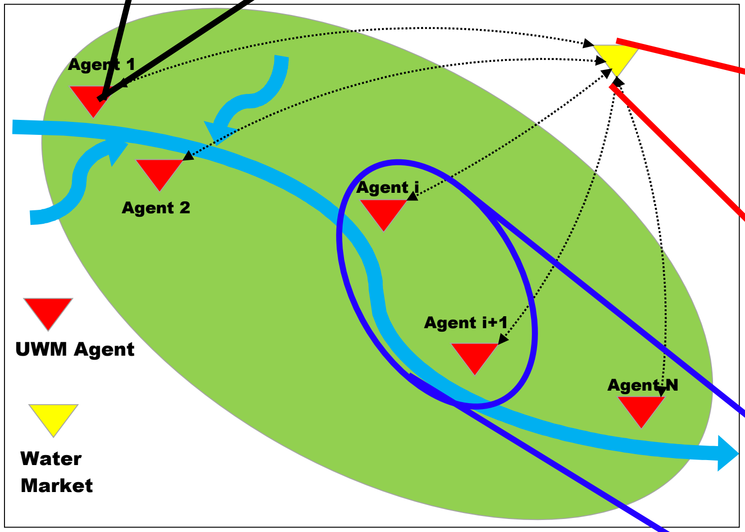
$$s.t. \begin{cases} C_{gi} = f_1(y_i), \\ C_{si}, C_{wi} = f_2(x_i), \\ C_{ti} = p(\sum_i^N t_i) \cdot t_i, \\ g_1(y_i) \leq 0, \\ g_2(x_i) \leq 0, \\ g_3(x_i, t_i) \leq 0, \\ x_i, y_i, t_i \geq 0 \end{cases}$$

Coupling



extended IGWM Optimization model

Urban water balance simulation model



Agent-based model for city-scale IGWM

water trading market model

$$P = p(\sum_i^N t_i); SG(t_i) = 0$$

Social connection

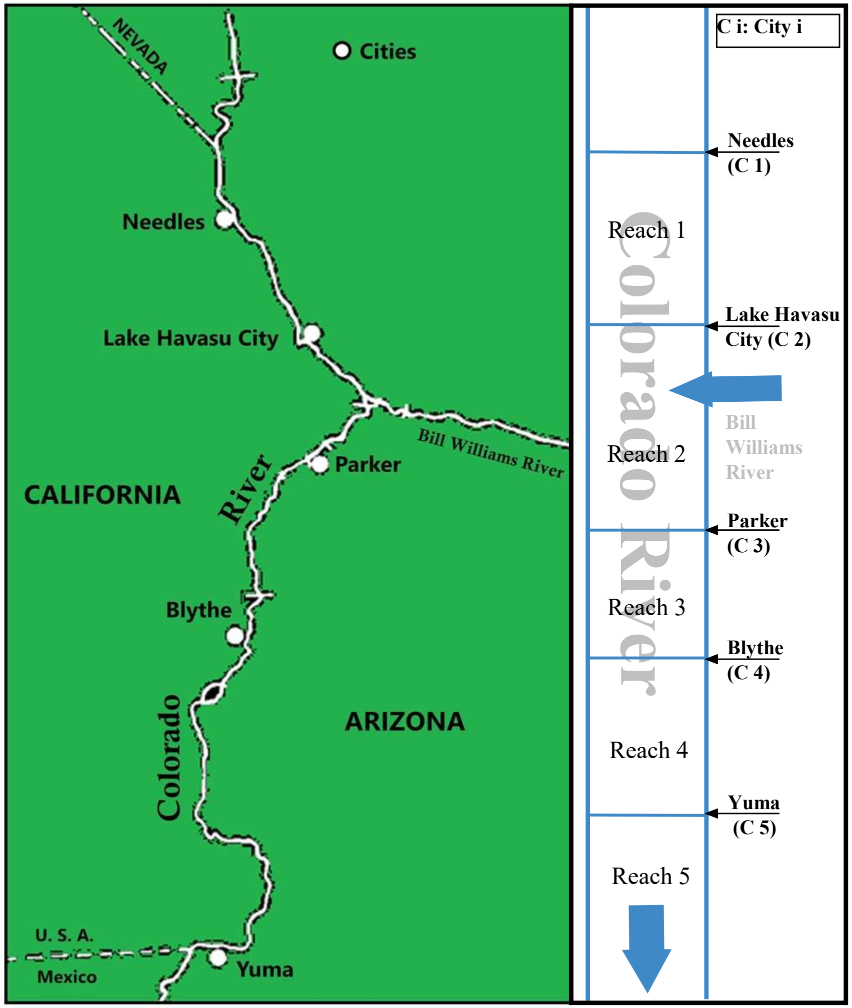
Hydrologic connection

$$IQ^t(i+1) = c_1 \cdot OQ^t(i) + c_2 \cdot OQ^{t-1}(i) + c_3 \cdot IQ^{t-1}(i+1)$$

channel-flow routing model

extended MAS for IGWM

Overview of the study system



Colorado River Lower Basin

5 cities: Needles; Lake Havasu City; Parker; Blythe; Yuma

Data collection

- **Open data:** websites, government documents, research reports and papers
- **Estimation**

