Potential of rainwater in city groundwater recharge

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1. Urbanization in China and major environmental challenges

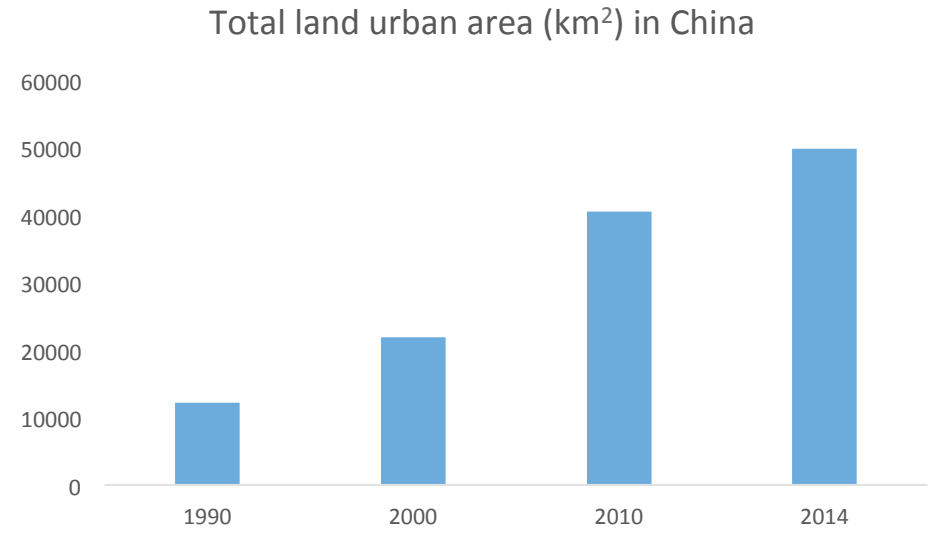
- China is a big construction site in the past thirty years
- Urbanization at present: 56.1%
- By 2030, another 390 million rural population living in urban areas
- Probably another 20 years fast urbanization

