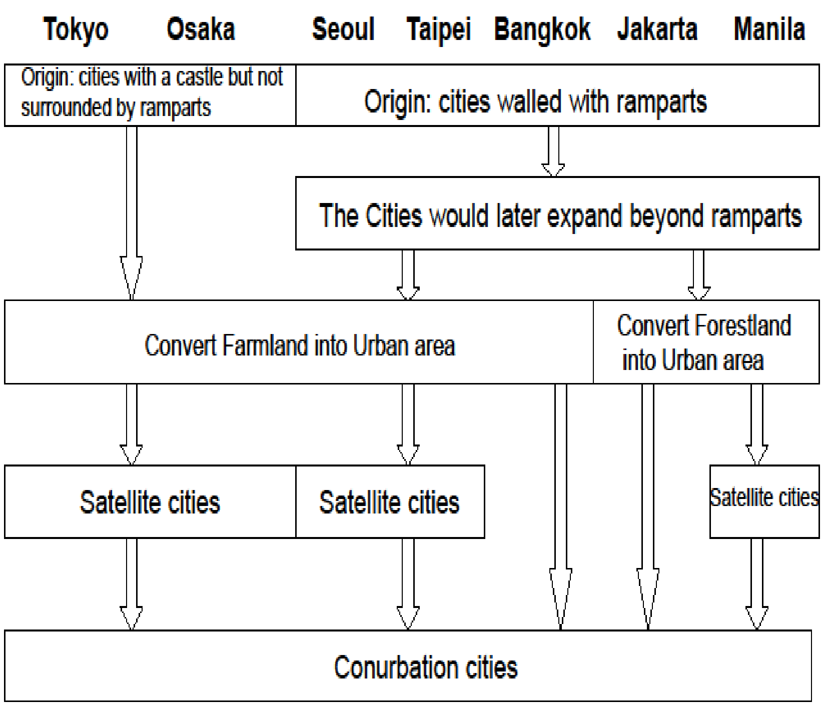
Urban Development Process Model

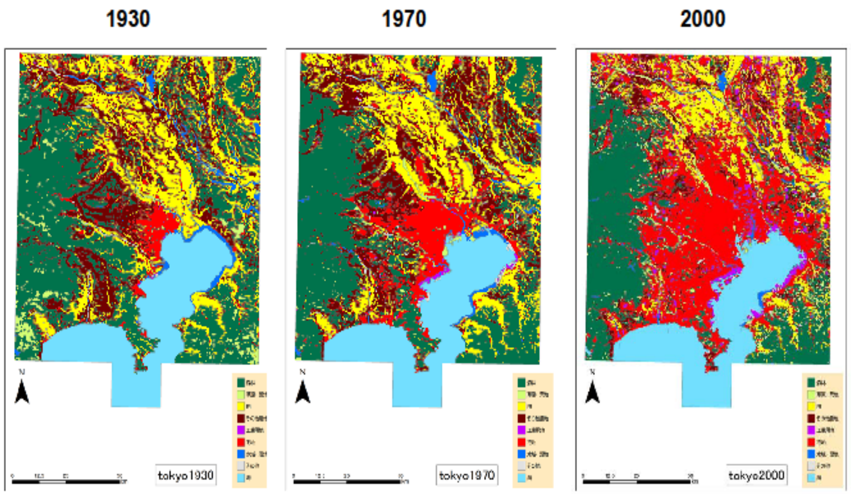
Akihisa YOSHIKOSHI(Ritsumeikan University)



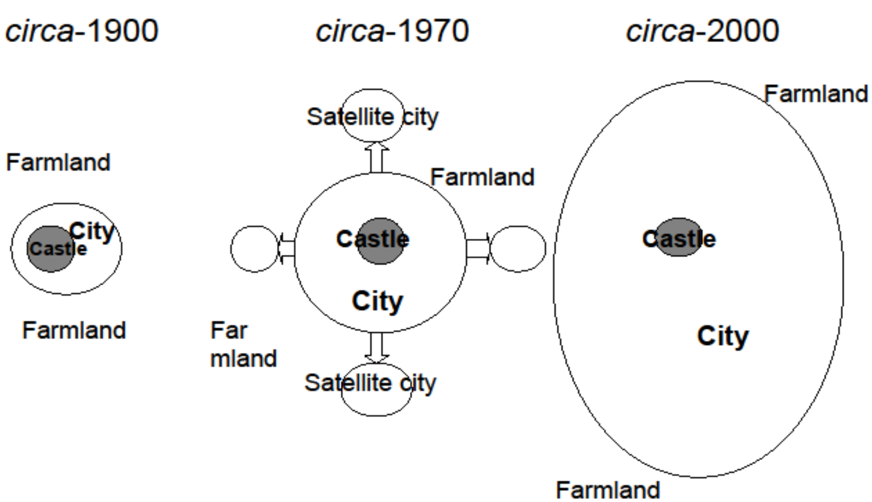
The Process of Urban Development

Modern Asian megacities were originally walled cities or castle towns. As the cities developed, the urban areas expanded to the surrounding farmland and forestland. In the process, many cities (with the exceptions of Bangkok and Jakarta developed satellite cities. These cities then became megacities as a result of continuing expansion, absorbing the satellite cities. The urban development timeline differs for each city.

Issues regarding water environment began as soon as the cities began to experience urban development. We will now look at the development of Tokyo, Osaka, Seoul, Taipei, Bangkok, Jakarta, and Manila.



