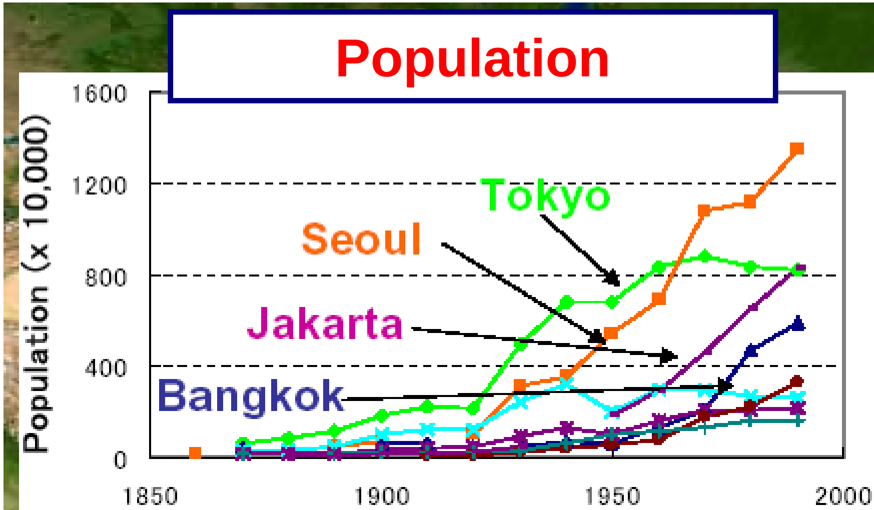
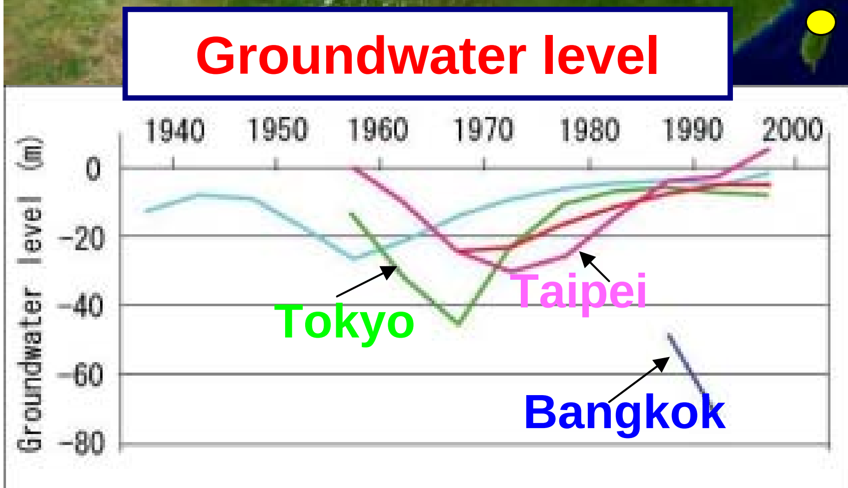
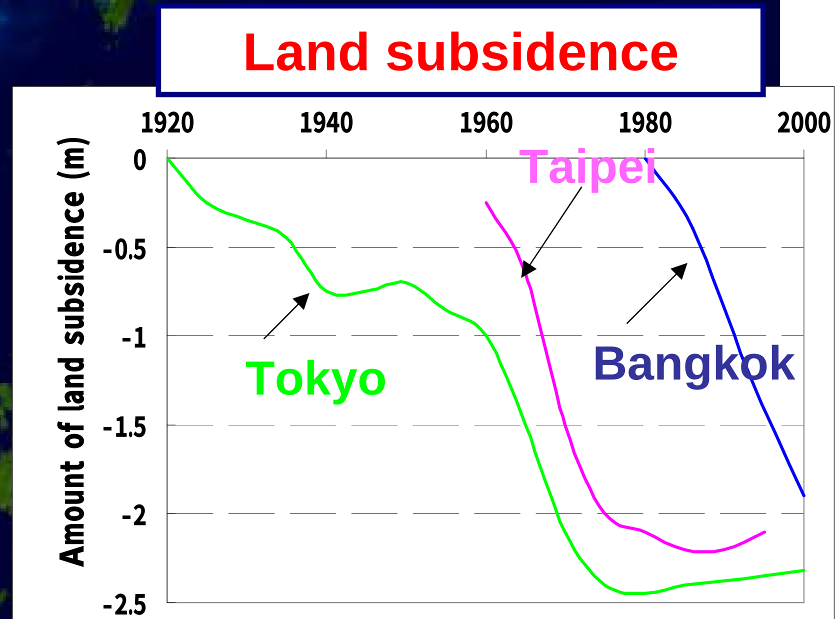
Human impacts on urban subsurface environment

Makoto Taniguchi
Research Institute for Humanity and Nature (RIHN)

Repeated tragedy of subsurface environment in Asia







Subsurface environmental problems such as <u>land subsidence</u>, <u>groundwater contamination</u>, and <u>subsurface thermal anomalies</u>, occurred one after another in Asian major cities with a time lag depending on the development stage of city.

RHIN project (2005-2010)

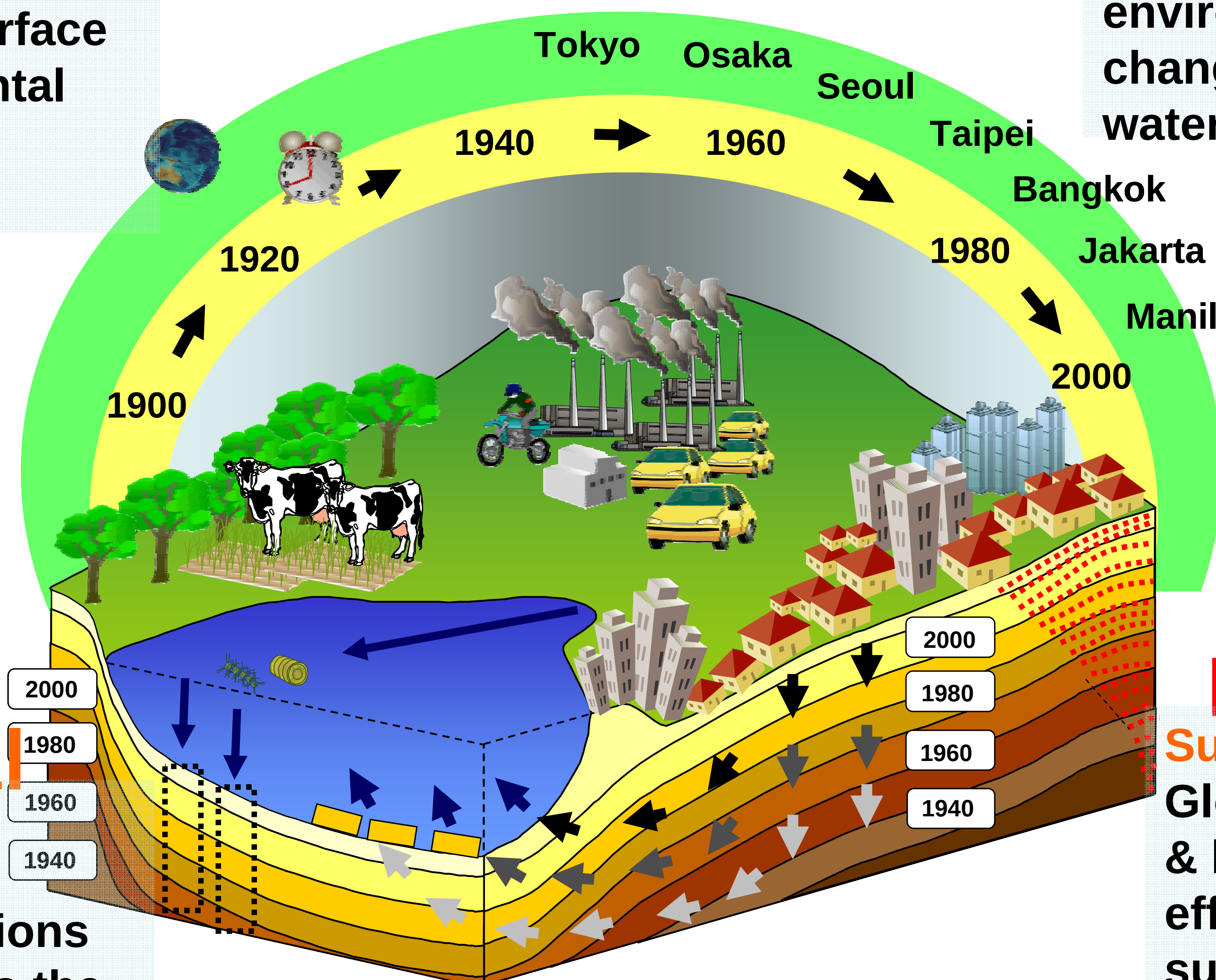
Human impacts on urban subsurface environment