Environmental challenges in urbanization

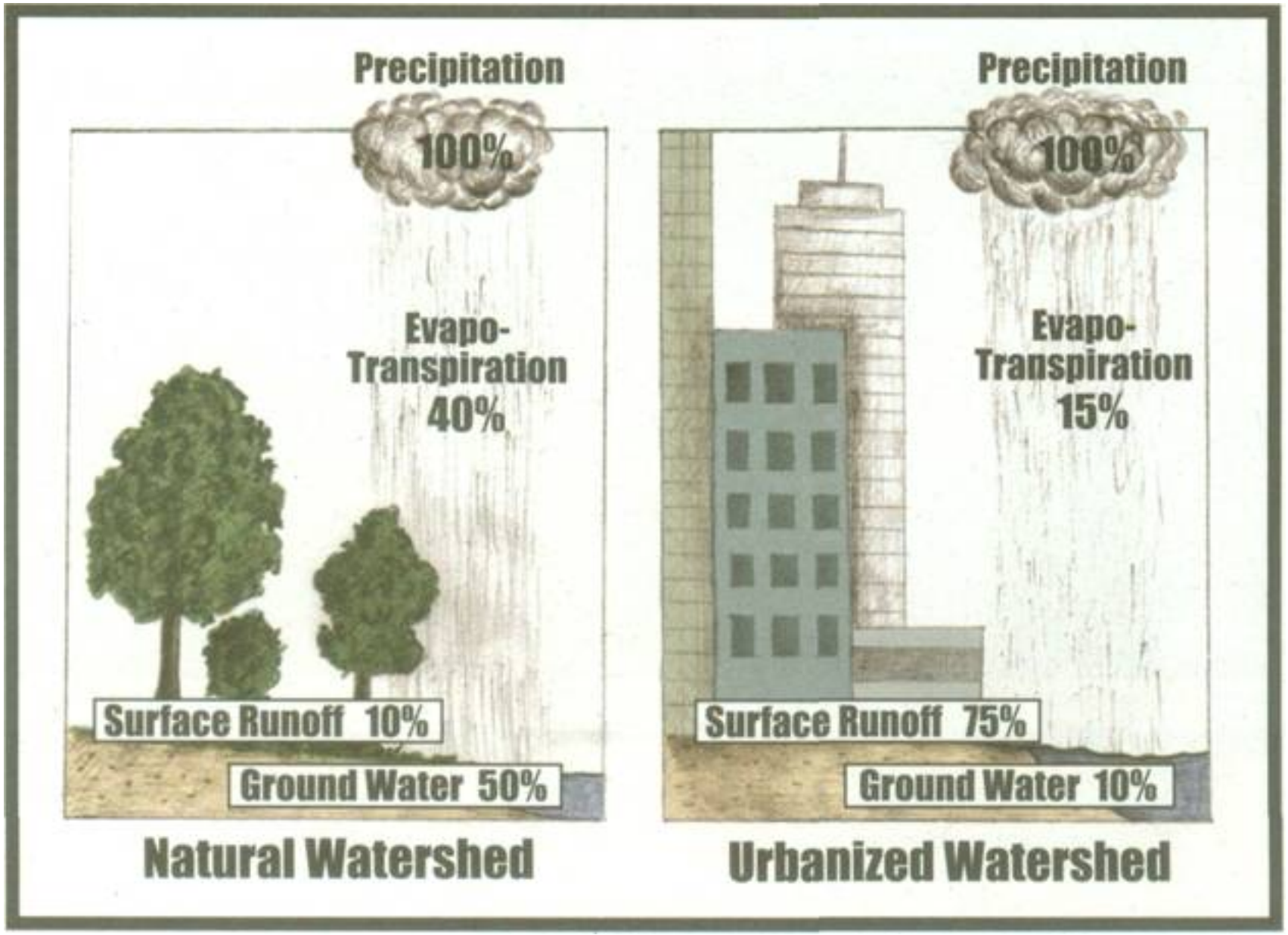
- Replacement of vegetation with impermeable lands/buildings
- Effects on surface water quality and runoff
  - Increasing magnitude of peak flood runoff
  - Causing deterioration in water quality
- Changes in groundwater recharge regime
  - Reduced surface runoff infiltration period
  - Reduced recharge quantity

Urbanization changes underlying surface

- Natural land surface with vegetation enhance infiltration and reduce runoff. Hardened (indurative) ground increases runoff
  - Vegetation slow down runoff, hardened surface increases runoff (both rate and amount)
  - Increased runoff for the same rain
  - Completely change conventional groundwater recharge regime
  - Increased city flooding risks
- A complete change in land surface
  - Increased impermeable area
  - Reduced permeable area