Land use of Tokyo



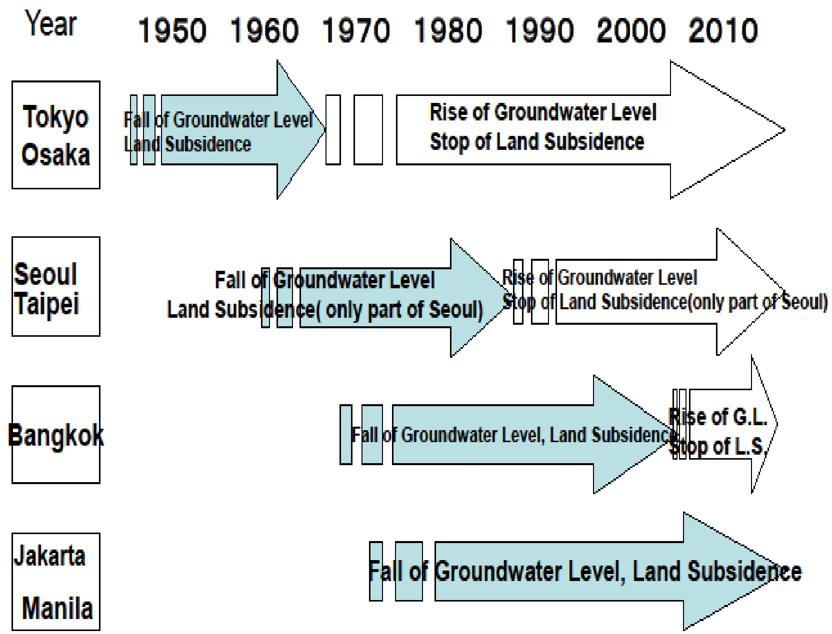
Urban development model of Tokyo

When urban development processes are closely investigated, unique and interesting features appear for each city. If such investigations occur in Asian megacities, the process is very complicated. Because of this, it was decided, for the purposes of this study, to divide the development of each city into three stages, in an attempt to simplify the comparisons.

First, authors investigated land use using topographical maps, and then created a land use map using GIS.

The upper figure is the land use map showing the three stages. The lower figure shows the three stages of the Tokyo development model. Thus, by using these three-stage figures, comparisons of the development processes for each city were simplified.

The results showed significant development process differences for each city.



Change of Water Environment Issues

Environmental issues regarding water, arrived with the urban development of each city. Although there are many environmental water issues, this paper has focused solely on two: decreases in groundwater levels and land subsidence.

Figure 1 shows when the environmental water issue occurred, and when it was resolved. In both Tokyo and Osaka, the issue arose early in the developmental process, and was quickly resolved.

The other megacities have experienced a time lag of approximately 20 years in the appearance of this phenomenon. If the lessons learned in Tokyo and Osaka are applied to these other cities, then they too may enjoy a speedy resolution.

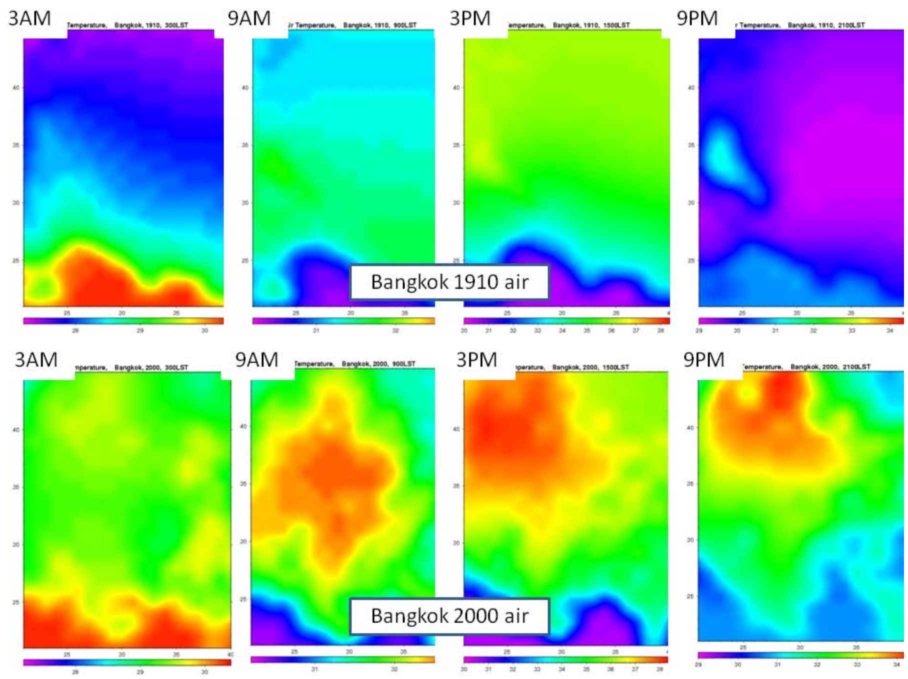
Akihisa Yoshikoshi, Itsu Adachi, Tomomasa Taniguchi, Yuichi Kagawa, Masahiro Kato, Akio Yamashita, Taiko Todokoro, Makoto Taniguchi : Hydro-environmental changes and their influence on the subsurface environment in the context of urban development,*Science of the total environment* 407-9, 3105-3111,2009

Akihisa Yoshikoshi : The viewpoints of the hydrological environment research of the urban area, *Journal of Japanese Association of Hydrological Sciences*,38—2,99-104,2008

Akihisa Yoshikoshi : Urban development of Asia, and water environmental change, Makoto Taniguchi ed. 「Underground environment of Asia」 *Gakuhosha*, 67-88, 2010

Numerical Simulations of Recent Urban Warming in Seven Asian Megacities

Toshiaki Ichinose (National Institute for Environmental Studies)



Diurnal change of surface air temperature map in Bangkok (1910 and 2000)

Numerical simulations of urban warming caused by urban expansion in the 20th century were performed for seven Asian megacities. Digital land use data was categorized into three stages, and used as surface boundary conditions in a climate model. The calculated warming of skin temperatures were compared with vertical profiles of historical ground temperatures.