Urban

Subject 1: Development stages of cities and sub-surface environmental problems

Water

Subject 2: Degradation of subsurface environments and change in reliable water resources



Material

Subject 3: Subsurface contaminations and loads to the coast

Heat

Subject 4: Global warming & heat island effects on subsurface environment

RIHN project core members

Makoto Taniguchi
RIHN

Water
Jun SHIMADA
Faculty of Science,
Kumamoto University

Social economy
Shinji KANEKO
Graduate School for International
Development and Cooperation,
Hiroshima University

Urban geography
Akihisa YOSHIKOSHI
College of Letters,
Ritsumeikan University

Gravity
oichi FUKUDA
raduate School of
nce, Kyoto University

Material
Shin-ichi ONODERA
duate School of Integrated Arts
Sciences, Hiroshima University

Heat
Makoto YAMANO
Earthquake Research
Institute, Tokyo University

William C Burnett
FSU, USA

Shaopeng Huang
U of Michigan ,
USA

Gayl Ness
U of Michigan ,
USA

and more…..

Key Questions

(1) When did reliable water resources change between surface and subsurface ? and Why ?

(2) What type of groundwater contamination occurred in Asia ? and How does it relate to social activities, geology etc. ?

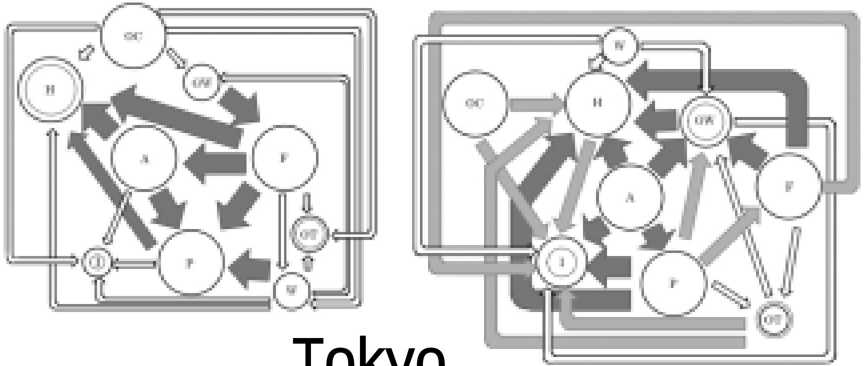
(3) How does subsurface thermal storage change related to global warming and urbanization ?

(4) What kind of stage of subsurface environment is now each Asian cities ?

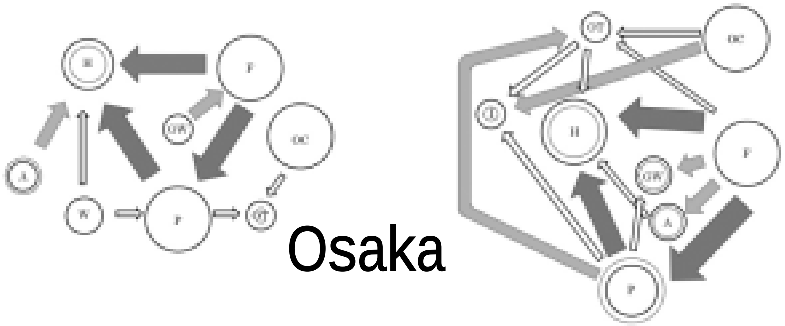
(5) How can we manage the surface/subsurface environments effectively ?

Land use analyses

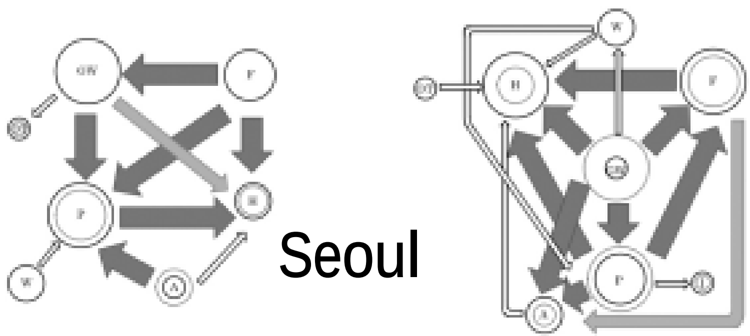
1930 → 1970 1970 → 2000



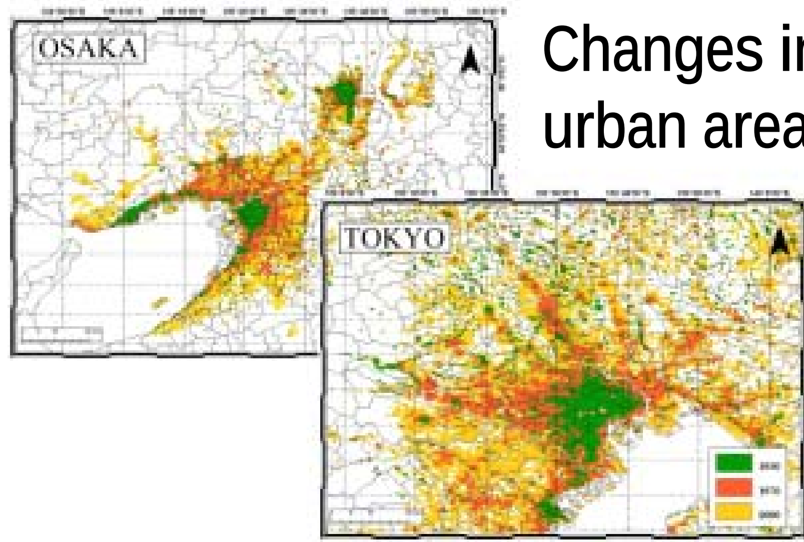
Tokyo



Osaka

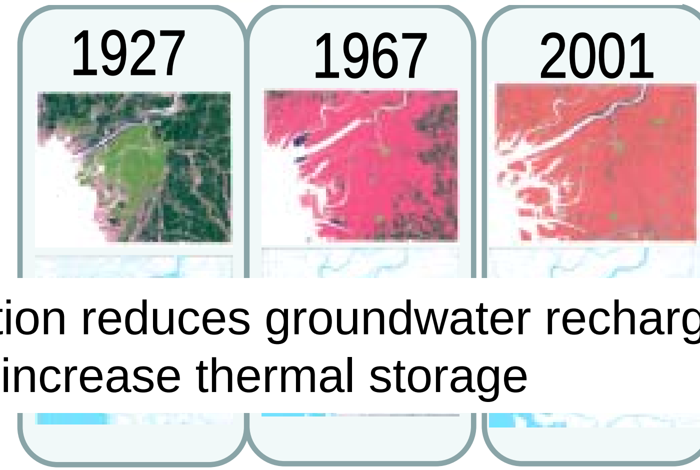


Seoul



Changes in urban area

Osaka



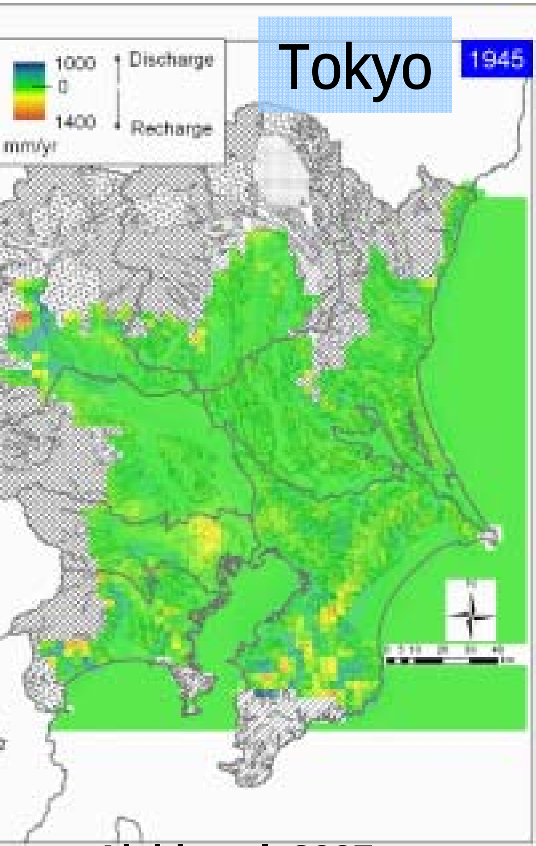
Urbanization reduces groundwater recharg
rate and increase thermal storage