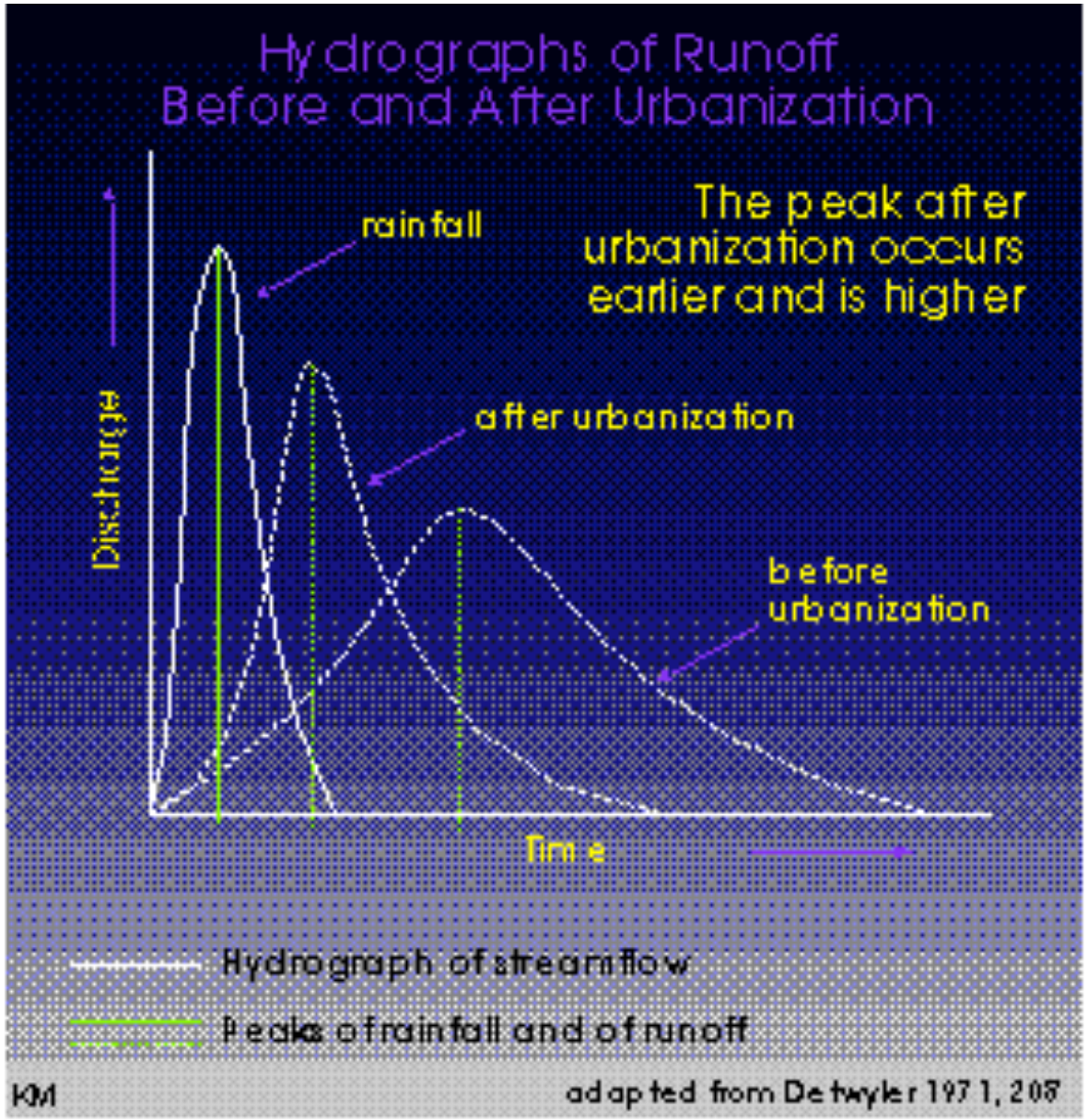


Urbanization changes water cycle in urban areas



- Surface runoff
  - Increased by 65%
- Evapotranspiration
  - Reduced by 25%
- Groundwater
  - Reduced by 40%

Urbanization changes hydrology



- Increased surface runoff
  - Increasing flooding events
  - Higher flood peak

A slightly higher than average rainfall event may cause flooding in cities. *Come to see "sea"* in many inland cities

Continuously declining groundwater “sources” in cities

- Rainfall is important source for groundwater recharge but urbanization has changed this.
  - Increased impermeable land area causes large amount of surface runoff to drain out of cities, leading to highly insufficient groundwater recharge
- Changes in city underlying surface is the main factor contributing to increasing flooding in cities

Increased groundwater exploitation

- Increasing exploitation of groundwater resources to meet increasing need of increasing urban population
- Overuse of groundwater causes declining groundwater resources
- Construction of flood control channels and massive sewage system can also cause drawdown of groundwater table

- **Therefore, a result of continued reducing recharge and continued over-exploitation of groundwater is great drawdown of groundwater table.**