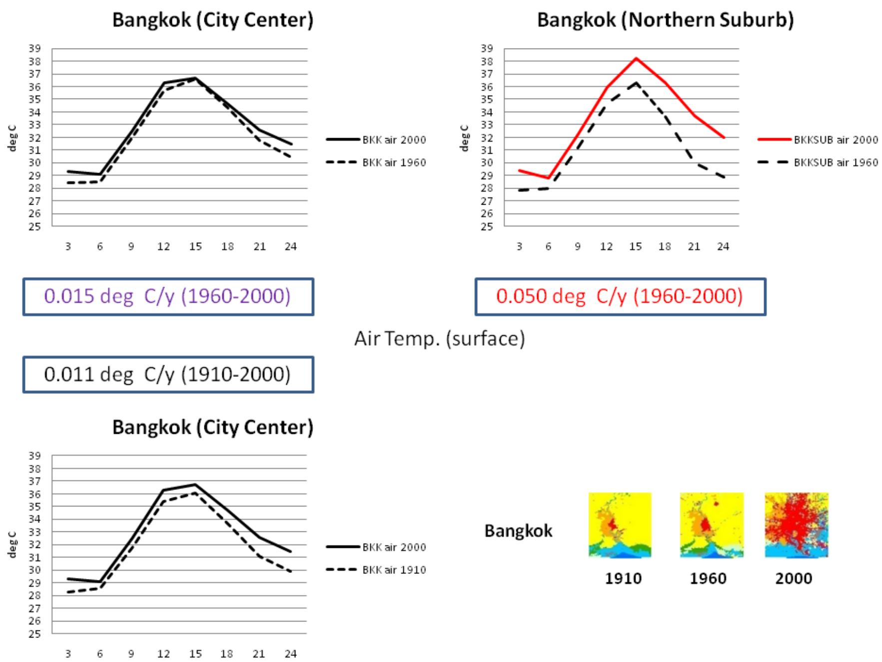


Fig. 2 Diurnal change in surface air temperatures during three stages in Bangkok.
City center (1910, 1960, 2000) and northern suburbs (1960, 2000).
Warming of 5 (° C/century) in northern suburbs over last 40 years

The city centers of all the seven cities, were already urbanized by the beginning of the 20th century. Warming of approximately 1 °C occurred in each city. However, warming of 2–3 °C occurred in the northern suburbs of Bangkok (leeward of the city center), between the middle of the 20th century and 2000. This area experienced a radical change from paddy fields to urbanized suburbs. Shifts of high temperature zones by daytime sea breezes into inland areas were noted in Seoul, Tokyo, Osaka, Bangkok, Jakarta.

Toshiaki Ichinose, Ippei Harada, Tomoyo Toyota (2010): Numerical simulations of recent urban warming in seven Asian mega-cities, Japan Geoscience Union Meeting, Chiba.

Changes in Urban Development, Water Sources, and Groundwater Use in Asia

Tomomasa Taniguchi
(Rissho University)

The use of water resources in Asian cities has increased due to economic development and population growth. In the past, we obtained our water from a number of sources: I used to get water from a nearby river and spring, or a shallow well. However, I currently get my water from a distant river and from deep subsurface sources.
As my city has developed, I have had to change the way I source my water.

Emergency water well, Tokyo

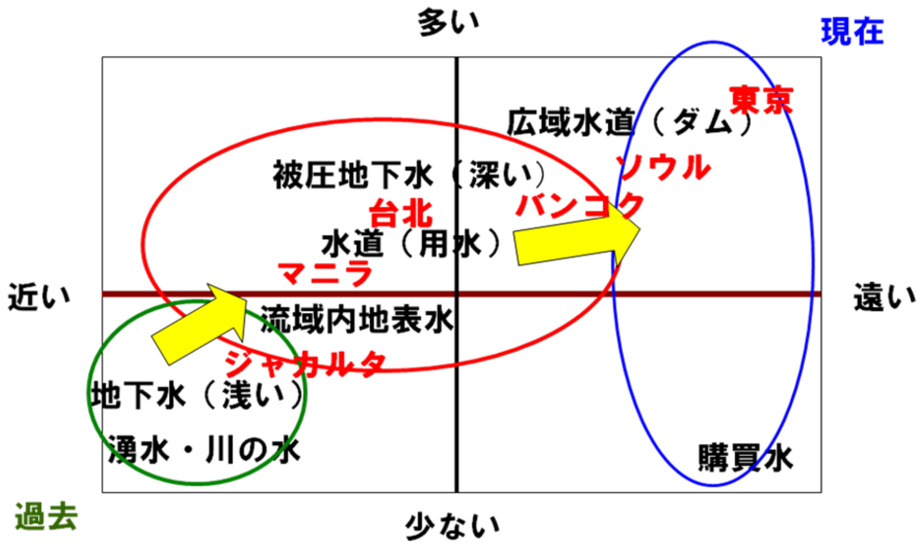
Ewha Girls High School well, Seoul

Temple well, Bangkok

Old school well, Taipei

Village well, Manila

Private dwelling well, Jakarta



	Life Water	Various uses	Disaster prevention	Old well
Tokyo	×	○	○	○
Seoul	×	○	×	○
Bangkok	×	○	×	×
Taipei	×	○	△	○
Manila	△	△	×	△
Jakarta	○	△	×	×

○ : use	△ : literr use	× : None

The development of modern tap water services has led to the decrease of wells within Asian megacities. For those wells that still exist, their purpose is now different under urbanization. Modern tap water services are dominant in Tokyo, but many old wells are now used as emergency water. The old wells are no longer used in Seoul, Taipei and Bangkok. However, both Jakarta and Manila continue to use theirs.