1920's IP：P＝ 68：88 (44%)
1960's IP：P ＝158：30 (84%)
2000's IP：P ＝183：17 (92%)
IP: impermeable, P: Permeable

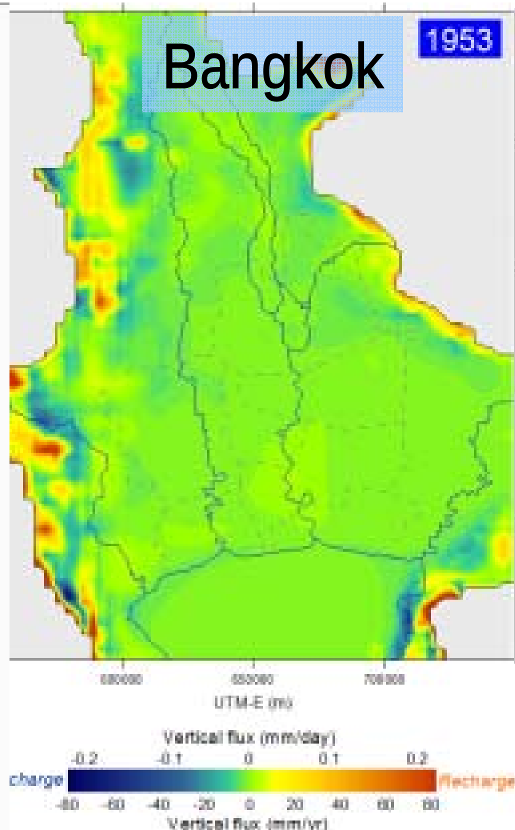
GW: Grass & Wasteland
OC: Ocean
W: Water & wetland
OT: Others

F: Forest
H: House
I: Industries
P: Paddy field
A: Agriculture field

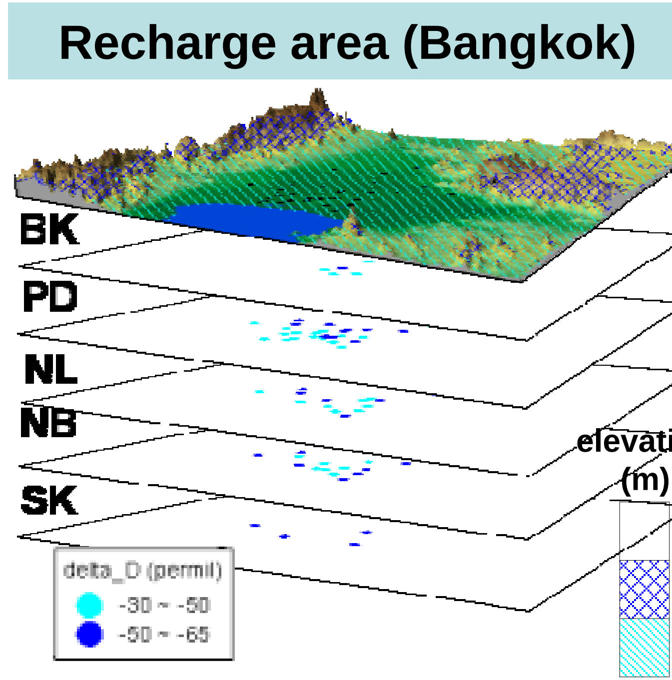
Changes in recharge area after regulation

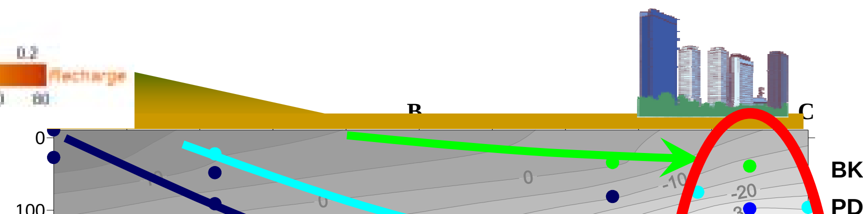


Aichi et al. 2007



Yamanaka et al. 2009

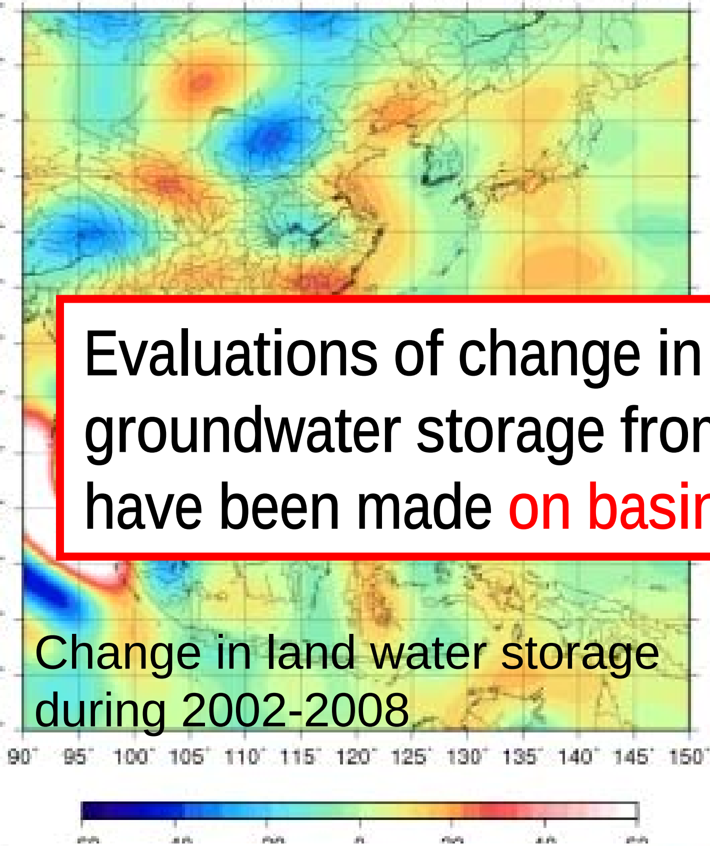




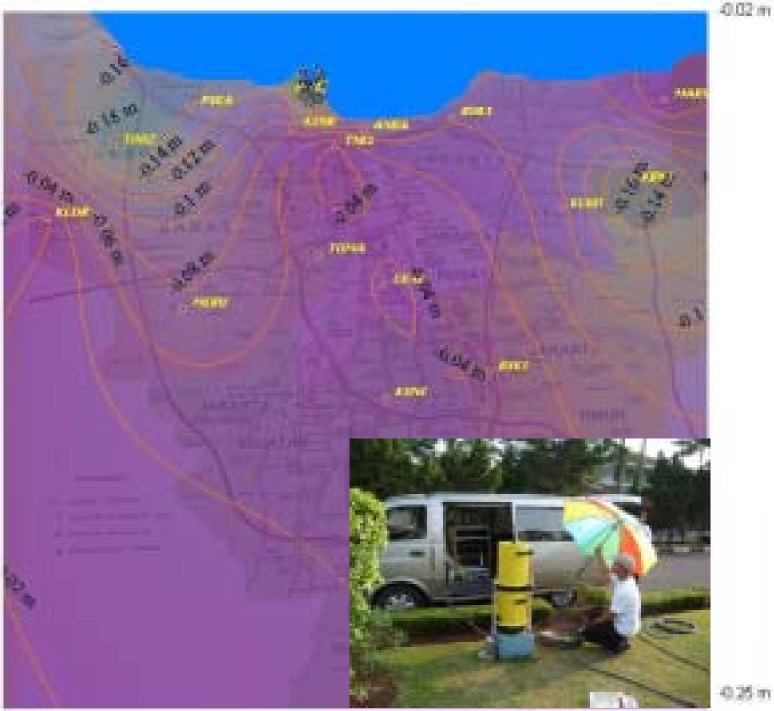
The area (origin) of groundwater recharge moved from city center to suburb area due to regulation of groundwater pumping