Model calibration

NSGA-II algorithm with Kling-Gupta Efficiency based on streamflow data: Urban water balance model and Channel-flow routing model

Algorithm

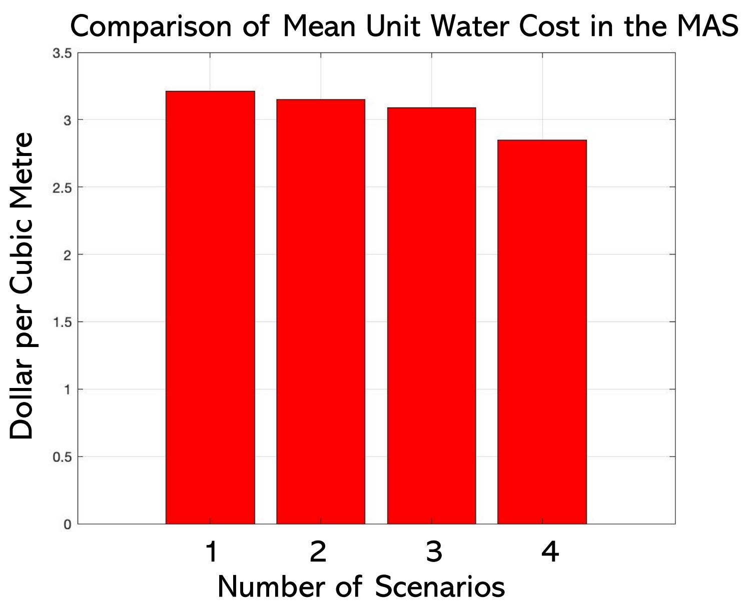
Simulation-based adaptive particle swarm optimization (S-PSO) for ABM

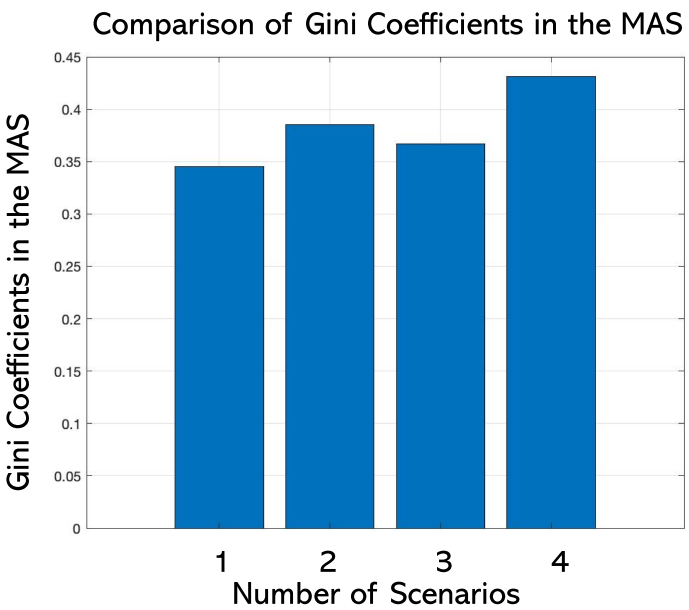
Multi-S-APSO framework for MAS

Comparative analysis via extended MAS for IGWM

For Problem 2 & 3 – To analyze the effects of the water trading scheme (WTS) and GIs on watershed socio-hydrologic environments via using the extended MAS for IGWM.

4 Scenarios: 1) Neither of WTS and GIs; 2) Only WTS; 3) Only GIs; 4) Both of WTS and GIs





- **Water-trading scheme effectively allocates limited water resources with a minimized system cost;**
- **Developing GIs to use rainwater resources might further reduce the cost induced by the water trading scheme;** 🙂
- **GIs might exacerbate water resource allocation inequity among cities.** ☹

Summary

- A multiagent system (MAS) framework is constructed to support integrated green infrastructure and water resources management (IGWM) in a watershed;
- A water trading scheme is designed and anaylzed via using the extended MAS framework;
- Economically, developing GIs to use rainwater might affect the performance of the water trading scheme;
- Various watershed policies for IGWM can be explored via using the flexible MAS framework.

Thank you！

Q & A