谷口智雅、都市における水の景観と水利用、『人と水　水と生活』45−75、秋道智彌・小松和彦・中村康夫編、勉誠出版

Collection of Official Maps for the Seven Asian Cities

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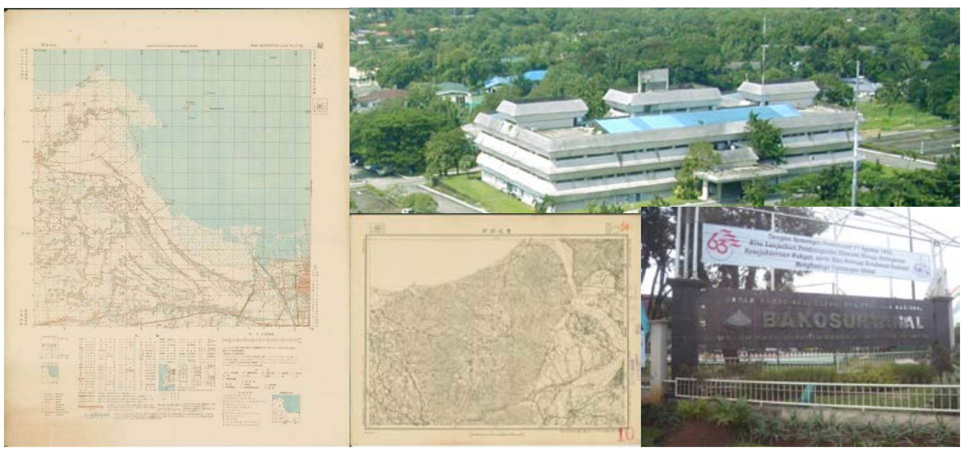
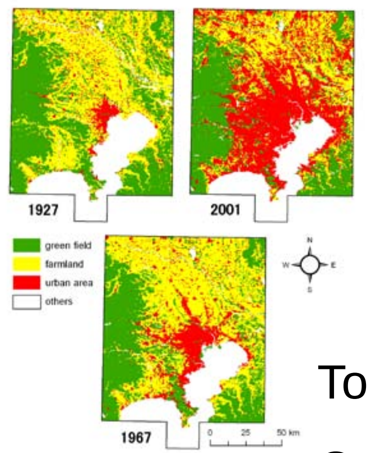


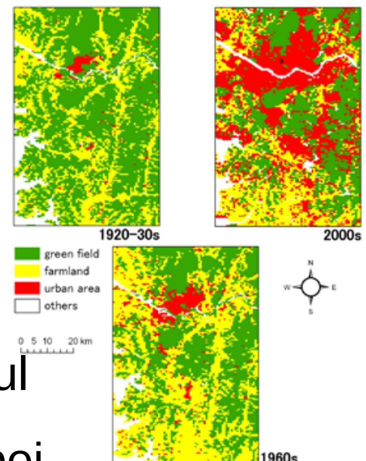
Topographical maps of each country were collected for the analysis of urbanization of each of the seven cities. The Asian topographical maps from World War II can be found in Japan.

Akihisa Yoshikoshi, Itsu Adachi, Tomomasa Taniguchi, Yuichi Kagawa, Masahiro Kato, Akio Yamashita, Taiko Todokoro and Makoto Taniguchi (2009) Hydro-environmental changes and their influence on the subsurface environment in the context of urban development. *Science of The Total Environment*, 407-9, pp.3105-3111.

Creation of Land Use Mesh Data for Three Stages

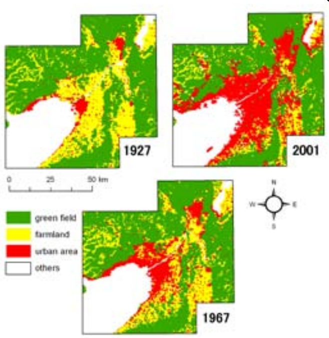
Akio Yamashita (University of Tsukuba)