Groundwater flow system and the recharge area were revealed by tracers, and mixture of shallow and deep GW were found

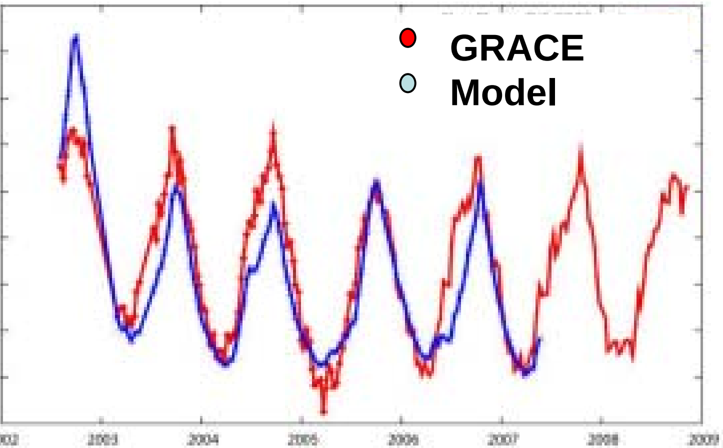
Gravity

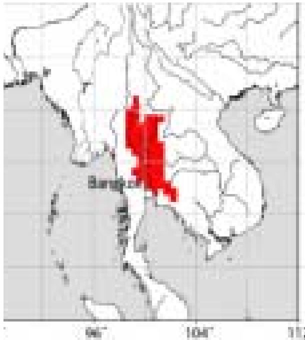


Evaluations of change in groundwater storage from GRACE have been made on basin scale



Gravity / GPS measurements reveled land subsidence and groundwater storage change





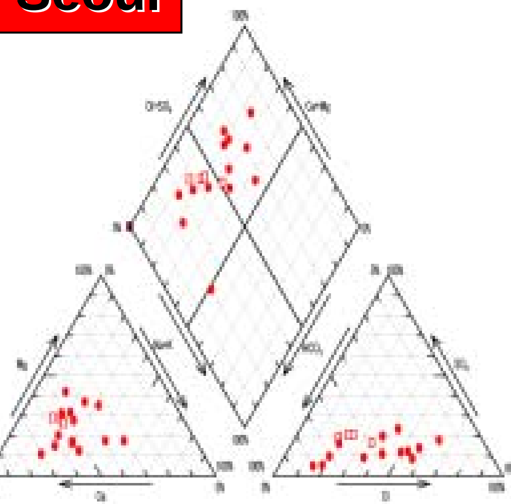
Chao Phraya basin

Comparisons between GRACE and MODFLOW/SWAT will be made.

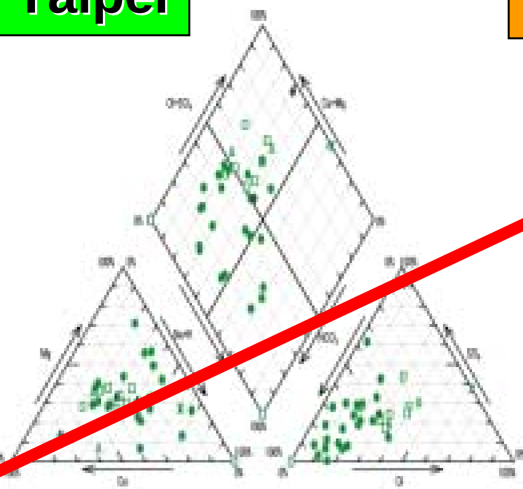
Groundwater contamination

Material

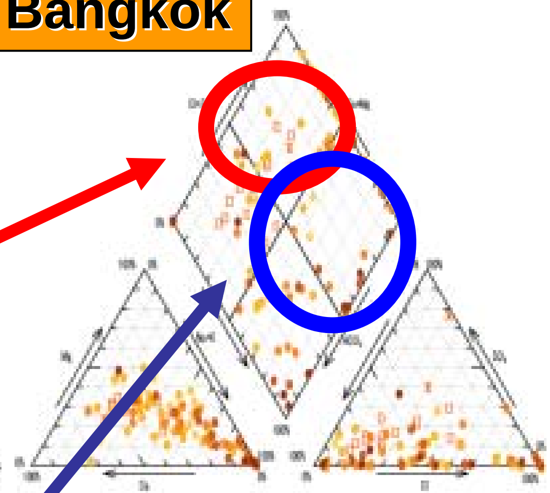
Seoul



Taipei

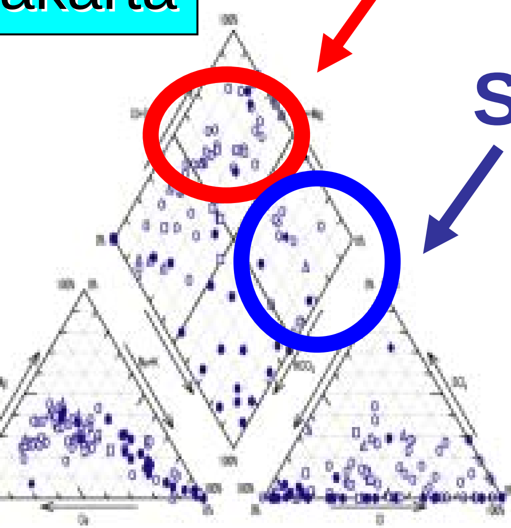


Bangkok

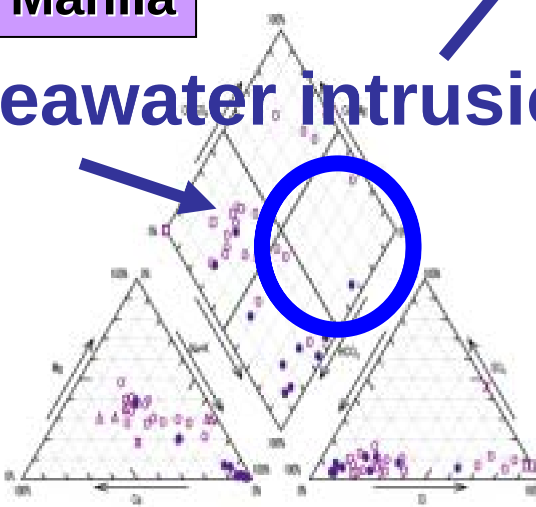


Anthropogenic

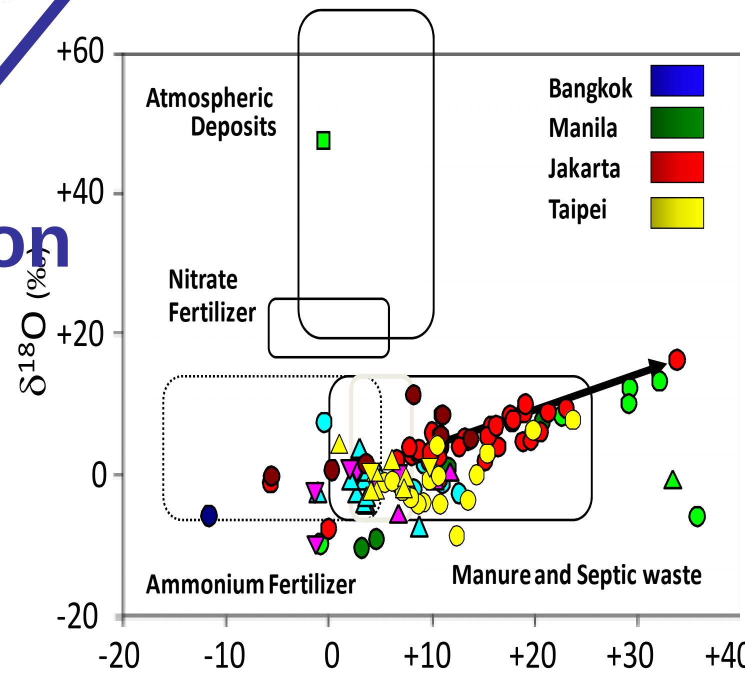
Jakarta



Manila



Seawater intrusion



Groundwater contamination (N)