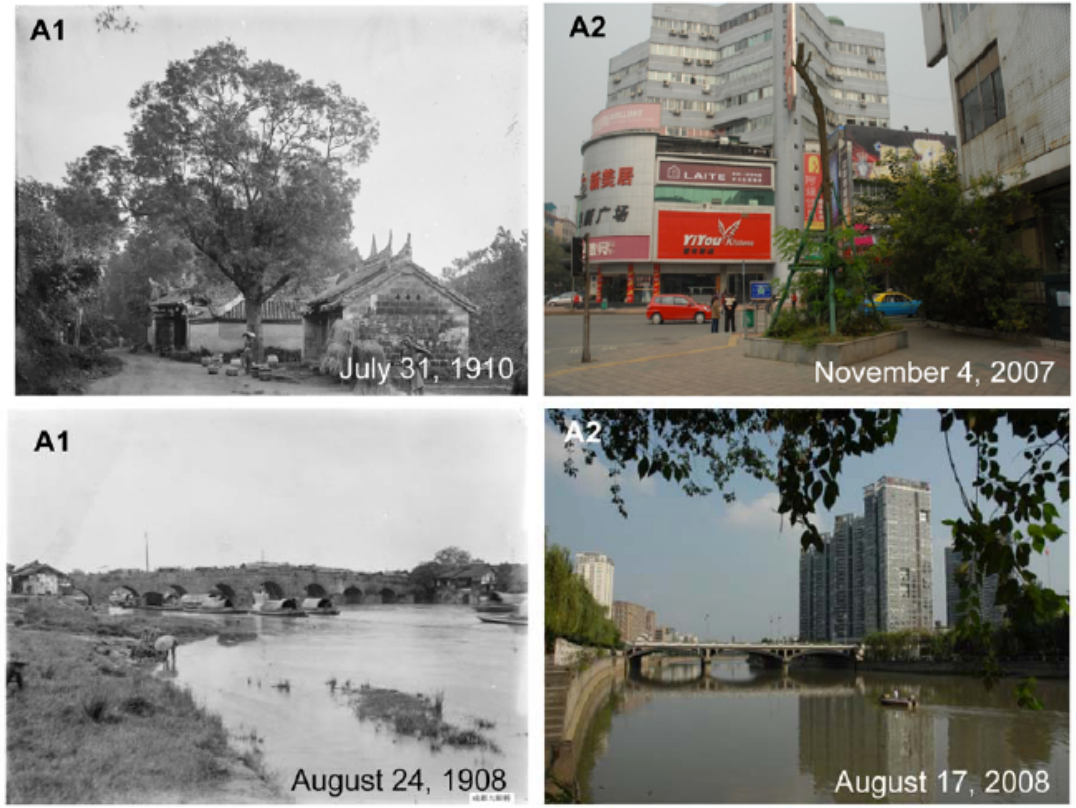
- Continued over-exploitation of groundwater causes similar groundwater drawdown in nearby areas
- Largely due to over-exploitation of groundwater, land subsidence is common in many cities

2. Rainwater and groundwater recharge

- **Strange resource exploitation**: highly prioritizing on resources exploitation but little focusing on resources saving. Compared with many other countries:
  - Agricultural irrigation ratio: 0.4 VS 0.7-0.8
  - Industrial water use: 222 m^3/RMB 10 000 yuan GDP
  - Industrial wastewater recycle: 40% VS 75-85%
- Use of rainfall in groundwater recharge is rare in China

Is this feasible for Chengdu?

- Urbanization has been fast in Chengdu
- Groundwater status (2010) (Chengdu Bureau of Water Resources)
  - Whole Chengdu: reduced by 17.6%
  - Metropolitan area: reduced by 18.4%
- Quantity?
- Quality?