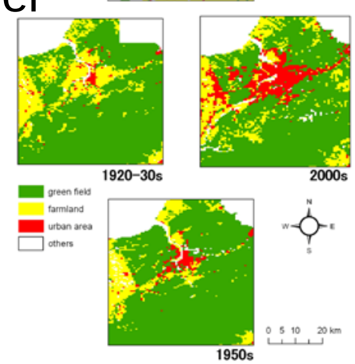




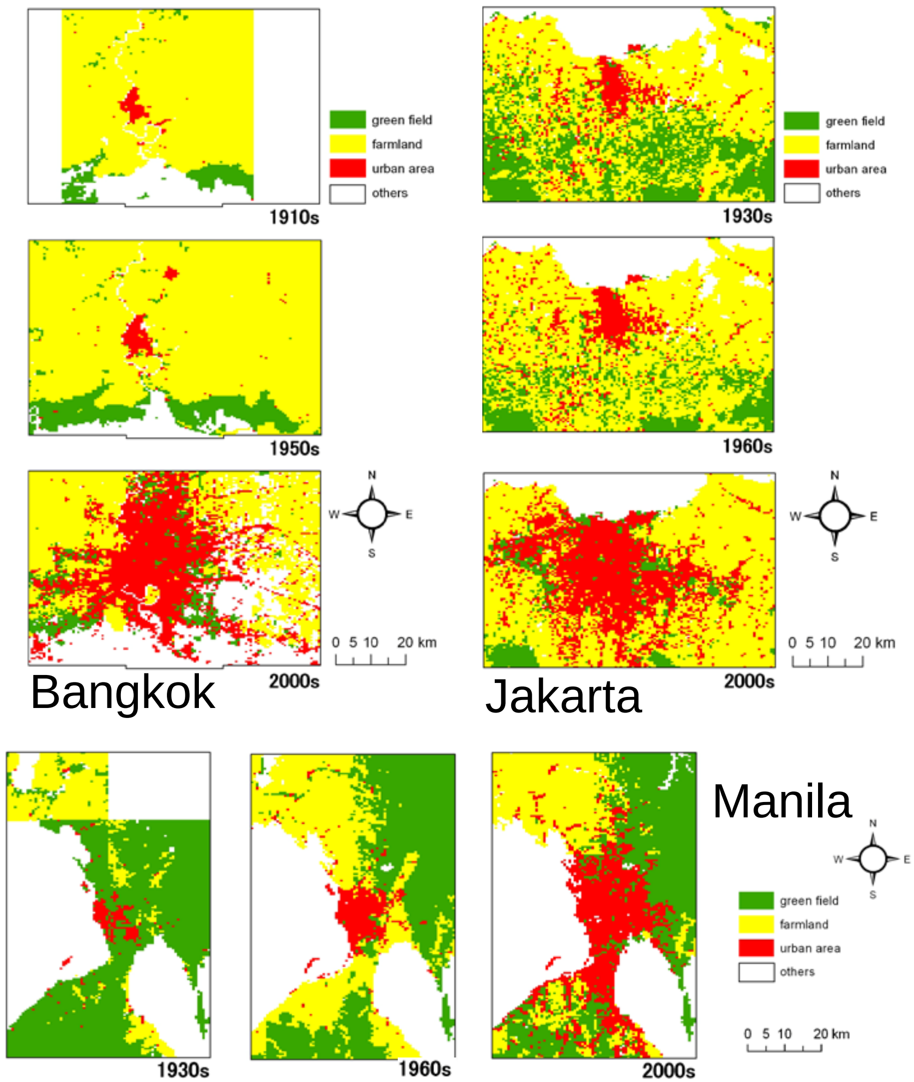
Tokyo Seoul

Osaka Taipei





Land use mesh maps were created to compare Asian megacity indices regarding the progress of urbanization and industrialization, and accompanying urban environmental problems. 1:50000 scale topographic maps of the three stages of the seven cities were collected as base maps, where possible.



This study adopted subdivided 1/2 grid-square meshes (500 m × 500 m mesh) as the data unit. The following nine land use items were used in the study: 1. "forests" (needle-leaved trees, broad-leaved trees, bamboo groves); 2. "grasslands, wastelands" (including parks, artificial grass, and golf courses); 3. "rice fields"; 4. "other agricultural lands" (fields, orchards, pastures); 5. "industrial sites"; 6. "residential areas" (urban land use other than industrial sites); 7. "water areas, wetlands"; 8. "other" (developed land, unused land, etc.); and 9. "oceans."

・Yamashita, A. "Comparative analysis on land use distributions and their changes in Asian mega cities. In *Groundwater and Subsurface Environment -Human Impacts on Urban Subsurface Environment in Asia-*, Springer. (in press)

Long-term urbanization and land subsidence in Asian mega-cities: An indicator system approach

Tomoyo Toyota（JICA-RI）・Kaneko Shinji（Hiroshima University）

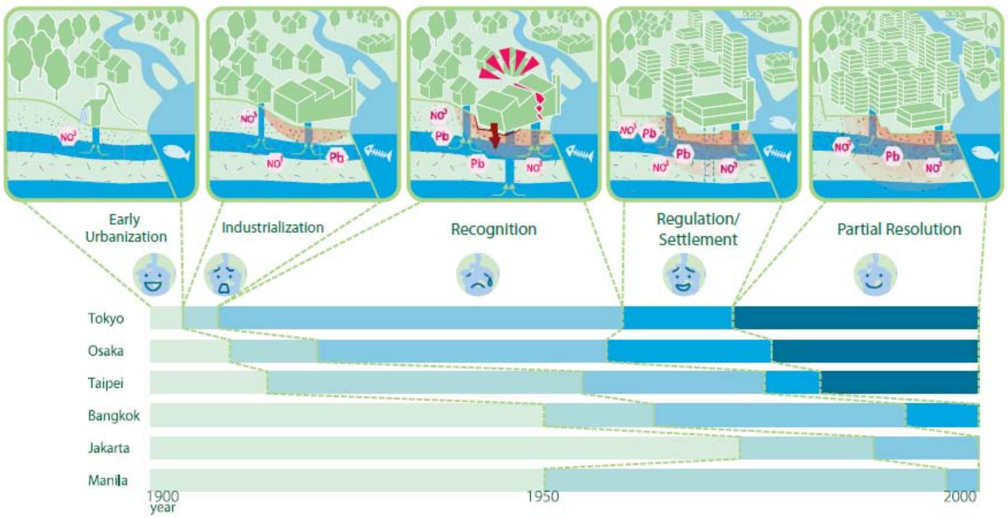


Figure 2 **Cross Cutting : Integrated Model**
Observed and statistical data are compared in seven cities based on five stages of development.
The bar figure shows the stages of land subsidence at each city in comparison with Tokyo.

We have attempted to define our stage model as a reference for other cities
using Tokyo's experience regarding the relationship between urban development and land subsidence. As shown, Osaka and Taipei are already very close to having land subsidence under control. In contrast, Bangkok is still in the process of controlling land subsidence by supplying alternative water sources to industries. They also possess a relatively large groundwater storage capacity (Taniguchi et al., 2009). Jakarta and Manila have not yet implemented effective countermeasures, despite the recognition of land subsidence by their respective governments.