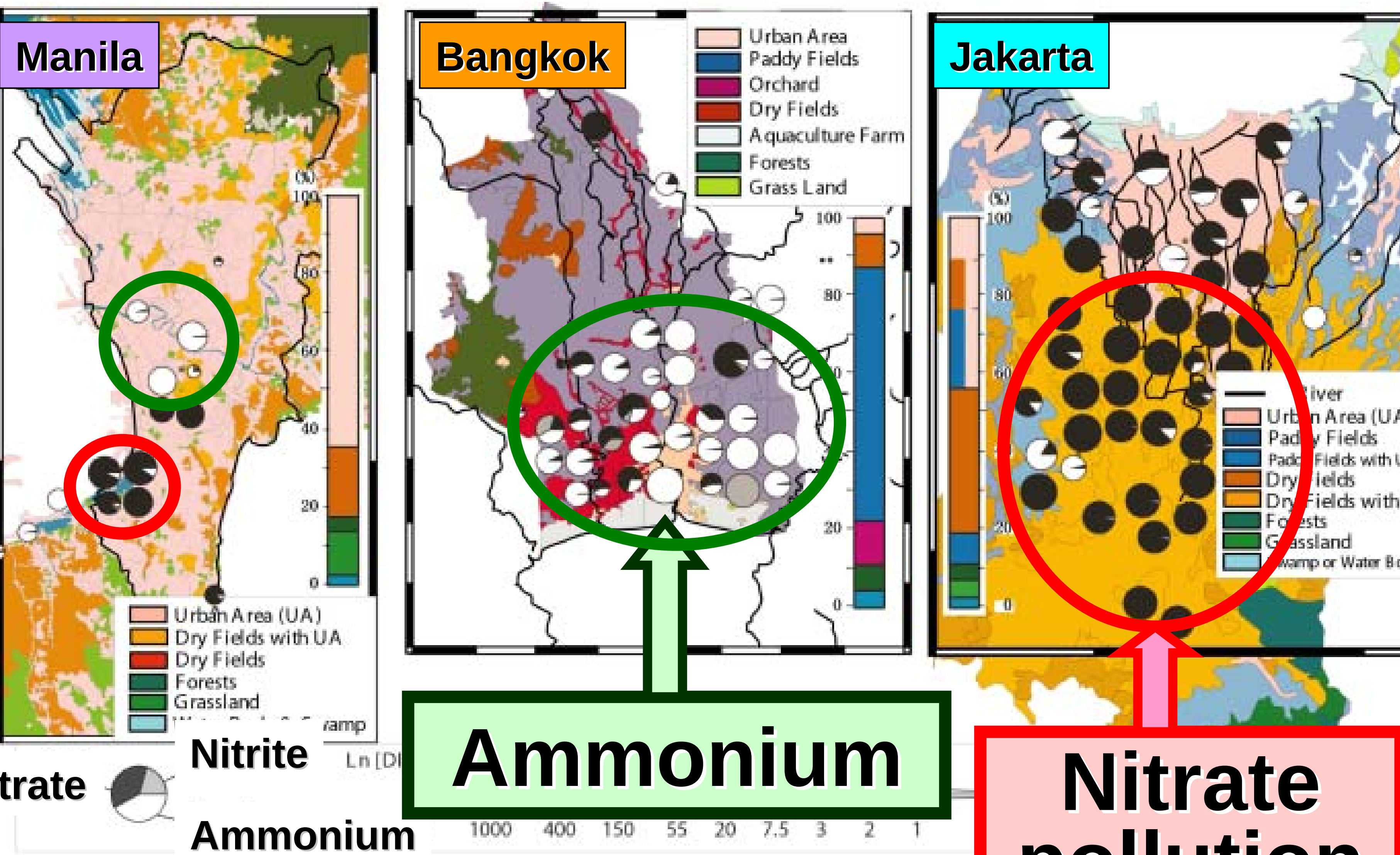


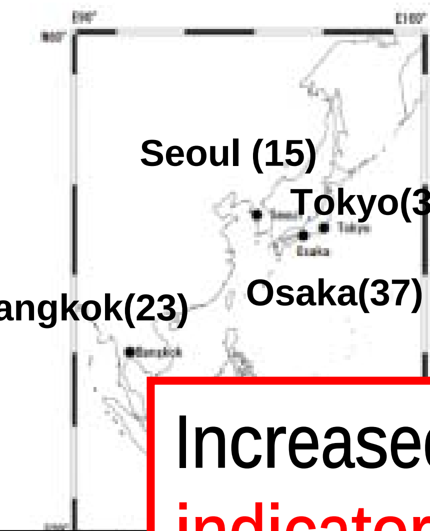
Figure 7 Distribution of nutrient compositions in shallow groundwater drawn on the

The data classified into 6 or 7 categories were compiled from the full classification provided by JICA subside

Department of Groundwater Resources (Ministry of Natural Resources an Environment, Thailand) and Research Center

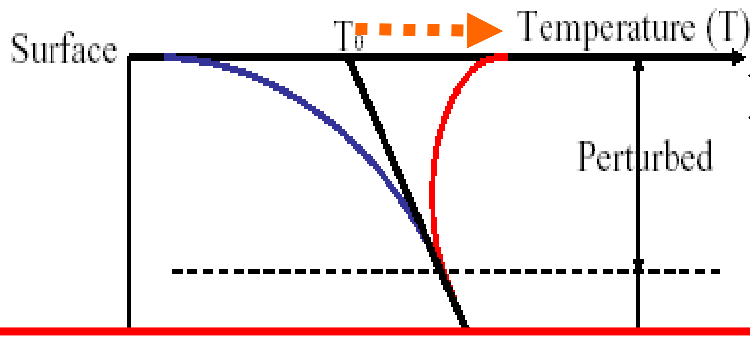
Effects of global warming and heat island on subsurface

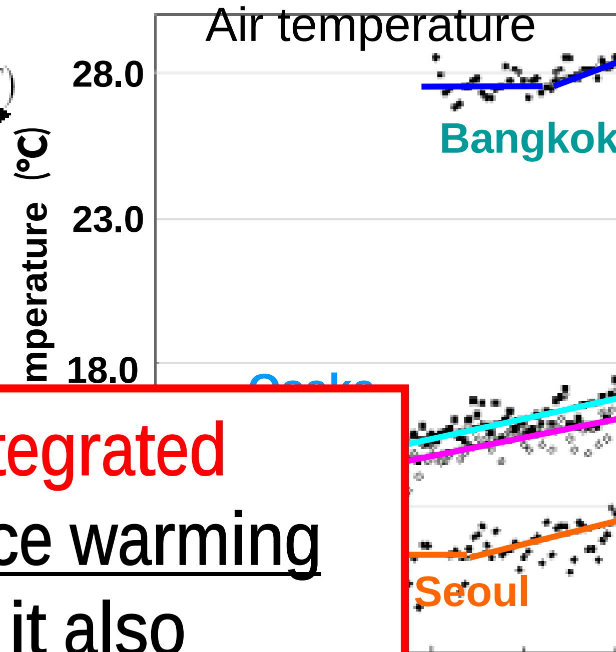
Heat



Boreho

Surface warming





Increased thermal storage is the integrated indicator of the magnitude of surface warming and time starting urbanization, and it also depends on thermal gradient which is related to natural capacity for thermal storage.