Chen et al., 2011, Plos One 6(9): e25008

Quantity

- Urban land area 529 km^2 (2014)
- Impermeable rate 45%, runoff coefficient 0.85, annual rainfall 1000 mm
  - Annual available: 3.3 x 10^8 m^3
- In addition, rainwater drain directly from roof, road and residential compound is about 2.5 x 10^8 m^3
- **Total: 5.8 x 10^8 m^3**
- Total water consumption in 2015: 1.23 billion.

Ways to increase rainwater harvesting and storage

- Increasing permeability
  - Natural: green areas
  - Artificial: permeable ground, parking area, etc
- Use green areas to recharge groundwater
  - Increase groundwater recharge by rain water
  - Save water for irrigating vegetation
  - Reduce runoff peak

Role of vegetation in rainwater harvesting

- Vegetation can increase infiltration
  - 25 years natural forest: 150 mm/h
  - Grassland: 10 mm/h
  - Bare land: < 5 mm/h
- Forest
  - 25% canopy interception
  - 35% groundwater
- Grassland
  - Infiltration 15-20% higher than bare land
- On bare land
  - 55% runoff
  - 5% groundwater

- **Rainfall infiltration: 7 time in forested land as much as in bare land**

Use of green areas to harvest and store rainwater

- Some preliminary results (% of infiltration to rainfall)
  - High grassland (0.3 m above ground): 6%
  - Level grassland (same level as ground): 19%
  - Lowered grassland (0.1-0.2 m lower than ground): 30%

Use of rivers to harvest and recharge groundwater

- Rivers play an important role in groundwater recharge. But in Chengdu and other cities, most channels/canals are cemented
- Promote ecological riparian ecosystem to restore recharging function of groundwater recharge

Use of roads and green belts

- Impermeable land is efficient in rainwater harvesting
- All harvested rainwater drains out of city
- Almost all green belts are higher than ground

Potential ways

- Lower playground, green land, parks, green belts, 0.1-0.5 m lower than ground, enhancing rainfall infiltration
- Construct permeable ground in parking lot, public ground
- Leave slits along roadside to increase infiltration
- Restore river ecosystem

Some preliminary results on infiltration (infiltration/rainfall)

- Green areas 0.3 m higher than land surface: 6%
- Green areas on land surface: 19%
- Green areas 0.1-0.2 m lower than land surface: 30%

Quality

Groundwater pollution by hydrocarbon fuels, industrial chemical spillages

- Soil and vegetation help
- Rainwater goes through 3-4 layers: plant, land surface, plant roots and microorganism, soil
- Rainwater going through green areas
  - NH_4 -N: reduced from 2.1 to 0.8 mg/L
  - Sulphate and nitrate reduced greatly

3. Opportunities and Challenges

- Changes from no to poor and then to better planning in urban development

Opportunities and Challenges

Urbanization and urban development involves a number of government agencies. Each agency works on its own, poor inter-agency collaboration. In terms of groundwater recharge, at least the following are involved:

- Bureau of Water Resources
- Urban-Rural Development Commission
- Bureau of Environmental Protection
- Bureau of Forestry and Horticulture
- Bureau of Planning
- Bureau for City Management and Administrative law-Enforcement

Plant species test

- 10 species, flooded 15 cm for 2, 4. 6 days
- No effects are observed 14 days after flooding
  - 2 days: 9 species
  - 4 days: 7 species
  - 6 days: 4 species

- Hydrological data indicate very rare flooding in Chengdu, if so, mostly 1 day

- Most constructed wetlands are lined to prevent leaking
- Many artificial lakes are lined to prevent leaking
- Many lakes in public parks

Conclusion

- Urban ecosystem is controlled, managed by people.
- Management philosophy and idea change is crucial to make fully use of ecological ways to recharge groundwater.
- In China, the program promoted by the top leader will go quickly. As President Xi Jinping has specific instructions on sponge city development, it will go quickly.
- More research opportunities available

Thanks for your intention!