Karen Ann B. Jago-on and Shinji Kaneko (2008) "Long-term urban growth and water demand in Asian mega-cities" From *Headwaters to the Ocean, Hydrological Changes and Watershed Management*, pp.483-489.
Karen Ann Bianet Jago-on, Shinji Kaneko, Ryo Fujikura, Akimasa Fujiwara, Tsuyoshi Imai, Toru Matsumoto, Junyi Zhang, Hiroki Tanikawa, Katsuya Tanaka, Backjin Lee, Makoto Taniguchi. "Urbanization and subsurface environmental issues: An attempt at DPSIR model application in Asian cities."*Science of the Total Environment* (in press).
Kaneko, S. and T, Toyota(Forthcoming) "Long-term urbanization and land subsidence in Asian megacities: An indicators system approach", Groundwater and Subsurface Environment, Springer.
金子慎治・豊田知世(2010)「都市の経済発展と地盤沈下」、谷口編『アジアの地下環境』、学報社, 37-65

Model Working Group

Jun Yasumoto（University of the Ryukyus）･Tsutomu Yamanaka (University of Tsukuba) ･
Masaomi Aichi（ The University of Tokyo ）･Makoto Kagabu（Kumamoto University）

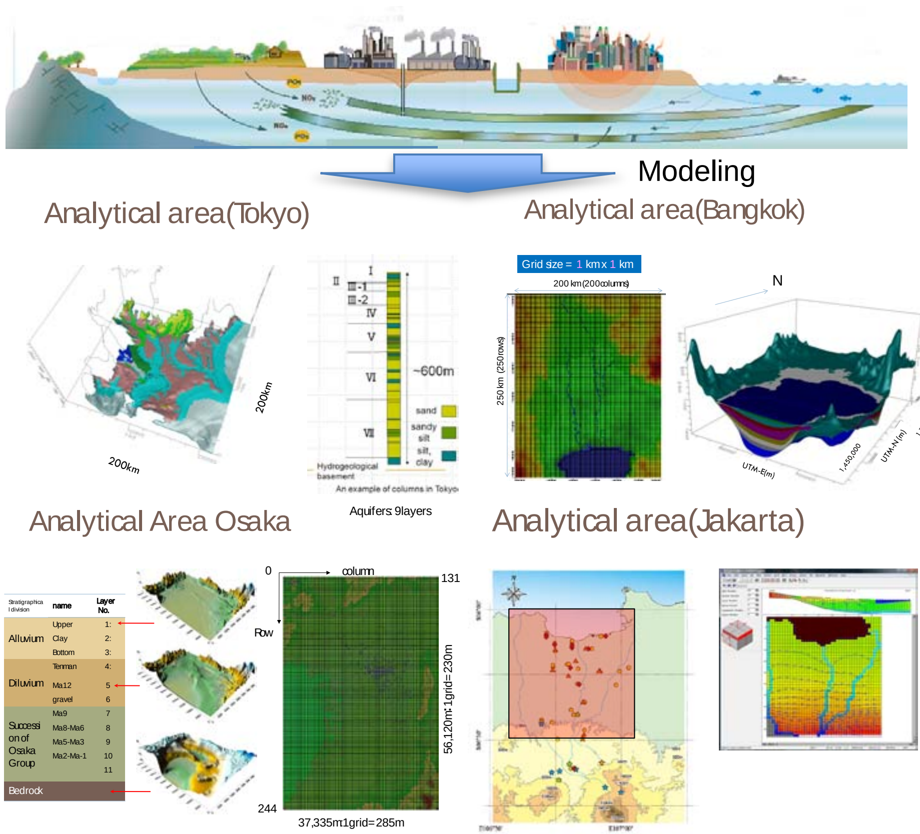


Fig.1　Analytical area of each city

The Model Working Group (MWG) was formed to integrate the observation data from each area, collected by the Subsurface Environment Project. The groundwater flow in each city was analyzed using numerical simulation.

A framework was constructed to compare the seven urban cities and common indices were determined for each groundwater flow model. The natural and human factors in the urban subsurface environments were estimated using the common indices extracted from each cities’ groundwater analysis results.