ncrease
emperat

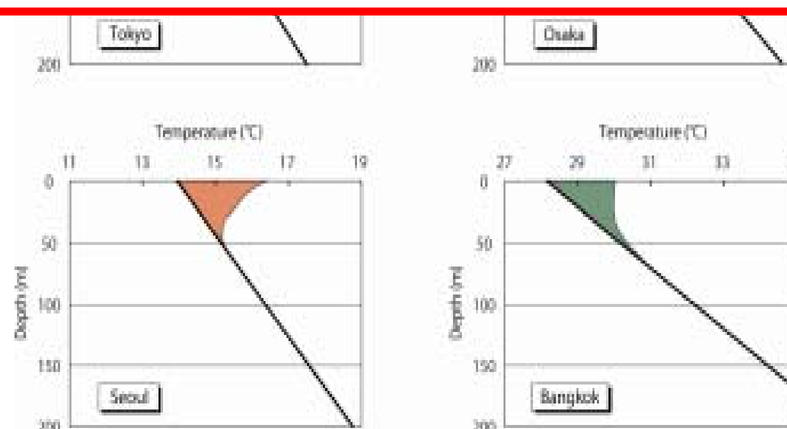
Tokyo：+2.8℃

Seoul：+ 2.5 ℃

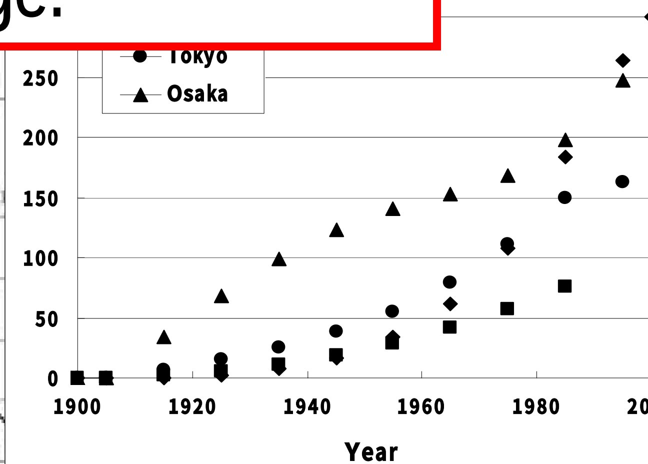
Osaka：+ 2.2℃

Bangkok：+ 1.8 ℃

Jakarta：+ 1.2℃



h subsurfac
torage



Integrated Indicators

A: Subsurface Capacity for Resilience

A-1: Hydrology and Climate (quantity)
- (a) Groundwater storage
- (b) Groundwater recharge rate
- (c) Residence time

A-2: Geology and Geomorphology (quality)
- (d) redox condition (nitrate vs arsenic)
- (e) gradient for discharge
- (f) thermal properties

Natural Sci. G + Model WG

B: Changing Society & Environment

B-1: Driving forces
- (a) Population
- (b) Income
- (c) Industrial structure
- (d) Urbanization

B-2 :Pressures
- (e) Domestic water
- (f) Subsurface development
- (g) Groundwater dependency

B-3: States
- (h) Groundwater level
- (i) Contamination
- (j) thermal storage

B-4: Impacts
- (k) Land subsidence

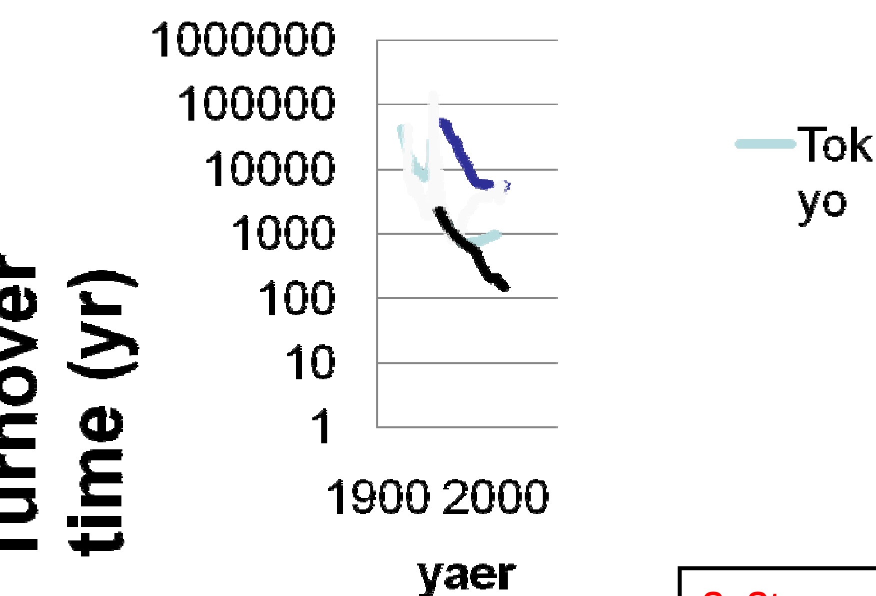
B-5: Responses
- (l) Regulation of public water
- (m) Sewage

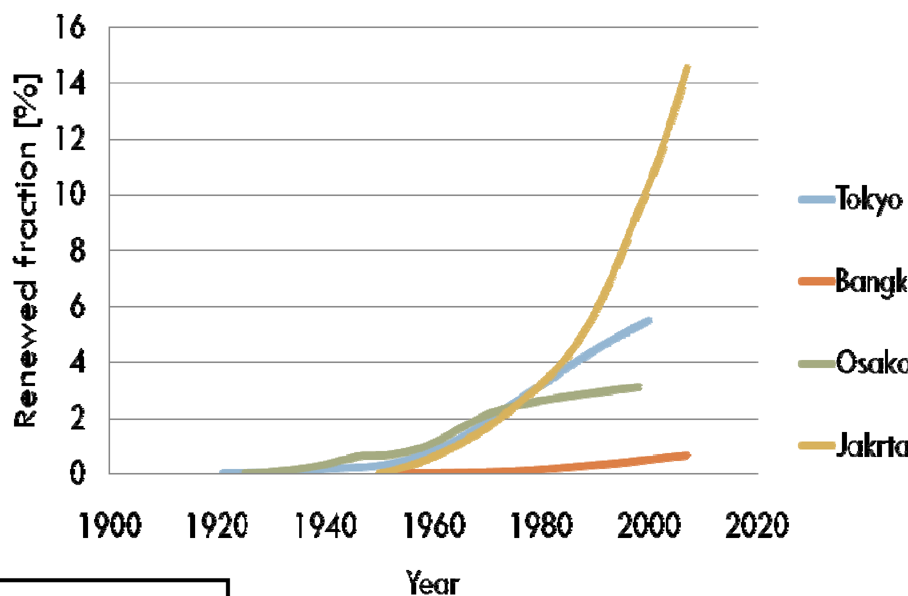
Social Sci. G + DB WG

A: Subsurface Capacity for Resilience

Model W

	Period (year)	Model area (km2)	Average depth (m)	Storage capacity (10^6 m3)	Total extraction (10^6 m3)	Renewed fraction [%]
Jakarta	1950-2007	1,670	100	33,400	5,250	15.7
Osaka	1925-2005	937	1,200	223,626	10,583	4.7
Tokyo	1920-2005	40,000	212	1,700,000	99,752	5.8
Bangkok	1950-2007	31,284	329	2,057,789	20,404	0.6