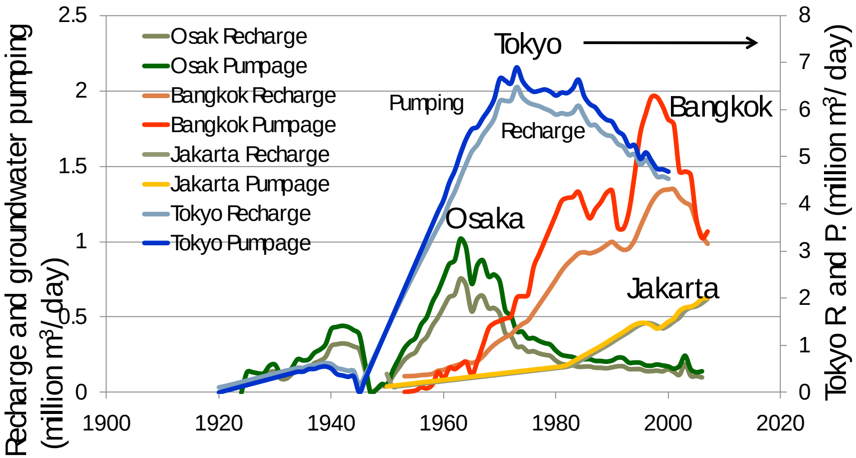


Fig. 2 Groundwater recharge and extraction rate

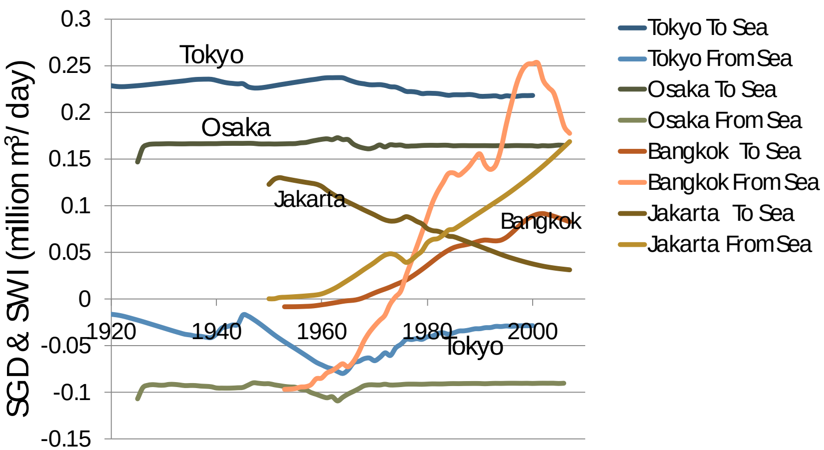
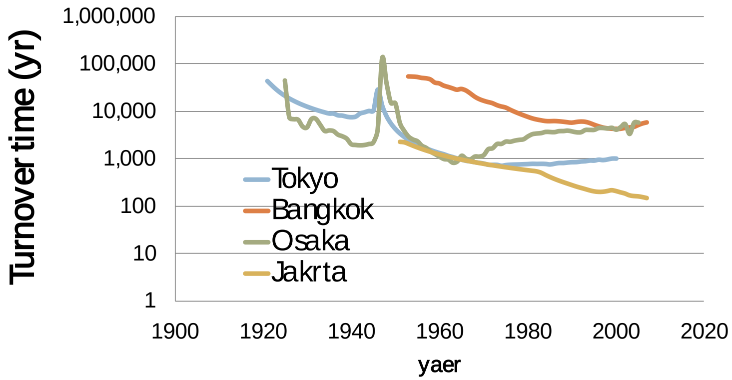


Fig. 3 Submarine groundwater discharge and seawater intrusion

There are several common indices. These common indices are divided into inflow and outflow. 'Inflow' represents the inflow into the analytical domain of the model (all aquifers), and is then divided into: 1. inflow from the top; 2. inflow from the side; and 3. inflow from the sea to the analytical domain. Inflow from the top refers to the volume of groundwater recharge into the aquifers. Inflow from the sea refers to the volume of saltwater intrusion (SWI) into the aquifers. Outflow refers to the volume of discharge from the analytical domain (all aquifers), and is divided into the volume of flow to the sea and the volume of discharge extracted from the analytical domain.

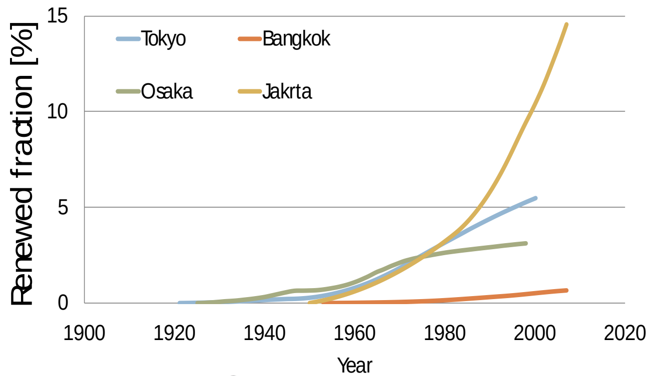
Fig. 2 shows the rate of recharge and pumping extraction. Groundwater development began in Tokyo and Osaka in 1920. Pumping extraction increased rapidly after 1945, peaking in the 1960s. Pumping extraction also increased in Bangkok and Jakarta in 1950; Jakarta's extraction rates are still increasing, though Bangkok levels have declined since peaking in 2000. Fig. 3 shows results for submarine groundwater discharge (SGD) and seawater intrusion in each city.



$$\tau = S/Q$$

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

Fig. 4 Turnover time for each city



$$\alpha = \frac{\int_0^t Q}{S}$$

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

Fig. 5 Renewed fraction for each city

Inflow from the sea is calculated using total seawater intrusion minus total SGD.
In Tokyo and Osaka, groundwater discharge to the sea has been constant. However, SGD was not identified in Bangkok and Jakarta until 1970; instead, increasing levels of SWI occurred.
These results reflect the characteristic features of aquifers, for example, groundwater gradients.
Fig. 4 shows turnover time results for each city. Turnover time is storage capacity divided by recharge per year. S is the storage capacity for groundwater, and Q is the recharge rate (m3/year). Bangkok has the longest turnover time (Osaka has a similar rate), but this decreases after groundwater abstraction.
The renewed fraction is the integral value of the groundwater recharge. Fig. 5 shows the renewed fraction results for each city. Jakarta obtained the largest value for the exchange of groundwater, followed by Tokyo, Osaka, and Bangkok. These results show that Jakarta has the most developed groundwater system.
The effect of human activities on the subsurface environments in each city was quantitatively clarified using the MWG determined common indices.

Monitoring of groundwater variations through precise gravity measurements on land and from space

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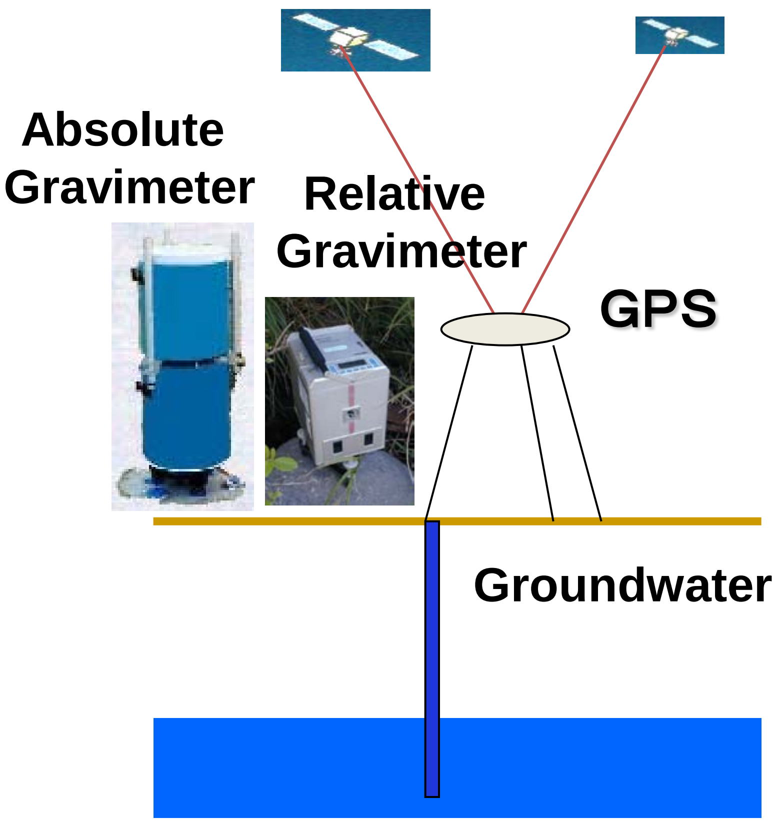
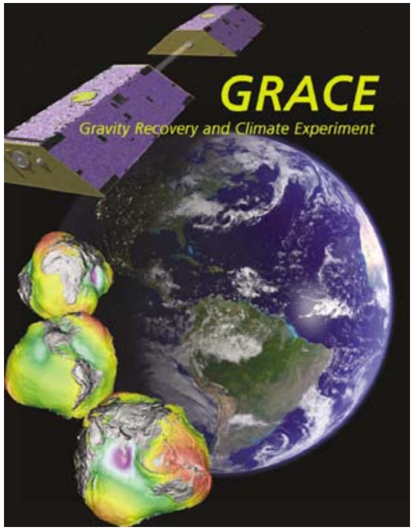
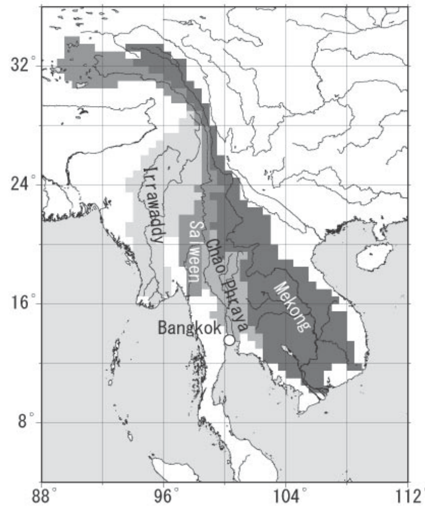
T. Nakaegawa （MRI）・ T. Hasegawa (Kyoto University)

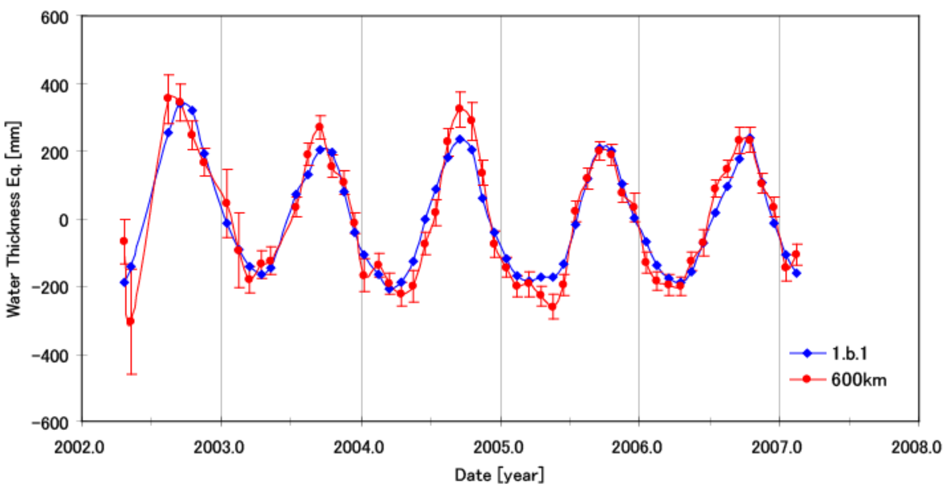


We propose a combined method of precise in-situ gravity measurements, GPS measurements and groundwater level measurements for monitoring groundwater variations and associated land subsidence.

The figure shows the configuration of the combined measurements. Absolute gravity measurements and GPS measurements are conducted at the observation point.







The GRACE (Gravity Recovery and Climate Experiment) satellite records extremely precise gravity data from space. These data are precise enough to reveal gravity changes from large-scale groundwater variations.

Using the GRACE data, we estimated terrestrial water storage (TWS) variations in the Indochina Peninsula. The GRACE TWS product agrees well with a hydrological model. The GRACE data can be used as a constraining condition to improve the hydrological model.

Fukuda Y, Yamamoto K, Hasegawa T, Nakaegawa T, Nishijima J, Taniguchi M (2009) Monitoring groundwater variation by satellite and implications for in-situ gravity measurements, Science of the Total Environment, 3173-3180, doi:10.1016/j.scitotenv.2008.05.018.