Turnover time (yr) $\tau = S/Q$

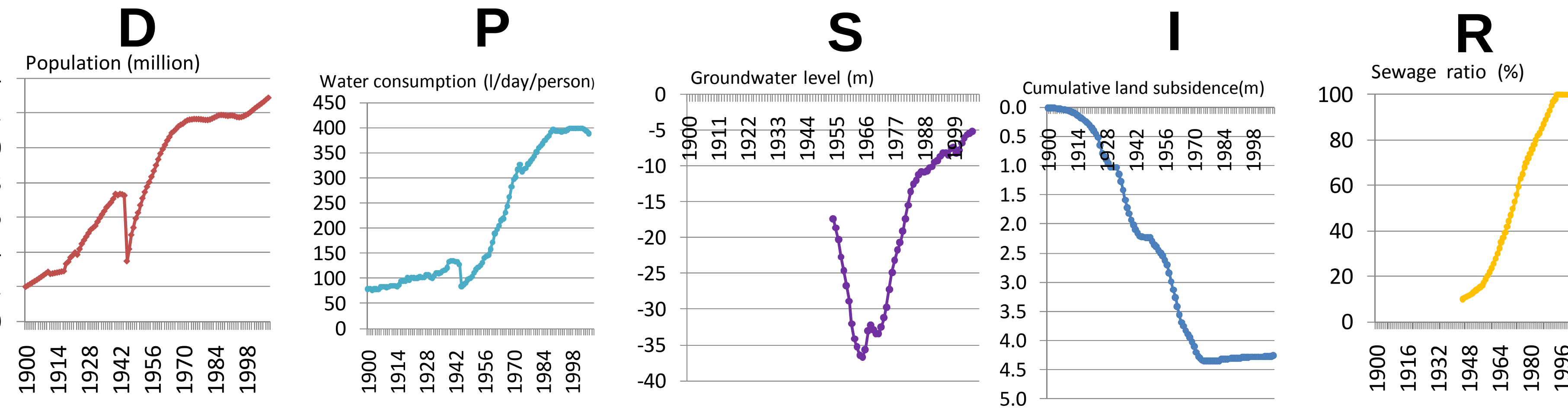
S: Storage capacity(m3)
Q: Recharge (m3/year)

Renewed fraction [%] $\alpha =$

Stage model with DPSIR framework

Social economic

B: Changing society and environment



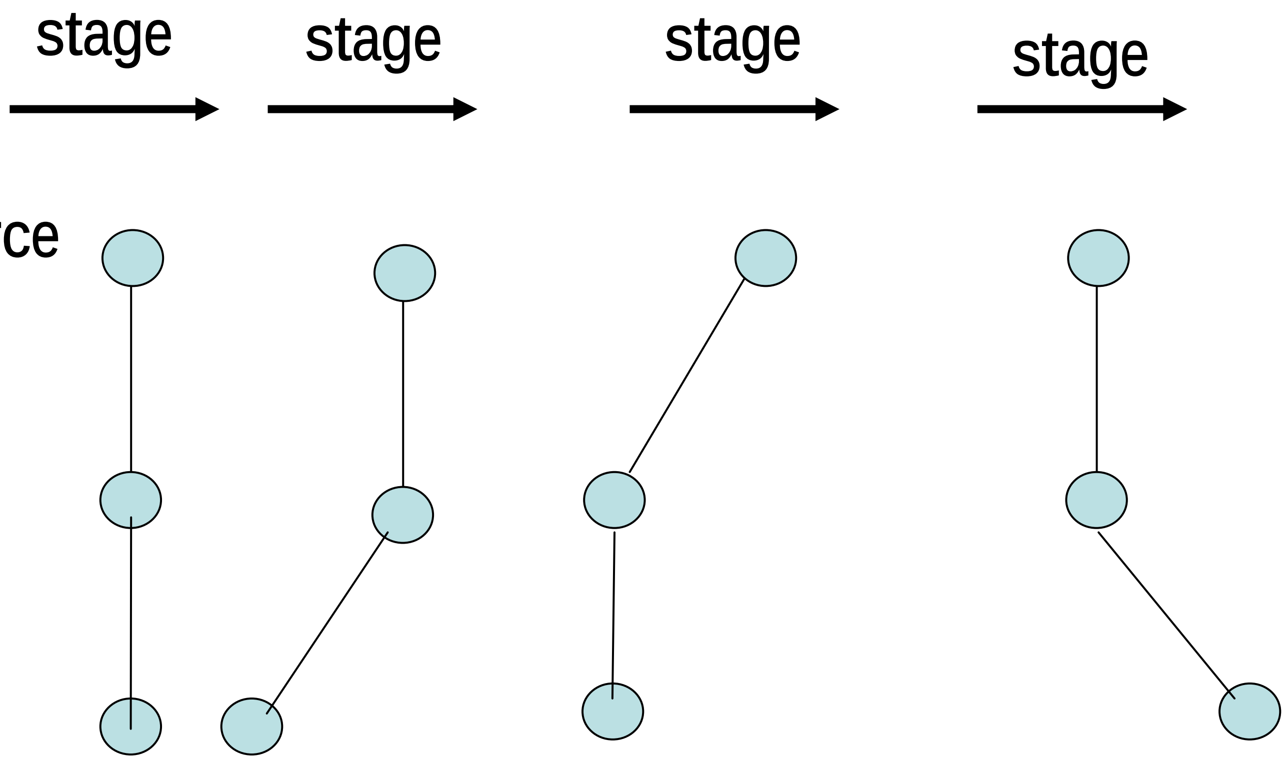
	1st Stage	2nd Stage	3rd Stage	4th Stage	5th Stage
Tokyo	1900-1923	1923-1947	1947-1962	1962-1975	1975-2000
Osaka	1900-1936	1936-1950	1950-1962	1962-1975	1975-2000
Seoul			1947-1965	1965-1977	1975-2000
Taipei	1900-1955	1955-1965	1965-1977	1977-1982	1982-2000
Bangkok	1900-1960	1955-1965	1965-1977	1983-2000	
Jakarta	1900-1928	1928-1978	1978-2000		
Manila	1900-1965	1965-1985	1985-2000		

Integrated indicators

D: Driving Force
P: Pressure

S: State
I: Impact

R: Response



A：Following Tokyo
【repeated tragedy】

B: Worse
Scenario

C: Dependence on
natural capacity

D: Benefit as
follower

Summary

Subsurface environment is an "alternative resources/capacity" and "adaptation/resilience" to changing climate and human impacts.

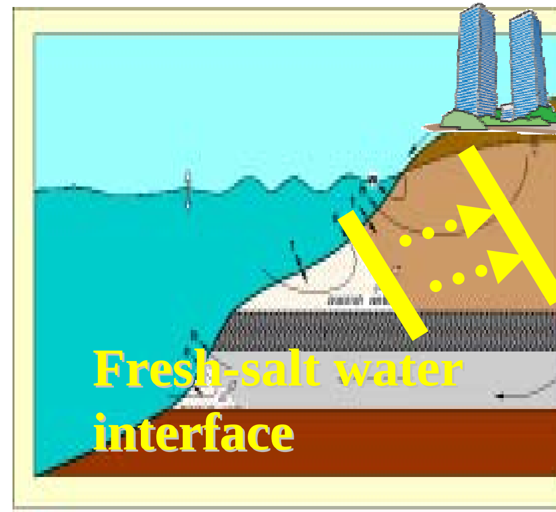
To avoid the repeated tragedy, the city with earlier stage should make "followers benefit" maximum under the limitation of natural capacity in subsurface environment (water, heat, contamination).

- I would like to acknowledge all member of RIHN project,
- I hope to discuss all results of the project and integrate our knowledge through this symposium.

More than 1/3 population rely on groundwater

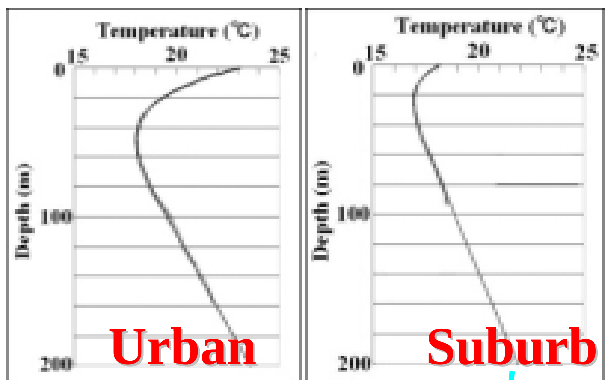
Traditional problems

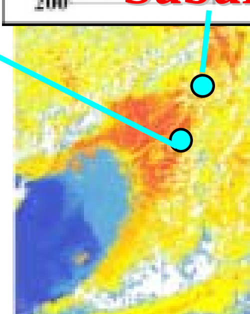
- Land subsidence by over-pumping
- Contamination of groundwater / Saltwater intrusion

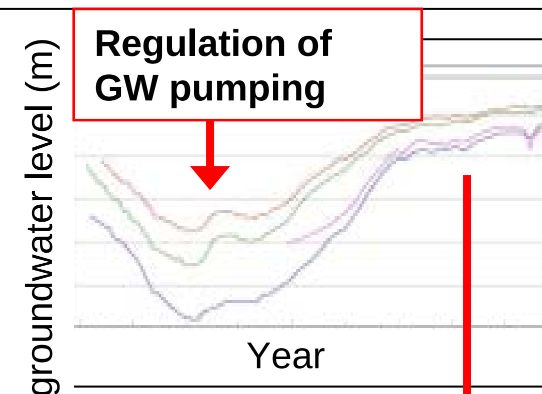


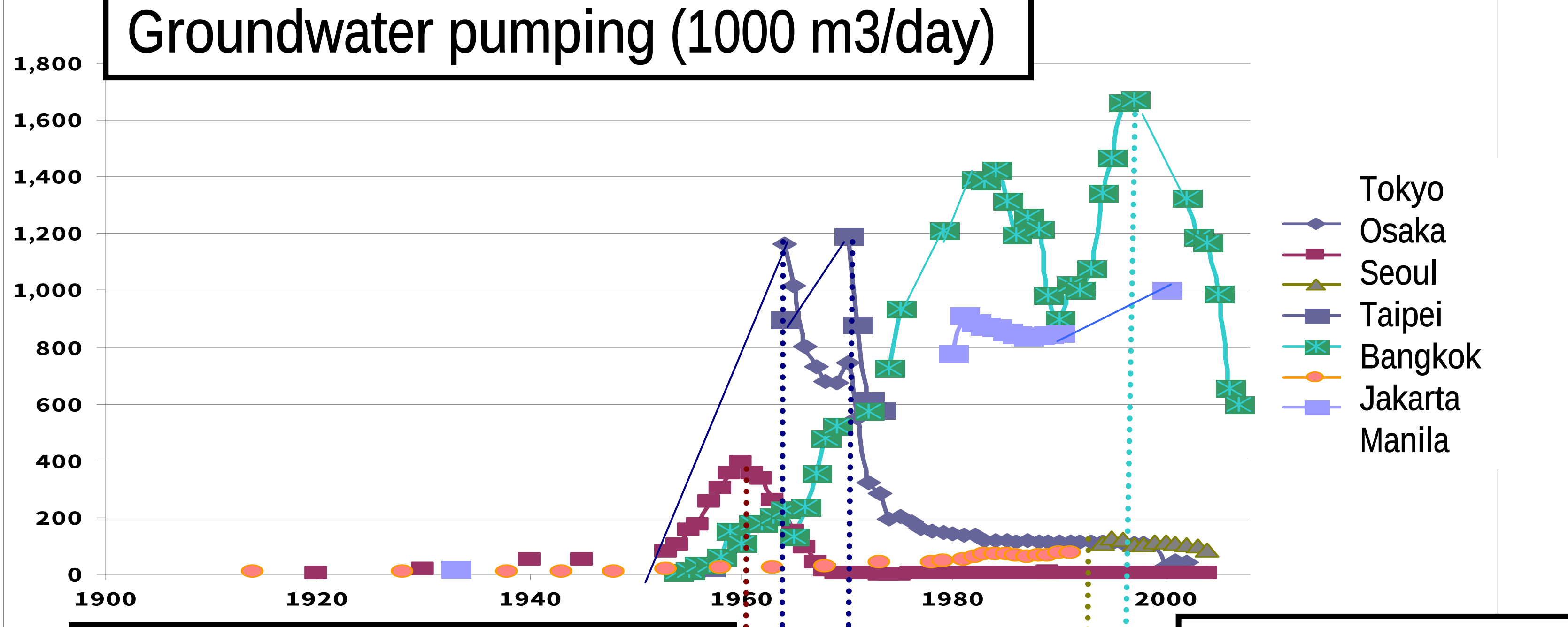
New problems

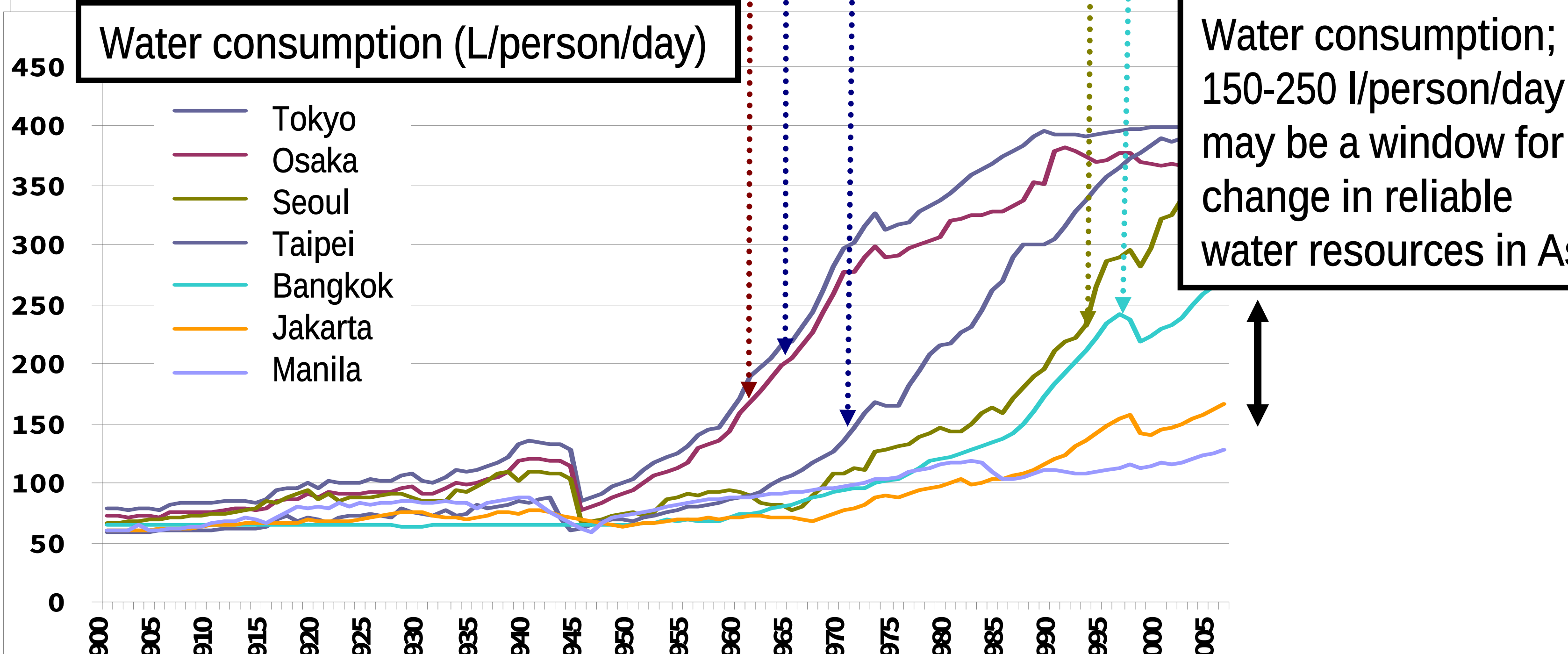
- Increase of subsurface temperature → increase of micro biomass activities → increase of carbon efflux
- Recovery of groundwater storage → buoyancy → floating stations








Groundwater pumping (1000 m3/day)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1900
1920
1940
1960
1980
2000
Tokyo
Osaka
Seoul
Taipei
Bangkok
Jakarta
Manila


Water consumption (L/person/day)
450
400
350
300
250
200
150
100
50
0
Tokyo
Osaka
Seoul
Taipei
Bangkok
Jakarta
Manila
Water consumption;
150-250 l/person/day
may be a window for
change in reliable
water resources in As